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# Explaining China's Position in the Global Supply Chain

Judith M. Dean,* U.S. International Trade Commission
K.C. Fung, University of California, Santa Cruz and USITC

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Judith Dean, Office of Economics, USITC, 500 E St. SW, Washington, DC, 20436; Tel: 202-205-3051; Fax: 202-205-2340; Judith.Dean@usitc.gov; http://works.bepress.com/judith_dean/.

K. C. Fung, Dept. of Economics, UC Santa Cruz, Santa Cruz, CA, 95064; Tel: 831- 459-3273; Fax: 831-459-5077; kcfung@ucsc.edu; http://people.ucsc.edu/~kcfung/

## 1. Introduction

A large number of recent research papers on international trade focus on the phenomenon of international production fragmentation, often also called the global supply chain (Jones and Kierzkowski 2001, Deardorff 2005, Yi 2003). This form of global production involves slicing the stages of production thinner and thinner and parceling out each specialized stage to various geographic locations. Given the growing importance of China as an emerging international trading powerhouse, there is now also a small but rapidly evolving literature on the role of China in this global production chain (Athukorala and Yamashita 2006, 2009; Dean, Fung and Wang, 2009; [1] Dean, Lovely and Mora, forthcoming; Koopman, Wang and Wei, 2008; Wang and Wei, forthcoming; Xu and Lu, forthcoming).

A very useful concept in empirically gauging the importance of supply chain-related trade for an economy is the notion of vertical specialization shares (Hummels, Ishii and Yi 2001). The use of vertical specialization shares (VS shares) for measuring the extent of China's participation in the global supply chain is particularly meaningful since China has an unusually large proportion of trade in the form of processing trade: the policy regime whereby inputs can be imported duty free as long as they are used for further assembly and then exported. Two recent papers, Dean, Fung and Wang (DFW) (2009) and Koopman, Wang and Wei (KWW) (2008) utilize this concept of VS shares to study the characteristics of Chinese exports. These papers find IT related products, such as electronic computers, telecommunication equipment, cultural and office equipment, telecommunication equipment, and computer peripheral equipment, to be among China's most vertically specialized exports.

Sectoral VS shares give us some indication of how far up China is along the global value chain for various industries. A high VS share indicates that a substantial amount of the content comes from abroad, suggesting that China is mainly engaged in final stages of assembly. A low VS share indicates that a larger degree of the production process is being done within China. This could mean some technological constraint on the degree of

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[1] Dean, Fung and Wang (2009) is a revised version of the earlier working paper, Judith M. Dean, K.C. Fung and Zhi Wang, "How Vertically Specialized is Chinese Trade?" USITC Working Paper No. 2008-09-D. (2008). http://www.usitc.gov/research_and_analysis/staff_products.htm#2008.

fragmentation in the industry, or that China is producing more of the stages of production than simply final assembly. The evidence shown in DFW indicates that VS shares vary extensively across Chinese industries.

But what explains China's position in the global supply chain across these industries? Antras (2005) posits that when a firm considers offshoring part of its production, two industry characteristics play important roles in the decision: research and development (R &D) spending and relative wages. If the product is new, and research and development (R&D) accounts for a large share of the costs of production, then due to contract incompleteness, transnational offshoring may not take place. Savings through offshoring the low-tech stages of production are likely to be outweighed by the risk of low-quality, low-tech inputs. As the product matures, and more stages of production are standardized, this risk diminishes compared to the cost-savings from relatively cheaper labor inputs abroad. The ability to reduce risk by producing offshore in an affiliate firm increases the likelihood of offshoring.

In this paper we make use of Antras' theoretical model and the DFW estimates of industrial VS shares to explain China's position in the global supply chain. We adapt the Antras model to a cross-section of industries at a single point in time, and econometrically test the role of R&D intensity and relative wages in determining VS share. A cursory examination of the data reveals patterns quite contrary to Antras' predictions. However, using a simple two-stage econometric model, we find strong evidence that in relatively R&D-intensive industries, there is less offshoring to China, and very high foreign content in Chinese processing exports. As R & D intensity falls, Chinese industries undertake more processing trade, and that processing trade has lower foreign content, suggesting that more of the stages of production take place in China. We also find that offshoring increases, for all R&D intensities, if Chinese processing trade is conducted by foreign-invested firms (FIEs).

The rest of the paper will be organized as follows: in the next section, we discuss several papers that are relevant to our analysis.. We examine the model by Antras (2005) in more detail in section 3, and use it to explore the VS share data in section 4. Section 5 presents the econometric analysis and results, with extensions in section VI. The last section concludes.

**2. Literature and Background**

Vertical specialization refers to the proportion of imported intermediate goods contained in an economy's exports. Imported intermediate goods are used in successive rounds of production in an economy, often in combination with other domestically produced inputs. Measuring the extent of production fragmentation requires the use of the economy's input-output tables, to capture the uses of imported intermediates in various rounds of production--the "cumulative use" of imported inputs.[2] It also requires accurate identification of imported intermediates under both types of processing trade: "processing and assembly," under which inputs are imported but remain under the foreign party's control; "processing with imported inputs," under which the ownership of the inputs is given to the producers in China.

DFW (2009) combine the use of processing import and export data with the use of input-output tables to measure the VS shares of Chinese trade for two years, 1997 and 2002.[3] To capture the additional complications arising from different intensities of imported inputs in processing and non-processing trade, the DFW study also measures VS shares using the separate inferred input-output tables for processing and non-processing trade developed in the KWW study.[4] Figures 1 and 2 reproduce a sample of DFW's VS share estimates using both methods (denoted non-split and split, respectively) for Chinese merchandise exports in 2002.[5]

As shown in figure 1, the highest VS shares, under either method, are largely in IT-related products: electronic computers, cultural and office equipment, telecommunications equipment, computer peripheral equipment, electronic elements and devices, radio, TV and other communications equipment. High VS shares indicate very little Chinese content, and

[2] Specifically, we use the Leontief inverse matrix to capture the total, cumulative use of imported intermediates in the production of exports.
[3] 1997 and 2002 are the two latest years when the benchmark Chinese input-output tables were available.
[4] Koopman, Wang and Wei (2008) use an algorithm to split the official input-output tables into two tables, one for processing trade and one for non-processing trade.
[5] Figure 1 and 2 are taken from Figures 5a and 5b from Dean, Fung and Wang (2008).

suggest that China is actually at the low-tech assembly end of the supply chain. But there are large differences in the positions of the supply chain across sectors. Over all industries exporting merchandise, DFW find split VS shares ranging from 4.3% to 95.4%. In Figure 2, DFW highlight the distinction between VS shares for processing and normal exports. They find a correlation of 0.89 between an industry's VS share and the share of processing exports in that industry's total exports. Thus, industries heavily involved in processing exports typically have very high foreign content in their exports.

Evidence on the firm's choice to offshore production is found in Feenstra and Hanson (2005). They present a rich model that tests some of the elements of property rights theory as well as the Chinese incentive system framework. In their model, a multinational firm has already decided to set up an export-processing plant in a relatively low-wage country. The firm faces the problem of reducing costs by offshoring vs. providing sufficient incentives to the processing plant to produce a high quality input. The multinational has two tools at her/his disposal to maximize the joint surplus from the supply-chain arrangement: control over the inputs and ownership of the firm. Feenstra and Hanson apply this model to China, using the share of processing trade accounted for by each possible factory control/input control pair to represent the probability that a particular contractual arrangement is chosen. Comparing these shares in China's total processing exports over the period 1997–2002, they found that multinational firms tended to split ownership of the factories and input control. The most common arrangement was to have the foreigner own the factory (an affiliate firm) and the Chinese control the inputs (processing with imported inputs).

Some additional evidence on contractual arrangements in global supply chains is found in Dean, Lovely and Mora (2009). These authors apply the Feenstra-Hanson analysis to US-China and Japan-China processing trade. They found that in 1996, the two most common arrangements for processing exports to the U.S. were foreign-owned factories with Chinese control over inputs (66%) and Chinese owned factories with foreign control over inputs (25%). For Japan, these figures were 56.% and 17.8% , respectively. By 2007 the foreign factory control/Chinese input control arrangement accounted for almost 75% of the processing exports from China to the US and China to Japan. There was also a growing share of foreign factory control/foreign input control (processing and assembly). Delving deeper, Dean, Lovely and Mora found that the choice of foreign factory ownership was also important. For processing exports to both the US and Japan, more than 50% came from *wholly-owned* foreign factories with Chinese control over the inputs. However, processing exports to Japan were somewhat more likely to come from *wholly-owned* foreign factories with foreign control over the inputs, than those to the US.

**3. Product Cycle of Offshoring**

Antras (2005) proposes a theory of international offshoring that will motivate our econometric work. In this model, a product is produced by combining a high-tech input and a low-tech input. The high-tech input is produced in the North (e.g., the US), which has a comparative advantage in R&D intensive goods. The low-tech input can either be produced in the North or the South (e.g., China). With relatively lower wages in China, the low-tech input would normally be produced in China. However, Antras introduces contractual incompleteness, which limits the initial degree of production fragmentation. With increased standardization of the product, the production of low-tech input will then be shifted to the South. As will be discussed below, relative wages and the characteristics of the industries at the moment of the decision are among the factors that determine the extent of international production sharing. Foreign direct investment is also important, since foreign control over the factory can ameliorate the risk generated by incomplete contracts.

Antras makes the standard assumption that there is only contract incompleteness when the North chooses to locate the production of the low-tech input in China. Contract incompleteness occurs because the northern research center cannot guarantee that the southern manufacturing center will produce a good quality intermediate good. This results in underinvestment in both inputs. If the product is new, and thus uses the high-tech input intensively, this distortion becomes more severe if the research and development center has lower bargaining power over the joint surplus. Conversely, if the product uses the low-tech input intensively, then the distortion is more severe if the southern manufacturing plant has lower bargaining power. As the product becomes more standardized, it becomes more intensive in the use of the low-tech input. There is a critical level of this intensity such that the relative wage advantage of the South overcomes the risk of a low-quality input. Thus, the low-tech input will be produced in China if:

$$A(z) \equiv [(1-\alpha)/ (1-\alpha(ø (1-z) + (1- ø)z) ]^{(1-\alpha)/ \alpha z} [ø^{-(1-z)/z}/ (1-ø)] \leq w^N/w^S \quad (1)$$

where a high z denotes more intensive use of low-tech input, ø is the bargaining power of the research center manager, $1/\alpha$ is the constant markup over marginal cost, $w^N$ is the wage in the North (US) and $w^S$ is the wage in the South (China).

This scenario is illustrated Antras' figure 2, reproduced here in figure 3. For new goods in which R&D constitutes a high proportion of the value of output (low z), the relative profitability of producing the low-tech input in the North will outweigh any cost advantage from engaging in assembly in the South: $A(z) > w^N/w^S$ . Thus, initially, there will be no fragmentation of production. The low-tech and high-tech inputs will be produced in the North. As the good becomes more standardized, the low-tech input accounts for a growing proportion of the value of the product. When $A(z) < w^N/w^S$ , the firm gains more from splitting production shifting production of the low-tech input to China.

If the Northern research manager has the option to produce the low-tech input in China in its own subsidiary firm, this is likely to induce fragmentation to the South earlier in the maturation process. Vertical integration will make the manager of the manufacturing plant in China an employee of the North. This increases (reduces) the incentive of the research center manager (manufacturing plant manager) to invest, since the Northern manager can fire the southern manager if she/he refuses to trade after sunk costs are made. Antras assumes that if the manager is fired, a fraction $1-\delta$ of the low-tech input will be lost. The manager in the North now will have to choose the manufacturing location and ownership structure. It turns out that the profits of the Northern research center are higher as a multinational if

$$A_M(z) \equiv [(1-\alpha)/ (1-(1/2\alpha)(1+ \delta^\alpha (1-2z) )]^{(1-\alpha)/ \alpha z} [2/[(1+ \delta^\alpha)^{(1-z)}(1- \delta^\alpha)^2]^{1/2} \leq w^N/w^S \quad (2)$$

where the other parameters are the same as in (1). With (2), the North would prefer to offshore to China in the form of a multinational. There is a further choice for the Northern research center, i.e. to have China produce the low-tech input either via an integrated firm (multinational) or via an independent assembler in China. If $A_M(z) < A(z)$ , assembly will be done by U.S. affiliate. If $A_M(z) > A(z)$, the low-tech input will be produced by an independent firm in China instead.

Antras' figure 4 illustrates this scenario, reproduced here as figure 4. Again, the main determinant of fragmentation is the degree of the standardization of the product in relation to the relative wage in the north. When the good is relatively new, all stages of production stay in the North (US). However, since the risk of low-quality low-tech inputs is reduced by producing as a multinational affiliate, fragmentation can potentially begin earlier if $A_M(z)> A(z) = w^N/w^S$. Thus, there will be a wider range of z over which offshoring to China takes place, but initially this will take the done through a foreign affiliate. Finally, when the good is further standardized, production will be shifted to an independent unaffiliated Chinese firm.

**III. Examining the VS Share in Chinese Exports through Antras' Lens**

Antras' model yields several testable hypotheses regarding variation in offshoring. Assume that a cross-section of industries at a point in time will generally mimic the offshoring pattern of a single good over its maturation. Then the Antras' model would suggest that:

i. Offshoring increases as the "high-tech intensity" of the product falls relative to the wage in the north.

ii. For a given level of high-tech intensity, offshoring increases as the relative wage in the north rises.

iii. For a given level of high-tech intensity, the possibility of offshoring through a foreign affiliate increases with the amount of offshoring.

iv. As the high tech intensity of the product diminishes, offshoring will be done less through foreign affiliates and more through independent southern firms.

To consider the usefulness of this model in explaining the vertical specialization in Chinese exports, we begin by examining the relation between northern high-tech intensities, relative wages, and Chinese VS share. We use the split VS share estimates from DFW, data on Chinese industry characteristics, such as employment and wages, from the NBS Industrial Enterprise Survey, and trade data from China Customs. These data are then concorded to ISIC Revision 3 at the 4-digit level.[6] To proxy the high-tech intensity of northern industries, we use US 2002 R & D expenditures as a percent of output (current value) in each sector, from the OECD.[7]

To keep things simple, assume that the relative profitability of producing completely in the US versus offshoring to China is proportional to R&D intensity. Figure 5 plots US R&D intensity and the US wage relative to the Chinese wage in each of the 113 industries for which we have R&D intensity data.[8] The Chinese 2002 average wage is calculated as average payroll divided by average employment in each 4-digit industry. The US average wage is calculated as average wages and salaries divided by average number of employees in each 4-digit industry, using data again from UNIDO INDSTAT Data[9] Figure 5 bears a strong resemblance to Antras' graph presented in figure 3.

In our sample, all industries show some level of processing exports. Thus, we expect to see processing even for industries in the highest RD intensities (to the left of the gridline showing the intersection of the two curves). However, based on Antras' model, we expect that processing trade, and thus VS share, would rise as RD intensity falls with respect to relative wages. In figure 6 we show Chinese 2002 VS shares, as well as R&D intensity and relative wages. The results are not encouraging. The highest VS shares appear to be in industries with the highest R&D intensity, such as medical and precision instruments. While there is a little evidence that VS shares rise as R&D intensity falls to the left of the gridline,

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[6] The VS share data are originally in input-output classification, while the enterprise data are in 2002 Chinese standard industrial classification (CSIC). One official concordance maps the IO classification to the 2002 Chinese standard industrial classification (CSIC), and another official concordance maps the CSIC 4-digit classification to ISIC Revision 3 data. The trade data are originally in HS 8-digit, and are mapped to ISIC using a concordance from WITS.

[7] Data are from OECD STAN R&D Expenditure in Industry (ISIC Rev. 3) ANBERD ed2009, http://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV3.

[8] Where 4-digit data on RD expenditures were not available, 3-digit or 2-digit data were used.

[9] Wages and salaries data: http://data.un.org/Data.aspx?d=UNIDO&f=tableCode%3a05 . Number of employees data: http://data.un.org/Data.aspx?q=employees&d=UNIDO&f=tableCode%3a04. US wage and salary data were only available for 2004. These were converted to Yuan using the average market exchange rate from IMF's IFS database. We assume that the distribution of US 2004 wages across industries is sufficiently similar to the 2002 distribution that it will not bias the 2002 relative wage variable.

this pattern is short-lived and does not appear in any consistent way once R&D intensity falls below the relative wage.

However, recall that the vertical specialization in Chinese exports from a particular industry (*VSshare$_i$*) will depend upon (1) the extent of processing exports in that industry (*PXshare$_i$*), and (2) the foreign content in those processing exports (*PVSShare$_i$*), i.e.,

$$VSshare_i = f(PXshare_i, PVSshare_i) \tag{3}$$

where $f_1 > 0$ and $f_2 > 0$. Antras' model suggests that *PXshare$_i$* is negatively related to R&D intensity (*RDInt$_i$*), controlling for the relative wage (*RelWage$_i$*). Thus,

$$PXshare_i = g(RDInt_i, RelWage_i, RDInt_i * PXshare_i^{FIE}) \tag{4}$$

where $g_1 < 0$ and $g_2 > 0$. The option of carrying out offshoring via a foreign-invested enterprise ($PXshare_i^{FIE}$) means that firms are more likely to engage in offshoring regardless of R&D intensity, because ownership of the firm in the south again helps increase quality control ($g_3 > 0$). In contrast, *PVSShare$_i$* is positively related to *RDInt$_i$*. As R& D intensity rises, northern firms reduce their risk by producing most of the product in the north (high foreign content), and only offshoring some assembly or packaging activities. Thus,

$$PVSshare_i = h(RDInt_i, RelWage_i) \tag{5}$$

where $h_1 > 0$. However, $h_2 < 0$, since a higher relative wage raises the incentive to offshore more of the product to the south.

Table 1 examines these hypotheses using industries grouped by US R&D intensity. At the top end are firms that spend on average more than 20% of the value of output on R & D. At the lowest end are firms that spend on average less than 0.5% on R & D. Industries to the left of the gridline in figures 5 and 6 are shaded in grey. Column 3 shows that average *VSshare$_i$* rises as average R&D falls for the top two R&D-intensive groups. But, in all other groups, *VSshare$_i$* falls with *RDInt$_i$*.—the opposite of the prediction from Antras' model. In column 5 we see that in fact that R&D-intensive industry groups have the highest levels of *PXshare$_i$* .

The predictions that the most R&D-intensive industries will have the highest $PVSShare_{i.}$ (the highest foreign content) is evident in column 4 of table 3. China produces only the last link in the global chain in these industries--a small portion of the value of the product. There is little evidence that the R&D-intensive industries conduct more processing through FIEs (column 6), nor that they choose a wholly-owned subsidiary ("fully-funded enterprise," or FFE) more often than the other industry groups (column 7). But column 8 does show some evidence that R&D-intensive firms preserve control over their offshored inputs by relying more on the "processing and assembly" customs regime than other industry groups.

**IV. An econometric investigation**

If we treat the decision to engage in offshoring and the decision regarding how much of the product to produce offshore as a simultaneous one, we can insert equations (4) and (5) into (3) to yield:

$$VSshare_i = a_0 lnRDInt_i + a_1 lnRelWage_i + a_2 lnRDInt_i * PXshare_i^{FIE} \qquad (6)$$

where ln indicates natural log and $PXshare_i^{FIE}$ is measured as the proportion of processing exports conducted by FIEs in China.[10] Since the signs on $lnRDInt_i$ and on $lnRelWage_i$ are opposite in equations (4) and (5), the net result is not predictable *a priori*. We first estimate (6) using GLS, including industry fixed effects (defined at the two-digit level) and robust standard errors corrected for industry clustering.

The first column in table 2 shows results for equation (3), confirming our expectation that VS Share is a positive function both of $PXshare_i$ .and $PVSShare_{i.}$ These results suggest that the $VSshare_i$ in Chinese exports responds much more to an increase in the foreign content of processing exports than to an increase in the share of processing exports in an industry. The second column in table 2 shows the results for equation (6). Here we find strong evidence supporting Antras' predictions. $VSshare_i$ is strongly negatively related to the R&D

[10] Chinese customs data do not report the parent firm's country of origin. Thus, we cannot measure the share of an industry's processing exports by US FIEs, but only the share of an industry's processing exports by FIEs from all source countries.

intensity of the industry. The more R&D-intensive the industry, the less vertical specialization in Chinese exports in that industry. In addition, interacting R&D intensity with the share of processing trade carried out by FIEs increases $VSshare_i$. Thus, the ability to carry out offshoring via a subsidiary in China increases the vertical specialization in Chinese exports even for the most RD-intensive industries. Contrary to expectations, the relative wage has no significant impact on VS share.

Because equations (4) and (5) have opposing signs on the key variables of interest, we consider a two-stage decision process. Suppose the firm first decides how much processing to undertake and then decides how much foreign content will be in the offshored product—i.e., the stages produced at home vs. those offshored. Then we would estimate:

$$\begin{aligned} &\text{First stage:} \quad PXshare_i = g(RDInt_i, RelWage_i, RDInt_i * PXshare_i^{FIE}) \\ &\text{Second Stage:} \quad VSshare_i = b_0 lnRDInt_i + b_1 lnRelWage_i + b_2 PXshare_i . \end{aligned} \tag{7}$$

using instrumental variables. $PXshare_i^{FIE}$ is the instrument used to identify the system. The first stage expression is simply equation (4) and the instrumented $PXshare_i$ appears in the second stage.

Table 3 shows the results of this two-stage estimation, again including robust standard errors corrected for clustering in both stages, and industry fixed effects in the first stage. Comparing the results in the two columns we see clearly the opposing signs on R&D intensity. A 1 percent increase in $RDInt_i$ reduces the share of processing exports in an industry by about 18 percentage points (column 1). This, in turn, reduces $VSshare_i$ by about 0.56*18, or about 10.1 percentage points (column 2). However, the same 1 percent increase in $RDInt_i$ raises $VSshare_i$ directly by about 2.3 percentage points (column 2) because it raises the foreign content of processing exports. Note that these two effects together imply that China's role in the global supply chain *falls* as the R&D-intensity of an industry rises. The first effect reduces the extent of processing exports done in China, and the second effect raises the foreign content of the processing exports that are done in China, making it more likely that Chinese production will be in the final, lower-tech stages of the production process.

The results for the relative wage in both columns of table 3 are the opposite of what we would have expected given our model. This may be due to the fact that the wage itself is endogenous, and is a function of both R&D intensity and the ownership of the firm doing the offshoring. In addition, as we noted earlier, there are in reality several ways in which northern firms can reduce the risk of offshoring. We have yet to incorporate the firms' ability to retain control over the inputs via choosing the Chinese processing and assembly customs regime. Nor have we incorporated the firms' ability to choose offshoring via a wholly-owned subsidiary, joint venture, or an independent Chinese firm. These extensions will be explored next.

V. Extensions (to be completed)

VI. Conclusions (to be completed)

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**Figure 1. Vertical Specialization of Chinese Merchandise Exports by Sector, 2002: Non-Split and Split Methods**

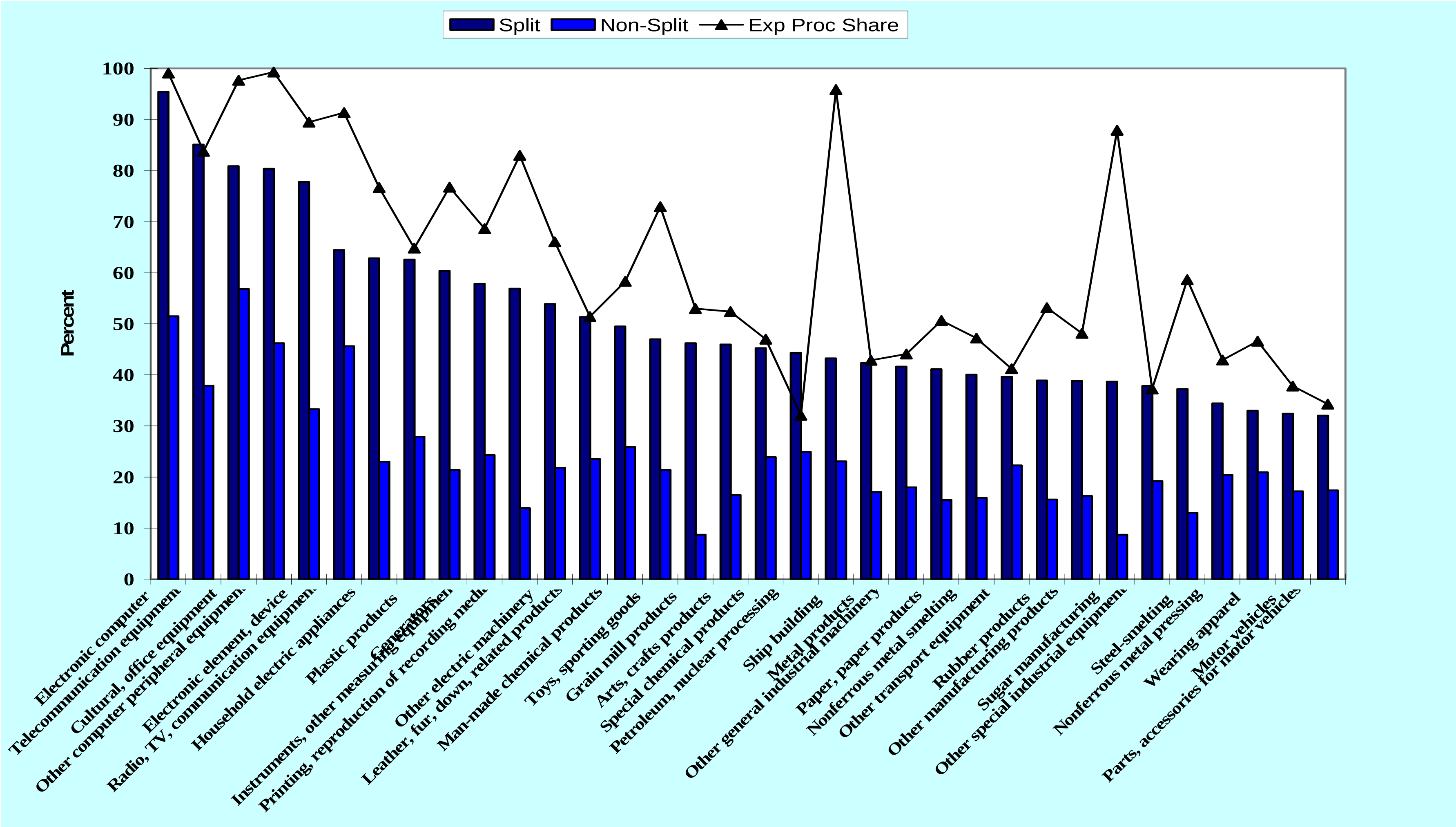


**Figure 2. Vertical Specialization of Chinese Merchandise Exports by Sector and Trade Regime, 2002: Split Method**

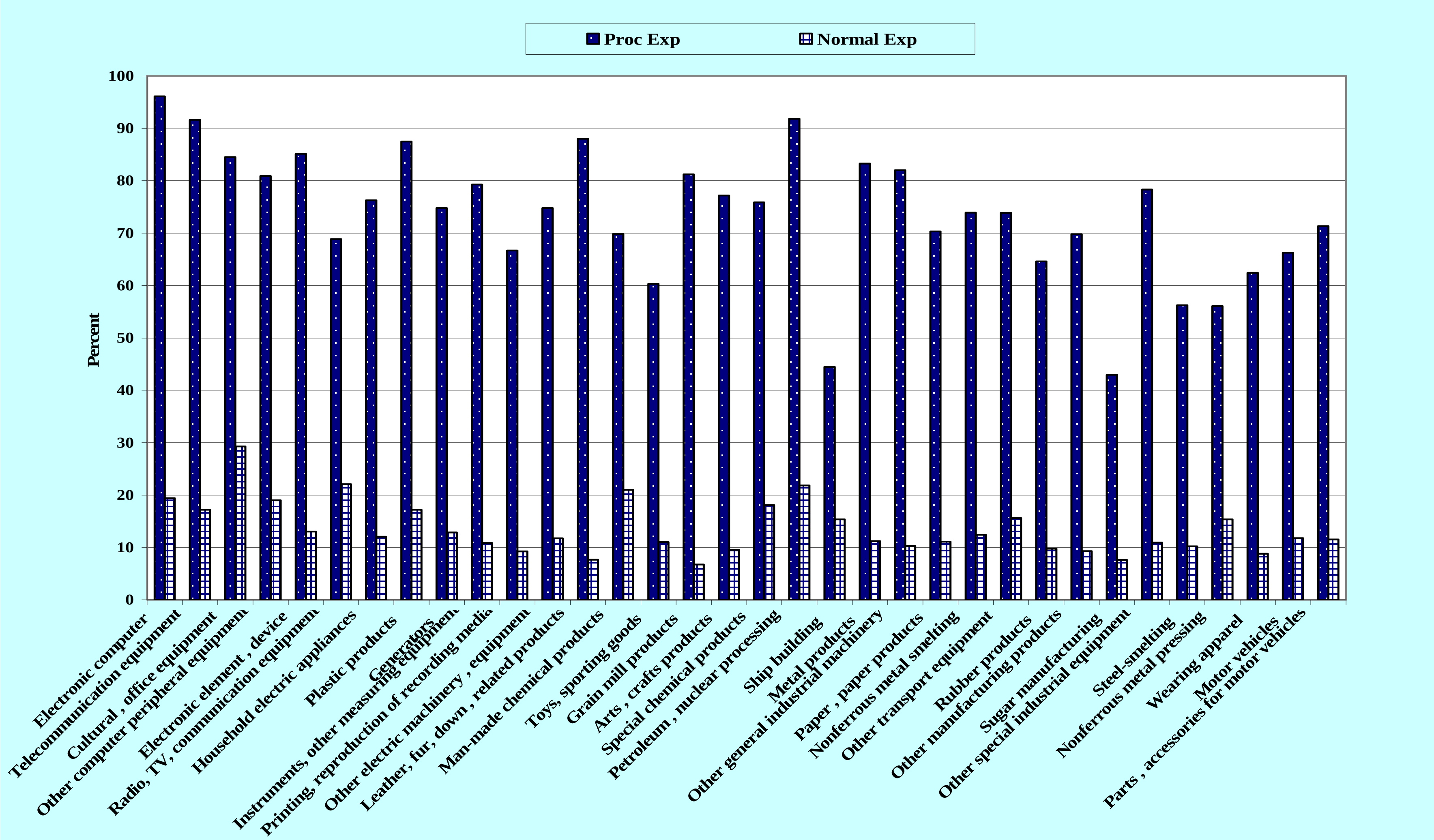
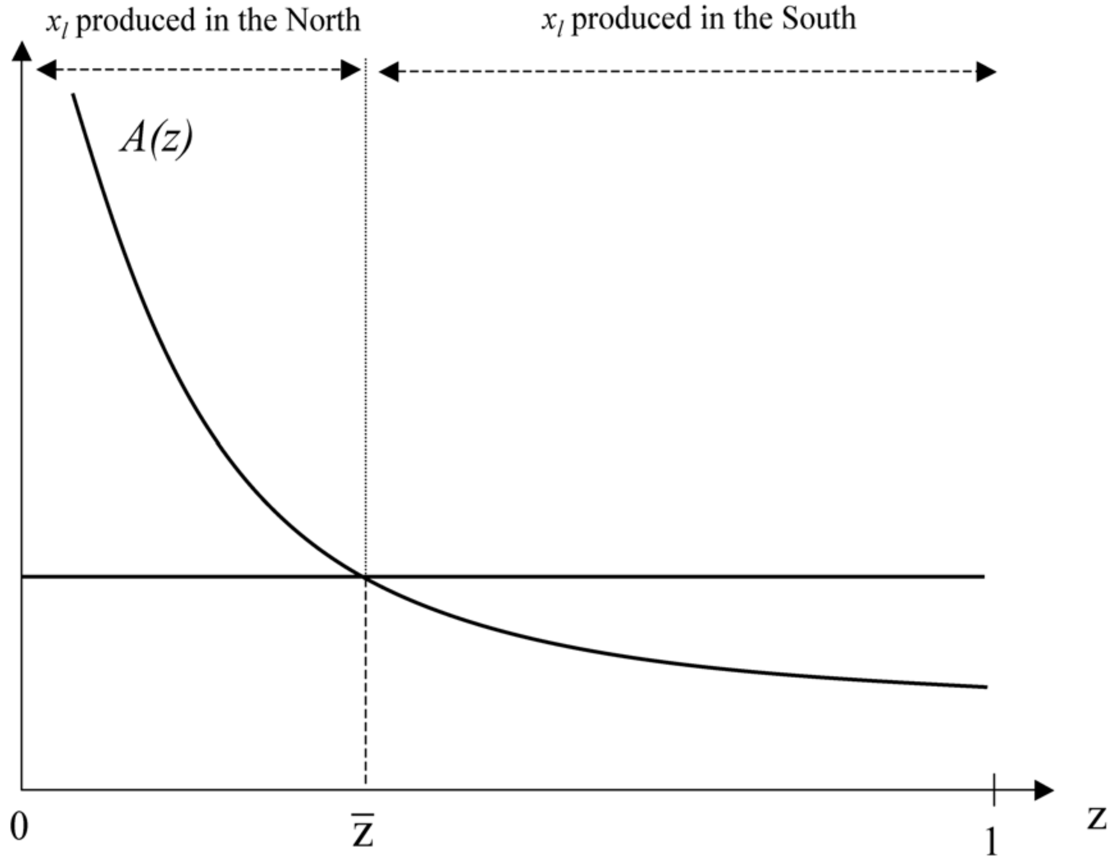
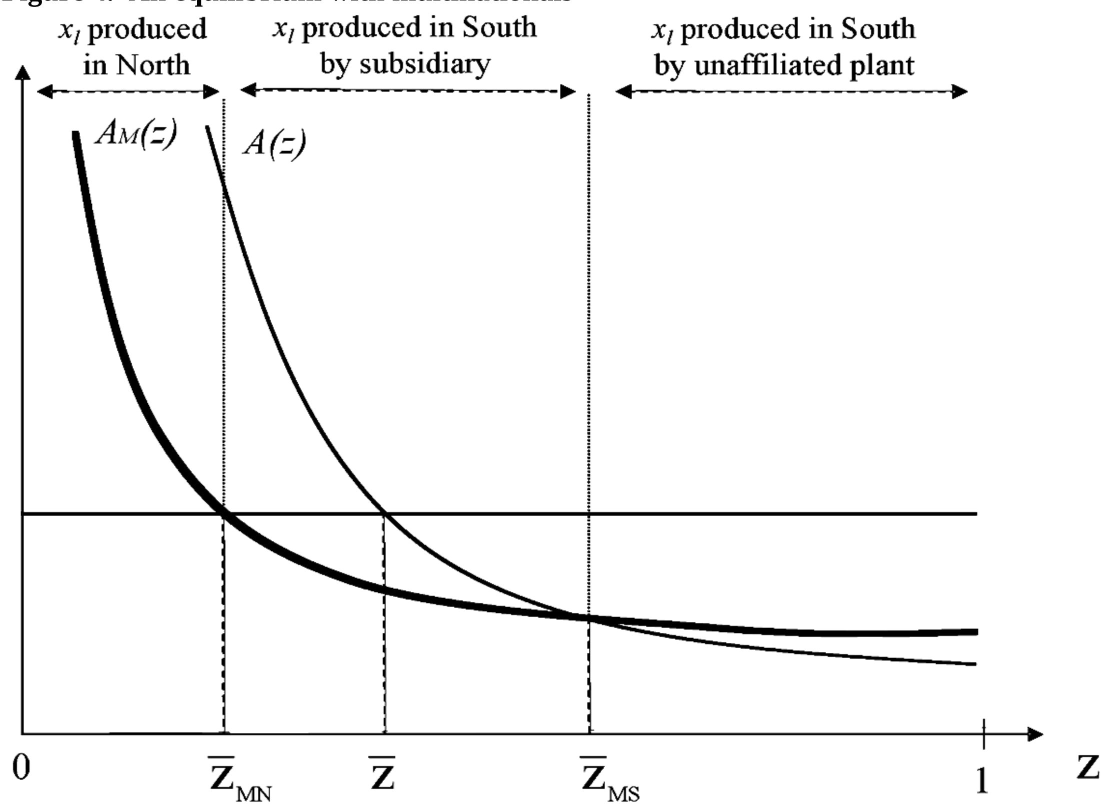


**Figure 3. Location Choices of the low-tech input $x_l$**




Source: Antras 2005

**Figure 4. An equilibrium with multinationals**




Source: Antras 2005

**Figure 5: US R&D Intensity and US-China Relative Wages, 2002**

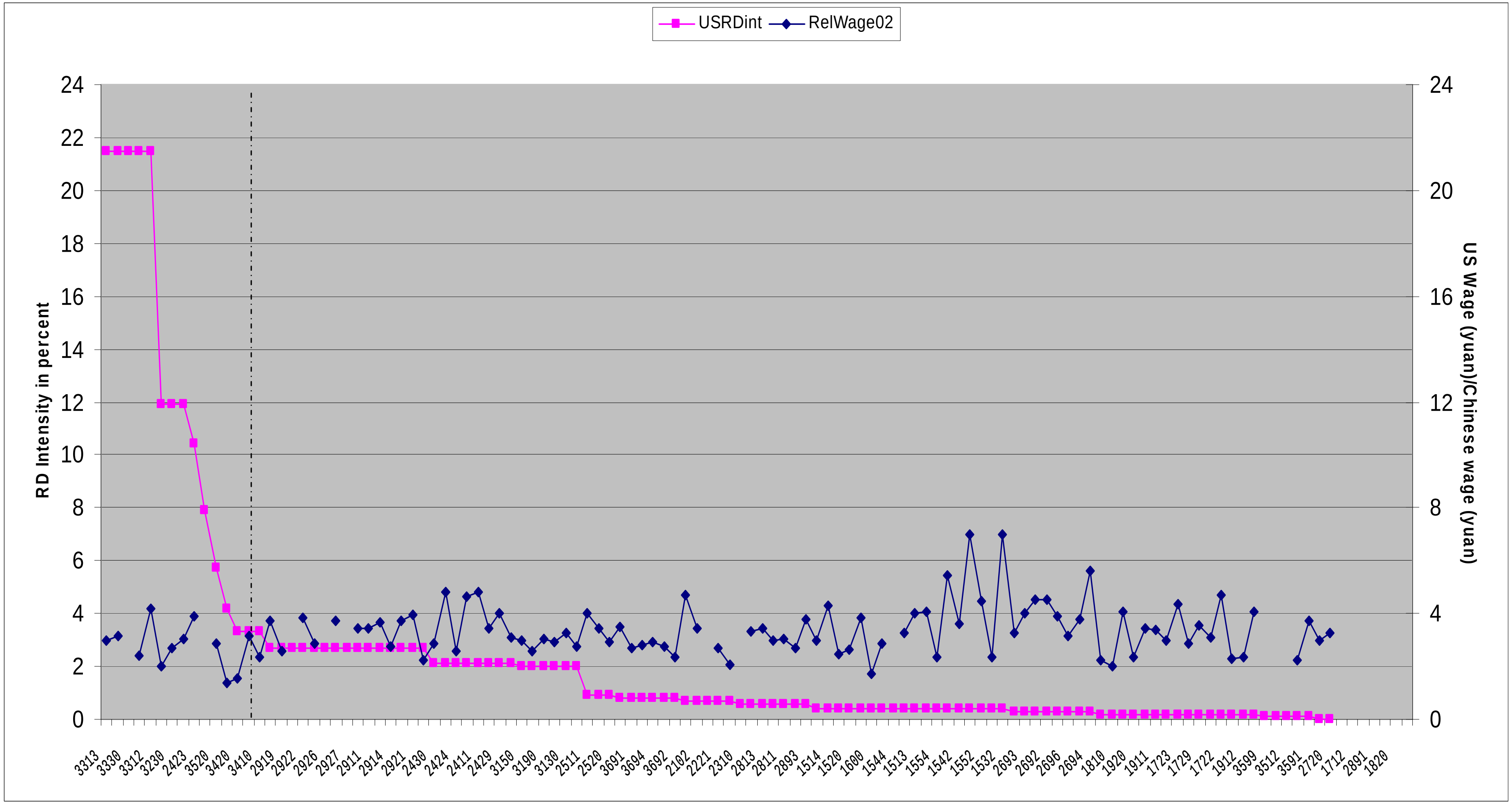


**Figure 6: VS Share in Chinese Exports by Sector, 2002**

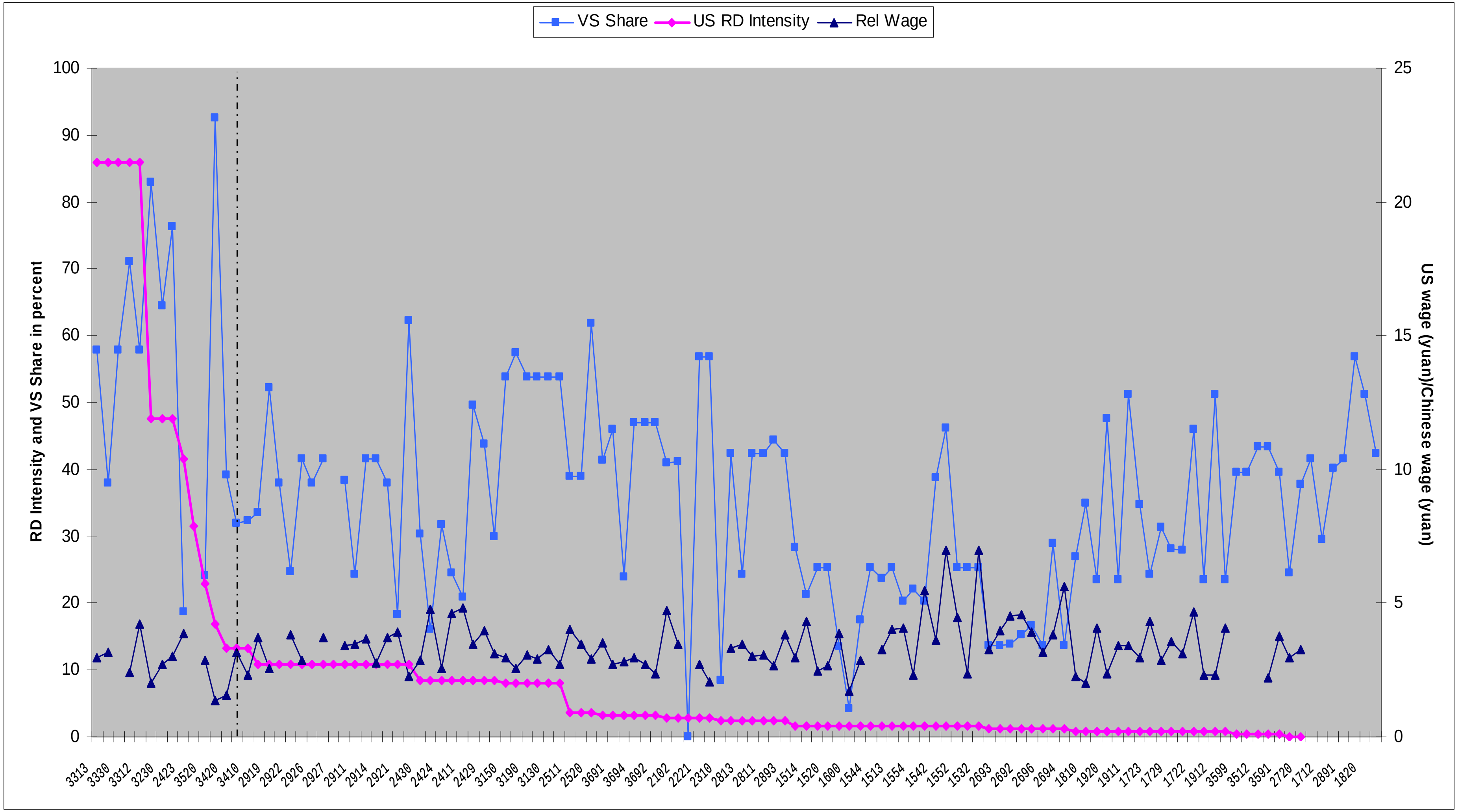


Table 1. Sector Descriptive Statistics by RD Intensity (mean values), 2002

| ***Sectors Grouped by RD Intensity*** | **(1) US RD Intensity** | **(2) Relative Wage** | **(3) VS Share** | **(4) Processing VS Share** | **(5) Processing Export Share** | **(6) FIE Share of Processing Exports** | **(7) FFE Share of FIE Processing Exports** | **(8) P & A Share of Processing Exports** |
|---|---|---|---|---|---|---|---|---|
| **>20%** | **21.50** | 3.19 | 56.47 | 79.72 | 0.71 | 0.71 | 0.24 | 0.29 |
| **10-20%** | **10.80** | 2.91 | 60.61 | 76.76 | 0.61 | 0.69 | 0.60 | 0.23 |
| **4-8%** | **3.96** | 2.25 | 44.02 | 75.22 | 0.52 | 0.70 | 0.34 | 0.08 |
| **1-3%** | **2.39** | 3.37 | 39.55 | 72.59 | 0.40 | 0.70 | 0.35 | 0.15 |
| **<1%** | **0.42** | 3.44 | 31.34 | 66.57 | 0.38 | 0.68 | 0.40 | 0.22 |
| **All Sectors** | 2.47 | 3.33 | 36.17 | 69.44 | 0.42 | 0.69 | 0.39 | 0.20 |

Table 2. The Determinants of VS Share in Chinese 2002 Exports, by Sector

| *Dependent var: VS Share* | Equation (3) GLS | Equation (6) GLS |
|---|---|---|
| **Processing VS Share** | **0.21****<br>**(4.72)** | |
| **Processing Export Share** | **0.44****<br>**(4.38)** | |
| **ln US R&D Intensity** | | **-8.26****<br>**(-3.61)** |
| **ln Relative Wage** | | **-3.96**<br>**(-0.54)** |
| **ln US RD Intensity * FIE Share of Processing Exports** | | **9.28****<br>**(2.87)** |
| **Constant** | **-11.75**<br>**(-1.65)** | **28.67****<br>**(3.10)** |
| *Industry effects* | yes | yes |
| *Clustering* | yes | yes |
| **Obs** | **112** | **100** |
| **$R^2$** | **0.87** | **0.80** |
| **Root MSE** | **6.75** | **8.39** |

** and * indicate significance at the 1% and 5% levels, respectively.

**Table 3. The Determinants of VS Share in Chinese 2002 Exports: Two Stage Decision**

| | (6)<br>IV First Stage<br>(t-statistics) | (6)<br>IV Second Stage<br>(z-statistics) |
|---|---|---|
| ***Dependent Variable*** | ***Processing Export Share*** | ***VS Share*** |
| **ln US R&D Intensity** | **-18.21****<br>**(-4.49)** | **2.32***<br>**(2.36)** |
| **ln Relative Wage** | **-31.44****<br>**(-3.09)** | **3.46**<br>**(0.56)** |
| **ln US RD Intensity * FIE Share of Processing Exports** | **26.38***<br>**(2.47)** | **-** |
| **Instrument: Processing Export Share** | **-** | **0.56****<br>**(7.68)** |
| **Constant** | **0.70****<br>**(4.97)** | **9.46**<br>**(1.00)** |
| ***Industry Effects*** | | |
| ***Clustering*** | | |
| ***Obs*** | ***100*** | ***100*** |
| $R^2$ | ***0.67*** | ***0.48*** |
| ***F-statistic*** | ***27.22**** | ***-*** |
| ***Root MSE*** | ***0.17*** | ***11.77*** |
| ***Wald*** $X^2$ | ***-*** | ***118.60**** |

** and * indicate significance at the 1% and 5% levels, respectively.

# 中国高技术产业的国际分工地位分析

## ——以浙江平湖光机电产业集群为例

黄先海　杨高举　陆菁

（浙江大学经济学院）

**摘　要：**本文以浙江平湖光机电产业集群为例，分析了中国高技术产业在国际分工中的地位。研究认为，平湖光机电产业集群是一种典型的中国高技术产业“外源型产业集群成长模式”，其基本的运行机理是：政府引导下的外资驱动—→本土企业学习跟进—→政府搭建公共技术创新平台—→外资企业与本土企业互动发展—→产业集群成长壮大。光机电产业集群发展的初始推动力是政府，主要引擎是外资，持续推动力是公共技术平台的构建与产业配套能力。通过对比分析发现，平湖光机电产业集群中企业的表现优于全国平均水平，但和其他发达国家相比，平均增加值率和单位产品售价偏低，进口中间投入品比例较高，这表明平湖光机电产业集群的发展在全国处于较为领先的地位，但在国际分工中尚处于组装加工的低端生产环节。

**关键词：**高技术　国际分工　光机电产业　产业集群

## 一、引言

根据比较优势理论，作为拥有众多低技术水平劳动力的最大发展中国家，生产并出口高技术产品似乎并不应该是中国的强项，然而自上世纪 90 年代以来，中国的高技术产品出口快速增长(如图 1)，至 2007 年中国高技术制造业的规模和产品出口总额都已位居世界第 2 位[1]。学者们认为这主要是由于全球生产的片段化和产品内分工的发展，大量的跨国企业将其组装加工阶段的生产转移到劳动力资源丰富且低廉的发展中国家的结果(Lall，2000；Mani, 2000; Mayer et al., 2002；Branstetter and Lardy, 2006；Srholec, 2007)。然而从微观具体的区域来讲，中国的一个个产业或产业集群是依靠什么机制嵌入到全球高技术产业链当中，又在国际分工中扮演着怎样的角色，需要通过具体的案例分析才能作出深入而具体的解答，也只有通过这些个案的研究，才能从中总结出中国高技术产业发展的一般规律，从而为与中国类似的后发国家和地区的发展提供经验借鉴。因此我们选择浙江省平湖市这个早在 12 世纪的南宋就开辟了通往阿拉伯和东南亚的国际远洋航线的县级市作为研究的典型个案，对其光机电产业集群从无到有、从小到大的发展过程进行分析。

平湖的光机电产业从 1999 年起步，经过最近 10 年的发展，不仅成为了全省县级市中最大的日商投资基地，而且在利用外资发展光机电产业集群方面走在了全国的前列，是浙江省唯一的光机电高新技术特色产业基地。让人感兴趣的问题就是，平湖这个曾经以服装业为主导的县级市，其光机电产业如何能够在短短的 10 年间取得如此快速的进步？其核心的推动力是什么？其光机电产业在全球价值链和产业链中处于怎样的地位？其发展对其他地区有何借鉴意义？王立军

[1] http://www.gov.cn/wszb/zhibo156/content_762801.htm

(2006)认为平湖的外生型的光机电产业集群的形成和发展，主要是靠当地政府的招商引资和专业化服务推动，这无疑指出了平湖光机电产业集群形成和发展的重要因素。但对于平湖的研究仍然有几个问题有待深入考察，一是平湖光机电产业集群形成的原动力是什么，二是平湖光机电产业集群在国际分工中处于怎样的地位，三是对平湖的研究缺乏基于企业实证调研的第一手资料的分析。本文研究的重点正是从这些方面入手，通过对平湖 120 家光机电企业的实地调研分析，试图进一步丰富对后发国家和地区如何通过嵌入全球高技术产业链并逐步实现升级的研究。

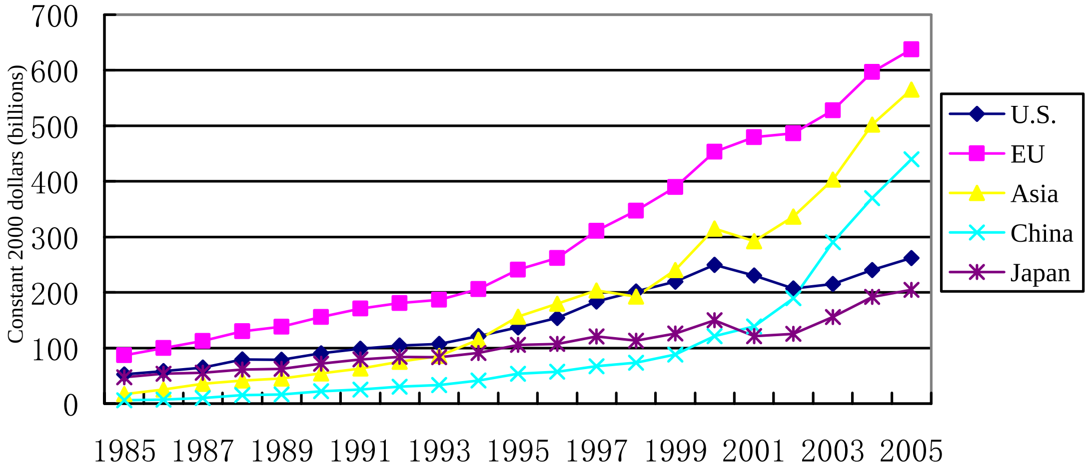



图 1 **Export volume of high-technology manufactures, by region/ country: 1985–2005**

EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Global Insight, Inc., World Industry Service database, special tabulations. Science and Engineering Indicators 2008

全文其余的基本安排如下：第二部分介绍平湖光机电产业集群的发展概况，并对调研情况进行说明；第三部分基于调研数据分析平湖光机电产业集群形成与发展的动力源；第四部分通过跨国比较来分析平湖光机电产业集群的国际分工地位；第五部分为总结。

## 二、平湖光机电产业集群概况及调研设计

### 1、平湖光机电产业集群概况

浙江平湖，作为良渚文化的发祥地之一，自古以来就有“金平湖”的美称，是一个经济、社会、文化发达的地区，属杭嘉湖平原、濒临杭州湾，依山傍海，河网纵横，位处于上海、杭州、苏州、宁波四大城市组成的菱形对角线交点，距四城市均在 100 公里左右，区位优势得天独厚。光电产业在平湖的集聚最早要追溯到日本芝浦制作所与平湖之间的加工贸易[2]，1993 年芝浦委托平湖一家地方国营电子企业加工“变压器”，由于与该企业的合作很顺利，芝浦 1995 年在平湖投资了 20 万美元与该企业成立了一家中日合资企业。其后，日本电产(NIDEC)在

[2] 日本芝浦制作所是一家世界上重要的马达生产企业，其许多类型的马达产品国际市场占有率都在 50%以上。

1998 年收购了日本芝浦制作所。同年，日本电产株式会社的董事长永守重信到平湖对日本电产芝浦(浙江)有限公司进行投资考察和签约的时候，地方政府的大力支持坚定了他在平湖的投资决心，由此拉开了平湖光机电产业高速发展的序幕。

自日本电产 1999 年投资之后，平湖的光机电产业从零起步，到 2007 年全市光机电规模企业工业总产值达 124.57 亿元，占全市规模以上工业比例达 22.72%(表 1)。目前全市拥有光机电企业 128 家，其中国家火炬计划重点高新技术企业 2 家、省高新技术企业 15 家，嘉兴市级高新技术企业 23 家，全市工业总产值超亿元的企业达 17 家。基地内光机电企业已列入省高新技术产业化项目 13 项，2007 年全市拥有光机电省级研发中心 2 家（正业智能机器省级高新技术研发中心、平湖金刚石模具高新技术研发中心），嘉兴市级研发中心 5 家。有五家企业被国家科技部火炬中心列入基地重点骨干企业（关东辰美电子（平湖）有限公司、浙江汉脑数码科技有限公司、平湖美嘉保温容器工业有限公司、日本电产科宝（浙江）有限公司、嘉兴市恒业电子有限公司）。光机电企业主要以平湖市经济技术开发区(当湖镇)为核心，向外扩散到钟埭、林埭和黄姑等三个乡镇(图 1)。此外，该集群的金融服务和劳动力供给等又延伸到了上海和浙西、安徽等地。通过平湖光机电产业集群结构图可以看出，促使平湖光机电产业形成的主要力量来源于经济开发区内的日资企业(见图 2)。

**表 1　2002-2007 年平湖光机电产业工业总产值情况表**

| 年　份 | 企业数 | 总产值（亿元） | 占工业比重% | 同比增长% |
|---|---|---|---|---|
| 2002 年 | 22 | 21.1 | 13.8 | 45 |
| 2003 年 | 65 | 40.2 | 17.9 | 85.2 |
| 2004 年 | 71 | 65.9 | 24.4 | 64 |
| 2005 年 | 91 | 78.6 | 19 | 21 |
| 2006 年 | 102 | 101.5 | 27.4 | 22.68 |
| 2007 年 | 120 | 124.57 | 22.72 | 21.9 |

资料来源：浙江平湖光机电产业基地网 http://www.zjgjd.com/index.asp。

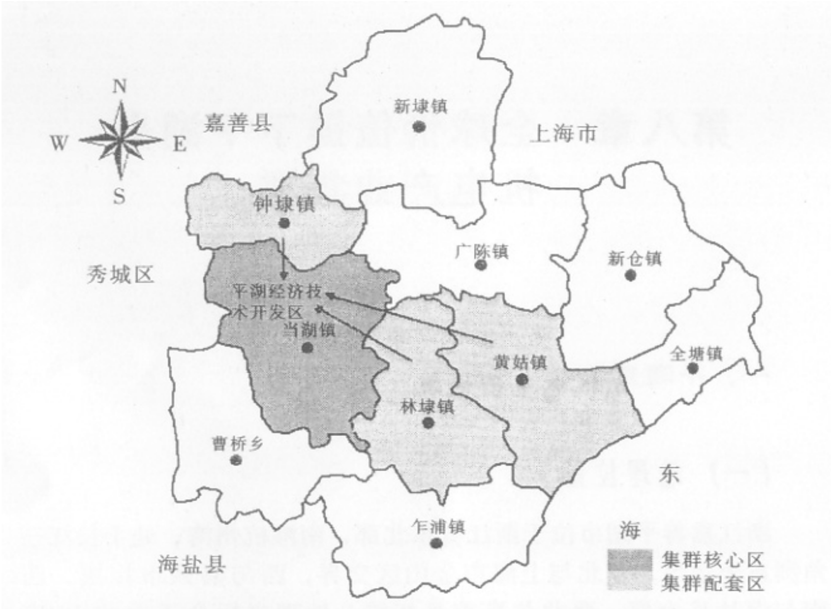



图 2 平湖光机电产业集群区位及地理范围

该基地光机电产品涉及数码相机快门、手机用摄像头、电子硬盘、MP3、光纤收发器、光纤分路器、流体动压精密轴承、微型电机、精密模具、光导纤维套管、数码相片冲印机、投影仪、精密测定仪器、电子零件传感器等高新技术产品。其中有很多企业的产品技术先进、竞争力强，在国际市场上占有相当份额。如日本电产(浙江)有限公司生产的笔记本电脑硬盘驱动主轴马达占国际市场的 70%，日本电产科宝(浙江)有限公司生产的手机震动马达占国际市场的 30%、照相机快门占国际市场的 70%，日本电产科宝电子(浙江)有限公司生产的多边形反光镜占国际市场的 80%，以及恩梯恩日本电产(浙江)有限公司生产的流体动压轴承、日本电产机器装置(浙江)有限公司生产的半导体检测设备、日本电产新宝(浙江)有限公司生产的变速器等，均属世界一流产品。

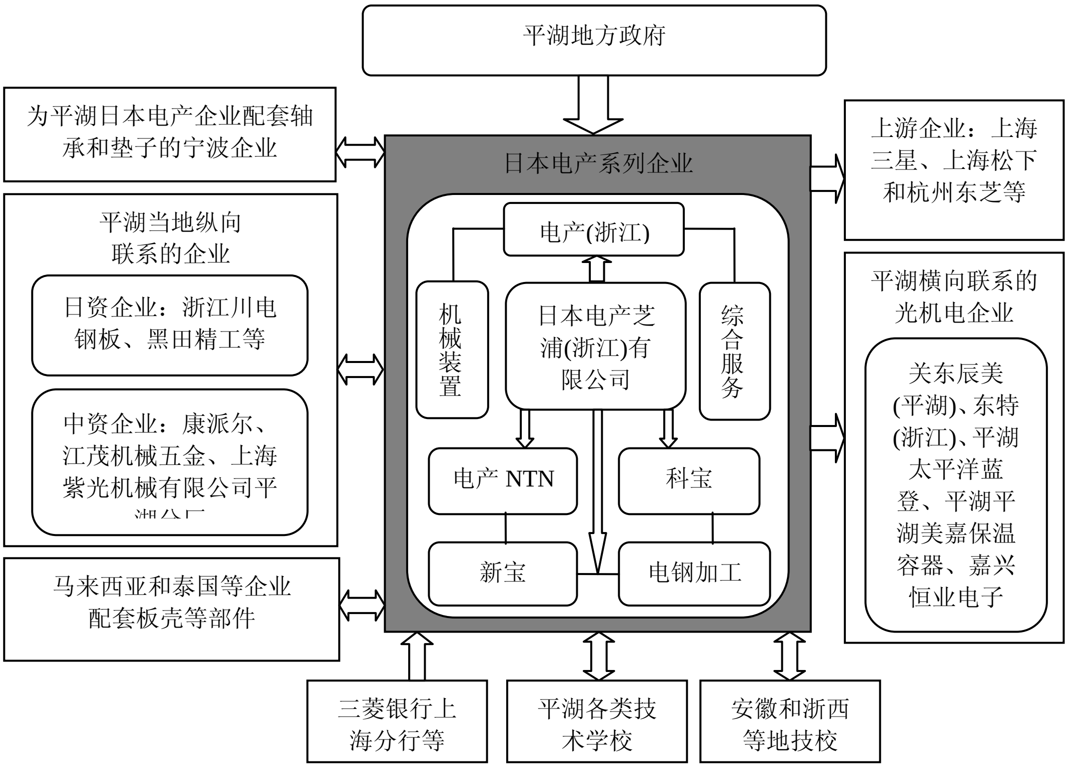



**图 3 平湖光机电产业集群结构图**

**2、研究设计**

我们首先收集了有关平湖公开资料，包括平湖的行政区划和地理区位，以及政府部门的经济社会统计数据和资料等，又通过与当地政府官员、行业协会成员以及企业家的前期访谈，以设计并完善我们的问卷。2009 年 6 月至 7 月，我们进行了正式的实地调研，主要走访了位于平湖经济技术开发区(当湖镇)的 108 家和位于钟埭镇、皇姑镇和林埭镇的 20 家光机电生产企业，调查先是和企业的主要管理层人员或负责人座谈，了解难以通过问卷获取的信息，然后请他们填写调查表。最终我们走访了平湖全部的 128 家光机电生产企业，获得了 120 份有效的调查问卷[3]，所访问的企业基本信息统计如下表 2 所示。

**表 2　调研企业的基本统计信息**

| 企业类型 | 所属行业 | 注册资本 | 年产值 | 职工数量 |
|---|---|---|---|---|
| 外商独资企业<br>38 (31.6%) | 电子信息<br>19 (15.8%) | 1000 万以上<br>44 (36.7%) | 1 亿以上<br>26 (21.7%) | 3000 以上<br>37 (30.8%) |
| 民营企业<br>56 (46.7%) | 光机电一体化<br>88 (73.3%) | 500-1000 万<br>50 (41.7%) | 5000-10000 万<br>47 (39.2) | 1000-3000<br>44 (36.7%) |
| 合资企业<br>22 18.3% | | 100-500 万<br>8 (9.6%) | 1000-5000 万<br>33 (27.5%) | 500-1000<br>12 (10%) |
| 其它 | 其它 | 100 万以下 | 1000 万以下 | 500 以下 |

[3] 据统计平湖市共有 128 家光机电生产企业，但通过实地调研发现其中 8 家企业的光机电产品产值很小，也不是企业的主导产品，对问卷中问题的回答难以满足研究需要，因此在研究中剔除这些样本。

| | | | | |
|---|---|---|---|---|
| 4 (3.4%) | 13 (10.9%) | 18 (15%) | 14 (11.7%) | 27 (22.5%) |

注：括号中为占总体的比例。本表并未反映调查表的全部信息。

## 三、平湖光机电产业集群形成与发展的主要推动力

一般认为促进产业集群形成的因素有自然资源、地理位置、规模经济、外贸性、知识外溢及交易成本等(曾咏梅，2006)。Porter(1998)指出产业集群演进的动力因素有：历史文化、需求刺激、上游产业或其他相关产业存在、新企业的创立、辅助机构、企业战略与结构、竞争和机遇。Brenner(2001)认为促进产业集群演进的动力因素有：人力资本、技术溢出、合作、公共意见、政府政策和风险资本。而 Saxenian(1996)通过对硅谷和 128 公路的对比研究则强调了分工、竞争和企业文化对产业集群成长的重要性。王发明、蔡宁(2009)通过对已有研究的总结认为，产业传统、地理位置、信任文化、创业氛围、政府政策和机遇是促使产业集群产生和发展的六大关键因素。

**表 3　不同时期企业选择在平湖投资的主要原因**

| 投资原因 / 设立年份 | 政府支持与服务的效能 | 优惠政策 | 地理区位便利 | 追随上下游企业 | 市场潜力 | 产业配套 |
|---|---|---|---|---|---|---|
| 1999-2001(20) | 9 (45%) | 5 (25%) | 3 (15%) | 2 (10%) | 0 (0%) | 1 (5%) |
| 2001-2004(51) | 16 (31.37%) | 7 (13.73%) | 5 (9.80%) | 5 (9.80%) | 8 (15.69%) | 10 (19.61%) |
| 2004-2007(49) | 10 (20.41%) | 7 (14.29%) | 7 (14.29%) | 6 (12.24%) | 8 (16.33%) | 11 (22.45%) |
| 2007-2008(13) | 2 (15.38%) | 2 (15.38%) | 1 (7.69%) | 2 (15.38%) | 4 (30.77%) | 7 (53.85%) |

注：括号中为占所在时期投资企业的比例。

已有研究基本上都将产业集群形成的初始推动力和形成之后促进产业集群发展的持续推动力等同起来，但平湖的例子却显示这两者可能是不同的。体现出这一差别的是不同企业对问卷中“选择在平湖投资的主要原因”的答案选择的差异，从表 3 可以看出，2004 年以前建立的企业选择的主要因素首先是“政府支持与服务的效能”，其次为“地理区位便利”以及“优惠政策”等；而那些在 2004 年之后设立的企业的选择主要是“产业配套”和“市场潜力”，这表明在满足地理区位要求的前提下，把是否靠近上下游企业、消费市场等产业发展的内生因素作为最重要的要素来考虑。因此，“外源型”产业集群刚开始出现尚未形成规模以前，吸引企业投资的主要因素是当地政府能否提供便捷高效的投资服务、有效落实相关的投资承诺，即企业力图避免因信息不对称带来的投资风险。但在产业集群形成规模之后，区内的各项投资优惠政策、配套措施、政府的诚信度都已成为显性信息，吸引企业投资的因素便转换为在当地投资的发展机遇和发展空间，以及相关产业的匹配状况。基于上述分析，我们把推动平湖光机电产业集群形成和促进其进一步发展的主要推动力分为两类：

### 1、初始推动力

在产业集群发展过程中，平湖市政府为平湖光机电产业集群作了很大的努力，制定了一系列特定的政策，有力地促进了平湖光机电产业集群的快速发展，可以说，平湖光机电集群形成与发展的初始推动力是平湖市政府。

(1)政府的热情支持引来了光机电的“种子”企业。平湖光机电产业集群，日电产芝浦（浙江）有限公司就是这样的“种子”企业，而芝浦落户平湖既有一

定的偶然性，更是平湖市政府积极努力的结果。1998 年，日本电产株式会社董事长永守重信赴平湖投资考察与签约时，受到平湖市的热情接待。永守重信董事长认为投资平湖并没有进行很好的前期论证，但地方政府的大力支持，坚定了他的投资决心。他也指出平湖的交通条件还是太差，从虹桥机场到平湖用了 4 个多小时，希望以后要有改善。次年永守重信再次光临平湖时，途经沪杭高速只用了 45 分钟。巨大的反差让永守重信董事长感觉到，平湖市政府是诚实可信的，平湖是日本电产株式会社可以长期合作与发展的地方。随后，日本电产株式会社陆续在平湖投资成立了一系列的独资与合资企业，并带动了关东美辰电子株式会社和东京特殊电线株式会社相继投资平湖。

(2)政府的专业化服务促进了光机电集群的快速成长。在日本电产芝浦（浙江）有限公司落户平湖之初，平湖光机电产业发展环境的众多方面远不如苏州工业园和昆山等地，但是平湖市政府通过专业化服务，如开办日语学校，为日资企业培训员工等，营造出适合光机电企业发展的产业环境，尤其是适合日资光机电企业发展的产业环境，吸引了众多光机电企业落户平湖。

**2、持续推动力**

在借助外力迈出第一步之后，平湖市结合本地实际把自主创新的重点放在了打造公共技术平台，提升本地光机电企业层次上。2003 年 8 月，平湖市成立了光机电高新技术特色产业促进中心和高新技术创业服务中心，为本地企业提供公共技术支撑。同时，建立高新技术产业发展专项资金，每年安排 1000 万元高新技术产业化专项资金，扶持本地光机电产业。政府科技投入的加大，激发了本地光机电企业的创新热情。如，嘉兴市恒业电子有限公司在得到市科技部门 50 多万元的项目资金后，于 2004 年成功开发出“小区集成抄表系统”; 浙江伴宇电子有限公司在得到科技部门 120 多万元的资金扶持后，则开发出了新款 MP3 和电子硬盘，并先后获得国家重点新产品计划和国家“火炬”计划的支持。

为了进一步增强自主创新能力，平湖市正在构筑公共科技创新服务平台。2003 年 7 月，该市与清华大学联合成立浙江清华长三角研究院平湖院区，创办了我国光机电领域的第一个研究中心——集成光学研究所，并正在筹建光纤传感实验室，主要从事集成光学技术和产品的研发及其产业化，研究院计划通过四到五年的努力，将研究所建设成为国内技术水平一流、在亚洲地区有重要影响、国际知名的集成光学研发基地。2004 年 6 月 21 日，平湖市又与中科院上海硅酸盐研究所签订了共建中科院嘉兴中心平湖无机非金属材料分中心的协议。同时，平湖天一公司与上海硅酸盐研究所总投资 4750 万元的“一体化半透明氧化铝灯管”高技术产业化合作项目正在实施。这些研发平台的先后建立，已经为平湖市引进了近 20 名博士、副高以上的高级科技人才，将为平湖光机电产业乃至整个高新技术产业提供源源不竭的发展动力，平湖市正在通过集成创新，引进、消化、吸收、再创新，实现产业结构的调整，探索依靠科技提高自主创新能力的路子。

这些本土企业的研发与创新，提高了其在平湖经济中的比重，带动了相关企业的发展从而产生了联动效应，也一定程度上减少了平湖发展对外资的依赖，更为重要的是，防范了平湖成为外商投资过程中的“飞地”，也即本土企业的发展使得整个产业集群即使外资撤出也不至于衰落。

## 四、平湖光机电产业集群在国际分工中的地位

张辉(2006)基于马达的基本生产流程(见下图 4)及其全球产业链和价值的分析，发现平湖光机电产业在全球价值链等级体系中处于低附加值的组装环节(如

图 5 所示)。我们通过对调研数据的分析得出的结论和张辉(2006)基本一致，但也有一些新的变化，主要是集群内民营企业有了较大发展，而且在研发投入方面比外资及合资企业表现要好。

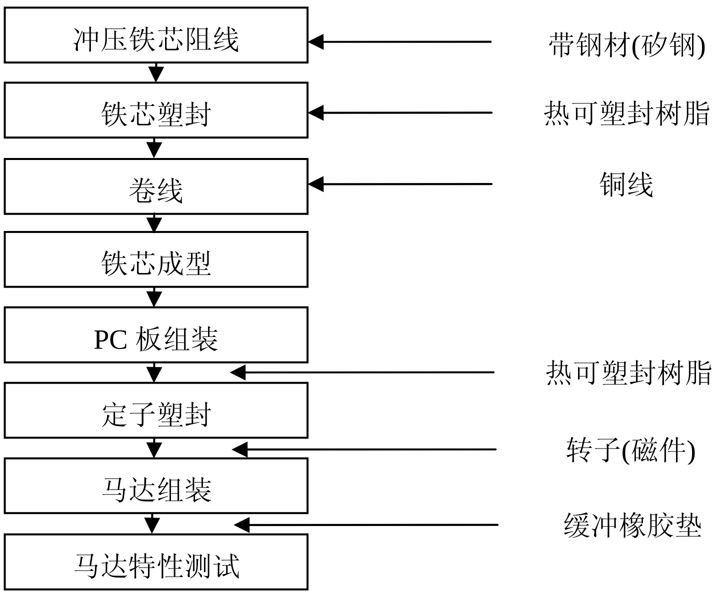



图 4 马达的基本生产流程和部件

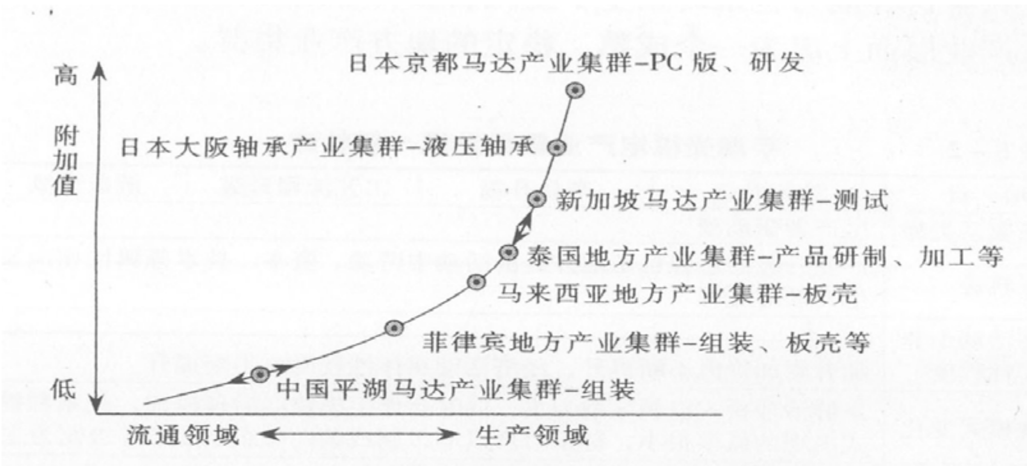



图 5 马达生产的全球价值链构成

资料来源：张辉(2006)第 215 页。

**1、调研数据分析**

在对平湖光机电产业集群形成与发展的动力进行分析之后，另一个需要探讨的问题是，作为浙江省唯一的光机电高新技术特色产业基地，而且在 2009 年 6 月被浙江省列为块状经济向现代产业集群转型升级的试点示范区，平湖光机电产业集群在国际分工中处于怎样的地位？其国际竞争力是否与其部分产品占据较高国际市场份额相匹配？黄先海、杨高举(2009)通过国内完全增加值率和劳动生

产率的跨国比较来确定一国产业在国际分工中的地位，认为该方法可避免“统计假象”问题引致的对一国产业国际分工地位的高估，但所采用的非竞争型投入产出法需要非竞争型投入产出表，因此无法对一国之内的特定区域产业的国际分工地位进行分析。我们沿着类似的思路，在调查表设置企业主要产品平均单价、直接增加值率、劳动生产率和进口的中间投入品所占比例，以及生产设备、产品设计、研发的来源和投入，产品主要销售渠道等内容的问题，通过企业对这些问题的回答来分析平湖光机电产业在国际分工中的地位。

由下表 4 可知，平湖光机电产业集群内企业总体的平均售价约为 180 元(约合 26 美元)，平均直接增加值率约为 48%，平均进口的中间投入品比例约为 28%，平均劳动生产率为 76821 元（约合 11240 美元），平均的 R&D 投入为 10%。具体来讲，外商独资企业的产品平均售价较高，约为 195 元，民营企业和其它类型企业产品售价最低，这可能是由于外资企业产品的技术含量较高，这和我们走访企业过程中了解到的信息相一致：如外资企业津上机床平均售价达几百万元，而为其做配套的民营企业恒业电子产品单价不超过百元；尽管外资企业产品售价较高，但其生产过程中产生的直接增加值占总产值的比例却在所有类型企业中最低，约为 32%，这和外资企业的生产使用了最多的进口中间投入相一致(比例约为 45%)；从研发投入来看，民营企业最高约为 12%，合资企业次之约为 11%，外商独资企业最低，仅约为 6%。综合这些信息可发现，尽管外商独资企业的进入带动了平湖光机电产业集群的形成与发展，但外资企业更多的只是将平湖作为加工制造的基地，很少进行研发、设计等高附加值的活动。因此可初步判断平湖光机电产业集群在国际分工中并不具有很大的优势，在国际贸易中直接或间接获得的利益相对有限。

**表 4　调研企业 2008 年的生产状况之一**

| 项目 | 平均单价(元/美元) | 直接增加值率(%) | 劳动生产率(元/美元) | 进口的中间投入品比例(%) | R&D 投入比例(%) |
|---|---|---|---|---|---|
| 总体平均 | 180.39 (26.39) | 47.54% | 76821 (11240) | 27.85% | 10.11% |
| 外商独资企业 | 195.44 (28.60) | 44.96% | 74907 (10960) | 44.55% | 6.37% |
| 民营企业 | 175.28 (25.65) | 51.73% | 75249 (11010) | 16.87% | 12.03% |
| 合资企业 | 178.5 (26.12) | 47.05% | 73199 (10710) | 31.09% | 11.3% |
| 其他 | 172.27 (25.21) | 46.43% | 75044 (10980) | 18.92% | 10.75% |

注：括号中为按当年汇率计算的美元值。

表 5 的信息进一步证实了这一判断：在平湖的企业中，平均约有 79%的企业从事最终产品的组装、装配，以及成品检测(88%)，接近三分之一的企业从事一般零件加工(32%)，仅有约 5%的企业从事核心部件的加工。而且，在三类企业中，内资的民营企业比外商独资企业、合资企业更多地从事核心及一般零部件加工，较少从事组装、装配等工序的生产；

61%的企业的生产设备通过从国外进口，国内购买的比例约为 24%，自主研发的约为 13%，这其中外商独资企业对进口的依赖程度最高(81%)，合资企业次之(55%)，民营企业最低为 48%，而且约有 15%和 30%的民营企业和合资企业的生产设备来自于自主研发和国内购买；在产品的设计和研发方面，仅有约 28%的外商独资企业依靠自主研发或设计，大部分(约 71%) 依赖于国外企业(其中大部

分应该是其国外母公司)，合资企业也基本类似，自主研发和进口的比例分别约为22%和60%，而民营企业中则有超过一半的企业进行产品的自主研发(约57%)、超过 1/5 的企业通过向国内企业购买(约 22%)；

在产品的销售方面，整体平均的产品出口和国内销售比重分别为 52.24%、47.76%，其中国内销售份额中有 36.7%是为了配套平湖企业的生产)。三类企业中，外商独资企业和合资企业产品出口的比例最高，分别约占其产出的 69.56%和 67.81%，而民营企业产品出口的比例仅约为 19.34%，但民营企业产品在国内销售的比例最高，达到了 80.66%(其中近 60%用于配套平湖企业生产)，而外资企业和合资企业的内销比例则基本在 30%左右(其中约 1/4 用于配套平湖企业生产)。

因此可见，从总体上来讲，平湖光机电产业集群中的企业所从事的生产阶段主要是组装、装配等工序、生产所需设备大多需要进口、产品设计和研发多来源于国外、产品主要在国内销售（而且有较大比例是为了配套平湖其它企业的生产），平湖光机电产业集群中的企业以加工生产为主，产品的研发和创新程度较低，因而生产过程的附加值也低，在国际分工中自然难以取得很强的优势地位。尽管部分平湖的企业的产品技术水平较为先进，占据了世界市场较大份额，如日本电产恩梯恩等，但这只是少数企业的情况。

**表 5 调研企业 2008 年的生产状况之二**

<table>
<tr><th>项目</th><th>主要从事的<br>生产工序</th><th>生产设备来源</th><th>产品设计、<br>研发来源</th><th>产品主要<br>销售渠道</th></tr>
<tr><td rowspan="4">总体平均</td><td>核心部件加工 5.16%</td><td>进口 61.45%</td><td>企业内部 28.3%</td><td>出口 52.24%</td></tr>
<tr><td>一般零件加工 32.50%</td><td>国内购买 23.51%</td><td>国内企业 8.9%</td><td rowspan="3">国内销售 47.76%(其中 36.7%配套平湖企业生产)</td></tr>
<tr><td>最终组装、装配 79.28%</td><td>自主研发 13.44%</td><td>国外企业 70.51%</td></tr>
<tr><td>成品检测 88.12%</td><td>其它 3.61%</td><td>其它 0.29%</td></tr>
<tr><td rowspan="4">外商独资企业</td><td>核心部件加工 4.52%</td><td>进口 81.45%</td><td>企业内部 28.3%</td><td>出口 69.56%</td></tr>
<tr><td>一般零件加工 17.57%</td><td>国内购买 5.7%</td><td>国内企业 8.9%</td><td rowspan="3">国内销售 30.44%(其中 24.5%配套平湖企业生产)</td></tr>
<tr><td>最终组装、装配 78.4%</td><td>自主研发 10.03%</td><td>国外企业 70.51%</td></tr>
<tr><td>成品检测 87.1%</td><td>其它 2.82%</td><td>其它 0.29%</td></tr>
<tr><td rowspan="4">民营企业</td><td>核心部件加工 8.79%</td><td>进口 47.9%</td><td>企业内部 56.77%</td><td>出口 19.34%</td></tr>
<tr><td>一般零件加工 75.5%</td><td>国内购买 33.81%</td><td>国内企业 21.9%</td><td rowspan="3">国内销售 80.66%(其中 59.49%配套平湖企业生产)</td></tr>
<tr><td>最终组装、装配 70.45%</td><td>自主研发 13.3%</td><td>国外企业 13.4%</td></tr>
<tr><td>成品检测 82.26%</td><td>其它 4.99%</td><td>其它 7.93%</td></tr>
<tr><td rowspan="4">合资企业</td><td>核心部件加工 2.18%</td><td>进口 55%</td><td>企业内部 22.09%</td><td>出口 67.81%</td></tr>
<tr><td>一般零件加工 4.44%</td><td>国内购买 31.01%</td><td>国内企业 9.4%</td><td rowspan="3">国内销售 32.19%(其中26.12%配套平湖企业生产)</td></tr>
<tr><td>最终组装、装配 89%</td><td>自主研发 17%</td><td>国外企业 60.12%</td></tr>
<tr><td>成品检测 95%</td><td>其它 3.01%</td><td>其它 8.39%</td></tr>
</table>

注：因为同一企业可能从事多项工序生产，因此“主要从事工序”中各项之和不是 100%。

**2、国际比较**

为了更准确地把握平湖光机电产业在国际分工中的地位，我们将平湖的调研数据和其他国家的数据进行对比。我们通过OECD. Stat数据库[4]取得了 7 个国家 2000 和 2005 年的相关数据，计算出相关的系数，具体见下表 6 所示。就表 4 和表 5 的数据进行对比：从单位产品平均售价来看，平湖光机电产业集群的产品售价要高于中国总体平均值[5]，和德国的数据较为接近，与日本及美国相比则有较大差距[6]，但高于其他国家的水平；从直接增加值率来看，平湖企业的表现也优于全国的平均值，与其他发达国家的差距不大，在劳动生产率方面，平湖企业的数据和全国的平均值基本持平，但和德国、日本及美国相比有很大差距，同样在研发投入方面也有类似的结果。

通过对比可发现，平湖光机电产业集群中企业的表现优于全国平均水平，但和其他发达国家相比，平均增加值率和单位产品售价偏低，进口中间投入品比例较高。这表明平湖光机电产业集群的发展在全国处于较为领先的地位，但在国际贸易中所能获得的利益并不多，在国际分工中处于组装加工的初级阶段。

表 6　不同国家高技术产业生产状况

| 年度 | 国家 | 平均单价(美元) | 直接增加值率(%) | 劳动生产率(千美元) | 中间投入品的进口比例(%) | R&D 投入比例(%) |
|---|---|---|---|---|---|---|
| 2000 | 巴西 | 12.57 | 48.91 | - | 58.44 | |
| | 中国 | 10.35 | 43.53 | 10.57 | 27.23 | |
| | 德国 | 17.24 | 46.76 | 51.64 | 67.68 | |
| | 印度 | 7.84 | 53.76 | 0.00 | 13.15 | |
| | 日本 | 42.98 | 46.43 | 75.60 | 25.94 | |
| | 韩国 | - | 47.47 | 20.21 | 57.96 | |
| | 美国 | 141.16 | 46.50 | 71.83 | 42.22 | |
| 2005 | 巴西 | 8.73 | 47.42 | - | 79.13 | |
| | 中国 | 20.92 | 41.32 | 10.85 | 55.39 | |
| | 德国 | 26.89 | 45.02 | 60.49 | 78.87 | 17.7(2004) |
| | 印度 | 20.63 | - | 0.00 | - | |
| | 日本 | 38.00 | 51.43 | 48.95 | 45.43 | 30.1(2003) |
| | 韩国 | - | - | - | - | 50%(2004) |
| | 美国 | 166.43 | 46.18 | 65.97 | 52.54 | 23%(2004) |

注：“R&D 投入比例”来源于 SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/ stat-ana/stats/eas_ anb.htm, accessed 22 May 2007. *Science and Engineering Indicators 2008*，其余均为作者根据 OECD.Stat 的数据计算而得。

# 五、平湖案例的经验借鉴

[4] www.OECD. Stat.org.
[5] 当然，表 3 中是平湖企业 2008 年的数据，而表 5 是 2005 年的数据，二者不完全可比，但在
[6] 美国的高技术产品单价之所以特别高，和美元与其他货币之间的汇率有一定关系。

**1、下游产业布局的调整是产业集群形成的条件**

作为国际上7家生产马达的著名企业之一，日本电产的下游企业正在源源不断地转移到长江三角洲地区(Yangtze Delta Region)，例如，中国台湾地区众多电子企业和西捷(Seagate Technology)、迈拓(Maxtor)、西部数据(Western Digital )、日立、东芝、富士通、三星等企业的制造环节都在向该地区转移，其中东芝和西捷分别在杭州和无锡投产，迈拓进入苏州进行生产，三星则人驻上海。随着这些个人电脑行业中大批日本电产的下游企业生产基地向长江三角洲地区的转移，作为上游零部件生产企业的日本电产也不得不跟进，以靠近这些需求商。这就为日本电产向平湖投资进而形成光机电产业集群提供了难得的机遇。

**2、区位优势和成本优势是产业集聚的基础**

在国外厂商向中国转移生产的过程中，具备地理区位优势和成本优势的地区往往成为外商投资的首选地，从而使这些地区成为产业发展的先行地。日本电产这样的零部件企业与下游企业的空间距离一般最好布置在 2 小时车程左右的空间范围。根据Porter (2006)的研究，通过将厂址设在顾客附近，企业可以提供竞争对手无法比拟的供应速度和用户定制的服务。换句话就是以无锡、苏州、杭州和上海等地为中心，2小时陆路车程为半径所做的圆形则是该类企业空间选址的硬约束。同时要求投资地区的商务成本要低，尽管苏州、无锡的基础设施很完善，但成本也很高，而电子零部件属于薄利多销的产品，对成本很敏感，因此选择周边地区成为必然。而平湖完全满足这些条件，因此具备吸引外商投资的良好基础。

**3、"种子"企业落户带动上游企业的转移和当地配套企业的出现**

在日本电产入驻平湖后，作为日本电产上游的企业，总部在大阪的日本三大轴承生产厂家之一的NTN等企业也不得不纷纷跟进。这些企业又从日本已经带来和即将吸引很多相关企业，同时在国内也涌现出一批配套供应商，如此才使平湖光机电产业集群逐渐发展了起来。在"日本电产"的成功带动下，目前已经有12家外资企业落户平湖，总投资4.1亿美元。这些企业生产的数码相机快门、手机用摄像头、微型精密电机、液体动压轴承等产品均达到国际一流水平，并且绝大部分出口。

平湖市政府在吸引日本电产芝浦（浙江）有限公司落户平湖时并没有对其产生过高的期望，但从平湖光机电集群的形成过程来看，这家企业在平湖光机电产业集群发展过程中发挥了重要的示范带动作用，推进了产业集群的快速成型。可见，政府在培育产业集群的过程中，吸引那些具有强大带动作用的"种子"企业落户集群，至关重要。

**4、政府有效的支持与服务体系，为产业集群的发展提供了有力的保障**

日本电产投资平湖，与当地政府信守承诺、落实支持政策密不可分。当初平湖市政府落实改善交通的承诺促使日电产决定投资平湖，并带动关东美辰电子株式会社和东京特殊电线株式会社等相继投资平湖。平湖市成立的光机电高新技术特色产业促进中心和高新技术创业服务中心，与清华大学联合成立浙江清华长三角研究院平湖院区，以及建立高新技术产业发展专项资金、每年安排1000万元高新技术产业化专项资金等一系列扶植政策，为区内企业的科技研发与合作创新提供了良好的平台和支持，促使企业通过引进、消化、吸收、再集成创新实现产业结构的调整和升级。

平湖市政府建设产业集群支持体系的主要经验有：

一是完善基础设施建设，把平湖建设成上海的卫星城。1999 年初，平湖市政府在沪杭高速行将开通之前，就建设好连接沪杭高速公路的快速干道，使从上

海虹桥机场至平湖的车程由 4 小时缩短为 45 分钟。同时，平湖市政府投入巨资进行城市改造，完善城市的基础设施，美化平湖的环境，让一些光机电企业感觉到平湖如同上海的卫星城，可以把生产基地落户平湖而将一些研发与服务部门设在上海，通过两地的便捷交通，既能享受大城市的商务环境又能大大降低企业的生产成本。

二是营造适合外商居住的环境，强化对日资企业的吸引力。面对日资光机电企业纷纷落户平湖的局面，平湖市政府在平湖市中心地段修建了日本一条街，建设了一批适合日本人居住的高级别墅，在平湖有线电视的新闻中加设日语字幕，在职业中专内增设了日语班，并要求政府相关官员学会日语的日常用语，努力营造适合日本人工作与居住的环境，让日资企业有一个融洽的生活、生产环境。

三是相关政府部门围绕光机电产业的发展，提供专业化服务，共同营造良好的光机电产业环境。为了促进光机电产业的发展，平湖市相关部门都主动提供行之有效的专业化服务，如发展计划局制定了平湖光机电产业发展规划，出台了光机电产业发展政策；科技局制定了更为细致的平湖光机电省级高新技术特色产业基地发展规划，并组建了光机电产业促进中心和光机电测试中心，同时积极为光机电企业申报各种科技项目；劳动人事局针对平湖光机电技术员工短缺的局面，一方面在本地举办培训班，培训光机电员工；另一方面，赴江苏、安徽、山西、陕西等地的职业中专学校联合办学，招揽人才；人事局为来平湖工作的日语与光机电专业的中高级人才大开绿灯；平湖开发区管委会更是提供全方位的服务，从开发区基础设施建设、廉价配套职工宿舍到代办各种证件，甚至协助办理出口退税工作，并将在园区内建设光机电创业中心。

**5、中国典型的外源型高技术产业集群成长模式**

从平湖光机电产业集群形成发展的过程中我们可以总结出这样一个发展模式：在政府推动下引进外资，启动了产业发展的“引擎”，本土企业通过为外资企业提供配套，积累起资本、技术及管理经验，在产业集群发展到一定规模时，当地政府通过搭建公共研发和创新的平台，推动本土企业的研发与创新，实现外资企业与本土企业互动发展，从而带动产业集群成长壮大。这种模式正是中国的外源型高技术产业集群成长的典范。

总体而言，平湖是抓住发达国家跨国公司生产基地向中国转移的机遇，成功嵌入到跨国公司全球产业链和价值链之中的典型案例，是中国的外源型高技术产业集群成长的典范，也是中国沿海地区产业发展的一个缩影。但通过我们的研究也发现，尽管平湖的光机电企业被称为高技术产业，每年的产值也很高，产品占世界市场的份额很大，但正如前文的分析所示，集群内的企业大多是跨国公司的加工组装基地，研发和设计等附加值高的生产活动很少。因此，如何通过促进集群内企业提高研发和创新的投入，通过产品和产业的升级来提升其在国际贸易中的获利能力以及在国际分工中的地位，是与平湖类似的产业集群亟待解决的重大课题，而这也正是浙江乃至全中国由制造业大国向制造业强国跨越的重点。

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# 附表:　　　　高 新 技 术 企 业 调 查 表

（所有涉及金额的单位为万元人民币）

| | | | | | |
|---|---|---|---|---|---|
| 基本信息 | 注册时间 | | 注册资本 | | |
| | 场地总面积 | | 联系电话 | | |
| | 企业属于 | A 国家火炬计划重点高新技术企业；B 省高新技术企业；C 嘉兴市级高新技术企业 | | | |
| | 企业类型_ | 1.国有；2.集体；3.私营；4.联营；5.股份制；6.合资；7.外资；8.与港澳台合资；9.港澳台独资；10.其他 | | | |
| | 所属行业 | 1.电子信息；2.新材料；3.生物医药；4.光机电一体化；5.环保；6.新能源；7.其它 | | | |
| 经济指标及产品情况 | | 2005 年 | 2006 年 | 2007 年 | 2008 年 |
| | 主要产品年产值 | | | | |
| | 主要产品年产量 | | | | |
| | 产值中增加值的比例 | | | | |
| | 出口总额(万美元) | | | | |
| | 主要原材料、中间投入品价值(万元) | ________其中<br>进口________ | ________其中<br>进口________ | ________其中<br>进口________ | ________其中<br>进口________ |
| | 产品市场占有率 | 国际市场______<br>国内市场______ | 国际市场______<br>国内市场______ | 国际市场______<br>国内市场______ | 国际市场______<br>国内市场______ |
| | 生产设备主要来源 | A 进口;B 国内购买;C 自主研发;D 其它 | 产品设计、研发的来源(　) | A 企业内部;B 国内企业;C 国外企业;D 其它 | |
| | 产品主要销售渠道 | 出口_____%;；国内销售_____%(其配套平湖企业生产_____%) | | | |
| | 从事的主要生产工序 | A 核心部件加工; B 一般零件加工;C 最终组装、装配;D 成品检测 | | | |
| 科技活动 | | 2005 年 | 2006 年 | 2007 年 | 2008 年 |
| | 研发人员(人) | | | | |
| | 年研发投入(万元) | | | | |
| 发展情况 | 选择在平湖投资的主要原因 | A 政府服务高效便捷 B 优惠政策 C 地理区位便利 D 追随上下游企业 E 利用平湖的资源 F 发现新的市场机遇 G 区内配套产业齐全 H 其它__________ | | | |
| | 发展过程中最困难的问题 | A 融资困难；B 人才缺乏；C 企业负担过重；D 面临环保、产业政策调整等压力 | | | |

# China's High-tech Industry in the International Division of Labor and Its Industrial Upgrading Strategies: A Case Study of the IC Industry

Ling Chen, Lan Xue
（School of Public Policy and Management, Tsinghua University）

ABSTRACT: The value chain of Integrated Circuit (IC) industry is composed of three segments including IC design, IC manufacturing, and packaging and testing. First, this paper analyzes the position of China's IC industry on international division of labor by exploring the industry scale, technology level and value added of three segments of China's IC industry and comparing those with their counterparts of the international IC industry. Secondly, based on production factors, technological features and investment scales of the three segments, the paper explains how the international IC industry is gradually migrating into China. The role of internal factors that have led to such transfer is also explored. Finally, the upgrading strategies and technology sources of those segments are also presented. The paper concludes that China's high-tech industries are located at the low end of the international value-train and are moving towards the intermediate and high ends. Policy suggestions are also included on how to enhance the competitiveness and indigenous innovation capacities of the industry.

## I. Introduction

With the accelerated development of economic globalization since the 1990s, the high-tech industry has also evolved from an industry concentrated in a few developed countries into a global production network with clear international division of labor for different countries. Especially in recent years, the migration of the high-tech industry into China, represented by the information industry, the aircraft manufacturing industry and the integrated circuit industry, has changed China into a manufacturing workshop of high-tech products. As a result, China has seen a continuous rise in its export of high-tech products which has generated concerns, and from time to time, trade sanctions, in the US and other developed countries. This phenomenon raises a set of questions: what are the forces that shape the international division of labor of different countries in the global production network? Does the relative position of a country in the international value-added chain embody the national industrial competitiveness in the international market? What is the position of China's high-tech industry in the global value chain? It is obviously too simple to answer these questions based on a country's output of high-tech products or its international trade volume. Using China's integrated circuit (IC) industry as an example, this study aims at exploring the international division of labor in IC industry, analyzing its value added and technological capabilities of each production stage, and investigating the forces that shape the pattern of industrial ecology at each stage of the value chain, with a particular focus on China.

**The Value Chain and Industrial Upgrade in IC industry**

The value chain refers to a series of production stages from raw materials supply to manufacturing and processing, and to marketing and product services. It also includes supporting sectors including research and development, human resources, strategic planning, and etc., all within a vertically integrated enterprise (Michael Porter, *Competitive Advantage*, 1985). Along with the development of the international outsourcing business and the globalization of the manufacturing network, the value chain has broken the boundary of one single enterprise and evolved into a global value chain (Gereffi, Zhang Hui). Industrial upgrade usually take place in four forms, namely process upgrade, product upgrade, functional upgrade and the overall upgrade of the value chain (Humphrey & Schmitz, 2000). Through enhancing the internal efficiency and improving the process technology, an enterprise realizes its process upgrade; through launching new products or improving outdated ones, it realizes the product upgrade; through switching to high value-added stages (such developing from manufacturers to designers or technology providers) by developing new capabilities and core competence, it realizes functional upgrade; and finally, when the value chain has completely upgraded to a new one, it realizes the overall industrial upgrade, such as the transformation of the traditional pharmaceutical industry into the bio-pharmaceutical one.

Previous researches have found that international division of labor in high-tech industry typically start with labor intensive and low value-added segments of high-tech industries, where developing countries typically have cost advantages. Such global industrial transfer and international division of labor would upgrade to higher stages on the value chain when having developed certain processing and manufacturing capabilities, thus realizing the overall upgrade of the industrial chain.

The logic it follows is that the industry in one country, through the manufacturing of products at lower stages of the value chain and technological assimilation, is able to gradually internalize it as local technology and upgrade it to higher levels. However, unlike elements such as labor or capital, technology will not spread from a higher value chain to a lower one or from the higher end to the lower end of the same chain. It is because on the one hand that technology is materialized into production elements such as machinery and equipment, and the transfer of machinery and equipment will not automatically improve the recipient's understanding and application of technology; on the other hand, technology is held by the multinational companies (transferor) in the form of patents or business secrets, which would cause enterprises in the hosting country higher costs for technology acquisition, incur local enterprises' long-term dependence on overseas technology and even hamper technological advance in the hosting country (Kokko, 1994[1]; McIntyer, 1986[2]; Peng Jisheng, 2003[3]).

**International Transfer of the IC Industry**

The history of the IC industry is connected with both industrial structure and international transfer. Leading semiconductor enterprises were initially all integrated device manufacturers (IDMs). After the 1980s, spinning off one after another from the mainstream industry, IC packaging and testing and IC manufacturing developed into independent packaging and testing factories and foundries and a large number of fabless companies consequently sprouted. Then the spun-off packaging and testing industry and manufacturing industry were transferred to Asia where labor cost is low and resources are cheap, thus realizing the global division of labor of the IC industry.

International transfer of the IC industry follows the path from the lower to the medium and higher ends of the value chain. Located at the lower end of the industrial chain, the packaging and testing industry is labor intensive and low in technological threshold. In the 1970s, it was first transferred to Asian countries such as Japan and Korea. With the rising labor cost in these countries, it was gradually transferred to Malaysia, Philippines, and China, etc. from the 1980s and the 1990s. Now, 80% of the global IC packaging industry is located in Asia. Since the 1990s, America, Japan and other major semiconductor powers have started to transfer their manufacturing industry abroad while retaining at home high-end stages of the value chain such as research and design. The IC design industry is knowledge intensive with its core technology represented by both the encoded technology such as block patents and design tools and tacit knowledge. Skilled system IC designers usually take ten or more years of development experience. It is just because of this fact that developed countries hold a solid grip on the advantage in the IC design industry with their patent strategies and advantageous human resources. Currently, the US is maintaining its lead in IC design with 80% of the world total both in the number of fabless companies and total sales.

Table 1 lists the interrelations among the factor features, technological forms and international transfer of the IC industry.

**Table 1 Factor Features, Technological Forms and Transfer of the IC Industry**

| **Value Chain** | IC Design Industry | IC Manufacturing Industry | IC Packaging and Testing Industry |
|---|---|---|---|
| **Value Added** | High | Relatively High | Low |
| **Factor features** | Knowledge Intensive | Technology and Capital Intensive | Labor Intensive |
| **Technological Forms** | Encoded Knowledge<br>Tacit Knowledge | Embodied Technology<br>Knowhow Technology | Embodied Technology |
| **International Transfer** | Not yet transferred with a very wide technological gap | Transferred with one to two generations of technological gap | First transferred with a narrow technological gap |

During the international transfer of IC industry, some countries and regions, such as Japan, Korea and Taiwan, have not only set up a complete IC industrial chain gradually, but also acquire proper technological capability for industrial upgrade, thus becoming global leading IC powers. In some other countries and regions, such as Malaysia and Philippines, however, the technology and scale of IC industry are still too insignificant to mention.

## The IC Industry in China

China's IC industry has started to introduce technology and production lines since the 1970s, but only to find itself stuck in the vicious cycle of introducing but lagging behind without exception for every generation of the new product, thus missing the golden period of development for the international IC industry in the 1970s and 1980s.

Since the year 2000, with the promulgation of *Document No.18* as the main policy support, China's IC industry has seen tremendous changes in both production capacity and technical level. With the door opened by *Document No.18* to foreign capital, a batch of IC manufacturing enterprises represented by Semiconductor Manufacturing International Corporation (SMIC) have started operations in China. At the same time, other stages of the value chain of the IC industry such as the chip design industry and the packaging and testing industry have also seen rapid development. Figure 1 shows the tremendous rise in China's IC production volume before and after the year 2000. (In consideration of the construction cycle, the rise in production volume would appear in 2002).

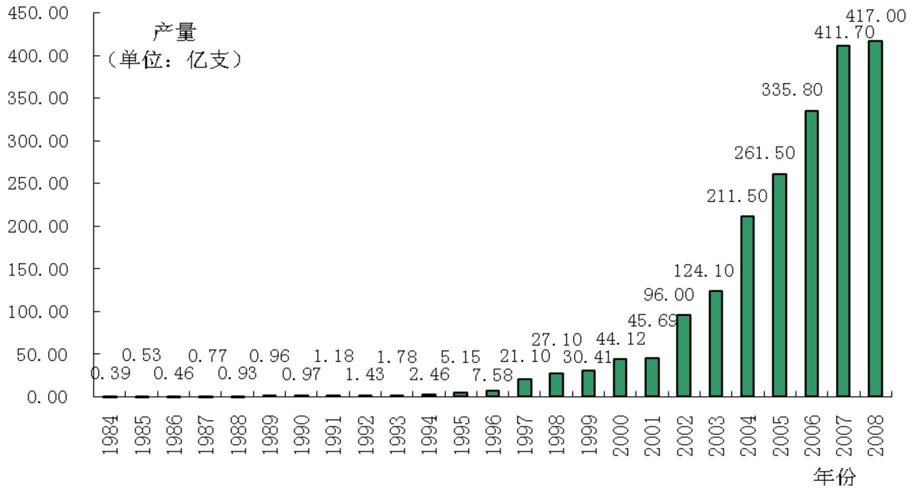


Table 1 IC Production Volume in China (between 1984 and 2008)

Source: The data is complied from *History, Current Status and Prospects of the IC Industry in China* written by Chen Wenhua, *Semiconductor Technology* No.3 issue, June, 1997, *Yearbook of the Electronics Industry*, and *Yearbook of the Information Industry* (1993-2008)

From 2000 to 2007, the total volume of output of Chinese IC manufacturing sector rose from 4.4 billion to 41.17 billion, at an average annual growth rate of 37.6%. And the total output value of IC industry (including design, manufacturing as well as packaging and testing industries) grew from 18.6 billion Yuan to 124.6 billion Yuan, at an average annual growth rate of 31.3%. Both the two indicators are far above the global average of IC industry. Thus, China has become a paradise for investment in the world's IC industry.

Has the IC industry in China formed its complete industrial chain? Whether the scale expansion of the IC industry in China since the year 2000 has brought the technological upgrade? What motivates and who leads the upgrade of the IC industry? How does the pattern of industrial ecology composed of different investment subjects influence the formation of technological capabilities and international division of labor of this industry? Answers to these questions are conducive to our understanding of both the position and the function of China's high-tech industry in the global value chain and international division of labor.

## II. The Position of China's IC Industry on the International Industrial Chain

### China's IC Industrial Chain

The domestic IC industry, which is different from the international IC industry, has gradually formed an industrial organization in which the three segments of the industry are separated. A large number of IC manufacturers which have introduced the large scale IC production line adopt the form of Foundry, an internationally popular production model. As a result, the auxiliary IC design enterprises and the packaging and testing companies have also grown up. In comparison, almost all the key companies in the Chinese IC industry previously were IDMs, except Hua Hong in Shanghai. The sales income and the growth rate of Chinese IC industry by sector from 2000 to 2008 are shown in Table 2.

**Table 2 Sales Income of Chinese Integrated Circuit Industry by Sector (2000-2008)**

**(Unit: 100 million Yuan)**

| ***Year*** | ***2000*** | ***2001*** | ***2002*** | ***2003*** | ***2004*** | ***2005*** | ***2006*** | ***2007*** | ***2008*** |
|---|---|---|---|---|---|---|---|---|---|
| Design Industry | 9.8 | 14.8 | 21.6 | 44.9 | 81.8 | 124.3 | 186.2 | 225.7 | 235.2 |
| Manufacturing | 48 | 27.7 | 33.6 | 60.5 | 180 | 232.9 | 323.5 | 397.9 | 392.7 |
| Packaging&Testing | 128.4 | 161.1 | 213.3 | 246 | 283.5 | 344.9 | 496.6 | 627.7 | 618.9 |
| Total | 186.2 | 203.6 | 268.5 | 351.4 | 545.3 | 702.1 | 1006.3 | 1251.3 | 1246.8 |

Data Source: *China Yearbook on IT Industry* (2001-2008)

From 2001-2007, a remarkable change had taken place in the structure of Chinese IC industry: the proportion of the packaging and testing industry in the IC industry decreased from 79% to 50%, that of the design industry increased from 7% to 19%, and that of the manufacturing rose from 14% to 31%. The ratio among the design industry, the manufacturing and the packaging and testing industry in China is about 2:3:5. There is still some way to go as compared with the balanced ratio of the international IC industry - 3:4:3. The proportion of the design industry is relatively low, while that of the packaging and testing industry is too high. The industrial chain formation of the IC industry in China is shown in Fig. 2:


**Fig. 2 Industrial Chain Formation of China’s IC industry (2000-2008)**

## The Position of Chinese IC Industry in the International Division of Labor

An international division of labor has been formed in the IC industry. About 80% of output value of the IC industry is created in America, while over 80% of the IC manufacturing and the packaging and testing industry is distributed in Asia. Chinese IC industry has also deeply integrated into the global IC industrial chain. Among the industries, the packaging and testing industry is the first transferred to China. Many large factories in the world, such as Intel, AMD, STMicron and Toshiba, have founded packing factories in China; since 2000, the growth in the IC manufacturing has mainly come from overseas investment and offshoring; and the IC design industry mainly serves for domestic demand, of which its scale is limited though making a rapid growth.

(1) IC Design Industry

The IC design industry is in the upper reaches of the IC industrial chain, enjoying a high industrial added value. In the world, there are about 600 Fabless companies with certain scale, and 476 companies among them are located in America, of which the sale volume accounts for about 80% of the global sale. Chinese Taiwan ranks second, accounting for less than 20%. And other areas in the world, including Japan and Korea, all make up only a small percentage in the IC design industry, i.e. Chinese mainland only accounts for less than less than 3% in the IC design industry.[5] In 2008, the sale volume of the top 10 domestic IC design enterprises was 9.402 billion Yuan in total, which was only equal to the ninth of worldwide Fabless (see Table 3, Table 4).

Table 3 Sales volume of Top 10 IC design enterprises worldwide, 2008

| ***IC design company*** | ***Sales*** ***（100 million US dollars）*** |
|---|---|
| Qualcomm – QCT | 64.77 |
| Broadcomm | 46.58 |
| Nvidia | 34.25 |
| Marvell Semiconductor | 29.51 |
| MediaTek | 27.55 |
| LSI | 26.77 |
| Xilinx | 19.06 |
| Avago Technologies | 16.65 |
| Altera | 13.67 |
| Sandisk – OEM Division | 10.30 |
| Total | 289.11 |

Data Source: GSA

Table 4 Sales volume of Top 10 Chinese IC design enterprises, 2008

| ***IC design company*** | ***Sales*** ***（100 million US dollars）*** |
|---|---|
| Hisilicon Technologies | 4.53 |
| CIDC | 2.11 |
| Datang Microelectronics | 1.22 |
| Hangzhou Silan Microelectronics | 1.19 |
| ACTS | 0.99 |
| SEMICO | 0.91 |
| HHNEC | 0.90 |
| VIMC | 0.91 |

| | |
|---|---|
| Beijing Tongfang Microelectronics | 0.58 |
| NEC Electronics (China) | 0.41 |
| Total | 13.76 |

Data Source: China semiconductor Association (at the exchange rate on Dec. 31, 2008, ￥6.8346 = US$1)

**(2) Manufacturing Sector**

Due to the notable scale economy in IC manufacturing sector, profits can be made only if the monthly production amount in one production line remains at 50,000. The domestic design market based on small-scale ASIC chips can not meet the capacity requirements of the manufacturing sector. Therefore, the IC manufacturing sector, contrary to the IC design industry which serves for local market, mainly meets the needs of foreign countries. For instance, in 2007, domestic IC output was 5.87 billion and sales volume was 5.59 billion, in which export reached 4.41 billion, accounting for 78.9% of the total sales.

In 2008, Chinese IC manufacturing accounted for 31% of the whole IC industry sales. Among all IC industries overworld, the SMIC in China ranked No. 4, HuaHong-NEC and He Jian ranked No. 8 and No. 9, respectively. Besides, GSMC and ASMC ranked No. 11 and No. 16 respectively (see Table 5).

Table 5 Top ten Pure-Play Foundry Companies overworld, 2008

| ***Ranking*** | ***IC Manufacturing Enterprises*** | ***Sales*** ***（100 million US dollars）*** |
|---|---|---|
| 1 | TSMC | 105.56 |
| 2 | UMC | 34.00 |
| 3 | Chartered | 17.43 |
| **4** | **SMIC** | 13.54 |
| 5 | Vanguard | 5.11 |
| 6 | Dongbu Hitek | 4.90 |
| 7 | X-Fab | 4.00 |
| **8** | **HHNEC** | 3.50 |
| **9** | **He Jian** | 3.45 |

| | | |
|---|---|---|
| 10 | SSMC | 3.40 |
| **11** | **Grace** | 3.35 |
| 12 | Tower | 2.52 |
| 13 | Jazz | 1.90 |
| 14 | Silterra | 1.75 |
| **15** | **ASMC** | 1.49 |
| 16 | Polar Semiconductor | 1.10 |
| 17 | Mosel-Vitelic | 1.00 |
| | Total | 208 |

Note: Chinese enterprises are in bold type. Data Source: IC Insights

By considering pure-play foundries and IDM foundries comprehensively, the rank in Chinese IC manufacturing industry can be found, which is shown in Table 6:

Table 6 Top 10 Chinese IC Manufacturing Enterprises, 2008

| ***IC Manufacturing Enterprises*** | ***Sales*** ***（100 million US dollars）*** |
|---|---|
| Wuxi Hynix – STMicroelectronics | 17.86 |
| SMIC | 13.61 |
| HHNEC | 6.85 |
| CR Microelectronics | 6.65 |
| GSMC | 2.12 |
| SG-NEC | 2.10 |
| He Jian | 1.96 |
| TSMC | 1.61 |
| Jilin Sino-microelectronics | 1.53 |
| ASMC | 1.37 |
| Total | 55.65 |

Data Source: China semiconductor Association (at the exchange rate on Dec. 31, 2008, ￥6.8346 = US$1). With different statistical criteria, data in Table 6 is slightly different from that in Table 5, possibly because the non-manufacturing businesses of some enterprises are also included in the statistics.

(3) The Packaging and Testing Industry

The packaging and testing industry is labor intensive industry, which is the first IC industry transferred abroad from some developed countries, such as America, and its investment is usually between 50 million and 100 million dollars. In recent years, the packaging and testing industry is mainly distributed in Asian countries, such as Japan, Malaysia, Chinese Taiwan, Philippines, Chinese mainland and Korea, and its output value accounts for about 80% in global semiconductor packing industry. Chinese mainland makes up 10% of the global packaging industry.

The sales volume of Chinese IC packaging and testing industry reached 62.77 billion Yuan in 2008, accounting for 50% of gross domestic IC product. However, Chinese enterprise did not find a place in the worldwide top 10 packaging and testing companies (see Table 7):

**Table 7 Top 10 IC Packaging and Testing Companies Worldwide, 2008**

| *IC Packaging and Testing Enterprises* | *Sales*<br>*（100 million US dollars）* |
|---|---|
| ASE Group | 29.98 |
| Amkor Technology | 26.59 |
| SPIL | 19.19 |
| STATS-ChipPAC | 16.58 |
| Powertech | 9.90 |
| UTAC | 7.11 |
| ChioMOS | 5.40 |
| KYEC | 4.99 |
| Carsem | 3.70 |
| Unisem | 3.52 |
| Total | 126.96 |

Data Source: IC Insights

The businesses of domestic packaging and testing factories mainly come from abroad. For instance, in 2007, the total product of Chinese IC packaging and testing industry was 12.15 billion. In a breakdown, export stood at 11.04 billion, accounting for 90.0%. By the end of 2007, there were 74 IC packaging and testing enterprises with certain scale at home. Among them, 21 companies were local enterprises or domestic-holding enterprises, and the rest companies were all foreign-capital enterprises and joint ventures. Table 8 shows the sales volume of China’s top 10 IC packaging and testing enterprises. Among the listed enterprises, only Jiangsu Xinchao and Nantong Fujitsu are domestic-funded or domestic-holding enterprises.

**Table 8 Top 10 Chinese IC Packaging and Testing Companies, 2008**

| ***IC Packaging and Testing Enterprises*** | ***Sales（100 million US dollars）*** |
|---|---|
| Freescale Semiconductor(China) Ltd | 16.98 |
| Qimonda Technologies (Suzhou) Co., Ltd. | 12.58 |
| RF Micro Devices( Beijing) Co., Ltd | 6.59 |
| Jiangsu Xinchao Group | 5.84 |
| Shanghai Panasonic Semiconductor Co., Ltd. | 5.72 |
| Shenzhen STS Microelectronics Co., Ltd. | 5.19 |
| Renesas Semiconductor (Beijing) Co., Ltd. | 4.22 |
| Nantong Fujitsu Microelectronics Co., Ltd. | 3.89 |
| Infineon Technologies (Suzhou) Co., Ltd. | 3.39 |
| Samsung Electronics (Suzhou) Semiconductor Corporation | 3.20 |
| Total | 67.60 |

Data Source: China semiconductor Association (at the exchange rate on Dec. 31, 2008, ￥6.8346 = US$1). It seems that domestic IC packaging and testing enterprises shall enter the rank of global top 10, as compared with Table 7. However, it is difficult to explain the data. The writer inferred that the output of foreign-owned packaging and testing enterprises at home was included in their parent companies during international ranking, and other businesses were included in the sales volume of domestic local companies.

In general, the Chinese IC industry, after 10 years' of rapid growth, has become a complete industrial chain, including design, manufacturing as well as packaging and testing, and the industrial structure has become increasingly reasonable. However, its overall scale, accounting for less than 5% of the world's IC total output, is still small. In China's domestic IC market, 80% of demand still depends on import.

Secondly, the growth of Chinese IC industry benefit directly from global division of labor. In particular, over 80% of sales from the IC manufacturing sector as well as the packaging and testing industry depend on export. It is different for the IC design industry. Developed countries will not take the initiative in transferring the IC design industry owning to its highest added value. Chinese IC design industry does not have the characteristic of undertaking global division of labor. Instead, it mainly serves for complete-system vendors at home, and shows the development potential of independent innovation.

At last, the inner link of Chinese IC industrial chain is still weak. And the export-oriented manufacturing, packing and testing will be affected by the international market easily. The IC design industry caters to the demands of the domestic market, and satisfies, to some extent, the productivity of low-end IC manufacturing as well as packing and testing at home. The development of IC design industry is the basis and primary driver for the overall upgrade of the IC industrial chain in the future.

# III. Technological Level of China’s IC Industry

### III. Chinese IC Industry’s Technology Capacity

It can be seen from the analysis on industrial chain that over 80% of Chinese IC manufacturing and packaging and testing industries is for export. That’s to say, Chinese IC industry has deeply entered the international division of labor of the IC industry. Unlike the IC industry of Japan and Korea, Chinese IC industry has not formed a functional upgrade between the links of the industrial chain as well as an upgrade of the industrial chain as a whole. Instead, the links have been embedded into the international market, and completed process upgrade and product upgrade respectively. Why? In order to answer this question, we shall look into the technology sources of various links and the driving force for the upgrade.

#### (1) IC Design Industry

As mentioned above, Chinese IC industry has grown up since 2000. Its development bottleneck is mainly the shortage of talents as well as the restriction of chip design patents, IPs and EDA Tools. Therefore, the first batch of IC design companies at home basically fall into two categories: one is small enterprises founded by returned scholars who have work experience in similar enterprises abroad and design patent of chip products, especially ASIC chips, such as chip for hearing aid, chip for cell phone as well as audio and video processing chip etc. A good sensibility to the final consumption market is required for the development of ASIC chips which directly serve for various consumer electronic products. However, the requirement on chip’s line width and integration level is relatively low, so are technical threshold and patent barrier. But single-typed ASIC chip is usually in small demand, like thousands of chips, so that the unit cost for R&D and Manufacturing is very high. Thus, it is difficult to reduce cost by scale economy.

Beijing Vimicro Corp. is an outstanding one among the enterprises of returnees. This corporation was founded by a body of doctors who had studied in America, such as Deng Zhonghan and Yang Xiaodong, in the Zhongguancun Science and Technology Park in 1999, with the direct investment of the Electronic Industry Development Fund and the policy support from the Department of Science and Technology, working at the R&D, design and industrialization of digital multimedia chip. In Nov. 2005, the Vimicro Corp. was listed on NASDAQ, thus becoming the first Chinese IC design corporation listed on NASDAQ. The technologies of the Vimicro Corp. are mainly developed independently. About 20% of its sales volume is used for R&D. This corporation has applied for more than 1,300 patents at home and abroad, among which 85% is patent of invention. In addition, it also owns the independently developed trademark, copyright, literary property and IC layout design etc. During its technological development, government departments, such as the Development and Reform Commission, the Ministry of Information Industry as well as local governments, have extended financial help, which amounts to about 68 million Yuan, accounting for about 10% of its R&D investment. At present, the company's multimedia processing chip for phone, core chip for digital camera and chip for surveillance camera have occupied the domestic mass market.

The other type refers to the IC design companies established by domestic scientific research institutions and state-owned enterprises, which is larger in scale, and specializes in the development of general- purpose chips , such as CPU and memory chip. General- purpose chips are more integrated and modularized, and their patented technologies are monopolized by foreign business barons, such as Intel, AMD and NEC, so that it is very difficult for development. However, due to the great strategic significance of general- purpose chip in economy and national defense, domestic scientific research institutions and state-owned enterprises have never given up the technical exploration into this field. For instance, the "Loongson" series product released by the BLX IC Design Corporation, which is based on the R&D team of the Institute of Computing Technology, CAS, is just a self-developed CPU. It is primarily used in government branches, defense industry enterprises and local microelectronic enterprises (they have been further supported by the government owning to the “Loongson” CPU core). China Integrated Circuit Design (Group) Corporation Limited (CIDC for short) is another large IC design company at home, which is a state-owned enterprise. Its predecessor is the research institute of original Ministry of Electronics Industry. CIDC’s chip products include the high volume products purchased by the government, such as chip for social security card, chip for tax control and chip for Enterprise Code Certificate. Meanwhile, CIDC is also China’s leading design company for security chip, which is widely used in defense and finance departments.

Therefore, the technologies of the IC design industry are mainly based on independent innovation. In fact, the independent innovation is “passive”, because the technology of chip design greatly attaches to human capital and patented technology, and is hard to be transferred from abroad. However, the rapid development of the IC design industry after 2000 has mainly benefited from three factors: (1) the vigorous growth of local consumer electronics products, such as home-made cell phone and cars (motor electronic); (2) the push from government on technological innovation and government procurement; and (3) the combination of the technological capability accumulated by domestic large research institutions over a long time with the market demand.

**(2) IC manufacturing industry**

The techniques of IC manufacturers are mainly embodied in three aspects: (1) Materialization of the manufacturing processes on production equipment, including software provided by equipment providers and general solutions to services such as process menu, process control and process integration; (2) The technology licensing acquired by foundries from high-end customers, which is embodied in the technological level of products; (3) Process technologies and organization capabilities embodied in process management, quality control and the strategy for intellectual properties.

The IC manufacturing industry of China has been relied on international production lines ever since 1970s. Before 2000, the dominant IC companies in China are IDM companies which introduced chip products, such as color TV chips and memory chips, along with production lines. After the product renewal, the enterprises remained no power to develop new products, which resulted in idle production lines and serious loss. New IC companies founded after 2000, such as SMIC, Hejian, Grace, Wuxi Hynix-ST and TSMC (Shanghai), are all pure-play foundries; IDM companies founded before 2000, such as HH-NEC and ASMC, also introduced new production lines to compete for international foundry businesses.

The technological capability of domestic IC manufacturers has been promoted greatly through the international foundry businesses. Taking SMIC for example, 0.25-micron processes were adopted at first; in 2001, SMIC acquired the 0.18-micron standard logic process technology and corresponding rights of patent using from the Chartered Semiconductor Co. (Singapore), and has been licensed by Toshiba (Japan) for using low-power SRAM and obtained orders. In 2002, SMIC acquired the technique of producing 0.14-micron standard memory chips (DRAM) from Infineon (Germany). Through studies, SMIC extended the 0.14-micron technique to 0.15-micron and 0.13-micron level. The 90 nano-technique of SMIC was licensed by the Texas Instruments (TI), Infineon and ARM, etc. Recently, SMIC signed a 45nm-technique license agreement with IBM. IBM transferred the 45-nm low-consumption and high-speed bulk CMOS technique to SMIC, which is so far the most advanced mass-production technique.

Apart from technology licensing, SMIC carried out self-development and cooperative development so as to gain technology independence. In China, SMIC established close technological cooperative relationships with Beijing University, Tsinghua University as well as the Chinese Academy of Sciences and other institutions, and even undertook basic research projects of the government. For example, the 973 projects and the key planned research projects launched in 2009 include some undertaken by the Shanghai Company of SMIC. [6]

Generally speaking, the technological capability of domestic IC manufacturers is directly benefited by equipment providers and high-end customers, which also promote their marketing and organizing capabilities. Domestic IC companies presently acquire technologies, funds and talents throughout the world for resource integration, utilization and redevelopment, and a benign circle has been formed. For instance, companies will not buy in a production line as a whole for introduction, but purchase high-tech key equipment in global scale and build their own production lines. Based on understanding, comparison and assembly of manufacturing equipment, domestic companies have formed corresponding technological capabilities from their structures. Besides, since foundries have to compete for foundry orders in the global market, the marketing abilities of domestic IC companies are developed. Despite all of these, international semiconductor superpowers generally build technical alliance to develop new-generation techniques and share the expenses and risks of research and development due to the rapid development of international semiconductor techniques and the huge investment on research and development. As for Chinese companies, they are yet to be placed in the alliance of advanced technologies.

**(3) Packaging and testing industry**

Compared with the IC design industry and the IC manufacturing industry, the situation of the packaging and testing industry is much better. Owing to relatively loose technical restricts and control plus less overall investment, the earlier investment of numerous international IDMs in China basically centered the field of packaging and testing. Intel, ST, Infineon, Renesas, Toshiba and other major international semiconductor providers have presently laid investment in Shanghai, Wuxi, Suzhou, Shenzhen and Chengdu, etc. to build packaging and testing bases. Fourteen out of the globally top 20 semiconductor providers have found joint or self-owned packaging and testing companies in China, which have become the leading ones in Chinese packaging and testing industry in terms of both production scale and technical standard.

The foreign-owned IDM packaging and testing companies in China basically serve for their parent companies. For instance, 100% of the products of Intel are exported, and 99.6% of Freescale products are exported. Middle and high end products dominate the orders sent to foreign-owned OEM packaging and testing companies, while those of domestic packaging and testing companies are basically conventional low-end products such as DIP and SOP.

In recent years, the development of the uprising Chinese IC design industry and IC manufacturing industry has given rise to effects of promoting the packaging and testing industry in China. Companies from the Chinese Mainland have made some break-through achievements in advanced packaging and testing techniques such as BGA, CSP and MCM, and lead-free packaging and testing techniques like QFN have been applied to mass production. The Nantong Fujitsu Microelectronics Co., Jiangsu Changdian Electronics Technology Co.,， Tianshui Huatian Co.,. and other companies have made great achievements in the development and application of advanced packaging modes such as PGA, BGA, CSP and MCM. As for foreign-owned companies, BGA, CSP, MCP, MCM, MEMS and other packaging techniques have been introduced for mass production. The overall technological capability gap between the Chinese packaging and testing industry and the international level is decreasing gradually.

Generally, the technological gap of Chinese IC industry against the world advanced level is shrinking; particularly, the technologies of the IC manufacturing industry and the IC packaging and testing industry have been ranked in the international mainstream. In terms of the sources of their technical capabilities, however, the techniques of the Chinese IC design industry are based on domestic self-development, while those of the IC manufacturing industry and the IC packaging and testing industry stem from other countries.

During the international transfer of IC industry, some countries and regions, such as Japan, Korea and Taiwan, have not only gradually set up a complete IC industrial chain, but also acquired proper technological capability for industrial upgrade, thus becoming global leading IC powers. In some other countries and regions, such as Malaysia and Philippines, however, the technology and scale of IC industry are still too insignificant to mention. So then, what is the determining factor for industrial upgrade in international industrial transfer?

# IV. Ecological Pattern of China’s IC Industry

The scale enlargement, technical progress and depth of participation in international division of labor of Chinese IC industry after 2000 are very impressive. Under the conditions of global industrial division, are the industrial scale and technical capability of one country’s high technology industry representative of the industrial competitiveness of that country?

**Two Foreign Capitals: Financial Investor and Strategic Investor**

As for foreign capitals of high-tech industry, it is necessary to distinguish the two investors: one refers to capital investors coming from the financial market, including stock market and private fund, aiming to get the high value-added profits of high-tech industry. The owner of the capital pays attention to enterprise’s business performance, but usually does not involved in the enterprise’s operation strategy and technological capability building. Some IC manufacturing enterprises, such as SMIC, GSMC and He Jian, belong to this class. This type of enterprises, which have grown up locally, pays attention to the development and accumulation of their own technological capabilities, and gradually forms the endogenous driver for technical development and industrial upgrade on the basis of market demand and their own capabilities. In addition, with the continuous development of enterprises, they will attract new investors to participate in, and then the influence of investors on enterprises will be further decreased. Therefore, the enterprises which take financial investors as the investment subject, in terms of the ecological pattern of industry, shall be perceived as localized component.

The other type of investors refers to the strategic investors in transnational enterprises. The transnational enterprises, based on their own scale enlargement and the global logistic strategies, transfer their manufacturing sectors and packing and testing sectors to China, so as to reduce cost, enhance production capacities and expand market share. The strategic investors intervene in the strategic management of their companies in China in the form of single venture or joint venture while controlling interest. Both their business planning and technical capability building are subject to the unified plan of their parent companies, but only have a weak tie with local market. Under the conditions of global market tightening or corporate strategy adjustment, the factories in China may be stopped, closed or transferred at any moment. This kind of enterprises does not belong to the localized component in the ecological pattern of industry.

**Indigenous Companies vs. MNC Branches in China IC Industry**

Thus, in view of the investment feature of the high-tech industry, Chinese IC enterprises can be divided into two classes, which are indigenous companies and MNC branches. Accordingly, the ecological pattern of IC industry has the following features:

(1) The top 9 out of the Chinese top 10 IC design enterprises are indigenous companies, and their incomes account for 97% of the gross earning of the top 10. For instance, No. 1, the Shenzhen Hisilicon Technologies Co. Ltd, which is the original Huawei IC Design Center, is headquartered in Shenzhen, and has design branches in Beijing, Shanghai, Silicon Valley and Sweden. And No. 10, the NEC Electronics (China) Co. Ltd is a wholly foreign-owned MNC branch, which works at the IC design, development, sales and technical support in China for Japan’s NEC Corporation.

(2) Among Chinese top 10 IC manufacturing enterprises, 8 are indigenous companies, and their incomes account for 65% of the gross earning of the top 10. Among the top 10, Wuxi Hynix-ST and TSMC (Shanghai), which are the world’s leading chip manufacturers, belong to the type of transnational enterprises with

strategic investors. TSMC’s chip foundry production accounts for near 50% of the world’s foundry. However, under the influence of 2008’s financial crisis, TSMC has reduced the production in Chinese factories rapidly, which accounts for less than 1% of that in Taiwan.

(3) Chinese IC packing and testing industry has basically been dominated by foreign capital. Among the top 10, there are 5 wholly foreign-owned companies, 8 foreign holding companies, and only 2 indigenous companies, which are Jiangsu Xinchao and Nantong Fujitsu. And the income of the two indigenous companies only accounts for 14% of the total earnings of the top 10. Besides, indigenous packing and testing companies are also at a disadvantage in terms of technical capability and market competition.

In general, under the bright light of rapid growth, Chinese IC industry has shown an ecological pattern which mingles hope and fear. On one hand, the design industry, which plays a leading role in the industrial chain with high added value, has built proper technological capability for localization based on local market demand, and initially had the endogenous power and capability for technical upgrade. Meanwhile, the IC manufacturing industry, as the main body of the industrial chain, benefits from new capital and enterprise operation mode. The localized manufacturing productivity has developed, and the technology basically approaches the international mainstream level. On the other hand, the IC packing and testing industry, of which the product makes up a half of China’s IC industry, is dominated by multinational corporations. Most productivities and technologies are controlled by MNC branches. Its localization is weak. With the weakening of costs advantages in relation to labor and resource, predictably, this industry will be transferred to South-East Asia, where has more costs advantage, in the future.

## V. Conclusions

Firstly, the rising of China as a big producing country for high-tech products is capturing the world’s attention. We shall carefully analyze the technological level and ecological pattern of China’s high-tech industry behind this scale enlargement and study the development trend of the industrial chain based on the localization of production, technology and market. The industrial chain with upgrade potential shall not only have a comprehensive industrial structure, but also have the following two factors:

(1) The connection between all production stages of the industrial chain;

(2) The endogenous technological capability of indigenous companies.

Secondly, when China's high-tech industry participates in the international division of labor, only a few enterprises acquire the endogenous power for technology upgrade. So, what kind of enterprises will be able to move towards the high end of the value chain in the international division of labor? The following factors are necessary:

(1) Indigenous companies, instead of MNC strategic branches;

(2) Chinese Returnees' team or national research institutions and state-owned enterprises with a long-term technological accumulation;

(3) Government support and favorable policies on technological innovation and industrialization.

Thirdly, high-tech industry is generally characterized by high investment costs and high risks. The international capital market, including international private funds, is of the utmost importance to the industrial development. As for the high-tech industry under the support of the international capital market, it cannot effectively disclose how international division of labor can help transfer the technology in the host country by simply dividing the capital property as domestic or foreign. In contrast, it is of great practical significance to analyze if it belongs to a MNC strategic branch.

In this study, the analysis on the participation of the high-tech industry in the international division of labor is restricted within the IC industry only. Relevant researches on other industries are welcomed.

# 中国高技术产业在国际分工中的地位及产业升级：以集成电路产业为例

陈玲 薛澜
(清华大学公共管理学院)

摘要：首先，基于集成电路设计业、制造业和封装测试业的生产要素特征、技术特征和投资规模，总结国际集成电路产业向国内转移的步骤和原因。其次，通过研究中国集成电路产业价值链各环节设计业、制造业和封装测试业的发展规模和技术水平，揭示了中国集成电路产业在国际分工中的地位。最后，对比研究设计业、制造业和封装测试业的技术来源和生态格局。对集成电路产业的案例研究表明，中国高技术产业在国际产业分工中占据价值链低端，价值链各环节的内在联系较弱，不足以形成产业链整体升级的能力。高技术产业升级……

关键词：高技术产业，国际分工，产业链，产业升级，技术能力，产业生态

## 一、引言

随着上个世纪 90 年代以来经济全球化的加速发展，高技术产业也深刻地融入全球分工体系里。特别是最近几年，以信息产业、飞机制造业、集成电路产业为代表的高技术产业向中国转移，使得中国成为高技术产品的“制造工厂”。同时，中国高技术产品的出口持续上升，甚至引发美国等发达国家的担忧，进而对中国不断采取种种贸易措施。新的问题浮现了：被国际分工“肢解”的高技术产业，如何在国际产业竞争中体现国家竞争力？中国高技术产业在全球价值链中的地位究竟如何？简单地以一国的高技术产品产量或国际贸易数据作为判断依据，显然过于武断。本文通过对中国集成电路产业的实证研究，考察高技术产业的国际分工，分析其各生产环节的价值构成和技术能力，研究各价值链环节的产业生态格局，试图对此问题给出回答。

## 二、文献综述和研究方法

### 价值链及产业升级

价值链是指在垂直一体化的企业内部，从原材料供应、生产加工、市场营销到产品服务等一系列企业生产环节和其他研究设计、人力资源、战略规划等辅助环节的总称（迈克尔·波特，竞争优势，1985）。随着国际外包业务发展和生产网络的全球化，价值链突破单一企业的限制，形成全球价值链（Gereffi，张辉）。产业升级表现为四种形式，即流程升级、产品升级、功能升级和价值链的整体升

级（Humphrey&Schmitz, 2000）。企业通过提高内部效率、改进制程技术来实现流程升级；通过推出新产品或改进老产品完成产品升级；通过调整自身的生产活动内容和核心竞争力(例如由制造商转变为设计商或技术服务商)转移到价值链中的高附加值环节，实现功能升级；最终，价值链整体升级到新的价值链，实现产业的整体升级。

以往的研究认为，世界产业转移和国际分工都是从低附加值的劳动密集型产业开始，形成一定的加工、制造能力后再向更高的价值链环节升级，进而实现产业链的整体升级。其背后的逻辑是，一国的产业能够通过较低价值链的产品生产和对技术的消化吸收，逐渐内化为本土的技术并升级到较高的技术水平。但是，研究也指出，技术不会向其他要素如劳动力、资金一样自动的从高的到价值链向低的价值链、或者从价值链的高端向低端扩散。一方面，技术“物化”在机器设备等生产要素中，机器设备的转移不会自动地提高接收方对技术的理解和运用；另一方面，技术以专利和商业秘密的方式掌握在跨国公司的手中，可能导致东道国企业获取技术的高成本，造成当地企业对国外技术的长期依赖，甚至阻碍东道国企业的技术进步。(Kokko, 1994;[1] McIntyer, 1986[2]；彭纪生，2003[3])。

IC 产业的国际转移

IC 产业的发展和国际转移与产业形态相关系。最初世界主要的半导体企业均为整机厂商（即 IDM, Integrated Device Manufacturer）。上个世纪 80 年代以后，IC 封装、测试、制造先后从主业中分离，成为独立的封装测试厂和代工企业（Foundry）,相应地诞生了一批无工厂的 IC 设计企业（Fabless）。独立出来的封装测试业、制造业绝大部分转移到劳动力成本和资源价格低廉的亚洲地区，实现了 IC 产业的全球分工。

IC 产业国际转移的路径，是从价值链的低端逐渐向中高端转移。封装测试业处于产业链低端，为劳动密集型产业，技术门槛低， 70 年代最先被转移到日本、韩国等亚洲国家；随着这些国家劳动力价格逐渐上涨，80 到 90 年代，封装测试业又逐渐转移到马来西亚、菲律宾、中国等国家，形成了目前封装业 80%以上在亚洲地区的格局。90 年代以后，美、日等主要半导体大国开始将制造业转移到国外，只保留价值链高端的研发和设计环节。IC 设计业属知识密集型企业，其核心技术一部分表现为布图专利、设计工具等编码技术，一部分则表现为不可编码的缄默知识。成熟的系统级 IC 设计人员往往需要经过十年左右的开发经验。

[1] E K Y. “Chen. Multinational Corporations and Technology Diffusion in Hong Kong Manufacturing”. Applied Economics. 1983(15). 309-321
[2] J. McIntyre & Papp. The Political Economy of International Technology Transfer. Quorum Books. 1986
[3] 彭纪生. 论经济全球化背景下的中国技术创新. 中国经济出版社. 北京. 2003 年

正因如此，发达国家利用专利战略及人力资源优势牢牢占据了 IC 设计业的领先优势。目前，美国 Fabless 企业数量和产值占全球 80%左右。

表 1 显示国际 IC 产业的生产要素特征、技术形态与国际转移的相互关系：

**表 1　IC 产业转移的要素特征、技术形态和转移情况**

| 价值链 | IC 设计业 | IC 制造业 | IC 封装、测试业 |
|---|---|---|---|
| **增加值** | 高 | 较高 | 低 |
| **要素特征** | 知识密集型 | 技术和资金密集型 | 劳动密集型 |
| **技术形态** | 编码知识、<br>缄默知识 | 物化技术、<br>Knowhow 技术 | 物化技术 |
| **产业转移的状况** | 不转移，技术差距显著 | 转移，保持 1-2 代技术差距 | 最先转移，技术差距小 |

在 IC 产业国际转移的过程中，日本、韩国、台湾等国家和地区的 IC 产业不但逐步建立了完整的 IC 产业链，而且还获得了产业升级的技术能力，成为国际领先的 IC 大国。但在另外一些国家和地区，如马来西亚、菲律宾等国，IC 产业的技术和规模仍然不足称道。那么，在承接国际产业转移的过程中，决定该产业升级与否的因素究竟是什么呢？

## 中国的 IC 产业

中国IC产业的发展极具戏剧性。中国从上个世纪七十年代开始引进IC技术和生产线，结果陷入“代代引进、代代落后”的恶性循环，错失了上个世纪七、八十年代国际IC产业的黄金发展期。戏剧性的转折出现在 2000 年，以“18 号文件”[4]的出台为标志，中国的IC产业发生了巨变，产能迅速扩展，技术水平也得到快速提高。“18 号文件”拉开了外资的闸门，以“中芯国际”为代表的一批IC制造企业在华建设、投产，同时，IC产业价值链的其他环节如芯片设计业、封装测试业也得到快速发展。图 1 显示 2000 年前后中国IC产量增长的巨大变化（考虑到建设周期，产量增长在 2002 年才显现）。

[4] 2000 年 6 月，国务院发布了《鼓励软件产业和集成电路产业发展的若干政策》（国发[2000]18 号文件，简称18 号文件）。

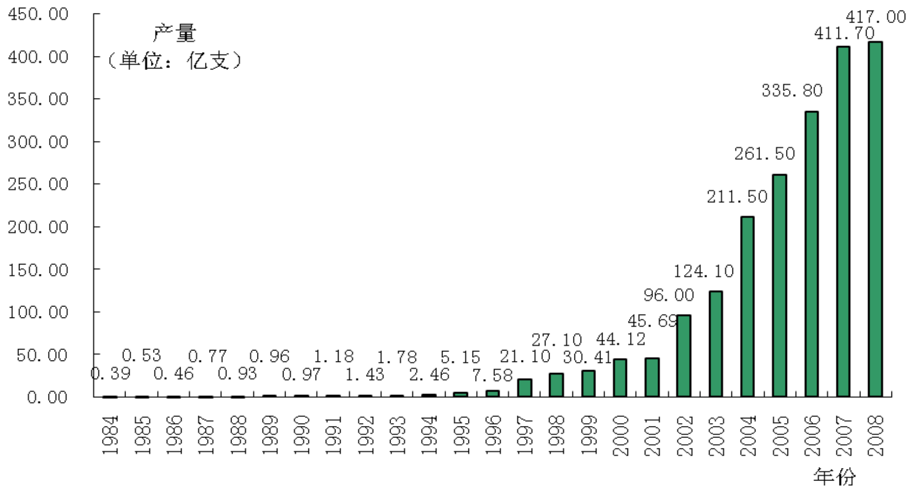


图 1 中国集成电路产量（1984-2008 年）

资料来源：根据陈文华《中国半导体行业的历史、现状及展望》,《半导体技术》, 1997 年 6 月第 3 期，以及《电子工业年鉴》、《信息产业年鉴》( 1993-2008 ) 整理。

2000 到 2007 年，中国 IC 制造业的总产量的从 44 亿块增长到 411.7 亿块，年均增长率为 37.6%。此外，IC 产业（包括设计、制造和封装测试业）的总产值从 186 亿元增加到 1246 亿元，年均增长率为 31.3%。这两项指标均远高于全球 IC 产业的平均水平。中国成为世界芯片业最炙手可热的投资乐土。

那么，中国 IC 产业是否已经形成了完整的产业链？2000 年后中国 IC 产业的规模扩张是否带来产业技术升级？IC 产业升级的驱动力是什么、由谁主导？由不同的投资主体形成的产业生态格局，是怎样影响该产业的技术能力形成和国际分工地位？对这些问题的回答，有助于我们真正了解中国高技术产业在全球产业链和国际分工中的地位和作用。

## 二、中国 IC 产业在国际产业链中的位置

### 中国 IC 产业链

滞后于国际 IC 产业的发展，中国 IC 产业从 2000 年后才逐渐形成三业分离的产业组织形态。一大批引进大规模集成电路生产线的 IC 制造业厂家采用国际流行的代工生产模式（Foundry)，与之配套的集成电路设计企业、封装测试企业也逐渐发展起来。而在此之前，国内的骨干 IC 企业除了华虹 NEC 以外，基本上都是 IDM。表 2 显示 2000-2008 年中国集成电路产业分行业的销售收入及增长率：

表 2 中国集成电路产业分行业销售收入（2000-2008 年）（单位：亿元）

| *年份* | *2000* | *2001* | *2002* | *2003* | *2004* | *2005* | *2006* | *2007* | *2008* |
|---|---|---|---|---|---|---|---|---|---|
| 设计业 | 9.8 | 14.8 | 21.6 | 44.9 | 81.8 | 124.3 | 186.2 | 225.7 | 235.2 |
| 制造业 | 48 | 27.7 | 33.6 | 60.5 | 180 | 232.9 | 323.5 | 397.9 | 392.7 |
| 封装测试业 | 128.4 | 161.1 | 213.3 | 246 | 283.5 | 344.9 | 496.6 | 627.7 | 618.9 |
| 合计 | 186.2 | 203.6 | 268.5 | 351.4 | 545.3 | 702.1 | 1006.3 | 1251.3 | 1246.8 |

数据来源：《中国信息产业年鉴(电子卷)》( 2001-2008 )。2008 年的数据收集自媒体报道。

从 2001 年到 2007 年，中国 IC 产业结构发生了显著变化、更趋合理：封装测试业在 IC 产业中的比重从 79%下降到 50%，而设计业从 7%增加到 19%，制造业从 14%增加到 31%。设计、制造和封装测试的比例约为 2:3:5，与全球 IC 产业 3:4:3 的均衡比例仍有差距，设计业比重较低，而封装测试业比重仍然过高。中国集成电路产业链构成如图 2 所示：


图 2 中国集成电路产业的产业链构成（2000-2008 年）

## 中国 IC 产业在全球分工中的位置

IC 产业在全球形成国际分工，其中 IC 设计业 80%左右的产值在美国，IC 制造业和封装测试业则 80%以上分布在亚洲地区。中国 IC 产业也深刻地融入到全球 IC 产业链中。其中，封装测试业最早转移到中国境内，国际大厂如 Intel、AMD、STMicron、东芝等都在中国设立封装厂。IC 制造业的增长也主要来自境外投资和产能转移。IC 设计业主要面向本土需求，增长虽快但规模仍然有限。

**（1）设计业比重低、规模小**

设计业在IC产业链中处于上游地位，产业增加值高。全球具一定规模以上的Fabless公司约有 600 家，其中美国有 476 家，其销售额约占全球销售额的 80%，而中国台湾地区为第二，占 10%以上。而包括日本、韩国等在内的全球其它地区在IC设计业中的比例都很小，中国大陆IC设计业的比重不到 3%。[5] 2008 年，国内IC设计业十强销售额合计 94.02 亿元，只相当于国外Fabless第九名的水平（表 3）。

表 3 IC 设计业的世界十强和中国大陆十强（2008）

| *全球十强* | *Sales（亿美元）* | | *国内十强* | *Sales（亿美元）* |
|---|---|---|---|---|
| Qualcomm – QCT | 64.77 | | 深圳市海思半导体 | 4.53 |
| Broadcomm | 46.58 | | 华大集团 | 2.11 |
| Nvidia | 34.25 | | 大唐微电子 | 1.22 |
| Marvell Semiconductor | 29.51 | | 杭州士兰微电子 | 1.19 |
| MediaTek | 27.55 | | 珠海炬力 | 0.99 |
| LSI | 26.77 | | 无锡华润矽科微电子 | 0.91 |
| Xilinx | 19.06 | | 上海华虹 | 0.90 |
| Avago Technologies | 16.65 | | 北京中星微电子 | 0.91 |
| Altera | 13.67 | | 北京同方微电子 | 0.58 |
| Sandisk – OEM Division | 10.30 | | 日电电子（中国） | 0.41 |
| 合计 | 289.11 | | 合计 | 13.76 |

数据来源：GSA，中国半导体协会（国内数据按 2008 年 12 月 31 日汇率 1 美元兑人民币 6.8346 元折算）

**（2）IC 制造业出口为主，规模经济显著**

由于 IC 制造业的规模经济显著，通常一条生产线每月的投片量要维持在 5 万片才能够盈利。国内以小规模专用芯片为主导的设计市场不能满足制造业的产能要求。因此，与 IC 设计业面向本土市场的情况不同，IC 制造业主要满足国外的需求。以 2007 年为例，当年国内 IC 产量为 58.7 亿片，销量为 55.9 亿片，其中出口 44.1 亿片，占总销量的 78.9%。

2008 年，我国 IC 制造业在 IC 产业中所占比例为 31%，占世界 IC 总产量的比例不足 5%[验证？]。全球销售额超过 1 亿美元的 17 家单一业务代工企业中，

[5]俞忠钰 关于我国集成电路产业未来发展思考 2006 年 2 月

5 家企业位于中国大陆，其中中芯国际（SMIC）位列第四，华虹 NEC 和和舰分别排在第 8、9 名。另外宏力也位于第 11 名、上海先进位于第 15 名（表 4）。

表 4 全球 IC 制造业中单一业务代工企业排名（2008）

| 排名 | IC 制造企业 | 所在地 | 销售收入（亿美元） |
|---|---|---|---|
| 1 | TSMC（台积电） | 中国台湾 | 105.56 |
| 2 | UMC（台联电） | 中国台湾 | 34.00 |
| 3 | Chartered（特许半导体） | 新加坡 | 17.43 |
| 4 | SMIC（中芯国际）* | 中国大陆 | 13.54 |
| 5 | Vanguard | | 5.11 |
| 6 | Dongbu Hitek | | 4.90 |
| 7 | X-Fab | | 4.00 |
| 8 | HHNEC（华虹 NEC）* | 中国大陆 | 3.50 |
| 9 | He Jian（和舰）* | 中国大陆 | 3.45 |
| 10 | SSMC | | 3.40 |
| 11 | Grace（宏力）* | 中国大陆 | 3.35 |
| 12 | Tower | | 2.52 |
| 13 | Jazz | | 1.90 |
| 14 | Silterra | | 1.75 |
| 15 | ASMC（先进）* | 中国大陆 | 1.49 |
| 16 | Polar Semiconductor | | 1.10 |
| 17 | Mosel-Vitelic | | 1.00 |
| | 合计 | | 208 |

注：加*为中国企业。 数据来源：IC Insights

**（3）IC 封装测试业主要出口**

封装测试业属于劳动密集型产业，其投资额一般在 5000 万到 1 亿美元之间，是美国等先进国家最早向国外转移的集成电路产业。近年来，封装测试业主要分布在以日本、马来西亚、中国台湾、菲律宾、中国内地和韩国为主的亚洲国家，其产值占全球半导体封装业的 80%左右。中国内地约占全球封装业的 10%左右。2008 年我国集成电路封装测试业销售额为 627.7 亿元，占国内 IC 总产值的 50%。

国内封装测试厂的业务主要来自国外，例如 2007 年，中国 IC 封装测试业的

总产量为 121.5 亿块，其中出口量为 110.4 亿块，占 90.9%。2007 年底，国内有一定规模的 IC 封装测试企业有 74 家，其中本土企业或内资控股企业 21 家，其余均为外资及合资企业。表 8 显示中国前 10 家 IC 封装测试企业的销售收入，其中只有江苏新潮和南通富士通为内资或内资控股的本土企业。

表 8 中国 IC 封装测试企业前 10 家（2008 年）

| *集成电路封装测试企业* | *销售收入（亿美元）* |
|---|---|
| 飞思卡尔半导体(中国)有限公司 | 16.98 |
| 奇梦达科技（苏州）有限公司 | 12.58 |
| 威讯联合半导体(北京)有限公司 | 6.59 |
| 江苏新潮科技集团有限公司* | 5.84 |
| 上海松下半导体有限公司 | 5.72 |
| 深圳赛意法半导体有限公司 | 5.19 |
| 瑞萨半导体（北京）有限公司 | 4.22 |
| 南通富士通微电子有限公司* | 3.89 |
| 英飞凌科技（苏州）有限公司 | 3.39 |
| 三星电子（苏州）半导体有限公司 | 3.20 |
| 合计 | 67.60 |

数据来源：中国半导体协会（按 2008 年 12 月 31 日汇率 1 美元兑人民币 6.8346 元折算）。

总体而言，中国 IC 产业经过了近十年的快速增长，已经建立起从设计、制造，到封装和测试的完整产业链，产业结构日趋合理。但中国 IC 产业的总体规模仍然偏小，占全世界 IC 总产量的比例不足 5%。中国国内 IC 市场的需求量 80%仍然依靠进口。

其次，中国 IC 产业的增长直接得益于产业的全球分工，尤其是 IC 制造业和封装测试业销售量的八成以上出口。IC 设计业则有所不同，由于 IC 设计业增加值最高，发达国家不愿意主动转移 IC 设计业。中国 IC 设计业不具有承接国际分工的特征，而主要面向国内的整机厂商，并显示出自主创新的发展潜力。

最后，中国 IC 产业链的内在联系还很弱。出口导向的制造、封装和测试极易受到国际市场波及的影响。IC 设计业面向国内需求市场，仅满足了一小部分国内中低端的 IC 制造和封装测试的产能。IC 设计业的发展是未来 IC 产业链整体升级的基础和动力。

# 三、中国 IC 产业的技术水平及其来源

从产业链的分析可以看出，与日本、韩国等国 IC 产业发展历程不同的是，中国的 IC 产业并没有形成产业链各个环节之间的功能升级、也没有形成产业链整体的升级，而是产业链的各个环节分别嵌入到国际和国内市场中、各自完成了流程升级和产品升级。其原因何在？对这个问题的回答，就要深入了解各个产业的技术水平和升级动力。

### （1） 自主开发的 IC 设计能力

中国 IC 设计业面向国内市场，技术主要源于自主创新。事实上，由于芯片设计的技术主要附着于人力资本和专利技术，不易于从国外转移，因而只能“被动的”实行自主创新。2000 年之后 IC 设计业的快速发展则得益于三个因素：（1）本土消费电子产品如国产手机、数字电视、汽车电子等的快速增长；（2）政府推动的技术创新和政府采购；（3）以及国内大型科研机构长期积累的技术能力与市场需求的结合。

上文提及，IC 设计业的发展瓶颈在于高端人才缺乏和外国知识产权的限制。因此，国内芯品设计公司分成两类：一类是由海归创业团队成立的小型企业，拥有国外同类企业工作的经验和芯片产品设计的专利，产品通常是专用芯片，如助听器芯片、手机芯片、音频和视频处理芯片等。开发专用芯片要求对终端消费市场非常敏感，直接服务于各种类型的消费电子产品，而对芯片的线宽和集成度要求相对较低，技术门槛和专利壁垒也比较低。但是，单款专用芯片的需求量往往不太大，通常在几千片左右，因而分摊到单位成本上的流片和测试的成本很高，难以通过规模经济降低成本。

北京中星微电子有限公司是这类海归企业中的佼佼者。该公司于 1999 年在国家电子发展基金直接投资及科技部政策支持下，由邓中翰、杨晓东等一批留美归国博士在中关村科技园区组建，致力于数字多媒体芯片的研发、设计及产业化工作。2005 年 11 月，中星微公司在纳斯达克上市，为第一家在纳斯达克上市的中国芯片设计公司。中星微公司的技术主要来自于自主开发，其销售收入的 20%左右用于研发，在国内外申请了 1300 多项专利，其中 85%为发明专利，并且拥有自主研发的商标、版权、著作权和集成电路布图设计等。在其技术发展过程中，政府各部门如发改委、信息产业部、地方政府等曾先后给予多项科研资助，总额约 6800 万元，约占企业研发投入的 10%左右。目前，该公司推出的手机多媒体处理芯片、数码相机核心芯片、摄像头监控芯片等产品已经占据国内主流市场。

另一类是由国内科研机构和国有企业设立的芯片设计公司，企业规模较前者

大，专注于通用芯片的开发，如中央处理器芯片（CPU)、存储芯片等。通用芯片的集成度和模块化程度非常高，其专利技术被国外巨头如英特尔、AMD、NEC等公司垄断，因而开发难度很大。但因为通用芯片具有经济、国防等战略上的重大意义，国内科研机构和国有企业从未放弃过这个领域的技术追踪和探索。例如以中科院计算所的研发团队为核心的神州龙芯集成电路设计公司推出"龙芯"系列产品，就是一款具有自主知识产权的 CPU 芯片，大量用于政府部门、军工企业和本土微电子公司（这些本土微电子公司因为采用了龙芯的 CPU 核而得到进一步的政府支持)。另一家大型的国内 IC 设计公司中国华大集成电路设计集团有限公司（简称"华大集团"）是一家国有企业，其前身是原中国电子工业部的研究机构。华大集团的芯片产品包括社会保障卡芯片、税控芯片、组织机构代码卡芯片等由政府采购的批量产品。同时，华大集团也是国内领先的安全芯片设计公司，安全芯片产品在国防、金融等部门有着广泛的应用。

**（2）自主引进并本土化的 IC 制造能力**

IC 制造企业的技术主要体现在 3 个方面：（1）"物化"在生产设备上的制造工艺，包括设备提供商提供的软件，如工艺菜单、工艺控制和工艺集成等服务的总体解决方案；（2）代工企业从高端客户中获得的技术授权，体现在产品的工艺水平上；（3）体现在流程管理、质量控制、知识产权战略上的制程技术和组织能力。

我国 IC 制造业自上个世纪七十年代以来一直依赖引进国外生产线。2000 年之前，国内 IC 企业基本上是 IDM 企业，引进生产线的同时引进芯片产品，如彩电芯片、存储器芯片等。产品更新换代后，企业又无力开发新的产品，造成生产线产能闲置、亏损严重。2000 年后新建的 IC 企业如中芯国际、和舰、宏力、无锡海力士-意法、台积电（上海）等均为单一业务代工企业（pure-play foundries），2000 年前建的 IDM 公司如华虹、华微、华晶、先进等企业也引进新的生产线，承接国际代工业务。

通过承接国际代工业务，国内 IC 制造企业的技术能力得到很大提升。以中芯国际（SMIC）为例， SMIC 最早采取 0.25 微米工艺，2001 年，SMIC 从新加坡特许半导体那里取得 0.18 微米标准逻辑制程技术及专利使用权，也曾从日本东芝获得低功率静态存储制程技术（Low power SRAM）的授权和定单。2002 年，中芯国际从德国英飞凌公司（Infineon）获得 0.14 微米标准存储器芯片（DRAM）的生产技术。通过消化吸收，SMIC 将 0.14 微米技术扩展到 0.15 微米和 0.13 微米。SMIC 的 90 纳米技术得到德州仪器(TI)、英飞凌、ARM 等公司的授权许可。最近，中芯国际与 IBM 签定 45nm 技术许可协议，IBM 将其 45 纳米低功耗以及高速 bulk CMOS 技术转让给中芯国际，这是目前为止最先进的量产技术。

除了技术授权，SMIC同时也进行自主开发和合作开发，以取得技术的自主权。在国内，SMIC与北京大学、清华大学以及中科院等研究机构建立了紧密的技术合作关系，甚至独立承担政府基础研究的课题。例如 2009 年新立项 973 及重大研究计划项目中就有SMIC上海公司承担的项目。[6]

总体而言，国内 IC 制造企业的技术能力直接受益于设备提供商和高端客户，并提高了市场能力和组织能力。目前，国内 IC 企业从全球获取技术、资金和人才资源，进行资源的整合、利用和再开发，形成了良性循环。例如，企业引进生产线时不是整条生产线一揽子买进，而是全球采购技术先进的重点设备、自行组建生产线。通过对制造装备的理解、比较和组装，国内企业从组织层面上构建起相应的技术能力。其次，代工企业不得不从全球市场获取代工订单，从而锻炼了国内 IC 企业的市场能力。尽管如此，由于世界半导体技术发展十分迅速，研发投入巨大，国际半导体巨头往往形成技术联盟来开发下一代技术，分担承担研发费用和风险。但中国企业还未跻身先进技术联盟的行列。

**（3）内嵌于跨国公司全球网络的 IC 封装测试能力**

与 IC 设计业和制造业相比，封装测试业由于技术限制管制较为宽松，再加上整体投资相对较少，国外众多 IDM 起初在中国的投资基本都集中在封装测试领域。目前，Intel、ST、Infineon、瑞萨、东芝等国际主要半导体公司已经在上海、无锡、苏州、深圳、成都等地投资设立了封装测试基地，全球前 20 大半导体厂商中已经有 14 家在国内独资或者合资建立了封装测试企业。这些企业无论在生产规模上还是技术水平上，都在中国封装测试行业内占据了主导地位。

国内外资 IDM 型封装测试企业主要为母公司服务，如英特尔的产品 100%出口，飞思卡尔的产品 99.6%出口。外资 OEM 型封装测试企业所接订单多为中高端产品，而内资封装测试企业的产品则集中在 DIP、SOP 等传统低端产品。

近几年来，中国崛起的 IC 设计和制造业的发展，对中国本土封测业的拉动效应已开始显现。中国内地企业已经在 BGA、CSP 和 MCM 等先进封装技术上开始取得一些突破，而且 QFN 等无引线封装技术也已经开始量产。南通富士通、江苏长电、天水华天等企业在 PGA、BGA 和 CSP 以及 MCM 等先进封装形式的开发和应用方面取得了显著成果。而在外资企业中，BGA、CSP、MCP、MCM、MEMS 等封装技术已经开始进入量产。中国封测行业的整体技术能力与国际水平的差距正在逐步缩小。

[6] 纳米磁性自旋存储器和半导体硅量子点存储器的研制及其器件物理研究　　中芯国际集成电路制造(上海)有限公司　　季明华

总体而言，中国 IC 产业的技术水平与世界先进水平的差距正在缩小，尤其 IC 制造业、IC 封装测试业的技术水平已经接近或达到国际主流的技术水平。但从其技术来源而言，IC 设计业的技术以国内自主开发为主，IC 制造业和封装测试业的技术主要来自国外。

# 四、中国 IC 产业的生态格局

2000 年后中国 IC 产业的规模扩张、技术进步，及其参与国际分工的深度令人印象深刻。在全球产业分工的态势下，一国高技术产业的生产规模和技术水平是否代表了该国的产业竞争力？

### 两种外国资本：金融投资者和策略投资者

对于高技术产业的外国资本，区别两种类型的投资者是必要的：一类是来自金融市场的资本投资者，包括股票市场和私墓基金，其投资目的是为了获取高技术产业的高额增值利润，资本拥有者关注企业的经营绩效，但通常不介入企业的运营战略和技术能力构建。中芯国际、宏力、和舰等 IC 制造企业属于该类型。这类企业生长于本地，专注于发展和积累自身的技术能力，并且基于市场需求和自身能力，逐渐形成技术发展和产业升级的内生动力。不仅如此，随着企业的不断发展壮大，企业还会不断吸引新的投资者加入，投资者对企业的影响被进一步稀释。因此，对于金融投资者为投资主体的企业，从其产业生态格局而言，应被视为本地化的成分。

另一类型的投资者是跨国企业的策略投资者。跨国公司基于企业自身规模扩张和全球布局的策略，对华转移其制造部门和封装测试部门，以求降低成本、扩大产能和市场份额。策略投资者以独资或合资控股的方式介入在华企业的战略管理，其生产经营规划和技术能力构建均服从于母公司的统一部署，而与本地市场的联系很弱。在遇到全球市场紧缩或企业战略调整的情况下，在华工厂随时可能被停产、关闭或转移。这类企业并非产业生态格局中的本地化的成分。

### 本土企业和跨国公司分支机构

因此，考虑到高技术产业的投资特性，我们将中国 IC 企业分成两类，即本土企业和跨国公司分支机构。据此，IC 产业的生态格局呈现出如下特征：

（1）中国 IC 设计业 10 强企业中的前 9 家均为本土企业，收入占十强总收

入的 97%。如排名第 1 的深圳海思半导体有限公司，前身是华为集成电路设计中心。海思公司总部位于深圳，在北京、上海、美国硅谷和瑞典设有设计分部。排名第 10 的日电电子（中国）有限公司是外商独资的 MNC 分支，服务于日本 NEC 公司在中国的 IC 设计、开发、销售和技术支持工作。

（2）中国 IC 制造业十强中本土企业共 8 家，收入占十强总收入的 65%。十强中的无锡海力士-意法、台积电（上海）均为跨国公司策略投资者类型的企业。海力士、意法和台积电分别是国际市场上领先的芯片制造商。台积电的芯片代工产量占世界代工的近五成，但在 2008 年金融危机的影响下，TMC 迅速收缩大陆工厂产量，其大陆工厂的产量不足台湾工厂的 1%（验证？）

（3）中国 IC 封装测试业基本上被外资垄断，10 强中有 5 家外商独资企业、3 家外商控股企业，只有江苏新潮和南通富士通 2 家本土企业。本土企业的收入仅占十强总收入的 14%。不仅如此，本土的封装测试企业在技术水平和市场竞争中也处于劣势。

总体而言，在快速发展的绚丽光芒下，中国 IC 产业呈现出来的生态格局令人喜忧参半。一方面，作为产业链龙头和高附加值的设计业已经构建了本土化的技术能力，根植于中国本地的市场需求，初步具备技术升级的内生动力和能力。同时，作为产业链主体的 IC 制造业，得益于新的资本募集和企业运营模式，本土化的制造产能得以发展，技术基本接近国际主流的制造水平。另一方面，占据中国 IC 产业总产值半壁江山的 IC 封装测试业，却是跨国企业独霸天下的局面。绝大多数产能和技术掌握在跨国公司的分支机构中，本地化联系较弱。随着劳动力和资源成本优势的下降，可以预见未来将转移到更具成本优势的东南亚地区。

# 五、结论

首先，作为高技术产品的生产大国，中国的崛起令世界瞩目。在规模扩张的背后，仍需谨慎剖析中国高技术产业的技术水平和生态格局，从生产、技术和市场的本土化程度来考察产业链的发展趋势。具有升级潜力的产业链不仅应该具备完整的产业结构，而且还应该具备如下两个因素：

（1） 产业链内部各功能环节之间的联系；

（2） 本土企业内生的技术能力。

其次，高技术产业在承接国际分工的过程中，只有部分企业形成了技术升级的内生动力。究竟哪些企业能够在国际分工中进入价值链的上升通道呢？以下几点要素是必要的：

（1） 本地企业，而非跨国公司的策略性分支机构；

（2） 海归团队或本国科研机构、国有企业的长期技术积累；

（3） 政府和倾斜性政策对技术自主创新和产业化的推动。

第三，高技术产业普遍具有高投资、高风险的特征，国际资本市场包括国际私募基金对产业的发展至关重要。对于国际资本市场支持下高技术产业，简单的划分内资和外资的资本属性无法有效揭示国际分工对东道国的技术植入性。相比而言，是否属于跨国公司策略性分支机构，更具有现实分析意义。

本文对高技术产业参与国际分工的研究仅限于集成电路产业。我们欢迎和鼓励更多的学者提供其他产业的相关研究。

# Who Profits from Innovation in Global Value Chains? A Study of the iPod and notebook PCs

**Jason Dedrick, Kenneth L. Kraemer, Greg Linden***
**Personal Computing Industry Center, UC Irvine**
5251 California Ave., Ste. 250
Irvine, California 92697-4650
http://pcic.merage.uci.edu

jdedrick@uci.edu
kkraemer@uci.edu
glinden@uclink4.berkeley.edu

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*Authors listed alphabetically

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**Abstract**

This paper analyzes the distribution of financial value from innovation in the global supply chains of iPods and notebook computers. We find that Apple has captured a great deal of value from the innovation embodied in the iPod, while notebook makers capture a more modest share of the value from PC innovation. In order to understand these differences, we employ concepts from theories of innovation and industrial organization, finding significant roles for industry evolution, complementary assets, appropriability, system integration, and bargaining power.

## 1. Introduction

The power of innovation to reward pioneers with exceptional profits is well known. Yet, as recognized in various strains of the business strategy literature, the value generated from innovation is generally shared by the innovator with some combination of component suppliers, intellectual property owners, providers of complementary products and services, competitors, and consumers. This is all the more true as firms focus on a set of core activities and rely on a network of allies and suppliers to help them create and produce innovative products. In such innovation networks, a key question for managers and students of firm strategy is who captures the most value from innovation, and why?

This paper addresses the question of who benefits financially from innovation in global value chains by looking at specific products: higher-end iPods and notebook computers. We apply a novel methodology for measuring value captured by firms across the supply chains for a pair of globally innovated products that combine technologies from the U.S., Japan, and other countries, and are all assembled in China. This product-level approach allows us to break out the financial value embedded in each product and clarify how it is distributed across the primary participants in the supply chain.

Our analysis shows that the gross margins of Apple for its high-end iPod products are generally higher than those earned by notebook PC makers, although not so high as to be considered "supernormal." Other indicators such as operating profits and stock price performance suggest that Apple has captured a great deal of value from the innovation embodied in the iPod, while notebook PC makers capture a more modest share of the value of innovation in their supply chain.

In order to understand the differences in the profits from innovation between Apple and the notebook PC makers and their suppliers, we frame our analysis using a nested approach that draws on theories from two major business strategy traditions: profiting from innovation (PFI) and industrial organization (IO). These theories are prescriptive rather than predictive, so we are not testing them, but using their concepts to frame the analysis of our data. Specifically, we look at (1) the ability of lead firms to profit from their own innovations based on criteria identified by Teece (1986) and related studies in the PFI tradition. We also look at (2) the bargaining power of participants in the supply chain as a determinant of how the profits from innovation are divided, from the IO tradition (Porter, 1980). The PFI framework is based on the perspective of a focal firm and is not directly concerned with the profitability of other actors in the supply chain. The IO approach, concerned primarily with industry structure, is well suited to thinking about the bargaining power that determines the range of profit outcomes we observe along the supply chain.

For the lead firms, we apply the PFI framework and discuss how Apple built its iPod profit engine by keeping vital complements such as software in-house, dynamically innovating a business model that leveraged key external complements, and using proprietary technology to keep rivals at a distance. Within its supply chain, Apple has strong bargaining power, thanks to the large market opportunity it provides.

By contrast, notebook computer makers are part of a business ecosystem that they coordinate yet don't control. Two suppliers—Microsoft and Intel—stand out for making supernormal profits. These two were able to wrest control over key software and hardware standards from IBM in the late 1980s and have protected their positions ever since (Dedrick and Kraemer, 1998). Possessing tremendous bargaining power, they capture a large share of PC industry profits, leaving less for brand name vendors and others in the supply chain. We estimate that PC makers earn normal margins on the mid-priced notebook models analyzed here, as do many of their suppliers. The lead firms leverage the huge supply of complementary assets for Wintel PCs (software, peripherals, Internet content, services, etc.), while allowing Microsoft and Intel to shoulder much of the cost of sustaining the ecosystem that supplies those assets by dealing with compatibility issues and investing in the core operating system and microprocessor technologies.[1]

The following section of the paper frames the analysis using concepts from the fields of innovation management and industrial organization. We then present the methodology we use to analyze the distribution of profits for individual innovative products, and use that methodology to derive the gross profits for two models of iPod and notebook computers. We next compare the distribution of profits from innovation for iPods and notebook PCs across the supply chains of those products, using supplier data on gross and operating profits. Finally, we analyze why the differences occur using concepts from the industrial organization and innovation literature.

[1] "Wintel" is industry shorthand for the standard that features Microsoft's Windows operating system running on an Intel-compatible processor.

## 2. Theories of innovation, profits, and the supply chain

An innovation can take many forms, from disembodied technology to a new product or process. We are concerned here with innovations that are tied to products manufactured by extended global supply chains. In the case of the iPod, the initial model was innovative in terms of its design and user interface, with subsequent models introducing various modifications, such as the video playback capability in the Video iPod analyzed in this article. Within two years of the first iPod sale, Apple also created a new business model for digital music, as we discuss further below.

As an innovative product moves from concept to market, the lead firm must assess the constellation of complementary technologies to identify those that might be sufficiently specialized to its innovation and which fit with its own capabilities to justify internal provision (Jacobides et al., 2006). For the remaining complements, it must arrange for provision from supply chain partners.[2] The lead firm must also define its value proposition for customers and assess the competitive environment for its offering as part of creating a comprehensive business model (Chesbrough and Rosenbloom, 2002). The product price divides the available surplus (the difference between willingness to pay for a product and the actual cost of providing it) between the producers and consumers. That price, in turn, minus the total cost of production and distribution, determines the value that is available to be distributed among the supply chain participants.

[2] We use "supply chain" to mean the physical flow of goods, from materials through distribution and sale of the final product. We use "value chain" to refer to all the functions of a firm, including its support activities. And "global value chain" refers to all the functions, from initial concept to the provision of complementary products, needed to achieve a satisfactory user experience.

Value capture within the supply chain can be thought of as a two-level process: (1) the determination of producer surplus and (2) the division of that surplus among the supply chain partners. We apply a different analytical approach to each level: the analytically rich innovation framework to the producer surplus and the simpler bargaining perspective from industrial organization economics for the division of the surplus across the supply chain.

### *2.1 Profiting from innovation*

In an outsourced supply chain, a lead firm coordinates a partner network to develop and manufacture an innovative product and to maximize the market value of its innovation. The lead firm bears the primary responsibility for maximizing the profits that it divides with its partners and suppliers.

In the classic strategy literature, the ability of lead firms to maximize producer surplus and capture the highest value from their innovation depends first on preventing rivals from eroding profits. Firms can avoid this outcome by erecting barriers to entry that persist over time and charging higher prices that bring "supernormal profits" or "economic rents" (Porter, 1991). These barriers, or isolating mechanisms (Rumelt, 1987), can include government regulations (e.g., cable TV franchises), patents, control over raw material sources, branding, or advantages due to a unique location.

In dynamic, highly networked industries such as information technology and electronics, additional factors come into play. Each innovation at the core of a new product offering is likely to require access to and coordination with other innovations to provide value to users. The technologies at the heart of electronic products have a high rate of change, so entry barriers are often short-lived, and management must be capable of recognizing and responding to changing market characteristics (Teece *et al.,* 1997).

These features of high-technology industries have made them a special focus of a stream of literature on profiting from innovation. One of the most-cited studies in this literature, Teece (1986), identifies three important factors that influence the distribution of profits from innovation.

The first is *industry evolution*, and in particular whether the market has embraced a dominant design for a new innovation (Abernathy and Utterback, 1978; Anderson and Tushman, 1990). In the early stages of an industry, a variety of product solutions may be introduced with no clear leader. Once the market has chosen a winning set of product characteristics, less design heterogeneity is possible and competition becomes more price-based. The early phase often amounts to standards competition (David and Greenstein, 1990), in which groups of firms promoting alternative offerings in a single product space try to build sufficient market presence to become the dominant standard. A dominant design is, however, conceptually distinct from a standard (Gallagher, 2006), as evidenced by the case where multiple standards co-exist in the market after a dominant design (e.g. a product architecture) has become apparent. Examples include the competition between mobile phone standards, or between different video game standards.

The second issue is *appropriability*. This is defined by Teece (1986: 287) as “the environmental factors, excluding firm and market structure, that govern an innovator’s ability to capture the profits generated by an innovation.” Appropriability focuses more narrowly on the nature of the technology and the available legal mechanisms to protect an innovator. It explicitly deals with firm strategy and organization as a means to appropriate value from innovation (Winter, 2006).

The third element of the Teece framework is *complementarity*. For many electronics products, widespread acceptance depends on the availability of related goods that enable or enhance their functionality. For instance, computers need software, and DVD players need pre-recorded movies. Innovating firms must decide whether to produce such complements internally or to rely on others to do so (Teece 1986). Given consumer expectations of interoperability and the speed of change in the electronics industry, even the largest firms today must work with widely distributed alliance networks to bring new ideas to market. Innovators need to coordinate to varying degrees with a large number of firms, sometimes including competitors (Brandenburger and Nalebuff, 1996), to ensure a supply of complements in order to maximize the total value proposition, while also positioning themselves to capture as much as possible of the value that is created by the network.

These factors interact with each other. For example, when appropriability is low (i.e., when imitation is easy), innovators shaping their supply chain are more likely to see their advantage erode unless they keep specialized complements in-house or otherwise under control (Pisano, 2006). A common thread linking dominant design, appropriability and complementarity is the presence of *standards*. A dominant design often emerges from market-based standards competition, or, in the case of a formal standard-setting procedure, political maneuvering within an industry association. The nature of standards, which can vary in terms of technical openness, availability for licensing, and so on, helps to define the appropriability regime. Control of the key standards for a product manufactured by a modular supply chain can reside in different levels of the product architecture, and there is competition to prevent control from shifting to another layer (West and Dedrick, 2000). The classic case here is the PC, where the standards of the now-dominant design were originally set by IBM at the system level, but eventually usurped by Microsoft and Intel at the microprocessor and operating system levels.

An important adjunct of the original PFI framework that has particular relevance in the present study is system integration. This capability has become a key strategic function as industries become decentralized (Prencipe, et al., 2003). With innovation happening in different parts of the industry, a central actor must decide which technologies to incorporate into products, and then make those fast-changing elements work together in a product that is useful and affordable for customers (Pisano and Teece, 2007).

As will be seen later in Section 4, these concepts help to explain why Apple is able to capture more value from its iPod innovation than PC makers are able to capture from notebooks.

### *2.2 Bargaining within the supply chain*

The division of the producer surplus among the supply chain partners depends upon the relative bargaining power of participants (Porter, 1980; Bowman and Ambrosini, 2000). A lead firm must decide based on strategic concerns, such as competitive conditions in input markets, which activities to undertake in-house and which to turn over to an outside supplier (Chesbrough and Teece, 1996; Jacobides *et al*., 2006). Once it has decided on the composition of its supply chain, the lead firm bargains with its suppliers and partners in the supply chain over the distribution of profits. Buyer bargaining power is greater when there are only a few large buyers than when there are many smaller ones. Similarly, a seller's bargaining power is higher in a monopoly or oligopoly situation than in a highly competitive market.

Other factors influence bargaining power as well. For instance, access to proprietary information, such as a seller's cost structure or a buyer's inventory situation can provide bargaining power (Seidmann and Sundararajan, 1997). After a supplier is chosen, high switching costs from one supplier to another can give a seller greater bargaining power, a situation known as an *ex post* small numbers bargaining situation (Williamson, 1975). Specialized knowledge is another source of bargaining power, as only a few suppliers may have a particular expertise required by the buyer, which also leads to small numbers bargaining.

As will be seen in Section 5, these bargaining concepts help to explain why Apple is able to capture a greater share of the profits within its supply chain than PC makers are able to capture within theirs—even though they share much of the same general supply chain.

## 3. Methodology: Measuring who captures value in global value chains

Our supply chain perspective is similar to that adopted in studies such as Gereffi (1994), Gourevitch *et al*. (2000), and Kaplinsky and Fitter (2004). However, these earlier studies used an industry-level approach, whereas we are pursuing a product-level focus to estimate the value captured by the lead firm and its most important suppliers for a single model (Appendix 1 briefly introduces supply chain analysis). The products we analyze here in detail are Apple's Video iPod, released in late 2005, and the model nc6230 notebook computer released by Hewlett-Packard (H-P) in early 2005. We also analyzed an earlier model of the iPod and a Lenovo notebook computer which generated similar results. We summarize those results below, but do not analyze those supply chains in detail.

To model the value captured by a lead firm and its suppliers at the product level, we need to know the product's cost structure. However, product-level cost data are extremely hard to obtain directly from electronics firms, who jealously protect information about the pricing deals they have negotiated and often require the silence of their suppliers and contractors through non-disclosure agreements.

For many electronic products, lists of components and their factory prices are available from industry analysts' "teardown" reports, which capture the composition of the product at a specific point in time. These can be used to estimate a product's value added by subtracting the input prices from the wholesale price, which must be estimated with additional research.

Based on teardowns from Portelligent (Portelligent 2005b; 2006), Table 1 shows the key inputs in one model of Apple's iPod (30GB Video iPod) and a Hewlett-Packard notebook computer (nc6230). Although a notebook computer, with its programmability and multiple functions, may seem radically different from an iPod, the latter is essentially a portable computer dedicated to media processing. This comparability is underscored by the similarity across the two products of each functional input as a percentage of the lead firm's manufacturing cost.

One major difference is that software does not figure in Apple's bill of materials. The iPod's software was developed in-house, which spares Apple from paying license or royalty fees on each unit sold. In contrast, software licenses for the operating system and applications are a major part (11 percent) of the bill of materials for the HP nc6230.

Another key difference is that the iPod's limited-purpose microprocessors are relatively inexpensive as a share of costs (9 percent) compared to the notebook's general-purpose processor chipset (27 percent). By contrast, the iPod's storage system, a hard disk drive, accounts for half the factory cost compared to just 12 percent in the notebook for both the hard disk and DVD drives.

Further details for these and two similar products (an earlier-model iPod and a Lenovo ThinkPad) are presented in four tables in Appendix 2.

**Table 1** Comparison of Inputs as Percentage of Factory Cost:
30GB Video iPod and HP nc6230 Notebook

| | Video iPod | HP nc6230 |
|---|---|---|
| **Software** | Not Applicable | 12% |
| **Storage** | 51% | 13% |
| **Display** | 16% | 16% |
| **Processors** | 9% | 27% |
| **Assembly** | 3% | 3% |
| **Battery** | 2% | 5% |
| **Memory** | 4% | 4% |
| **PCBs** | 2% | 3% |
| **Enclosure** | 2% | 1% |
| **Input Device(s)**[3] | 1% | 2% |
| **Subtotal for key components** | 90% | 86% |
| **Hundreds of other components** | 10% | 14% |
| **TOTAL** | 100% | 100% |
| **Total Parts** | 451 | 2,196 |

*Note*: iPod software was developed in-house by Apple so there is no software license fee in the bill of materials.
*Source*: Authors' calculations.

To estimate the value captured by the suppliers, we consider three firm-level measures of profit: gross margin, operating margin, and return on assets. Gross margin (GM) is the ratio of gross profit (the difference between "net sales" and "cost of goods sold") to net sales. GM tells what share of a firm's sales price is retained after the direct costs of making its goods or services are deducted; it's the measure that comes closest to the product-level profit that we analyze for the lead firm. Operating margin (OM) is the ratio of operating profit (which subtracts overhead costs including research, development, sales, general, and administrative expenses from gross profit) to net sales. OM shows the success of a firm's overall productive and innovative activity. Return on Assets (ROA), the ratio of net profit (or loss) to Total Assets (an accounting value

[3] "Input Device(s)" vary by product. For a notebook computer, it is the keyboard and trackpad (or other pointing device). For the iPod, it is the scroll wheel.

reported on a firm's balance sheet), shows the firm's economic efficiency in the use of capital from its shareholders and creditors.

Gross or operating margins above a "normal" level reflect the ability to charge more than the long-run competitive price level, which is a product's average variable cost. To determine whether or not unusually high or low profits are present, we need to compare the returns of individual firms to some "normal" profit margin. To estimate a normal margin, we began by calculating the average GM, OM, and ROA for 270 of the leading global electronics firms for 2004 as reported in Electronic Business' EB 300 listing, which were 32.8 percent, 11.5 percent, and 5.2 percent, respectively.

The standard deviation of the gross margin was 19.5 percent, so, assuming a normal distribution, the range of 13.3 to 52.3 percent should cover about two-thirds of the sample, which it does (71 percent of the sample is within one standard deviation of the mean, with nearly the same number of firms above and below that range). Gross margins above this range are defined as supernormal, and margins significantly lower are subnormal.

The standard deviation of the average operating margin was 13.5, giving a "normal" range of 25.0 down to –2.0. The fact that a negative operating margin can be within the normal range illustrates the fact that many companies in the industry operate on very thin margins, and each year some are likely to lose money. In 2004, 18 firms of the 196 for which data were available in the EB 300 had negative operating margins.

The standard deviation of the average ROA was 7.1, giving a "normal" range of 12.3 to –1.9 percent. The same thin-margin logic that applies to OM applies even more so to ROA because its numerator, net income, reflects subtractions from operating income, particularly taxes.

We estimated the product-level gross margins for lead firms, which we use to compare the value capture of Apple for two iPod models, and Lenovo and HP for notebook PCs. Company-wide operating margins are available for all publicly-traded firms in the supply chain, and can be used to compare value capture at the firm level after subtracting the costs of R&D, and the sales and administrative costs a firm incurs to achieve its gross margins. If a high gross margin is completely consumed by the cost of R&D and marketing, then it is not a sign of above-normal profits. This is better measured by operating margin after those costs are taken out. Software companies capitalize some of their development costs to be expensed over the life of the product. For this reason, ROA, which includes these capitalized costs in the denominator, is a useful metric for comparing software and manufacturing companies.

By examining all three measures, we can avoid faulty conclusions that might result from the use of just one. Table 2 summarizes the preceding discussion.

**Table 2** Three performance measures

| Measure | Definition | "Normal" Range, 2004 |
|---|---|---|
| Gross Margin | Gross Profit over Sales | 52.3% to 13.3% |
| Operating Margin | Operating Profit over Sales | 25.0% to –2.0% |
| Return On Assets | Net Profit over Total Assets | 12.3% to –1.9% |

*Source*: See text.

### 4. Lead firm gross profit

Given the factory cost, in order to estimate gross profit per unit, we need to know the wholesale price at which the lead firm releases its products to a distributor, who then adds an amount to that price when charging a retailer. Other supply chain configurations occur, but we will reason from this basic model of distribution and retail as follows.

The retail price of the 30GB Video iPod at the time of Portelligent's analysis was $299. Based on our research, we estimate a 25 percent wholesale discount for each unit, with 10 percent for distribution and 15 percent for retail for both iPod models.[4]

Applying these estimates to the retail price, we were able to arrive at an estimate of Apple's gross margin on each 30GB Video iPod sold. Apple is the lead firm in the iPod supply chain, incurring costs for R&D, marketing, coordination of the iPod's global value chain, and other overhead costs such as warranty. It is the residual claimant for value capture, as detailed in Table 3, in that it is the only company that bargains with all other actors in the supply chain.

**Table 3** Derivation of Apple's gross margin on 30GB Video iPod

| | | |
|---|---|---|
| **Retail Price** | $299 | |
| **Distributor Discount (10%)** | ($30) | |
| **Retailer Discount (15%)** | ($45) | |
| **Sub-Total (estimated wholesale price)** | | $224 |
| **Factory Cost** | ($144) | |
| **Remaining Balance (estimated Apple gross profit)** | | $80 |
| **Apple Gross Margin ($80/$224)** | | 36% |

*Source*: Authors' calculations; see text.

Apple's estimated gross profit on these units would be $80, which works out to a gross margin of 36 percent of the $224 estimated wholesale price. As a point of comparison, Apple's reported corporate gross margin for all products in the year ending September 30, 2006 was 29 percent.

For the notebook computer, lower discount rates were used for our estimation of distribution and retail because a notebook PC is a much more expensive product than an iPod and the costs of distribution and retail don't rise proportionately to the price. Our estimates of

[4] A gross profit margin of "less than 15 percent" for non-Apple sales is claimed in Damon Darlin, "The iPod Ecosystem," *New York Times*, February 3, 2006, so Apple's wholesale discount would need to be at least this large. The distribution estimate is from an industry interview. A typical retail and distribution margin for another small consumer product, a $99 digital camera, is 24% (Siu Han and Adam Hwang, "Taiwan ODM/OEM digital camera

notebook computer distribution and retail discounts are 5 percent and 10 percent, respectively. Applying these discounts, our estimate of the wholesale price received by Hewlett-Packard is $1,189 against our estimated factory cost of $856. The difference of $333 gives Hewlett-Packard an estimated near-average gross margin of 28 percent. This estimated notebook gross margin, which doesn't reflect warranty and other direct expenses, is higher than HP's overall gross margin of 24.3 percent in the fiscal year ending October 31, 2006.

Similar estimates of value capture were made for an older model of iPod and a Lenovo ThinkPad. The earlier-generation iPod earned a slightly higher margin (40 percent) than the later version (36 percent), while the ThinkPad-branded notebook earned slightly more (30 percent) than the competing Hewlett-Packard model (28 percent). However, for each pair of products (Table 4), the margins are so close as to be within the uncertainty range of our estimates.

**Table 4** Lead firm estimated gross margins for four products[5]

| Product | Retail Price | Estimated Wholesale Price | Estimated Gross Profit | Gross Margin (gross profit as percentage of wholesale price) |
|---|---|---|---|---|
| **30GB 3rd-Generation iPod, 2003** | $399 | $299 | $119 | 40% |
| **30GB Video iPod, 2005** | $299 | $224 | $80 | 36% |
| **Lenovo ThinkPad T43, 2005** | $1,479 | $1,257 | $382 | 30% |
| **Hewlett-Packard nc6230, 2005** | $1,399 | $1,189 | $333 | 28% |

*Source*: Authors' calculations; see text.

Apple's iPod gross margins are generally higher than those for the two notebook models, but these would be partly dissipated by Apple's extra overhead costs. As mentioned above, Apple's in-house software was critical to the iPod's success, but absent from the bill of materials.

makers to see more orders from Japan but shrinking net margins in 2008, says Asia Optical," DigiTimes.com, January 17, 2008).

[5] The product-specific gross margins in Table 3 are calculated as described in the text discussing Table 2. They are different from the gross margins for inputs listed in the Appendix tables, because those are company-wide values from published corporate reports.

Apple's internal electrical and mechanical engineering capability, which determine important details like the quality of an audio circuit, the ability to pack components in a limited space, and the materials chosen for the case, add value to the raw components that make an iPod.

HP, on the other hand, has transferred a great deal of the responsibility for its development engineering to its ODM contractors, while Lenovo relies more on internal engineering capabilities that it acquired along with the ThinkPad brand when it bought the IBM PC division. Both HP and Lenovo carry out the critical task of establishing initial specifications that balance market demand and technology trends.

**5. Distribution of profit along the supply chain**

As the component breakdowns above make clear, many companies contribute to every iPod and notebook PC. However, the price of the component a company provides does not correspond directly to the value that it captures, which also is determined by the supplier's cost of goods.

We measure value capture along the supply chain using gross margin (GM), operating margin (OM), and return on assets (ROA), described above. Our measures are calculated from the company-wide values in corporate financial reports.

The use of company-wide data for our purposes is not as good as product-specific data would be, but product-level data simply are not available for component suppliers. In the case of a focused company like the chip maker Broadcom, company data is a good approximation because such companies target a similar level of profitability for most projects they undertake. By contrast, a company like Samsung that makes everything from microchips to major household appliances, has a wide range of profit margins across its divisions. We note cases where, based on industry knowledge, we believe the corporate numbers don't accurately reflect the bargaining power of suppliers for a particular component.

Tables 5 and 6 below identify significant sub-groups of supply chain participants along the Video iPod and nc6230 notebook supply chains, shown in descending order of operating margin. The firm-level GM, OM, and ROA are shown in the right-hand columns. Cells where the value lies outside the "normal" range for that measure are shaded.

For a few inputs where we did not know the specific firm that was the primary supplier, we have used the data for one or more representative firms, as detailed below. Whether the specific firm is known or not, these data are intended to be indicative, not definitive. They give some idea of bargaining power and value capture along the supply chain, which we discuss below for lead firms and suppliers of key inputs.

The following discussion of bargaining power refers primarily to gross and operating margins. The discussion would not be substantially different if we used ROA. The three measures don't lead to exactly the same rank order, but they share a general ranking of firms into high, medium, or low groups.

**Table 5** Profit margins of primary firms in the Video iPod supply chain, 2005

| Function | Supplier | Gross Margin | Operating Margin | Return On Assets |
|---|---|---|---|---|
| Controller chip | PortalPlayer | 44.8% | 20.4% | 19.1% |
| Lead Firm | Apple | 29.0% | 11.8% | 16.6% |
| Video chip | Broadcom | 52.5% | 10.9% | 9.8% |
| Primary memory | Samsung | 31.5% | 9.4% | 10.3% |
| Battery | TDK | 26.3% | 7.6% | 4.8% |
| Retailer | Best Buy | 25% | 5.3% | 9.6% |
| Display | Toshiba-Matsushita Display | 28.2% | 3.9% | 1.8% |
| Hard Drive | Toshiba | 26.5% | 3.8% | 1.7% |
| Assembly | Inventec Appliances | 8.5% | 3.1% | 6.1% |
| Distribution | Ingram Micro | 5.50% | 1.3% | 3.1% |
| Minor memory | Elpida | 17.6% | 0.1% | -1.0% |
| Minor memory | Spansion | 9.6% | -14.2% | -9.2% |

Note: Shaded cells are outside the "normal" range for that profit measure.
*Source*: Calculated from corporate reports for the fiscal year that includes December 2005; data for Toshiba-Matsushita Display, a 60/40 joint venture, are weighted averages of consolidated data for Toshiba and Matsushita.

**Table 6** Profit margins of firms in the HP nc6230 supply chain, 2005

| Function | Supplier | Gross Margin | Operating Margin | Return On Assets |
|---|---|---|---|---|
| Operating System | Microsoft | 84.8% | 36.6% | 17.3% |
| Processor plus logic and wireless chips | Intel | 59.4% | 31.1% | 17.9% |
| DDR SDRAM (graphics memory) | Hynix Semiconductor | 37.3% | 24.9% | 17.7% |
| Cardbus and Battery Charge Controllers | Texas Instruments | 48.8% | 20.8% | 15.4% |
| Ethernet Controller w/ Transceiver | Broadcom | 52.5% | 10.9% | 9.8% |
| Memory Board (main memory) | Samsung | 31.5% | 9.4% | 10.3% |
| Retailer | Best Buy | 25.0% | 5.3% | 9.6% |
| I/O Controller | Standard Microsystems | 46.0% | 4.2% | 2.7% |
| DVD-ROM/CD-RW Drive | Matsushita | 30.8% | 4.1% | 1.9% |
| Battery Pack | Unknown | 24.0% | 4.0% | 2.4% |
| Lead Firm | H-P | 23.4% | 4.0% | 3.1% |
| Display Assembly | Toshiba Matsushita Display | 28.2% | 3.9% | 1.8% |
| Hard Drive | Fujitsu | 26.5% | 3.8% | 1.8% |
| Assembly | Unknown | 6.1% | 2.4% | 4.6% |
| Distributor | Unknown | 7.7% | 1.5% | 1.9% |
| Graphics Processor | ATI Technologies | 27.6% | 1.1% | 1.0% |

Note: Shaded cells are outside the "normal" range for that profit measure.
*Source*: Calculated from corporate reports for the fiscal year that includes December 2005; Battery Gross and Operating Margins are the average of the FYE 12/05 or 3/06 data for the five leading makers of notebook batteries (combined market share of approximately 90%); Assembly Gross and Operating Margins are the average of the

FYE 12/05 data for HP's four ODM partners (see text); Distributor Gross and Operating Margins are the average of the data for four leading distributors (see text).

### *5.1 Lead firms*

The most striking contrast between the iPod and notebook supply chain margins is how high Apple ranks in terms of operating margin within its supply chain (second of twelve) compared to Hewlett-Packard (eleventh of sixteen). Apple's company-wide operating margin is 11.8 percent. This is probably lower than the value that could be attributed to this iPod model alone. Apple's company wide gross margin that fiscal year was 29 percent, which is less than the 36 percent gross margin we estimated for this model (see Table 3 earlier).

As discussed above, Apple negotiates with every member of the iPod supply chain. It is both the "guarantor of quality" (Jacobides *et al*., 2006) to the consumer and the residual claimant for value after all expenses. It enhances both roles by working closely with its suppliers, and even its suppliers' suppliers.

HP, based on its company-wide gross and operating margins, appears far down the nc6230 list despite being the lead firm in its supply chain (Table 6). Our estimated nc6230-specific gross margin of 28 percent (Table 4) is only slightly higher than the 23.4 percent reported company-wide, so these numbers may be roughly representative of HP's value capture in the notebook market, adjusting for the fact that notebook margins are generally higher than those for the desktop systems that HP also sells.

At a company-wide level (Table 7), Apple has a much higher operating margin than HP in spite of a similar level of R&D expenditures. We discuss why this is so in Section 6 using the Teece model.

**Table 7** Selected operating ratios

| | Gross Margin | R&D/Sales | Operating Margin |
|---|---|---|---|
| **Apple, FYE 9/24/2005** | 29.0% | 3.8% | 11.8% |
| **HP, FYE 10/31/05** | 23.4% | 4.0% | 4.0% |

*Source*: Calculated from Apple 10-K for FYE 9/30/06, p.74, Hewlett-Packard 10-K for FYE 10/31/06, p.42.

*5.2 Main processor and software firms*

As expected, the highest margins in notebooks are earned by Microsoft and Intel, with supernormal operating margins of 36 percent and 31 percent, respectively. Their returns on assets are also above the normal range, which shows that Intel's multi-billion dollar factories and Microsoft's capitalized development costs do not offset the extraordinary profitability reflected in their gross and operating margins. Microsoft and Intel's ownership, maintenance, and vigorous defense of valuable standards (operating system and processor architecture, respectively) allow them to charge a considerable premium for their components while making it harder for systems vendors like H-P and Lenovo to differentiate their computers in the market. Network effects that favor these inputs make it hard for computer companies to find alternate suppliers.

For the iPod, Apple is responsible for its own software. The first-listed outside firm is the supplier of this model's key computer chip, PortalPlayer, with an operating margin of 20.4 percent in 2005. PortalPlayer, a Silicon Valley start-up founded in 1999, was a key partner in the iPod development process (Sherman, 2002), providing the main microchip that controlled the iPod's basic functionality, handling critical tasks like digital music processing and the user's database management.

If PortalPlayer had any market power with Apple, it was dissipated by its dependence on Apple for its revenues. In 2005, Apple's subcontractors for iPod assembly accounted for 93 percent of PortalPlayer's sales (PortalPlayer, 2005). PortalPlayer's above-average gross margin may therefore represent Apple's acknowledgement of its supplier's fragility; 2005 was only PortalPlayer's second year of profitability.

Although there is some short-term co-specialization with its processor supplier, Apple is no more than one product revision (about 18 months) from being able to replace even a key supplier like PortalPlayer with acceptable switching costs. This is in fact what happened in 2006 as Apple began designing iPods without PortalPlayer's processors in them. The chip company fell on hard times and was acquired by Nvidia, another chip company (Clarke, 2006).

### *5.3 Other microchip firms*

There are three main categories of microchips: logic, memory, and analog. *Analog chips* tend to have high margins due to their specialized nature but make up a small share of the cost of an iPod or notebook.

Some *digital logic chips* are as specialized as analog chips, and command higher prices as well. They derive bargaining power from unique features of their implementation that reduce cost or improve performance. A prime example in the iPod is Broadcom's video decoder. Broadcom's gross margin of 52.5 percent is high enough to land in the supernormal range for the electronics industry. Its 10.9 percent operating margin is near the electronics industry average, but at the high end for iPod suppliers.

Unlike PortalPlayer, Broadcom was a well-established chip supplier by 2005, when Apple selected it to add video playback to the iPod line. Moreover, Broadcom had over a billion dollars in annual revenue and a diverse customer base, so it wasn't dependent on Apple's business. Broadcom's strength lies in its proprietary technologies for designing chips and the efficiency (in terms of power usage, speed, etc.) of the algorithms the chips use to accomplish tasks such as decoding compressed video. This gives its products sufficient attractiveness to command relatively high margins.

In contrast, *memory chips* are more narrowly standards-based and subject to intense competition. The bargaining position of these firms is set primarily by supply and demand in the overall memory market, and their margins are determined by their ability to control their internal costs. The sector is notoriously volatile because of the difficulty of synchronizing demand and supply, which leads to cycles of glut and scarcity.

The iPod's main memory chips came from Samsung, which reported a 9.4 percent operating margin. Samsung has been the world's largest supplier of memory chips in recent years, which has allowed it to benefit from scale economies in addition to the cost benefits of its internal excellence in key aspects of manufacturing. The poor performance of the other memory suppliers in the iPod, Elpida (0.1 percent operating margin) and Spansion (-14.2 percent operating margin), reflect the volatility in the memory sector.

In the nc6230, we find Samsung again and also its fellow Korean memory giant, Hynix, which had an even better year, earning a 25 percent operating margin, which placed it third among the major nc6230 suppliers. This should be seen as an indication of the company's manufacturing prowess rather than an indication of bargaining power as such because all DRAM suppliers negotiate price based on general market conditions of supply and demand so that variations in margins are indicative of company cost structure.

*5.4  Hard drive firms*

The Video iPod's hard drive, its single most expensive component, was supplied by Toshiba. We used Toshiba's company-wide gross margin for the fiscal year ended March 2006, 26.5 percent. Industry interviews suggest that the gross margin on this unit is probably 20 percent or less because Toshiba is a relatively low-volume producer that doesn't maximize its economies of scale, and Seagate and Western Digital, two larger disk drive producers, had gross margins of 23.2 and 19.1 percent in FYE June 30, 2006.

The Toshiba drive was a standard part with little leverage despite the fact that Toshiba was the only major producer at the time Apple started up its iPod project (Sherman, 2002). Toshiba's operating margin in FYE March 31, 2006 was just 3.8 percent. A large gap between gross and operating margins is a pattern we see frequently in Japanese firms. By comparison, Seagate and Western Digital had operating margins of 9.5 and 8.4 percent, despite having lower gross margins than Toshiba.

The nc6230 hard drive came from Fujitsu, one of the smallest hard disk drive suppliers, with about 7 percent of the market in unit terms in 2005 (iSuppli, 2006). The fierce competition of the drive market and Fujitsu's relatively small scale are likely to have kept its margins on this unit low. Fujitsu's company-wide margins in the year ending March 2006 were 26.5 percent gross and 3.8 percent operating.

*5.5  Other Japanese-supplied parts*

Among all the suppliers, Japanese companies are the most prevalent in the supply chain. In the iPod, Japanese suppliers provided the hard drive, the display, the battery, and one of the memory chips. Apart from the memory company, Elpida, which had poor performance at the gross as well as the operating level, their gross margins fell between 26.3 and 28.2 percent, close to Apple’s 29 percent. Operating margins, however, fell between 3.8 and 7.6 percent, which was well below Apple’s 11.8 percent.

In the nc6230, Japanese companies supplied the optical disc (CD/DVD) device, the display, and hard drive. Their operating margins are between 3.8 and 4.1 percent, similar to the 4 percent earned by HP. Their gross margins are between 26.5 and 30.8 percent, which is more than HP’s 23.4 percent gross margin.

Across all these companies, the two measures of profit are highly correlated, with operating margin being about a third of gross margin. If a Japan “dummy variable” is introduced into a regression of operating margin on gross margin, the dummy’s coefficient shows that Japanese identity knocks off more than 3 percentage points from a firm’s operating margin. This represents a major loss of value for the Japanese firms relative to the 8.7 percent average operating margin for all firms in the sample.

Although this low operating margin represents poor value capture in the shareholder sense, it doesn’t represent weak bargaining power within the supply chain. Japanese firms have long tolerated inefficient cost structures for a variety of business and societal reasons, such as maintaining employment. More recently, a change in shareholder structure has increased pressure to improve performance in terms of returns to shareholders (Sapsford and Fackler, 2005).

We present a more detailed analysis of batteries, displays, and the CD/DVD drive in Appendix 2.

*5.6 Assembly firms*

All iPod manufacturing is outsourced to Taiwanese companies with factories in mainland China. Apple's initial manufacturing partner for the iPod was Taiwan's Inventec Appliances, which continues to handle the hard drive-based iPod models (Levy, 2006). Despite a low gross margin of 8.5 percent, careful cost control and limited research expense (2 percent of sales) helped Inventec Appliances achieve an operating margin of 3.1 percent.

As with key components, Apple would incur some switching costs to change manufacturing service providers. However, these costs can be minimized by synchronizing them with a product revision, hence the power in the relationship is once again mostly on Apple's side.

For the nc6230, we did not know the specific assembler. To estimate assembly profitability, we averaged the margins of the four ODMs (Compal, Inventec, Quanta, and Wistron – all Taiwanese) reported to be supplying HP with notebook computers in 2004 and 2005 (Tzeng and Hwang, 2003; Lin and Shen, 2006). The average gross margin was 6.1 percent and the average operating margin 2.4 percent. The highest operating margin in this group was 4.6 percent, but the rest were 2.3 percent or less.

Despite the contribution of ODM firms to the development process for the notebooks they manufacture, contract manufacturing is a notoriously competitive and low-margin business with vendors able to switch suppliers from one model to another.

*5.7 Retail firms*

After a product is manufactured, there is still a great deal of value to be captured from distribution and retail. Based on our research, we estimate a 15 percent discount to retailers for the Video iPod, which would more or less be the retailer's gross margin on any single unit since the firm's overhead is spread over a store's-worth of products. Our teardown estimate of the nc6230 retailer's gross margin was 10 percent. These margins are retained by the lead firms when they are able to sell directly to end users, which Apple does in large volumes through its Apple stores and website.

Looking at representative firms in the electronics retail sector, Best Buy, which sells both consumer and office goods, had a gross margin of 25 percent and operating margin of 5.3 percent in fiscal 2005. Circuit City, associated more with consumer electronics like the iPod, had a gross margin of 24.5 percent but an operating margin of only 1.9 percent after overhead costs were deducted. The gross margin of an office equipment retailer, Staples, was 28.5 percent, and its operating margin was 7.7 percent. These retailer margins, while far from stellar, are large enough to suggest that the big retailers exert some power in the electronics supply chain despite the well-known fierce competition in the sector.

### *5.8 Distribution firms*

The picture is less positive for distributors, which use low-margin, high-turnover business models. We estimated a 10 percent share of the retail price of the iPod for distribution, which works out to an estimated gross margin of 11.8 percent for the distributor ($30/$254). We allowed 5 percent of the nc6230 retail price for distribution, which works out to a 5.9 percent gross margin ($69/$1,189).

Ingram Micro, which is involved in distributing both iPods and HP computers, had gross margin of 5.5 percent in fiscal 2005. This fell to operating profits of 1.3 percent after overhead costs were deducted. These values are probably dominated by computers and other IT products and services, which are Ingram's main business. The average for four leading computer distributors (Ingram Micro, Tech Data, Avnet, and Bell Microproducts) in 2005 was 7.7 percent. The corresponding average operating margin of these four distributors was 1.5 percent.

## 6. Explaining why some lead firms capture more value

We now explain the value captured by lead firms like Apple and HP. The technology trajectory of the PC industry has been well-studied over its long history, so we begin by reviewing the evolution of the iPod. After that we compare the market positions of Apple and HP in terms of the factors identified as important in the literature on profiting from innovation.

### *6.1 Evolutionof the iPod business model*

Digital audio players had been marketed by small companies as early as 1998, but they suffered from low capacity, high cost, and complex interfaces. The pre-iPod hard drive based models used standard notebook PC drives, which kept the units too bulky for easy mobility. The iPod was the first unit to incorporate Toshiba's smaller drive to permit a strikingly thin design and also introduced a wheel-based interface for control and file navigation in place of the buttons that featured on the front of competing products.

The iPod is not just a hardware innovation, but an integrated system comprising the iPod product family and closely integrated with its iTunes software and iTunes Store. Apple built up its iPod ecosystem in stages. The initial iPod, introduced in Fall 2001, was integrated with iTunes only on Apple's own Macintosh platform, with no thought to Apple involvement in content delivery (Levy, 2006: 154). In 2002, a Windows-compatible iPod was released using third-party software, greatly expanding the available market. In October 2003, Apple added iTunes support for the Windows platform.

In April 2003, Apple, having painstakingly negotiated cooperation from all the major music labels, introduced the iTunes Music Store (iTMS), which was the first service to legally permit the downloading of single tracks by a wide range of major artists as an alternative to illegal downloading or buying a whole CD for one song. The iTMS (now called the iTunes Store) uses an exclusive system of digital rights management (DRM) called FairPlay, which limited the number of computers on which the purchased tracks can be played.

Apple's control of the underlying digital rights management system for the first legal music downloading service with a large library added user switching costs to the iPod business model that helped keep Apple ahead of its rivals. To take advantage of this opportunity, Apple reportedly spent $200 million on advertising in the iPod's first four years, which was far more than the advertising of its music-player rivals at that time (Levy, 2006: 120). The advertising helped to expand the user base, and the switching costs associated with music purchased at the iTunes Store helped to ensure that buyers' second music player was also an iPod. The same logic applies to any iPod-specific accessories such as external speakers that use the iPod's "dock" connector; these also impose switching costs on future music player purchases.

In sharp contrast, notebook computers are sold without any particular associated method of content delivery or brand-specific accessories. The manufacturer may pre-install software or services, but the customer ultimately decides which applications to use on the machine and which networks to join for accessing content. Nearly all PC accessories also conform to industry-wide interface standards that are supported by all brands. Users face no penalty from choosing a different brand of notebook PC at their next purchase.

### *6.2 Explaining differences in profits from innovation*

Our data show that lead-firm gross margins for iPods are larger than for notebook computers. The average difference of 9 percent would be coveted by any manager, but we also note that it is less than half the 19.5 standard deviation of large electronics firm gross margins reported above, which means that the two numbers are not significantly different in the strict statistical sense.

What explains the difference in value capture between iPods and notebooks? And why is it that Intel and Microsoft capture such high margins in the PC supply chain?

In order to answer these questions, we look at the different positions of these players with respect to the key factors that can determine whether a firm will capture most of the value generated by its own innovative efforts. We will focus on the factors identified in the original Teece (1986) framework (industry evolution, appropriability, and complementarity) as well as other factors discussed above: system integration, and business models. In Section 7 we discuss the relevance of these factors to managers, while also providing new insights based on our own research of the industry.

#### *6.2.1 Industry evolution and the dominant design*

The current physical configuration for notebooks (keyboard, palm rest, and pointing device) was established by the early 1990s. Since then, almost everyone in the industry has innovated within the dominant physical design and, with the notable exception of Apple, within the Wintel standard. The innovation of HP and its suppliers in the nc6230 was limited to making the unit lighter yet more rugged by the use of a magnesium-alloy frame while Dell, HP's main rival in the notebook market, was still using all plastic. HP's rise to the top of the notebook ranking in the 2000s was driven primarily by price reductions made possible by the cost savings from its switch to outsourced manufacturing in the 1990s and the scale economies realized from its acquisition of Compaq in 2002.[6]

As Teece (1986: 288) argued, "once a dominant design emerges, competition shifts to price and away from design," while innovation tends to shift to the component level (Anderson and Tushman, 1990; Clark, 1985), and to process innovation, both of which have happened in notebook PCs. This results in incremental innovation, with occasional supplier-generated discontinuities such as 32-bit and 64-bit processing, graphical interfaces, multimedia, and wireless connectivity. Those transitions have been managed by Intel and Microsoft with no disruption of their position. This situation has made it very difficult for PC makers to differentiate their products, so competition has driven down their margins.

This can be seen starkly in terms of gross margin. In the HP nc6230, Intel and Microsoft combined have a gross margin of about 66 percent on inputs whose value equals about 30 percent of the wholesale price, which means their combined gross profit (i.e. the share of input price not directly related to the cost of providing the input) works out to 20 percent of the notebook's wholesale price. This leaves less for HP and everyone else in the supply chain since notebook PCs tend to target specific price points, which limits the potential for a positive-sum outcome.

Apple's ability to innovate in the then-emerging market for music players contrasts with the situation facing HP and Lenovo in the notebook PC market. The iPod was introduced before a dominant design was established for small digital music players, giving Apple a great deal of latitude in its design and integration choices. iPod clones, such as the Digital Jukebox launched

[6] Following a change in leadership in 2005, HP also improved the industrial design of its notebooks to enhance its consumer appeal, but the nc6230, marketed under the HP Compaq brand, was targeted primarily at budget-minded business users.

by Dell in 2003 to negative reviews, failed to dent iPod's market dominance.[7] The highly integrated iPod/iTunes system became a de facto dominant design, to the extent that Microsoft followed its example closely with the 2006 introduction of the Zune and the Zune Marketplace after shifting from its more modular "PlaysForSure" certification program that pushed Windows Media formats with loose ties to other companies' hardware and infrastructure.

*6.2.2 Appropriability*

Many of the individual innovations behind the components in electronic products enjoy high appropriability thanks to patents or other barriers to imitation, but for system firms like Apple, HP, or IBM, the appropriability regime is weaker, which increases the need for control over specialized complements (Pisano, 2006). IBM lost control over the key system interfaces by the late 1980s to its chief suppliers, Intel and Microsoft, and it failed to create any in-house complement important enough to appropriate the value of the system design and dominant standard it had created. IBM's award-winning ThinkPad line, introduced in 1992, was a good seller, but IBM failed to innovate fast enough to prevent rivals from duplicating its features over time, and IBM's loss-making PC business was finally sold to Lenovo. By contrast, Microsoft has achieved a very high level of user lock-in to Windows (Shapiro and Varian, 1999), while Intel has used a combination of aggressive IP protection, R&D resources, and scale economies to maintain its position in the face of challenges from various competitors over the years. With no PC maker having even 20 percent of the global market (versus over 90 percent for Microsoft and 80 percent for Intel), lead companies cannot do much to influence standards outcomes.

Unlike IBM, Apple kept control over key elements of the iPod, particularly the user interface, and the interfaces between the iPod, iTunes software and the online iTunes Store.

[7] See for example Lewis (2003): "Coming from the square world of Dell instead of the hip world of Apple, it's bigger, heavier, and clunkier than Apple's sleek, suave, elegant iPod..."

Through this strategy, Apple has been able to capture by far the largest share of profits from its innovation in the iPod. It has so far defended this position through an appropriability regime that includes extreme secrecy, refusing to open up the digital rights management system to others, and possession of a great deal of tacit knowledge in the areas of industrial design and user interfaces that others have tried and failed to imitate.

Patented innovations have played a limited role in the iPod's continued success. Apple was even sued in 2006 over the iPod user interface by Singapore's Creative Technology, a pioneer in the digital audio player market. Apple settled within a few months for a one-time licensing payment to Creative of $100 million.

Still, Apple's control over key iPod standards, such as the dock connector interface for external devices, has enabled it to access the necessary complementary assets while appropriating a share of profits from that growth. In 2005, Apple introduced a royalty fee for certifying products that interfaced with the iPod via its dock connection (Fried, 2005).

### *6.2.3 Complementary assets*

For many electronics products, a key factor is the availability of complementary goods and services that enable or enhance their functionality. Complements differ in terms of specialization. Generic complements, such as most simple electronics components, are readily redeployable to other supply chains. Unilaterally specialized complements, such as accessories using the iPod's unique connector, are dependent on the main product, but not vice-versa. Co-specialized complements, such as plastic moulds for unique product enclosures, involve mutual dependence.

One vital complement in which Apple has invested for many years is its brand image. Apple has a reputation as a "cool" and exciting company whose product announcements are newsworthy for the general public. This image has been maintained by many years of careful advertising and brand management that extended back to the company's earliest years. The iPod's success was partly due to this image, and the iPod itself also did much to enhance Apple's brand appeal.

Apple also maintains the role of "guarantor of quality" for its customers (Jacobides *et al.*, 2006), so that few iPod owners are even aware of what microchips power their music player, unlike the "Intel Inside" awareness of the PC market. Apple has also kept suppliers from gaining any significant market power by multiple sourcing where possible and by being willing to switch key suppliers from one model to the next.

One aspect of complementarity where Teece's original formulation proved inaccurate is manufacturing. According to Teece (1986), "the notion that the United States can adopt a 'designer role' in international commerce, while letting independent firms in other countries… do the manufacturing, is unlikely to be viable as a long term strategy. This is because profits will accrue primarily to the low cost manufacturers." Yet in our group of products, only China-based Lenovo does most of its own final assembly. While outsourcing is not universal throughout the electronics industry, for the most part, manufacturing has become a generic complementary asset, in the sense that the manufacturing equipment can be converted from one product line to another with relative ease.

The lead firm and its manufacturing partner may share co-specialized assets to the extent that technologies have been transferred and the manufacturer has set up specific proprietary facilities as a result. But this level of asset specificity is unlikely to keep the partners committed to one another beyond a design cycle (one to two years) should conflict arise or another CM/ODM offer a lower price.

Specialized complements are provided differently in the notebook PC and iPod ecosystems. In the notebook PC ecosystem, specialized hardware accessories and software programs are developed independently to meet published PC interface standards. Hardware peripherals have become quite generic, as they mostly rely on standard USB or Firewire interfaces and only need specialized software drivers to run on different operating systems. With the vast majority of PCs running on Windows and Intel-compatible processors, a huge supply of complementary assets is available, generating much of the value to PC owners, and in some cases very high profits to the providers of these assets (e.g., HP printers, Adobe software).

For the iPod, Apple has employed a range of strategies to secure the necessary complements. The highly specialized software in the iPod and the iTunes client software are developed by Apple internally. Unilaterally specialized accessories such as speaker systems and car connectors that use Apple's patented iPod connector (for which Apple receives a license fee) are provided mostly by third parties, as are lower-cost (but not necessarily low-margin) accessories, such as cases.

The iPod's most important complementary asset, content, is mostly generic (not iPod-specific) and comes from a variety of sources, only some of which required Apple's involvement. From the outset, consumers' CD collections provided a ready content source that could be encoded as unrestricted MP3s on a computer and transferred to the iPod, free of charge, and Apple provided a free encoder in its iTunes software. The presence of unofficial file sharing services made millions of tracks available free online (albeit illegally). In addition, Apple provides access to millions of music tracks and other restricted content for paid download through its iTunes Store, with Apple receiving a small share of the profits.

Another of the iPod's complementary assets, and one that can be too easily overlooked, is Apple's creation of its own brick-and-mortar retail channel. Absent the Apple Stores, the iPod could have been relegated to a couple of shelves in a large retailer without the effective sales efforts and attractive displays of the Apple Store. For the iPod, the Apple Store was a co-specialized asset that made sense to provide internally; the iPod needed such distribution, and the Apple Store needed a hot product to drive traffic in order to succeed. This is consistent with Teece (1986), which pointed to retail distribution as an important complementary asset.

*6.2.4 System integration*

A final profitability factor underscored by our analysis is the value of system integration skills. System integration proved to be important for both types of products that we analyzed, and we found that the integration can occur from the bottom up as well as the top down.

For the iPod, Apple's design expertise permitted it to generate a pleasingly thin product that offered users aesthetic, as well as practical, value. Although manufacturing was outsourced, Apple made the important engineering determinations that enabled the well-known iPod shape.

For notebook PCs, HP lets its manufacturing partners handle the bulk of physical design. HP retains responsibility for the product's look and feel and its responsiveness to customer needs (Parker and Anderson, 2002).

The company determining the important aspects of a system is not necessarily the one whose brand name is on the outside of the final product. In PCs, Microsoft and Intel evolved from just providing an operating system and processor to become the systems integrators of the Wintel PC ecosystem. Intel moved into chipsets and even motherboards, setting standards for much of the hardware interfaces in the PC (Gawer and Henderson, 2007), such as PCI Express, while Microsoft has pulled more and more functionality into the operating system. PC makers carry out systems integration at a functional level, but most of the important system-level decisions have already been made by Microsoft and Intel. This limits the ability of PC makers such as HP to differentiate their products through significant design innovations. Many microchip vendors pursue a similar strategy to Intel's, offering complete reference designs, including recommended system layout and software, that can be implemented rapidly by customers with limited internal expertise (Linden and Somaya, 2003).

## 7. Conclusions

This paper has applied a novel methodology for estimating and analyzing the profits of firms linked in a global value chain. Combining those results with insights from the business literature has provided insights into the opportunities and constraints facing firms in the electronics industry.

Because the electronics industry is a vast, open platform, a common set of complementary technologies is available to all firms. Lead firms, especially those working within a dominant design, must find ways to gain advantage through strategies such as branding, marketing, industrial design, rapid product development, business model, or channel strategy. Component suppliers must find unique ways to improve their customer's value capture prospects through means such as new functionality, lower cost, or shorter time-to-market. While only a few firms in a supply chain, if any, can earn supernormal profits, many can earn normal margins, and the electronics ecosystem as a whole generates enough profits to support the continued rapid innovation that the electronics industry has seen for decades.

Our analysis makes it clear that the efforts and bargaining power of all the firms in a supply chain set the size of the value "pie" by determining the cost and capabilities of the final product.  For instance, without a tiny hard drive or cheap flash memory or sophisticated software, there wouldn't be an iPod as we know it, and without ODMs to make it in China, it would be more expensive and possibly less successful as a consumer product.  In sharp contrast, the market power and high prices charged by Microsoft and Intel for their latest technologies have helped keep the cost of notebook computers too high for most global consumers, which has driven the search for alternative configurations such as netbooks priced at a few hundred dollars.

Limitations of the profit estimation methodology include the need for access to teardown reports, internal company cost data, or other sources of component pricing.  Our empirical approach also privileges detail over the wider picture, considering the supply chain to the exclusion of other complements and rival firms.  Another limitation is the absence of specific product volume information; firms may accept a lower gross profit against higher volume because it allows them to allocate overhead over a larger revenue base.

Because our method looks at the supply chain of a given model rather than multiple models, it also misses product variety.  Leading companies like HP or Lenovo field a complete range of notebook computers from high- to low-end, each of which may have different profit targets. According to Portelligent, the Lenovo model considered here may have been targeted "at the value-business market more than the traditional high-end ThinkPad buyer" with the HP notebook roughly similar.  Consumer models might have told a different story.  Similarly, the hard-drive-based iPods analyzed here were at the high end of Apple's media player line.  Apple sells more units of the lower-priced, flash-based Nano, which has a different gross margin profile.

Despite these limitations, it is our hope that this methodology will be of use to researchers studying different industries to identify who profits from innovation.  Our results show that profitable niches abound, in both a closed architecture such as Apple's iPod family and in the more open PC architecture. Studying the relative profitability of different participants in the supply chain will be of benefit both to scholars studying the profits from innovation, and to managers looking to capture more profit for their firms.

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# Appendix

## Appendix 1 Supply chain analysis

Leading examples of dispersed innovation networks can be found in the electronics industry. For decades, the industry was dominated by large vertically integrated companies like IBM, HP, Toshiba and Fujitsu that designed and built their own products, often using internally-produced components and proprietary technologies. Since then, there has been a shift by electronics firms to focus on systems integration and outsource other activities, creating global production networks or supply chains that cross corporate and national boundaries. Companies that formerly manufactured most products in-house, as well as start-ups that never had manufacturing capabilities, have outsourced production and even aspects of product development to turn-key suppliers known as contract manufacturers (CMs) and original design manufacturers (ODMs). They rely on outside component suppliers for production and innovation in core technologies such as semiconductors, displays, storage, batteries and software.

Here we describe a simplified, generic supply chain, which we use as the basis for introducing a method of calculating value capture by the companies in the chain.

Within a supply chain, each participant purchases inputs and then adds value, which becomes part of the cost for the next stage of production. The sum of the value added by everyone in the chain equals the final product price paid by the customer. Figure 1 shows a generic supply chain for a product that is assembled by a contract manufacturer, warehoused by the lead firm, then sold to customers via distribution and retail channels. Many other configurations are possible.

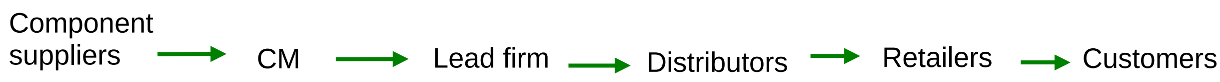


**Figure 1** Generic electronics supply chain

Although each product incorporates a large number of components (thousands, in the case of a notebook computer, or hundreds, in the case of an iPod), the large majority are low-value parts, such as capacitors and resistors that cost less than a penny each. Although the reliability of such parts is vital to overall system quality and suppliers of these components earn profits, they account for a small share of the total value added along the supply chain. Moreover, they typically compete with close substitutes, which reduces the potential for above-normal profits.

Most electronics products also contain a few high-value components, such as a visual display, hard drive or key integrated circuits. These components, which are themselves complicated systems, are responsible for the final product's functionality and performance. They most likely embody proprietary knowledge that helps to differentiate the final product and can command a commensurately high margin. By virtue of their high cost relative to other components, these few inputs also account for a relatively large share of total value added.

Many firms in the industry outsource assembly of these components into the final product to large multinational CMs such as Flextronics, Solectron, and Foxconn, or ODMs such as Quanta, and Compal, which also collaborate in product development. These assemblers compete fiercely for high-volume opportunities, limiting their margins. Apple outsources all final assembly, as does HP for notebooks. Lenovo keeps most of its notebook assembly in-house in facilities in China, and designs its Thinkpad products internally in the U.S. and Japan. Apple closely controls design and development in-house.

Lead firms coordinate the supply chain and handle product concept, branding and marketing. These brand-name firms contribute market knowledge, intellectual property, system integration and cost management skills, and a brand whose value reflects its reputation for quality, innovation, and customer service, for good or ill.

Distribution is done by a few global wholesalers such as Arrow, TechData and IngramMicro, and many smaller national or local distributors. Sales are by large retail chains such as Best Buy, Circuit City, and Fry's, as well as by general retailers such as Costco and WalMart, and smaller local dealers. They operate on a fixed margin from the vendor and seek scale and reach, but price competition plus high capital and operating costs keep net margins low. Sales are also handled increasingly by the branded vendors directly online and, with image-conscious companies such as Apple and Sony, through their own stores. The lower cost of direct sales contributes to the lead firm's margins, and own store sales may contribute to cross-selling of multiple products as well.[8]

Using maps like this as a guide, we calculate the value added at various stages of the value chain.

[8] Apple's 10-K for the fiscal year ending September 30, 2006, states: "The Company's direct sales, primarily through its retail and online stores, generally have higher associated profitability than its indirect sales" (p.30).

## Appendix 2 Japanese firms in the supply chain

There are many Japanese firms in the electronics supply base. As discussed in the main text, their operating margins tend to be below average. Here we discuss more of the components provided by Japanese firms.

*Battery firms*

In the case of the iPod's prismatic lithium-ion battery, Portelligent was not able to identify the supplier, nor were we able to do so through our own research. One of the leading makers of lithium-ion batteries for portable electronics, Amperex, is a Hong Kong-based firm that was acquired by Japan's TDK in 2005. We have used TDK's company-wide operating margin, 7.6 percent, to represent the battery supplier's margin.

For the nc6230 battery profit margins, we averaged the gross and operating margins of the five leading makers of notebook battery cells, with a combined market share of approximately 90 percent.[9] Three of these, Sanyo, Sony, and Matsushita, are Japanese firms, and their operating margins of 4 percent or less reflect loose cost control. The other two suppliers, Samsung and LG Chem, are Korean firms and had a 2005 operating margin of 9.4 percent and 5.7 percent, respectively.

These types of battery are typically produced to a custom size for each application, which may bring some short-term bargaining power for the supplier. But the field is sufficiently competitive that margins are not especially high relative to other types of components. As with most other components, the bargaining power lies with high-volume customers like Apple and HP.

[9] Joseph Tsai, "Notebook vendors considering battery cells from China, says paper," DigiTimes.com, March 31, 2008.

*Display firms*

The displays, one of the costlier inputs in both the iPod and nc6230, were supplied by Toshiba-Matsushita Display, a 60:40 joint venture. The weighted-average operating margin for Toshiba and Matsushita was 4.2 percent for the fiscal year ending in March 2006; gross margin was 28.2 percent.

Smaller display sizes such as that used in the iPod have been more profitable in recent years than standardized notebook and TV displays because there is a greater variety of niches for different sizes and resolutions, which allows for some differentiation by the supplier. The segment, however, is still overcrowded, with Korean and Taiwanese entrants pursuing the Japanese market leaders. Toshiba-Matsushita Display saw its market rank fall from second at the beginning of 2005 to third by the end of the year, having been displaced by Sanyo-Epson, another Japanese joint venture.[10] Toshiba's Annual Report for the period ending March 2006 described the business environment facing Toshiba-Matsushita Display as "very tough... characterized by rapid price deterioration" (p.26). The corporate gross margins of Sanyo (19 percent), Epson (18 percent), and the display sector leader, Sharp (23 percent), were even lower than those for Toshiba and Matsushita, so the 28 percent used in the tables may be on the high side.

*CD/DVD player firms*

The nc6230's DVD-ROM/CD-RW optical disc drive was supplied by Matsushita, the world's largest supplier of notebook-size optical disc drives at that time. Its closest rivals

[10] "Korean suppliers target small-to-medium-size display market, says iSuppli," DigiTimes.com, October 20, 2005 for first-quarter data and "iSuppli: Sharp and Sanyo Epson retain top spots in small- to medium-size LCD market," iSuppli Press Release, July 21, 2006 for fourth quarter data.

were two Japan-Korea joint ventures: Hitachi-LG Data Storage and Toshiba-Samsung Storage Technology, but Matsushita's shipments were growing faster.

Matsushita's gross margin in fiscal year ending March 2006 was an average 30.8 percent. Its operating margin was 4.7 percent, which is relatively low but still the highest of any of the nc6230's major Japanese suppliers. This reflects the benefits of several years of restructuring efforts aimed at improving competitiveness and profitability.[11]

[11] Ginny Parker Woods, "Matsushita's Net Surges 38% Amid Strong Plasma-TV Sales," Wall Street Journal, February 3, 2006, p.B6.

**Table A-1** Key inputs in the 30GB 3rd-Generation iPod, 2003

| Type | Input | Supplier | Supplier HQ Country | Estimated Input Price | Price as % of Factory Cost | Gross Margin | Estd. Value Capture |
|---|---|---|---|---|---|---|---|
| Storage | Hard drive | Toshiba | Japan | $112.00 | 62% | 27.0% | $30.24 |
| Processor | Controller chip | PortalPlayer | US | $6.18 | 3% | 41.4% | $2.56 |
| Display | Monochrome display assembly | ? | Japan* | $5.81 | 3% | 14.0% | $0.81 |
| Memory | SDRAM - 32MB | Samsung | Korea | $5.23 | 3% | 32.3% | $1.69 |
| Battery | Battery pack | ? | Japan* | $3.46 | 2% | 27.4% | $0.95 |
| | | Sub-Total | | $132.68 | 74% | | |
| | | Other Parts | | $42.64 | 24% | | |
| | | Estimated assembly and test | | $4.87 | 3% | | $4.87 |
| | | **Estimated factory cost** | | **$180.19** | **100%** | | **$41.12** |

* - supposition

*Source*: Portelligent, Inc. (2003), company reports, and authors' calculations.

Display GM calculated from 2003 data for Wintek (Taiwanese display specialist that supplied Nano screens) via DigiTimes

Battery GM calculated from FYE 3/04 data for TDK (consolidated) from TDK 20-F for FYE 3/06

**Table A-2** Key inputs in the 30GB 5th-Generation iPod (Video iPod), 2005

| **Type** | **Input** | **Supplier** | **Supplier HQ Country** | **Estimated Input Price** | **Price as % of Factory Cost** | **Gross Margin** | **Est'd. Value Capture** |
|---|---|---|---|---|---|---|---|
| Storage | Hard drive | Toshiba | Japan | $73.39 | 51% | 26.50% | $19.45 |
| Display | Display assembly | Toshiba-Matsushita | Japan | $23.27 | 16% | 28.22% | $6.57 |
| Processors | Video/Multimedia Processor | Broadcom | US | $8.36 | 6% | 52.5% | $4.39 |
| Processors | Controller chip | PortalPlayer | US | $4.94 | 3% | 44.8% | $2.21 |
| Battery | Battery Pack | Unknown | Japan* | $2.89 | 2% | 26.3% | $0.87 |
| Memory | Mobile SDRAM Memory - 32 MB | Samsung | Korea | $2.37 | 2% | 31.5% | $0.75 |
| Memory | Mobile RAM - 8 MBytes | Elpida | Japan | $1.85 | 1% | 17.6% | $0..33 |
| Memory | NOR Flash Memory - 1 MB | Spansion | US | $0.84 | 1% | 9.6% | $0.08 |
| | | Sub-Total | | $117.910 | 82% | | |
| | | Other Parts | | $22.790 | 16% | | |
| | | Estimated assembly and test | | $3.860 | 3% | | $3.86 |
| | | **Estimated factory cost** | | **$144.56** | **100%** | | **$38.51** |

* - supposition
*Source*: Portelligent, Inc. (2006), company reports, and authors' calculations.
Data for Toshiba-Matsushita Display, a 60/40 joint venture, are weighted averages of consolidated data for Toshiba and Matsushita.
Battery GM calculated from FYE 3/06 data for TDK (consolidated) from TDK 20-F for FYE 3/06.

**Table A-3** The most expensive inputs in the Hewlett-Packard nc6230 notebook PC, 2005

| Type | Input | Supplier | Supplier HQ Country | Estimated Input Price | Price as % of Factory Cost | Gross Margin | Est'd. Value Capture |
|---|---|---|---|---|---|---|---|
| Processors | Main chipset + Wi-Fi | Intel | US | $205.43 | 24.0% | 59.4% | $122.03 |
| Processors | Graphics processor | ATI Technologies | US | $20.50 | 2.4% | 27.6% | $5.66 |
| Processors | Ethernet controller w/ Transceiver | Broadcom | US | $2.01 | 0.2% | 52.5% | $1.06 |
| Processors | Cardbus controller | Texas Instruments | US | $3.28 | 0.4% | 48.8% | $1.60 |
| Processors | I/O controller | Standard Micro-systems (SMSC) | US | $1.42 | 0.2% | 46.0% | $0.65 |
| Processors | Battery charge controller | Texas Instruments | US | $1.22 | 0.1% | 48.8% | $0.60 |
| Display | Display assembly | Toshiba Matsushita Display | Japan | $137.14 | 16.0% | 28.2% | $38.70 |
| Software | Windows XP Pro OEM license | Microsoft | US | $100.00 | 11.7% | 84.8% | $84.80 |
| Storage | 60GB hard drive | Fujitsu | Japan | $68.00 | 7.9% | 26.5% | $18.02 |
| Storage | DVD-ROM/CD-RW drive | Matsushita | Japan | $40.00 | 4.7% | 30.8% | $12.32 |
| Memory | Memory board (512 MB) | Samsung | Korea | $29.65 | 3.5% | 31.5% | $9.34 |
| Memory | DDR SDRAM Memory 2x32 MB | Hynix Semiconductor | Korea | $5.68 | 0.7% | 37.3% | $2.12 |
| Battery | Battery pack | Unknown | Japan* | $40.52 | 4.7% | 24.0% | $12.16 |
| | | | Sub-Total | $654.85 | 76.5% | | |
| | | | Other Parts | $177.72 | 20.8% | | |
| | | | Estimated assembly and test | $23.76 | 2.8% | | $23.76 |
| | | | **Estimated factory cost** | **$856.33** | **100.0%** | | **$332.80** |

* - supposition

*Source*: Portelligent, Inc. (2005b), company reports, and authors' calculations.

Battery GM is the average of the FYE 12/05 or 3/06 data for the five leading makers of notebook batteries (combined market share of approximately 90 percent).

**Table A-4** The most expensive inputs in the Lenovo ThinkPad T43 notebook PC, 2005

| Type | Input | Supplier | Supplier HQ Country | Estimated Input Price | Price as % of Factory Cost | Gross Margin | Est'd. Value Capture |
|---|---|---|---|---|---|---|---|
| Processors | Main chipset + Wi-Fi | Intel | US | $205.34 | 23.5% | 59% | $121.15 |
| Processors | Graphics processor | ATI Technologies | US | $21.70 | 2.5% | 28% | $6.08 |
| Processors | Microcontroller | Renesas | Japan | $2.83 | 0.3% | 24% | $0.68 |
| Processors | Power Supply Monitor / Controller | Toshiba | Japan | $2.11 | 0.2% | 26% | $0.55 |
| Processors | Single Chip LAN Controller | Broadcom | US | $2.01 | 0.2% | 53% | $1.07 |
| Processors | PC Card controller | Ricoh | Japan | $1.81 | 0.2% | 42% | $0.76 |
| Processors | Power management ASIC | IBM | US | $1.42 | 0.2% | 40% | $0.57 |
| Processors | Microcontroller | Philips | Europe | $1.16 | 0.1% | 32% | $0.37 |
| Display | Display module | Toshiba-Matsushita Display | Japan | $138.32 | 15.8% | 28% | $38.73 |
| Software | Windows XP Pro | Microsoft | US | $100.00 | 11.4% | 85% | $85.00 |
| Storage | 60GB hard drive | Hitachi | Japan | $68.00 | 7.8% | 23% | $15.64 |
| Storage | CD/DVD drive | Hitachi-LG Data Storage | Japan | $40.00 | 4.6% | 25% | $9.80 |
| Battery | Li-Ion battery pack | Sony | Japan | $41.06 | 4.7% | 37% | $15.19 |
| Memory | Memory module | Hynix | Korea | $29.68 | 3.4% | 41% | $12.17 |
| Memory | 32MB DDR SDRAM | Hynix | Korea | $5.68 | 0.6% | 41% | $2.33 |
| | | | Sub-Total | $661.12 | 75.5% | | |
| | | | Other Parts | $192.21 | 22.0% | | |
| | | | Estimated assembly and test | $21.86 | 2.5% | | $21.86 |
| | | | **Estimated factory cost** | **$875.19** | **100.0%** | | **$331.94** |

*Source*: Portelligent, Inc. (2005a), company reports, and authors' calculations.
*Note*: Assembly and test estimate excludes final assembly, which was done in-house by Lenovo.

# A Tale of Two Cities: A Comparison of Patent-based Innovative Performance of Domestic and Multinational Companies in China

Dr. Zheng Liang[1] and Dr. Lan Xue[2]

China Institute for S&T Policy (CISTP)

School of Public Policy and Management (SPPM)

Tsinghua University, Beijing 100084

People's Republic of China

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[1] Associate Professor, School of Public Policy and Management(SPPM), Tsinghua University; Assistant Director, China Institute for Science &Technology Policy at Tsinghua University (CISTP). Email:liangzheng@tsinghua.edu.cn

[2] Professor and Dean, School of Public Policy and Management (SPPM), Tsinghua University; Director, China Institute for Science &Technology Policy at Tsinghua University (CISTP). Email:xuelan@tsinghua.edu.cn

## Introduction

The year of 2008 marks the 30th anniversary of China's openness and economic reform, which has generated astonishing high economic growth in China for the past 30 years. According to the World Bank's statistics (World Bank, 2003), for example, the average growth rate of Chinese Gross Domestic Product (GDP) during the 1980s and the 1990s were 10.1% and 11.2%, respectively, making it one of the fastest growing economies in the world. The abandonment of centralized planning and the establishment of market institutions, as well as the market opening to foreign investment, were credited as keys to the success of this growth. However, the economy miracle of China is often described as the result of intensive inputs such as labor, resources and capitals, not oriented on innovations. Is it true? How about the innovative performance of China's domestic enterprises, in comparison with their competitor from abroad? In this paper, we will explore it mainly based on patent data, the most popular indicator used to estimate the innovative performance of firms.

The conventional wisdom about IPR is that strong IPR protection generates incentives for the investment in Research and Development (R&D) and hence for the technological progress in society (Arrow, 1962; Nordhaus, 1962; Scherer, 1972). In addition, IPR protection also helps to disseminate technical information and reduce social cost (Malchup, 1958), which is always referred to as "information disclosure effect". All of these not only make patent become the indicator of innovative performance and capabilities, but also change it into the source of new innovations. At the same time, protecting IPR through assigning monopolistic right to the knowledge also entail economic costs. The monopoly position on the technology deters other firms from trying themselves to invent "in the neighborhood" (Scotchmer and Green 1990; Green and Scotchmer, 1995). As the result, interactions between patent players have multidimensional effect on innovation.

But understanding patent's role in China is further complicated by the fact that Chinese economy in the reform era has been far more open than many other countries at its comparable stage. The patent system in China from the very start faced with the double challenges of meeting the demand of multinational companies which required strong protection of IPRs while at the same time satisfying the appeal of domestic companies which favored an IPR regime conducive to technology transfer and diffusion, which may lead to the strategic utilization of this system and make which patenting behaviors couldn't reflect the real innovative performance to some extent (Liang and Xue, 2010, forthcoming).

Despite these obstacles, in this paper, using some empirical evidence from China, we still try to analyze the patenting behaviors of domestic and multinational firms in China and compare their innovative performance based on patent data. Our analysis will be carried out at the two levels. The first level is based on data at the national level, including patent data on application, grants, and so on. The second level is based on data at the enterprise level. Here we use 500 China's biggest corporations in 2006[3] as the sample. From the list provided by SIPO[4], we selected 652 related corporations[5] which have at least 1 invention[6] application until the end of 2004 and found 16109 pieces of invention application of these firms during April 1st, 1985 to Dec 31st, 2004, which account for 4.62% of the total domestic invention applications in same period. For each piece of invention application, we obtained the following information of it: application date, grant date, prior-right[7], patentee, inventors and their residences, IPC section number, and IPC class number[8]. As the comparison samples, we choose Fortune Global 500 list (2006) as the population of investigation. From the list provided by SIPO of foreign firms that have at least 1 invention application until the end of 2004, we selected 775 related corporations. We then searched in SIPO's database and found 108747 pieces of invention application by these firms during April 1st, 1985 to Dec 31st, 2004, which account for 30.47% of the total foreign invention applications in China the same period.

The remainder of the paper is organized as follows: part Ⅰ is a brief introduction of the evolution of China's patent system; part Ⅱ investigates the patenting behavior of multinational firms and domestic players based on national level data; part Ⅲ and part IV evaluate the innovative performance of domestic and multinational firms in China based on the firm level dataset described above. Part V concludes the paper.

## Ⅰ. Background: The Evolution of China's Patent System

China enacted its first patent law in 1984 which came into force in April, 1985. In general, the Chinese patent system shares more similarities with the Japan patent system than with that of the United States. For example, the primary purpose for China's patent law is to facilitate diffusion of new technologies, which is demonstrated by the kinds of patents allowed (invention, design, and utility model),

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[3] The list are jointly issued by Chinese Enterprise Alliance and Chinese Entrepreneur Association annually since 2004 and ranked by total revenues. The 2006 ranking list could be acquired from http://www.cec-ceda.org.cn/huodong/2006china500.(in Chinese)

[4] SIPO is the abbreviation of State Intellectual Property Office of the People's Republic of China.

[5] One same firm might has several sub firms applying for patents in China.

[6] Here we use invention data instead of patent data because inventions represent most technology creation comparing with other two forms of patents. And this is also the only comparable patent field between multinationals and domestic firms because most of the patent applications of multinationals in China are In-service inventions, and domestic firm is also the only dominant applicants in domestic In-service invention applications.

[7] In patent, a priority right or right of priority is a time-limited right, triggered by the first filing of an application for a patent. The priority right belongs to the applicant or his successor in title and allows him to file a subsequent application for the same invention and benefit, for this subsequent application, from the date of filing of the first application for the examination of certain requirements. When filing the subsequent application, the applicant must "claim the priority" of the first application in order to make use of the right of priority. The period of priority is usually 12 months for patents.

[8] The Strasbourg Agreement (of 1971) concerning the International Patent Classification provides for a common classification for patents for invention including published patent applications, utility models and utility certificates. The International Patent Classification (IPC) is a hierarchical system in which the whole area of technology is divided into a range of sections, classes, subclasses and groups. This system is indispensable for the retrieval of patent documents in the search for establishing the novelty of an invention or determining the state of the art in a particular area of technology.

their shorter grace period, the adoption of the principle of ‘‘first-to-file’’ instead of “first-to-invent’’, public disclosure of the invention after 18 months, and mixed requirement of single and multiple-claims. Typically, the adoption of ‘Petit Patents’ such as utility models and designs are mainly based on the intention to encourage gradual innovation which is often very important for the native applicants. This ambition had been achieved partially according to some empirical studies (Liu et. al, 2003; A. Hu, 2006)

Generally, China’s patent system has evolved through three stages. The first stage is from 1985 to 1992, which is the founding stage of China’s IPR system. Before 1985, China only had a Management System of Science & Technology Outcome, which presumably belonged to the entire country. While China’s first patent law made it possible for individuals to file patents, it was difficult for inventors to extract monopoly rents except to get some promised material rewards (Alford, 1995). At the same time, without the permission of relevant administrative department in the government, SOEs couldn’t deal with their patents autonomously, for example, licensing out. These limitations dampened the enthusiasm of SOEs as well as their technical staffs who were key players in industrial R&D. The first Patent Law also excluded chemical, pharmaceutical, and alimentary or process inventions from patent coverage, which were regarded as the intended predilection on domestic industries and additional disadvantages for foreign applicants. These issues reflected the dynamic balances between stimulating indigenous innovations and sharing the worldwide knowledge pools by enforcement of patent protection.

The second stage is from 1992 to 2000, when China’s patent system made substantial progress. In the first revision of Patent Law in 1992, the duration of patent protection of inventions was extended from 15 to 20 years and the duration of utility model and design patents was extended from 5 to 10 years; food, beverages, flavoring, pharmaceutical products, and substances obtained by means of chemical processes were also covered by patent protection, as well as adding the domestic priorities for filing applications. Individuals were allowed to own patents for invention-creations during work time if an agreement was made between individuals and employers. All these amendments inspired rapid growth in patent applications.

The third stage is from 2001 till now, where China’s patent Law experienced the second major revision in 2001. In this revision, state-owned and privately owned enterprises were treated as equals for obtaining patent rights. Other amendments were mainly made to fit the WTO requirement, especially those in TRIPs, for example, the simplification of examination process. This revision led to another surge in patent applications.

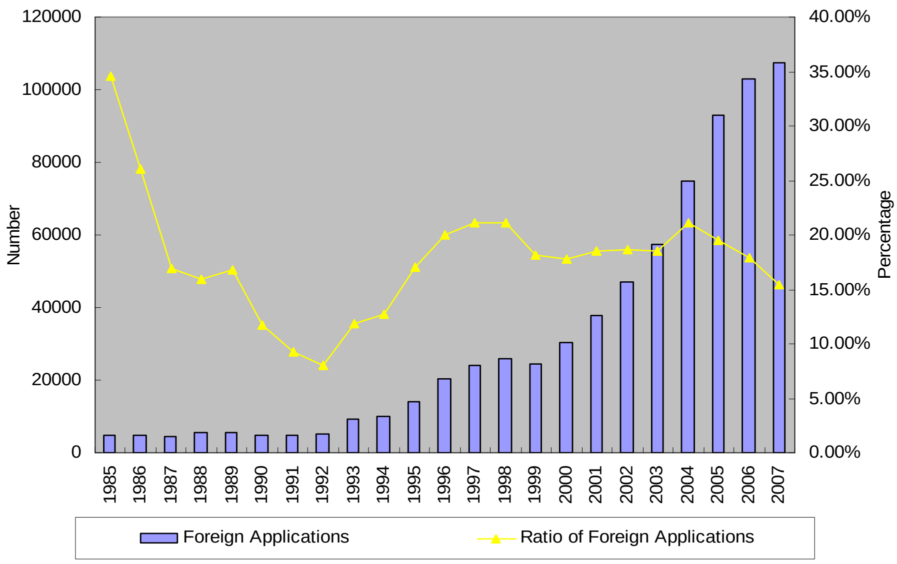
## Ⅱ. A Comparison of Patenting Behaviors of Domestic and Multinational Companies in China

As discussed above, the evolution of patent system in China echoed the needs of different entities. Once it was founded, it will inevitably mould and affect the behaviors of these entities, although they may have totally opposite motivations. The observation of different behaviors by multinationals and domestic firms under the same patent system is one of the main concerns of this paper. In this section, we used the annual data issued by SIPO to examine their patent application, grant and validity in China, in order to disclose their innovative performance[9].

### 2.1 Sources of Patents

As Fig 3 reveals, after a lukewarm start for the first 5-6 years of China's patent system, foreign patent applications began to pick up after the first revision of patent law in 1992, which can be seen not only through the absolute numbers but also the percentage of foreign applications as the total applications. However, it seems that the second revision of patent law in 2000 induced fast increase of domestic and foreign applications simultaneously, which resulted in the stability of foreign application ratios since 2000 till 2003 and even the modest decreases in recent years after 2004. The different emphases of these two revisions may be the main cause.

Figure 3 Applications for Three Kinds of Patents Received from Abroad and its Ratio in Total Applications (1985-2007)

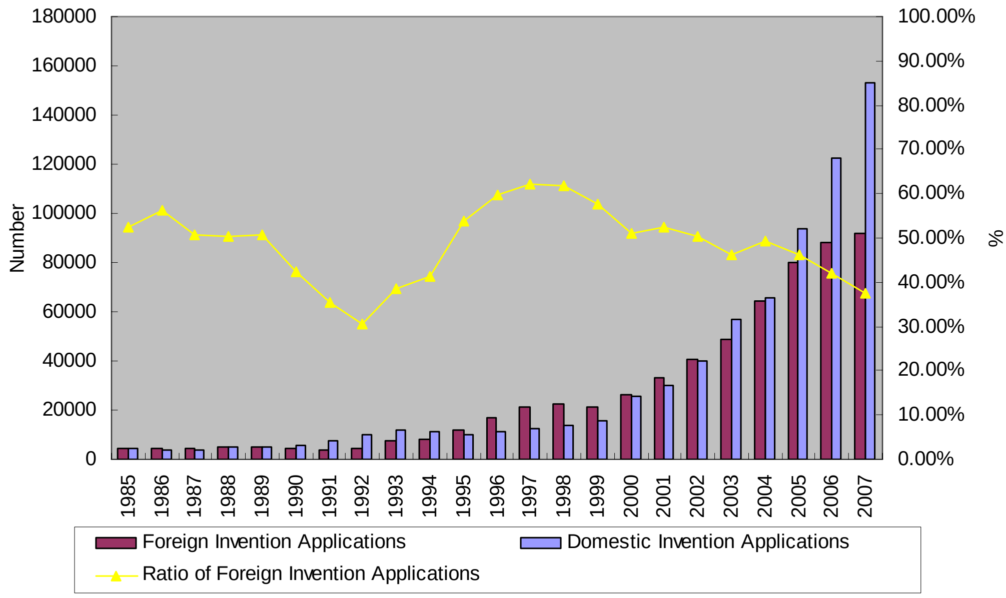



More interesting findings could be revealed when we pay attention to different kinds of patents. As introduced before, the main changes in 1992 Patent Law were extension of patent protection duration and expansion of patent protection scope, which coincided with the standards in most counties. It seems that this revision really inspired the enthusiasm of foreign applicants, especially for invention

[9] All the data used here are cited from SIPO Statistical Annals, if not indicated specially.

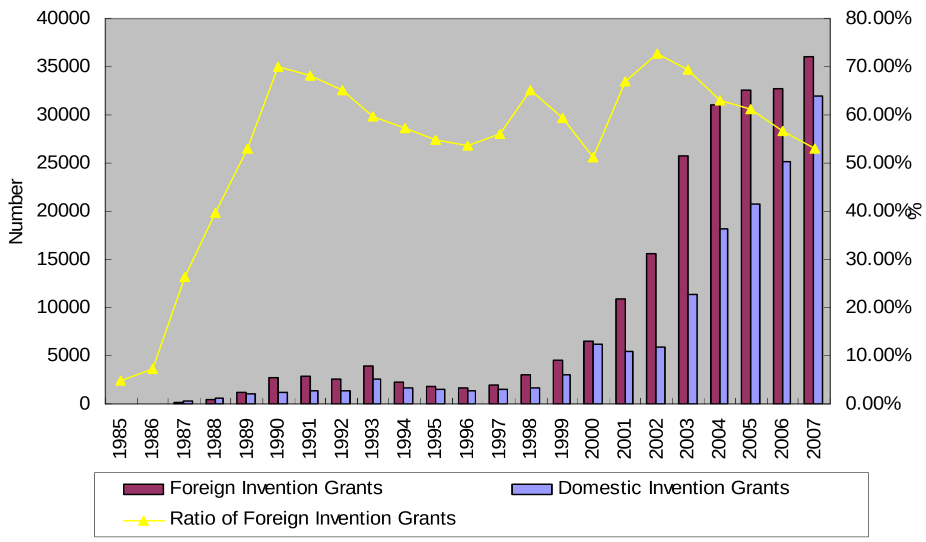
applications. As Fig 4 show, there were really a surge of foreign invention applications and its ratio in total invention applications reached the peak in 1997(62.24%). After that year, the domestic applications grew faster and surpassed foreign applications in 2003 despite the fact that foreign applications were still increasing.

Figure 4 Distribution of Annual Applications for Inventions Received from Home and Abroad (1985-2007)




But as to patent grants, even till now, the invention patents granted to foreigners are still higher than native, although the gap has narrowed quickly in past five years. From Fig 5 we can find distinct fluctuations on the invention grants during past 20 years. Especially, there appeared to be a several years' decrease of invention patent grants, right after the first revision of Patent Law. Furthermore, comparing to the drop of domestic grants, the decrease of foreign grants is faster, and it resulted in the first decrease of foreign ratios in total invention grants during 1990 to 1996.

Figure 5 Distribution of Annual Grants for Inventions Received from Home and Abroad (1985-2007)



As a comparison, if we look at the behaviors of foreign and domestic applications of utility model and design patents, we can find very big differences. As Table 1 depicts, since the patent system founded in China till nowadays, more than 99% applications for utility models, and more than 93% applications for designs are issued by domestic applicants. The same results could be found in granting side. It seems that the original design of three-tier patent system really acted, the 'petit patents' are mainly utilized by domestic players, which actually gave incentives to incremental innovations and the diffusion of knowledge.

Table 1 The Total Applications for Three Kinds of Patents Received from Home and Abroad (1985.4-2008.9) Unit: File

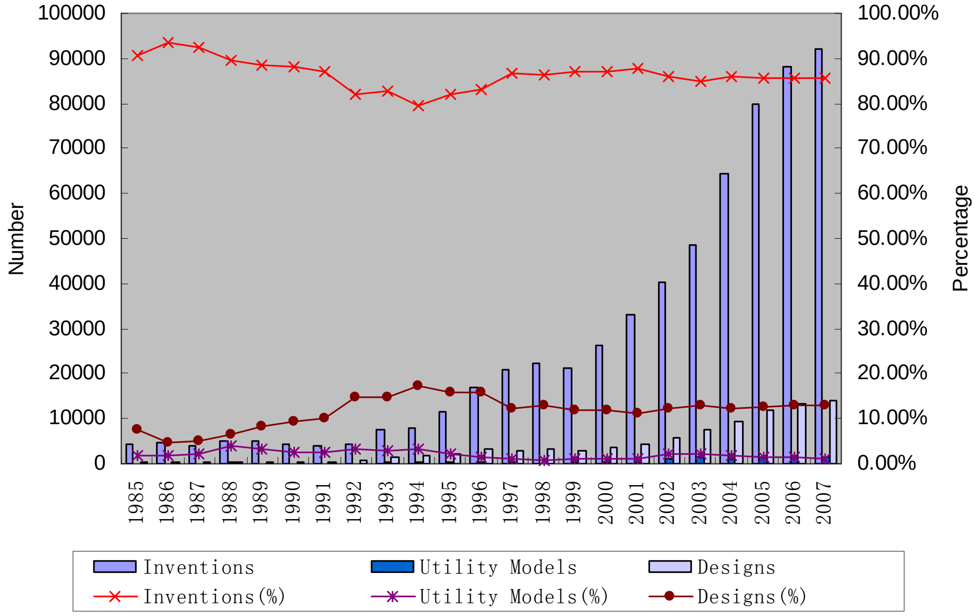
| | | Total | | Invention | | Utility Model | | Design | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number | Ratio | Number | Ratio | Number | Ratio | Number | Ratio |
| Total | Sum | 4576636 | 100.00% | 1534934 | 100.00% | 1623279 | 100.00% | 1418423 | 100.00% |
| | In-service | 2310455 | 50.50% | 1184568 | 77.20% | 516158 | 31.80% | 609729 | 43.00% |
| | Non-service | 2266181 | 49.50% | 350366 | 22.80% | 1107121 | 68.20% | 808694 | 57.00% |
| Domestic | Sum | 3780652 | 100/82.6 | 848390 | 100/55.3 | 1611467 | 100/99.3 | 1320795 | 100/93.1 |
| | In-service | 1545971 | 40.90% | 522632 | 61.60% | 507198 | 31.50% | 516141 | 39.10% |
| | Non-service | 2234681 | 59.10% | 325758 | 38.40% | 1104269 | 68.50% | 804654 | 60.90% |
| Foreign | Sum | 795984 | 100/17.4 | 686544 | 100/44.7 | 11812 | 100/0.7 | 97628 | 100/6.9 |
| | In-service | 764484 | 96.00% | 661936 | 96.40% | 8960 | 75.90% | 93588 | 95.90% |
| | Non-service | 31500 | 4.00% | 24608 | 3.60% | 2852 | 24.10% | 4040 | 4.10% |

Source: SIPO, http://www.sipo.gov.cn/sipo2008/ghfzs/zltj/zljb

## 2.2 Structure of Patents

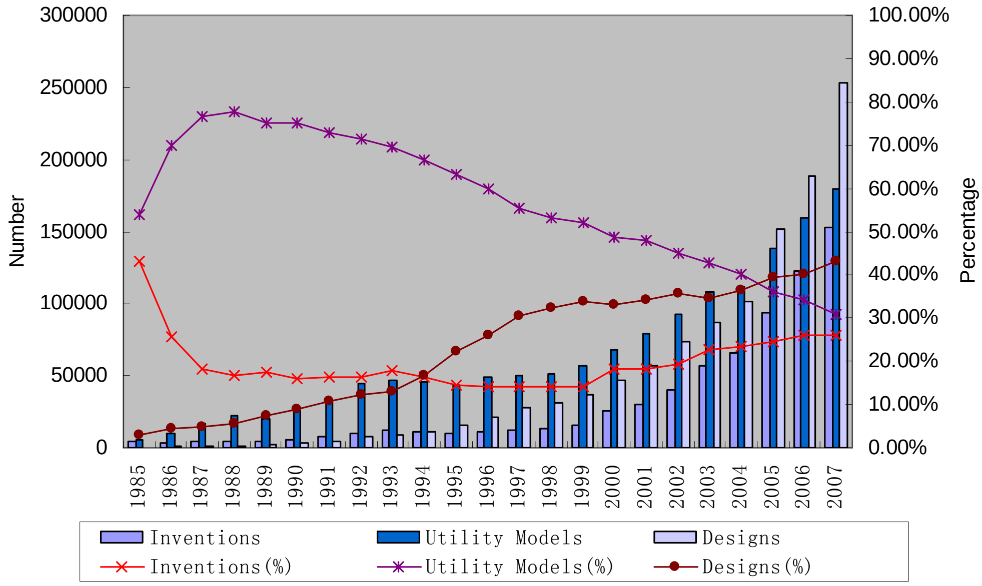
Fig 6 and Fig 7 give us a clearer scene on the different behaviors of foreign and domestic patent applicants. As Fig 6 depicts, the distribution of three kinds of patent applications issued by foreigners were very stable during past 23 years, and the invention applications were dominant. In most years, invention applications accounted for more than 85% of the total applications. We can also find another interesting phenomenon; foreign applicants seldom applied utility model patents, although it was regarded as 'part of inventions' by China's Patent Law. But they really applied quite a few design patents, although its ratio in total applications never exceeded 18% after reached its peak in 1994(17.42%). Even in 2007, the foreigners just submitted 1325 utility applications, no more than 14 times that they issued in 1985 (97). But during the same period, their invention applications in China expanded 20 times (4493 to 92101), and the design applications expanded nearly 38 times(371 to 13993).

Figure 6 Distributions of Annual Applications for Three Kinds of Patents Received from Abroad




As Fig 7 shows, the distributions of domestic patent applications are very different from foreign ones. Although in quite a long term, the utility models were dominant, its ratio in total applications began to decrease continuously even since 1988 after reached a peak (77.64%), due to the faster increase of invention and design applications, especially designs. As Fig 7 depicts, there really emerged a surge of invention applications since 2000, but the design applications increased more quickly. So, as a result, among all patent applications received from home in 2007, designs are dominant (43.21%), utility models rank the second (30.69%), inventions just account for 26.1%. Furthermore, the big changes of patent application structures in China are mainly caused by domestic players.

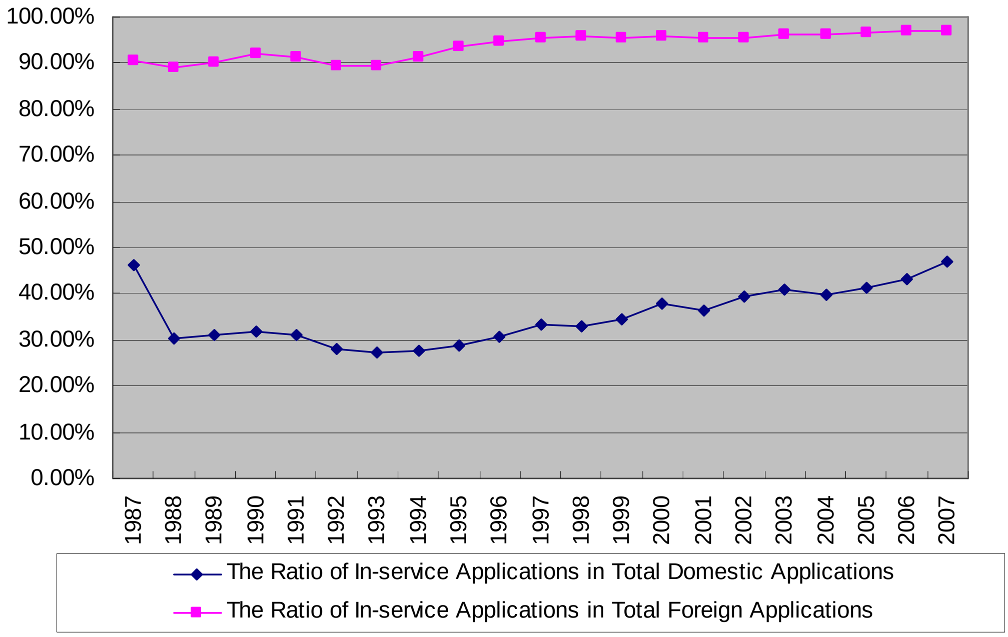
Figure 7 Distributions of Annual Applications for Three Kinds of Patents Received from Home



## 2.3 Character of Applicants

If we have more detailed investigation on the character of foreign and domestic applicants, we can also find major differences. As Fig 8 and Table 1 shows, In-service applications occupied absolute dominant situations in total applications received from abroad, and as we know, most of these applications are issued by multinationals. Besides, the ratios of In-service applications in total foreign applications during past 20 years were very stable and seldom fell under 90%, just as Fig 8 depicts. On the other side, the In-service applications hadn't exceeded 50% in annual domestic applications until 2007. What reason makes this difference? If we divide all the applications into three kinds of patents, maybe the answer could be a little clear. As Table 1 shows, there aren't distinct differences among In-service application ratios for three kinds of patent issued by foreigners, except the relatively low ratios for utility models (75.90%). As we found before, the annual quantities of foreign applications for utility models were much lower than the other two kinds of patents. It seems that multinationals didn't care about utility models. On the other side, we can observe nearly total opposite behaviors of domestic applications for different kinds of patents. Among total domestic applications for inventions, more than 60% were In-service. But for utility models, this ratio just exceeds 30%, and for designs, the ratio is nearly 40%. So we can conclude, even till now, most of the 'Petit Patents' in China is developed by domestic individuals, not the firms and other organizations.

Figure 8 Comparisons of the Ratios of Domestic and Foreign In-service Patent Applications




## 2.4 Patent Validity

As we know, once a patent was granted, the patentee must pay annual fees to maintain the validity of this patent. Generally said, the patentee will pay this fee only when he estimates the return from this patent will exceed the cost to maintain it. So, we can partially estimate the quality and value of one patent from its validity. As Table 2 depicts, till the end of 2007, among all granting patents by SIPO in past 23 years, only 40% were still valid (in force). The valid ratios of three kinds of patents granted to foreigners are all higher than the ones granted to domestic patentees. The gap on inventions is not very big (66% to 80%), comparing to the huge ones on utility models and designs. These gaps revealed a fact, although the domestic applications and grants of 'Petit Patents' grew very fast in China and attributed to the total increase of patents, their qualities were still poor, comparing to the same kind of patents hold by foreigners. Quite a lot 'Petit Patents' were given up by the patentees themselves after a short term of maintaining. From Table 2 we can also found that, whether foreign or domestic, the valid ratios of invention patents are highest. It approved the potential high value of inventions again.

Table 2 Total Applications/Grants/In Force for Three Kinds of Patents Received from Home and Abroad(1985.4 - 2007.12) Unit: File

| | | Total | | Invention | | Utility Model | | Design | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number | % | Number | % | Number | % | Number | % |
| Total | Application | 4028284 | 100.00% | 1334676 | 33.10% | 1471191 | 36.50% | 1222417 | 30.30% |
| | Grant | 2089286 | 100.00% | 364451 | 17.40% | 988264 | 47.30% | 736571 | 35.30% |
| | In Force | 850043 | 100.00% | 271917 | 32.00% | 299242 | 35.20% | 278884 | 32.80% |
| | Grant/Application | | 51.87% | | 27.31% | | 67.17% | | 60.26% |
| | In Force/Grant | | 40.69% | | 74.61% | | 30.28% | | 37.86% |
| Domestic | Application | 3314355 | 82.30% | 718207 | 21.70% | 1460557 | 44.10% | 1135591 | 34.30% |
| | Grant | 1790379 | 85.70% | 144387 | 8.10% | 980029 | 54.70% | 665963 | 37.20% |
| | In Force | 622409 | 73.20% | 95678 | 15.40% | 294463 | 47.30% | 232268 | 37.30% |
| | Grant/Application | | 54.02% | | 20.10% | | 67.10% | | 58.64% |
| | In Force/Grant | | 34.76% | | 66.26% | | 30.05% | | 34.88% |
| Foreign | Application | 713929 | 17.70% | 616469 | 86.30% | 10634 | 1.50% | 86826 | 12.20% |
| | Grant | 298907 | 14.30% | 220064 | 73.60% | 8235 | 2.80% | 70608 | 23.60% |
| | In Force | 227634 | 26.80% | 176239 | 77.40% | 4779 | 2.10% | 46616 | 20.50% |
| | Grant/Application | | 41.87% | | 35.70% | | 77.44% | | 81.32% |
| | In Force/Grant | | 76.16% | | 80.09% | | 58.03% | | 66.02% |

Source: SIPO Patent Statistical Annals, 2007.

## Ⅲ. Innovative Performance of Domestic Firms: Evaluation by Patent Data

As introduced, we choose 500 China's biggest corporations in 2006 as our population of investigation. During past 20 years, sampled domestic firms have applied for totally 16109 inventions in China. Figure 9 presents annual number of domestic sample firms' invention applications. As it depicts, before the year 1999, there were rarely any invention applications. The first round of patent law amendment in some degree boosted domestic firms' invention application activities but it was not evident enough. After 2000, with the second round of patent law amendment, domestic firms' innovation motivation increased obviously. Especially in the year 2002, there were totally 3625 invention applications, increasing by 92% than the previous year.

Figure 9 Invention Applications of Domestic Sample Firms (1985-2004)

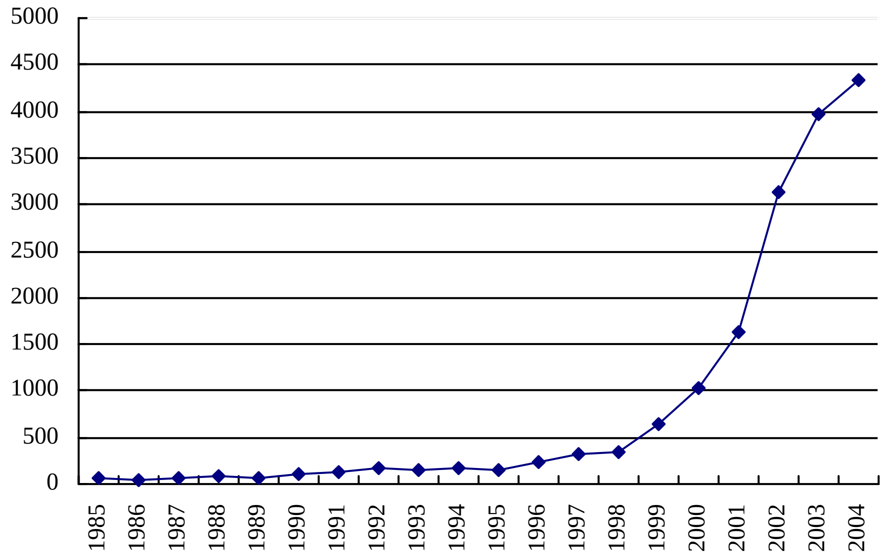



Table 3 presents the province distribution of domestic sample firms' invention application. Beijing, Guangdong and Shanghai are the three provinces with most invention applications, taking up over four fifth of the total applications.

Table 3 Province Distribution of Domestic Sample Firms' Invention Application (First 10)

| Province | Invention application | Percentage | Accumulative Percentage |
|---|---|---|---|
| Beijing | 6586 | 39.08 | 39.08 |
| Guangdong | 6544 | 38.83 | 77.90 |
| Shanghai | 917 | 5.44 | 83.35 |
| Shandong | 552 | 3.28 | 86.62 |
| Liaoning | 341 | 2.02 | 88.64 |
| Jiangsu | 277 | 1.64 | 90.29 |
| Hubei | 240 | 1.42 | 91.71 |
| Sichuan | 226 | 1.34 | 93.05 |
| Hunan | 166 | 0.98 | 94.04 |
| Hebei | 160 | 0.95 | 94.99 |

Table 4 lists domestic firms with over 200 invention application during the 20 years. Huawei Technology Ltd. applied for 5365 inventions, ranking first of all, taking up as high as 33.3% of the overall invention applications. China Petroleum and Chemical Group, Lenovo Ltd., and ZTE Corporations follow Huawei Technology. These five corporations applied for more than 60% of the overall inventions in China, which reflected the domestic invention applications are highly concentrated and the main players are just several large corporations. As Table 3 and Table 4 reflect, innovation of China's domestic firms is limited to a few firms, in a few industries, and a few regions.

Table 4 Domestic Sample Firms with over 200 Invention Applications

| Patentee | Industry | Invention application | Percentage | Accumulative percentage |
|---|---|---|---|---|
| Huawei Technology Ltd. | IT | 5365 | 33.30 | 33.30 |
| China Petroleum and Chemical Ltd. | Chemicals | 2093 | 12.99 | 46.30 |
| China Petroleum and Chemical Group | Chemicals | 782 | 4.85 | 51.15 |
| Lenovo Ltd. | IT | 745 | 4.62 | 55.78 |
| ZTE Corporation | IT | 739 | 4.59 | 60.36 |
| China Petroleum and Chemical Corporation | Chemicals | 458 | 2.84 | 63.21 |
| PetroChina Company Limited | Chemicals | 346 | 2.15 | 65.35 |
| Baosteel Ltd. | Steel | 325 | 2.02 | 67.37 |
| Haier Ltd. | Household Durables | 256 | 1.59 | 68.96 |

Figure 10 demonstrates invention applications of the top five firms listed in above, in comparison with the total applications of sample firms. Before 1998, these firms had rarely any patent applications. During 1999 to 2002, the share of invention applications by top five firms kept rising, taking up to 80% of overall annual applications. After 2002 however, these top five firms slowed down their application paces and was outstripped by other firms, which may means the growth of other domestic firms.

Figure 10 Invention Applications of Domestic Top 5 Firms (1985-2004)

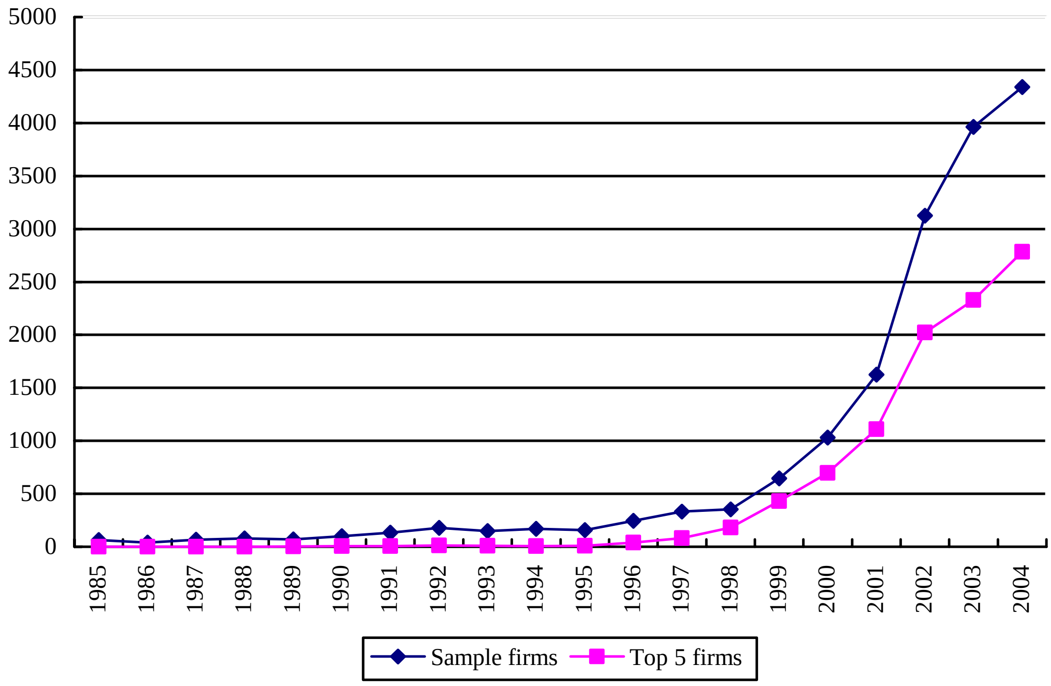



Table 5 lists the IPC subclass distribution of sample firms' invention applications (above 200 files). We can observe that H04L (Transmission of digital information, e.g. Telegraphic communication), H04Q (Selecting), G06F (Electric digital data processing), C10G (Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerisation), B01J (Chemical or physical processes, e.g. Catalysis, colloid chemistry; their relevant apparatus) are the concentrated areas of invention applications which take up 45.21% of the overall applications.

Table 5 IPC Subclass Distribution of Domestic Sample Firms' Invention Applications (Above 200 files)

| IPC Subclass Number | IPC Subclass | Invention Applications | Percentage | Accumulative Percentage |
|---|---|---|---|---|
| H04L | Transmission of digital information, e.g. Telegraphic communication | 2675 | 16.61 | 16.61 |
| H04Q | Selecting | 1595 | 9.90 | 26.51 |
| G06F | Electric digital data processing | 1120 | 6.95 | 33.46 |
| C10G | Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. By destructive hydrogenation, oligomerisation, polymerisation | 1067 | 6.62 | 40.08 |
| B01J | Chemical or physical processes, e.g. Catalysis, colloid chemistry; their relevant apparatus | 826 | 5.13 | 45.21 |
| H04J | Multiplex communication | 726 | 4.51 | 49.72 |

| | | | | |
|---|---|---|---|---|
| H04B | Transmission | 598 | 3.71 | 53.43 |
| C07C | Acyclic or carbocyclic compounds | 570 | 3.54 | 56.97 |
| H04M | Telephonic communication | 539 | 3.35 | 60.31 |
| C08F | Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds | 396 | 2.46 | 62.77 |
| H04N | Pictorial communication, e.g. Television | 368 | 2.28 | 65.06 |
| C01B | Non-metallic elements; compounds thereof | 274 | 1.70 | 66.76 |
| G01N | Investigating or analyzing materials by determining their chemical or physical properties | 251 | 1.56 | 68.32 |
| C22C | Alloys | 226 | 1.40 | 69.72 |

Table 6 lists the five top IPC subclass classifications of each top five corporations listed in Table 4. We can find that each top corporation's inventions are highly concentrated on limited number of IPC subclasses. Generally, the top five categories of IPC subclasses take up 70% to 80% of the overall invention application of the very corporation.

Table 6 IPC Subclasses Distribution of Domestic Sample Firms (Top Five)

| IPC Subclass Number | IPC subclass | Invention Application | Percentage | Accumulative percentage |
|---|---|---|---|---|
| Huawei | | | | |
| H04L | Transmission of digital information, e.g. Telegraphic communication | 2107 | 39.27 | 39.27 |
| H04Q | Selecting | 1134 | 21.14 | 60.41 |
| H04J | Multiplex communication | 496 | 9.25 | 69.66 |
| G06F | Electric digital data processing | 390 | 7.27 | 76.92 |
| H04B | Transmission | 385 | 7.18 | 84.10 |
| SINOPEC[10] | | | | |
| C10G | Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. By destructive hydrogenation, oligomerisation, polymerization | 921 | 27.63 | 27.63 |
| B01J | Chemical or physical processes, e.g. Catalysis, colloid chemistry; their relevant apparatus | 669 | 20.07 | 47.70 |
| C07C | Acyclic or carbocyclic compounds | 421 | 12.63 | 60.34 |
| C08F | Macromolecular compounds obtained by reactions only | 279 | 8.37 | 68.71 |

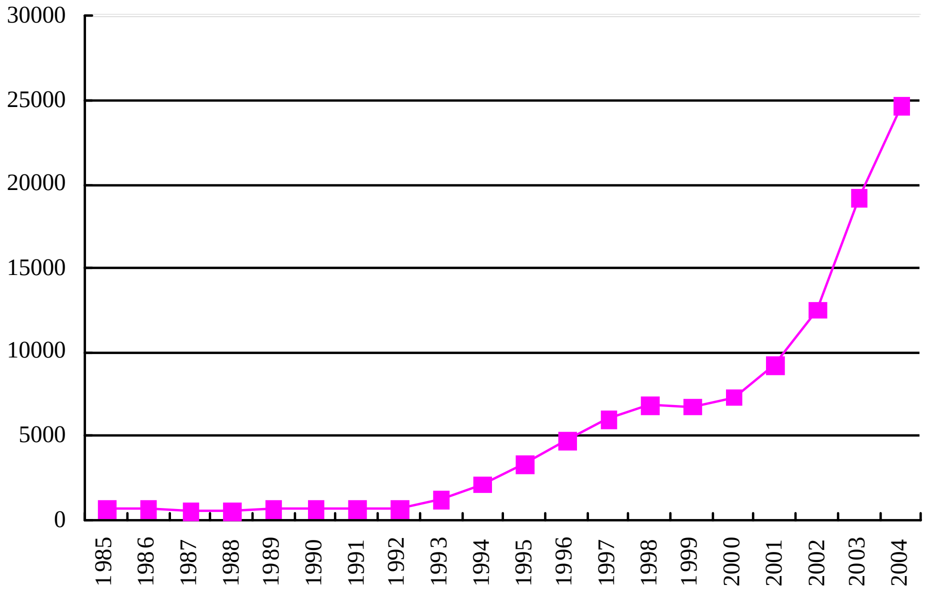
[10] Including China Petroleum and Chemical Ltd., China Petroleum and Chemical Group, China Petroleum and Chemical Corporation

| | | | | |
|---|---|---|---|---|
| | involving carbon-to-carbon unsaturated bonds | | | |
| C01B | Non-metallic elements; compounds thereof | 184 | 5.52 | 74.23 |
| Lenovo | | | | |
| G06F | Electric digital data processing | 454 | 60.94 | 60.94 |
| H04L | Transmission of digital information, e.g. Telegraphic communication | 129 | 17.32 | 78.26 |
| H04M | Telephonic communication | 30 | 4.03 | 82.28 |
| H04Q | Selecting | 26 | 3.49 | 85.77 |
| H04N | Pictorial communication, e.g. Television | 19 | 2.55 | 88.32 |
| ZTE | | | | |
| H04L | Transmission of digital information, e.g. Telegraphic communication | 179 | 24.22 | 24.22 |
| H04Q | Selecting | 152 | 20.57 | 44.79 |
| H04J | Multiplex communication | 128 | 17.32 | 62.11 |
| G06F | Electric digital data processing | 63 | 8.53 | 70.64 |
| H04B | Transmission | 63 | 8.53 | 79.16 |
| PetroChina | | | | |
| C10G | Cracking hydrocarbon oils; production of liquid hydrocarbon mixtures, e.g. By destructive hydrogenation, oligomerisation, polymerization | 41 | 11.85 | 11.85 |
| C08F | Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds | 35 | 10.12 | 21.97 |
| C10M | Lubricating compositions; use of chemical substances either alone or as lubricating ingredients in a lubricating composition | 31 | 8.96 | 30.92 |
| C07C | Acyclic or carbocyclic compounds | 29 | 8.38 | 39.31 |
| B01J | Chemical or physical processes, e.g. Catalysis, colloid chemistry; their relevant apparatus | 24 | 6.94 | 46.24 |

Comparing Table 6 with Table 5, we can find that the IPC subclass distributions of top domestic firms' invention applications are very similar to the IPC subclass distributions of all domestic samples, which reflect China's domestic invention applications are highly concentrated in several firms which invention categories have great influences on domestic firms' invention category distribution. For example, Huawei has applied for 2107 inventions in the H04L subclass, taking up nearly 40% of its total application, which also accounts for 78.8% of the overall invention applications in that subclass issued by all sample firms.

## Ⅳ. Innovative Performance of Multinational Companies: Evaluation by Patent Data

Similar to the sample in above, we use Fortune Global 500 list (2006) as our population of foreign companies. During past 20 years (1985-2004), foreign sample




companies have applied for totally 108747 inventions in China, about 10 times of the applications issued by domestic sample firms in total. Figure 11 presents annual number of foreign sample firms' invention application. As it depicts, multinational companies' invention applications in China have two upsurges, the first around 1993 and the second around 2001. After 1993, foreign applications increased by over 50% annually. From 1997 to 2000, their applications accelerated moderately and even decreased in 1999. And after the second upsurge from 2002 to 2004, totally 56432 inventions were applied for, taking up over 50% of the overall applications.

Figure 11 Invention Applications of Foreign Sample Firms (1985-2004)

Figure 12 compares the invention applications of domestic firms and foreign firms in China. It is obvious that before 2000, there was huge gap between the two groups. Applications of domestic firms are less than 1/15 of that of foreign firms, which reflects the huge technology gap. After 2000, however, domestic firms' applications increased dramatically and reached 1/5 of foreign firms', which also indicates the domestic innovative capabilities increased very fast.

Figure 12 Invention Applications of Domestic Sample Firms and Foreign Sample Firms （1985-2004）

With regard to parent country distribution, Japanese companies ranks first as many as 50779 files totally, taking up 46.7%; US companies ranks second as many as 24001 files, taking up 22.1%; Korean companies ranks third as many as 13115 files, taking up 12.1%; Netherlands and Germany companies rank respectively fourth and fifth. The companies from these five countries applied for over 95% of the total foreign inventions.

Figure 13 describes annual invention applications of the above five countries during 1985 and 2004. As it depicts, before 1993, there were rarely any invention applications. Korean firms applied for their first invention in 1989, indicating their lateness in entering China's market. After 1993, Japanese firms applied for more and more inventions every year in accelerating speed. Comparatively, U.S. firms' applications accelerated rather moderately. It is also interesting to notice that German firms' invention applications decreased these years.

Figure 13 Annual Invention Applications of the Sample Companies from Top Five Countries (1985-2004)

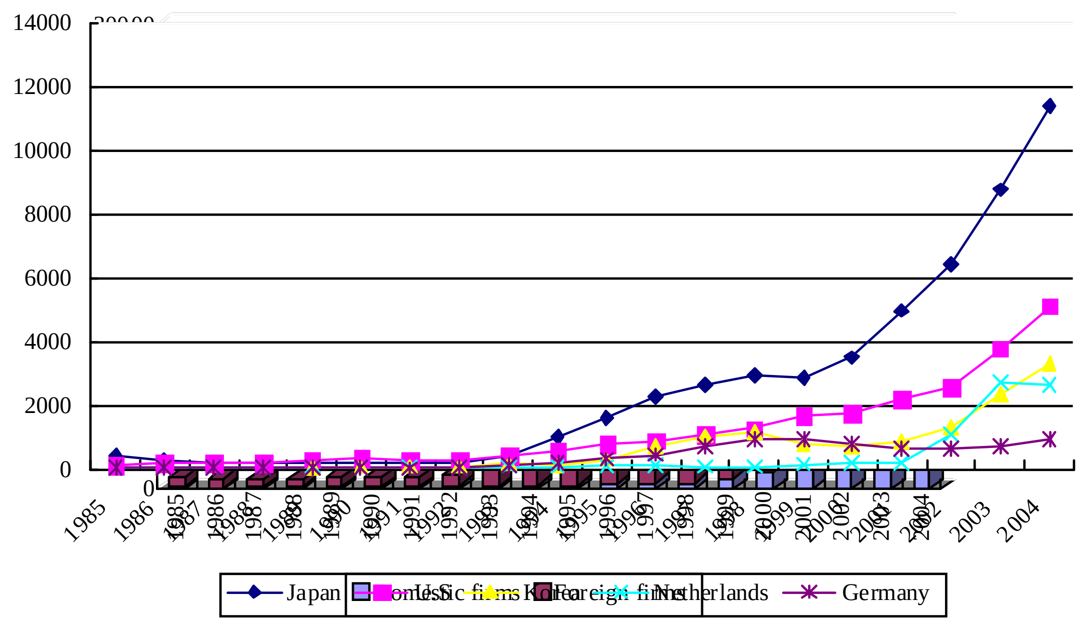



Table 7 lists foreign firms with over 1000 invention applications during 1985 to 2004. Panasonic from Japan applied for 12644 inventions, ranking first of all, taking up 11.63% in overall applications; Samsung ranks second as many as 9998 files, taking up 9.19%; Philips ranks third as many as 5586 files, taking up 5.14%. And out of the top five multinational companies, five are from Japan, two from U.S., and one respectively from Korea, Netherlands and Germany. Generally, the applications of Japanese companies are more concentrated, comparing with U.S firms. Samsung, Philips, and Simense all composed a large amount of the total applications of their parent countries.

Table 7 Foreign Firms with over 1000 Invention Applications

| Patentee | Parent Country | Invention Application | Percentage | Accumulative Percentage |
|---|---|---|---|---|
| Panasonic | Japan | 12644 | 11.63 | 11.63 |
| Samsung | Korea | 9998 | 9.19 | 20.82 |
| Philips | Netherlands | 5586 | 5.14 | 25.96 |
| Simense | Germany | 4713 | 4.33 | 30.29 |
| Mitsubishi | Japan | 4454 | 4.10 | 34.39 |
| IBM | U.S | 4119 | 3.79 | 38.17 |
| Canon | Japan | 4117 | 3.79 | 41.96 |
| Sony Electronics | Japan | 3832 | 3.52 | 45.48 |
| Sanyo Electronics | Japan | 3122 | 2.87 | 48.36 |
| Motorola | U.S | 2769 | 2.55 | 50.90 |
| Sony | Japan | 2762 | 2.54 | 53.44 |
| Honda | Japan | 2559 | 2.35 | 55.79 |
| Intel | U.S | 2199 | 2.02 | 57.82 |
| Dupont | U.S | 2183 | 2.01 | 59.82 |
| GE | U.S | 2135 | 1.96 | 61.79 |
| Fujitsu | Japan | 2060 | 1.89 | 63.68 |
| P&G | U.S | 1817 | 1.67 | 65.35 |
| 3M | U.S | 1557 | 1.43 | 66.78 |
| Shell | Holland | 1458 | 1.34 | 68.13 |
| Sharp | Japan | 1424 | 1.31 | 69.43 |
| Microsoft | U.S | 1011 | 0.93 | 70.36 |
| Sumitomo Chemical | Japan | 1009 | 0.93 | 71.29 |

Comparing the patentee distribution of foreign firms with that of domestic firms, we can find much more concentration for domestic firms. For example, only Huawei Technology one company takes up 1/3 of domestic applications while top five foreign firms take up the same percentage of foreign applications.

Table 8 describes the IPC subclasses distribution of foreign sample firms' invention applications (above 2000 files). From which we can find that G06F (Electric digital data processing), G11B (Information storage based on relative movement between record carrier and transducer), H04N (Pictorial communication, e.g. Television), H01L (Semiconductor devices; electric solid state devices not otherwise provided for), and H04L (Transmission of digital information, e.g. Telegraphic communication) are the main subclasses of foreign firms' invention applications. These five subclasses account for as many as 29.11% of foreign sample firms' total inventions applications. And if we compare Table 8 with Table 5, we can find that the IPC distribution of foreign sample firms is quite similar to that of domestic firms except fewer differences in chemical category, which means that there are really competitions between multinationals and China's leading domestic companies, especially in certain areas such as telecommunication.

Table 8 IPC Subclasses Distribution of Foreign Sample Firms (Above 2000 files)

| IPC Subclass Number | IPC subclass | Invention Applications | Percentage | Accumulative percentage |
|---|---|---|---|---|
| G06F | Electric digital data processing | 8320 | 7.65 | 7.65 |
| G11B | Information storage based on relative movement between record carrier and transducer | 7064 | 6.50 | 14.15 |
| H04N | Pictorial communication, e.g. Television | 5971 | 5.49 | 19.64 |
| H01L | Semiconductor devices; electric solid state devices not otherwise provided for | 5450 | 5.01 | 24.65 |
| H04L | Transmission of digital information, e.g. Telegraphic communication | 4856 | 4.47 | 29.11 |
| H04Q | Selecting | 3801 | 3.50 | 32.61 |
| H04B | Transmission | 3204 | 2.95 | 35.56 |
| H01M | Processes or means, e.g. Batteries, for the direct conversion of chemical energy into electrical energy | 2182 | 2.01 | 37.56 |
| H01J | Electric discharge tubes or discharge lamps | 2137 | 1.97 | 39.53 |
| G03G | Electrography; electrophotography; magnetography | 2055 | 1.89 | 41.42 |

The patent data analysis also reveals that, during past 20 years, 104091 files out of the total 108747 invention applications issued by foreign companies have priorities, taking up nearly 96% of overall applications, which means most of foreign companies' invention applications in China have been applied in abroad before, most likely in their home countries. It also confirms Hu's speculation that when foreign companies bring forward invention applications to SIPO, they do not need to wait for the technologies to be perfect but rather the market being ready. It is likely that multinationals in these foreign countries are patenting a larger proportion of their existing inventions in China (Hu, 2006). Another research performed by our team also proved this (Zhu&Liang, 2006).

## Ⅴ. Conclusion

As the patent data reflect, multinational companies' innovative performance exceeds the China's domestic firms faraway, either in quantity or in quality. Most of their patent applications are inventions, in-service applications and have higher granting and valid ratios, which makes distinct contrast to domestic applications. But multinationals' patent applications in China are mainly regarded as competition tools oriented on market thinking instead of representative of their actual and holistic innovative capabilities. They use China's patent system to provide them with strategic competitive advantage rather than to gain monopoly rent from their technological advantage. But at the same time, their patent applications in China not only inspire the "patent competition" in corresponding areas, but also give the chance for domestic firms to imitate and "invent around". Some empirical studies reveal that there are correlations between foreign invention applications and domestic utility/design applications, which partly proved this (Liu et al., 2003; Hu, 2006).

Local firms also adapted to China's patent system through gradual innovation, taking advantage of the two kinds of minor innovation. But most of Chinese firms have not been able to become true innovators in their corresponding industries, as evidenced by the lower invention granting ratio, with a few exceptions such as Huawei. Besides, although there emerged domestic patent surge recent years, their understanding of patent and patent strategies is still at the early stage. The small quantities and low concentration of leading firms on domestic invention applications partially revealed this. Especially, the low-level orientations on innovations and pervasively following and imitating behaviors among domestic firms may also harm the cultivation of their long-term and core competences.

However, accompanied with China's domestic firms' growth, the innovative performance of the two groups may also converge. Huawei's story is a typical case. In fact, Cisco's litigation directly stimulated the formulation of Huawei's IPR Strategy. Huawei founded the pre-research department which includes more than 1000 persons and gave more emphasizes on the cutting-edge technology research. At the same time, it strengthened patent analysis and concentrated on the breakthrough of technologies with comparative advantages, such as WCDMA. It improved collaborations with multinationals and founded strategic partnerships with most of the industry peers, such as 3Com and Simense, and make every efforts to obtain technologies through licensing and M&A. It also actively participated in the process of international standards establishment and became members of 83 standardization organizations. And finally as the result, the accumulative patent applications of Huawei reached 29666 by June 2008[11]. It also became the 4th largest patent applicant under the WIPO PCT, with 1,365 applications published in 2007, just

[11] Source, http://www.huawei.com/corporate_infomation/research_development.do.

behind Matsushita, Philips and Siemens[12]. Huawei followed a competitive strategy not only relying heavily on IPR protection of the core technologies, but also using its own technological advantage to integrate global innovation resources. During this process, Huawei developed new collaborative relationships with multinationals, whose roles also changed towards Huwei: first as "teachers", then as competitors, and finally as collaborators, which had become a typical road of China's domestic leading companies such as Lenovo, Cherry etc.

[12] WIPO, Unprecedented Number of International Patent Filings in 2007, Geneva, February 21, 2008. Source,http://www.wipo.int/pressroom/en/articles/2008/article_0006.html.

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# Innovation in Biotechnology Seeds: Public and Private Initiatives in India and China [1]

**Katherine Linton**
**Mihir Torsekar**

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# Abstract

This paper compares and contrasts how innovation—the successful introduction of new products, services, or techniques—is occurring in biotechnology seeds in China and India. The paper begins with an overview of the agricultural challenges faced by China and India and the substantial investments that both countries are making in agricultural research and development and biotechnology to address these challenges. The paper next describes each country's approach to three supply-side factors identified by industry sources as important to innovation in biotech seeds: market access, intellectual property protection, and regulatory review processes. The paper concludes with a case study highlighting how these three factors impacted the introduction and adoption of the first widely commercialized biotech crop in China and India, Bt cotton.

# Innovation in Biotechnology Seeds: Public and Private Initiatives in India and China

## Introduction

This paper compares and contrasts how innovation—the successful introduction of new products, services, or techniques—is occurring in biotechnology seeds in China and India. We begin with an overview of the agricultural challenges faced by China and India and the substantial investments that both countries are making in agricultural research and development (R&D) and biotechnology to address these challenges. We next describe each country's approach to three supply-side factors identified by industry sources as important to innovation in biotech seeds: market access, intellectual property (IP) protection, and regulatory review processes. We conclude with a case study highlighting how these three factors impacted the introduction and adoption of the first widely commercialized biotech crop in China and India, Bt cotton.[1]

With regard to the three factors identified as important to biotech seed innovation, we find that China significantly limits the market access of foreign firms while India has liberalized its seed sector and permits foreign and domestic firms to participate on equal terms. However, Indian state governments have implemented price restrictions that severely limit the ability of all firms to charge market prices for biotech seeds. We next find that both countries have patent and plant variety protection laws that provide some protection for new plant technologies. The public sector is an important user of IP protection systems, particularly in China. Foreign firms are active in seeking patent protections in both countries; by contrast, domestic firms are not active users of the patent system. With regard to regulatory review, both countries appear to be in a holding pattern; products sponsored by the public and private sectors are languishing in the review pipeline. Both countries consider factors unrelated to biosafety in determining whether to approve new biotech seeds, a practice that can cause unreasonable delays and undermine public confidence in the regulatory process. Both countries also have difficulties with the enforcement of IP and regulatory laws. Illegal seeds—those that violate IP laws and/or have not undergone regulatory review—are an ongoing and substantial problem in India and China.

## Agricultural Challenges in China and India

India and China have achieved remarkable economic growth over the last decade; however, growth in the agricultural sector has lagged that in the general economy. Since 2000, India has experienced average real GDP gains of about 7 percent, and China of almost 10 percent (IMF 2009). In Indian agriculture, however, annual growth rates declined to 2.5 percent during the period 1997–2007 (compared to 3.7 percent in the previous five year period) (Government of India, Ministry of Finance

[1] Bt cotton is a genetically modified crop that includes a gene from the soil bacterium, *Bacillus thuringiensis*. The bacteria produce a protein that is toxic when ingested by certain Lepidopteran insect, particularly the bollworm. Cotton containing the Bt gene is able to produce the toxin thereby providing insect resistance to the plant (USDA, ERS 2009a).

2008). While in China, agricultural output has grown about 7 percent per year during the period 1997–2007 (USDA, ERS 2009b).

In both countries, the agricultural sector faces the tremendous challenge of producing more with fewer resources including diminishing per capita arable land and water. Climate change, plant diseases and pests, pollution, and depleted ecosystems resulting from the heavy application of fertilizers and pesticides present significant additional challenges (Tuli et al. 2009, 319). In an effort to overcome these obstacles, governments in both countries have made investing in agricultural R&D, and particularly in agricultural biotechnology, a priority.

Biotechnology is broadly defined as the use of the biological processes of microbes and plant and animal cells for the benefit of humans (USDA, ERS 2009a). Agricultural biotechnology provides a more sophisticated and precise means of modifying plant genetics than that practiced by plant breeders for centuries through breeding and crossbreeding. Biotechnology enables the transfer of selected genes instead of transferring thousands of genes as occurs with traditional plant breeding methods. Moreover, by expanding the possible universe of transferable genes to include essentially any living organism, biotechnology enables the introduction of new beneficial traits that would be difficult or impossible to create through traditional breeding methods. First generation biotech crops include those that have been genetically engineered to improve resistance to insects and tolerance to herbicides, thus enabling farmers to use fewer pesticides and obtain higher yields. Genetic engineering to increase a plant's tolerance to drought and high salinity levels, as well as to improve the nutritional content of crops, are promising emerging areas of agricultural biotechnology (Giddings and Chassy 2009; CEI 2009).

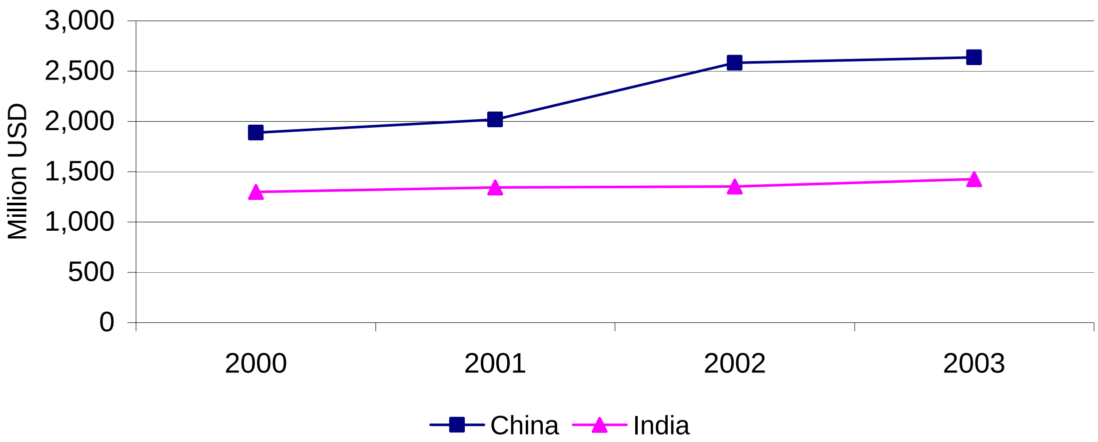
# Government Investments in Agricultural Biotechnology

Increased agricultural productivity depends on R&D to support innovation. China and India have made significant investments in agricultural R&D. They are ranked third and fourth respectively in public sector agricultural R&D spending behind the United States and Japan. In 2000, the United States invested the equivalent of about $4.4 billion in agricultural R&D, compared to $2.5 billion for Japan, $1.9 billion for China, and $1.3 billion for India (Beintema et al. 2008).[2] Since 2000, agricultural R&D spending has grown much more rapidly in China, reaching $2.6 billion in 2003. By contrast, public sector R&D spending remained relatively unchanged in India during the period, figure 1.

Within the general field of agricultural R&D, China and India have identified biotechnology and genetic engineering as critical tools for overcoming the significant challenges to increasing productivity. According to a leading official in India's agricultural R&D program, "the search, characterization, isolation and utilization of new genes through application of biotechnology are essential for the revitalization of Indian agriculture" (Rai 2006). During the years 2002–06, the Indian Ministry of Science and Technology's Department of Biotechnology (DBT) implemented 481 agricultural

[2] The authors' calculations are in international dollars, calculated by deflating expenditures in current local currency units using a local implicit GDP deflator for 2005 and then converting to international dollars using a 2005 purchasing power parity (PPP) index. PPP measures provide some advantages over market exchange rates: they are relatively stable over time and they take into account nontraded goods and services, which are often the largest components of a country's agricultural R&D expenditures (Beintema and Stads 2008, 4-5).

**FIGURE 1** China and India total public sector agricultural R&D spending (million, PPP $), 2000-




*Source*: ASTI database.

biotechnology programs. Going forward, the DBT has identified as R&D priorities the development of biotech crops that are disease and pest resistant, drought and salinity tolerant, and nutritionally enhanced (Government of India, Ministry of Science and Technology 2006, 8, 180). In addition to the DBT, public sector institutions substantially involved in agricultural biotechnology R&D include the Indian Council of Agricultural Research (ICAR) and the State Agricultural Universities (SAUs) (Beintema et al. 2008).

There are few published estimates India's total R&D expenditures on agricultural biotechnology across the relevant agencies. One exception is James (2008, 60) who estimates that India's public sector investments in crop biotechnology R&D have been approximately $1.5 billion over the last 5 years, or $300 million per year.

Like India, China has promoted biotechnology as an important tool for boosting agricultural productivity, food security, and rural incomes. Agricultural biotechnology R&D programs are overwhelmingly financed and implemented by the public sector. As of 2001, there were more than 150 national and local laboratories in more than 50 research institutes and universities working on agricultural biotechnology, under the direction of the Ministry of Science and Technology and the Ministry of Agriculture. One of the most important public funding programs for agricultural biotechnology is the National High Technology Research and Development Program (known as the 863 program). Agricultural biotechnology funding under the 863 program has grown significantly from $4.2 million when the program began in 1986 to $55.9 million in 2003 (Huang et al. 2004).

In recent years, China has elevated the status of agricultural biotechnology. As Chinese Premier Wen Jiabao stated in 2008, "to solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on GM" (James 2008, 93). Agricultural biotechnology is an important focus of China's Medium-and Long-term Science and Technology Development Plan (2006–20). In July of 2008, the Premier announced a budget increase for genetically modified crops of 4–5 billion RMB per year ($584-$730 million). One of the aims of this new initiative is for China to "obtain genes with great potential commercial value whose intellectual property rights belong to China, and to develop high quality, high yield, and pest resistant genetically modified new species" (James 2008, 93; Shuping 2008). Government policies in areas such as IP have a significant impact on innovation in agricultural biotechnology in China and India, as set forth below.

# Government Policies Impacting Agricultural Biotechnology

Industry sources have identified government policies in three areas as important to successful innovation in agricultural biotechnology in India and China: market access conditions; the availability of IP protections; and the speed and manner in which regulatory systems review new biotech products.

## *Private Sector Access to Seed Markets in India and China*

Seeds were predominantly a public sector business in India and China until recently; the situation has changed dramatically in India but not in China. Until the late 1980s, private firm participation in the seed industry in India was limited by economy-wide policies that restricted foreign investment and licensing and by seed-specific policies that limited the sector to "small scale" participants and severely restricted imports of research or breeder seeds. With India's implementation of the Seed Policy of 1988, the "small scale" limitation was removed, large domestic and foreign firms were permitted entry, and import restrictions were substantially lifted. Economy-wide liberalization occurred in India in 1991, including the abolishment of the industrial licensing system and the easing of restrictions on foreign direct investment (FDI) (Pray, Ramaswami, and Kelley 2001, 589).

These reforms effectively opened the market to private participation. Pray, Ramaswami, and Kelley (2001) found that as a result of the reforms, new foreign and domestic firms entered the market, competition increased, and private sector R&D expenditures grew rapidly as domestic firms spent more on technology to compete with the entry of new research intensive foreign firms. Another important motivation for firms' increased R&D expenditures has been the market's transition away from open pollinated varieties (OPVs), which farmers can save and reuse in subsequent years, to hybrids, which cannot be reused without a significant reduction in yield and quality. Farmers' need to purchase seeds each year enables firms to recoup R&D investments (Pray, Ramaswami, and Kelley 2001, 596–97).

U.S. and other global seed companies with a substantial presence in the Indian hybrid and biotech seed markets include Monsanto (United States), Bayer CropScience (Germany), DuPont/Pioneer (United States), Syngenta (Switzerland), and Dow AgroScience (United States). Leading Indian firms include Rasi Seeds, the Maharashtra Hybrid Seed Company (Mahyco), Nuziveedu Seeds, and JK Agri-Genetics (Bayer CropScience 2006). The agricultural biotechnology sector in India reportedly had total revenues of about $318 million in 2008, an increase of 353 percent in the last five years (BioSpectrum 2009).

The Indian seed market is competitive. Murugkar, Ramaswami, and Shelar (2007) found that the cotton seed market, which accounts for about one fourth of the overall seed market, has low levels of market concentration, a diverse group of foreign and domestic firms of various sizes, and market leadership that fluctuates over time and across Indian states. They noted, however, that two factors were detracting from healthy competition: state level price caps placed on biotech cotton seeds and a substantial market in illegal seeds. Price caps were particularly problematic for new entrants to the biotech seed market, including JK Agri-Genetics and Nath Seeds, two domestic companies attempting to bring new biotech cotton seeds to market at the time that price caps were being implemented (Murugkar, Ramaswami, and Shelar 2007, 19–21).

The U.S.-India Business Council (2009, 6) identifies non market-based pricing as one of the most significant disincentives to the commercialization of new biotech seeds by global seed firms in India. According to the founder of Rasi Seeds, continued state government interference in pricing also is harming the ability of indigenous companies to develop and commercialize biotech seeds (Suresh and Rao 2009, 299). The state government of Andhra Pradesh was the first to implement price restrictions; its 2006 directive capped prices for biotech cotton seeds at less than one half the prevailing market price. Today, price caps have since spread to states throughout the country including Maharashtra, Gujarat, Tamil Nadu, Karnataka, Madhya Pradesh and West Bengal (Mishra 2006).

India's liberalized seed market (albeit with significant price controls) stands in stark contrast to that of China. Despite the enactment of a seed law in 2000 that creates a role for private firms, China continues to severely restrict FDI and the trading of certain types of seeds, substantially limiting the operations of global firms (USCIB 2009, 32-33). Moreover, due to the historic role of state planning, Chinese seed markets are fragmented by geography and function. Historically, each province or prefecture had its own seed company, which generally had monopoly rights in its geographic area. Although the 2000 seed law facilitated the marketing of seeds across geographic areas, according to field research conducted by Keeley (2003, 33–34) local markets remained difficult for non-local firms to access. Fragmentation across functions is also the norm; few firms are vertically integrated across the R&D, breeding, production, sales, and marketing functions (Sanchez and Lei 2009, 5).

FDI restrictions are severe and, not coincidentally, arose at about the same time that Monsanto began to successfully market its biotech cotton product in China. In 1997, the year after the first approval of Monsanto's product, a new seed regulation required that any foreign company wishing to produce and sell cotton and other seeds enter into a partnership in which the Chinese partner maintained the controlling interest, invest prescribed amounts of capital, and obtain central government permission (Reddinger 1997). This new regulation required the reduction of Monsanto's initial controlling interest in its cotton joint venture; reportedly so that the Chinese partners could obtain more economic benefits from the partnership (Keeley 2003, 33).

FDI laws became even more restrictive in 2002 when China's Foreign Investment Guidance Catalogue prohibited any new foreign investment in the development and production of genetically engineered planting seeds (Gifford, Qing, and Branson 2002, 3). These restrictions are repeated in the most recent FDI catalogue issued in 2007. With regard to conventional seed production, foreign firms are limited to minority shareholder status in joint ventures with Chinese partners (Petry 2007, 2).

The FDI restrictions reportedly arose out of Chinese government concerns about food security and the competitiveness of the domestic industry in light of the commercial success that Monsanto experienced with its biotech cotton product (Thomas 2007, 55–56). Concerns about multinational companies dominating the seed industry persist today. The Chinese Academy of Science and Technology for Development (CASTED 2009), for example, recently noted that seed is a strategic industry and that the opening up of the industry threatens the survival of domestic firms and the security of China's germplasm resources.

Notwithstanding the market access restrictions, foreign firms have been permitted to undertake several new biotech R&D projects in China. Reportedly, new investments are permitted if they are limited to research and experimentation, and do not extend to commercialization of new products.[3] Syngenta, for example, is building a research center in Beijing for the early evaluation of genetically modified traits in key crops, and has a number of ongoing collaborations with Chinese research universities (Syngenta 2008). Bayer CropScience has entered into a Memorandum of Understanding with the Chinese Academy of Agricultural Science (CAAS) for the "joint development and global marketing of new agricultural products" using the latest plant breeding and biotechnology processes (Bayer CropScience 2008). Although FDI restrictions remain in place, foreign firms appear optimistic that the research they are permitted to do in China ultimately will lead to products they can commercialize there.[4]

## *The Importance of IP Protection*

IP protection for biotech seeds is an important framework condition for innovation because the development and commercialization of new products is characterized by large research expenditures, uncertain outcomes, and lengthy and costly regulatory procedures (Maskus 2004, 721). Monsanto, for example, estimates R&D investments for new biotech corn products of $5-10 million for the proof of concept phase, and $10-15 million for early product development (Monsanto India Ltd. 2009, 7). To obtain regulatory approval, Kalaitzandonakes, Alston, and Bradford (2007, 510) found that global seed firms incurred compliance costs ranging from $7–$15 million for herbicide-tolerant and insect-resistant corn submitted to regulators in ten countries. These large sunk R&D and regulatory compliance costs would be lost if competitors were permitted to free ride on the work of initial innovative firm.

An additional challenge arises from the "natural appropriation problem" of seeds (Maskus 2004, 722). OPVs can be reproduced simply by their cultivation and reuse and biotech seeds can be relatively easily copied by competitors through the latest biotechnology techniques. By contrast, hybrid seeds have some built in protection mechanisms: they lose their superior yield potential and other valuable characteristics in subsequent plantings thus reducing the motivation of farmers to save seed. Moreover, commercial competitors cannot reproduce hybrid seeds without access to the parental lines used to develop them; keeping the parental lines physically secure reduces the appropriation problem (World Bank 2006, 7–8). However, these built in protection mechanisms have their limitations. Seed production in India and China tends to be concentrated in geographic zones with favorable agronomic conditions; the presence of many competing firms working in a relatively small area creates numerous opportunities for misappropriation (Tripp, Louwaars, and Eaton 2007, 360).

As WTO members, China and India must make IP protection available for seed-related inventions. The WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) requires that

[3] Industry representative, e-mail message to Commission staff, August 18, 2009.

[4] China does not have price controls regulating the cost of biotech cottonseed. However, government decisions at the local level about which seeds will be subsidized reportedly can be biased and based on connections rather than on product quality. Industry representative, telephone interview with Commission staff, July 24, 2009.

members make patents available for inventions, whether products or processes, in all fields of technology without discrimination, subject to the normal tests of novelty, inventiveness and industrial applicability (TRIPS, art. 27.1). There is an exception to this general rule of patentability for plants and animals; however the exception is limited: patents must be provided for certain biotechnology processes for the production of plants and animals. Moreover, if a member country does not provide patents for plant varieties, it must provide an effective sui generis [or alternative] system (TRIPS, art. 27.3(b)). Some countries, including the United States, extend both patents and an alternative system to the protection of plants. Most developing countries, including India and China, provide only an alternative system, using the model supplied by the International Convention for the Protection of New Varieties of Plants (UPOV).

The TRIPS requirement that patent protection be provided for micro-organisms and non-biological and micro-biological processes for the production of plants should encompass many biotechnology products and processes. It is left to each WTO member, however, to determine if a particular product or process is novel, inventive, and has an industrial application, and to interpret essential terms such as micro-organisms, non-biological and micro-biological.

**Patents in India and China**

Both India and China exclude plants and seeds from patent protection but provide patents for micro-organisms, and non-biological and micro-biological processes that are inventive, novel, and have industrial application. However, global seed firms have expressed concern about the actual scope of coverage for biotechnology products and processes in both countries.[5]

In China, patentable genetic sequences must be “separate or extracted from nature for the first time, their sequences of base groups must not have been recorded in the literature, [and they] must be accurately characterized and have industrial value” (Zhan 2008, 35). Otherwise, a genetic substance will be considered a scientific discovery and not patentable. In India, a government-appointed expert group recently advised that strict guidelines should be followed in cases of micro-organisms and biotechnology processes to ensure “substantial human intervention and utility” (Technical Expert Group on Patent Law Issues March 2009, 15).

India and China’s cautious approaches have not prevented the granting of some agricultural biotechnology patents. According to online records of the Indian Patent Office, Monsanto holds the largest number of recently granted patents for seed technologies.[6] For example, it has obtained a patent for “Cotton Event Mon15985,” the genetics underlying the second generation of its biotech cotton product, as well as patents for biotechnology processes used in producing plants with herbicide tolerance, improved germination rates, and other valuable traits. Patents for other biotechnology methods for

[5] Global firms also have expressed concern about the requirement in both countries that patent applications identify the source and geographic origin of biological materials used to make an invention, stating that it is too open-ended, ambiguous, and burdensome. Patent law provisions in both countries that permit compulsory licensing under a wide variety of circumstances also give rise to industry concerns. See BIO 2009, 2-3; industry representatives, e-mail message to Commission staff, June 19 and August 18, 2009; and industry representatives, telephone interviews by Commission staff, August 10, 2009.

[6] The Controller General of Patents, Designs, and Trademarks (Indian Patent Office) has online search facilities that permit the searching by applicant name of “new records” of granted patents. See Indian Patent Office, Public Search for Patents, http://ipindia.nic.in/patsea.htm (accessed July 12, 2009). Although date parameters for new records are not provided, they appear to comprise patents granted since 2007. Patents related to fertilizers, pesticides, and other agricultural chemicals are not included in the totals reported here.

improved traits for rice, cotton, corn and other crops, as well as biotechnology-based seed coatings and treatments, have been issued to Bayer and Syngenta. Global seed firms also have a substantial number of patent applications pending for seed technologies.[7]

By contrast, most large domestic seed companies, such as Rasi Seeds and Nuziveedu, do not hold patents or pending applications for seed-related technologies. One exception is Mahyco, which has a number of pending applications for biotech seed technologies. Public sector research institutions, such as the Indian Council for Agricultural Research (ICAR) and the Council for Scientific and Industrial Research (CSIR) hold few patents or applications for biotech seed technologies at the Indian patent office.[8]

In China, there is substantial patenting of seed biotechnologies by foreign firms, figure 2.[9] Monsanto has the largest number of granted patents and pending applications. For example, it has obtained patents related to its insect resistant cottonseed and for genetic sequences in corn, bentgrass, and soybeans that confer tolerance to herbicides, improved trait qualities, and other benefits. Other global seed firms have only a handful of granted patents in China but have larger numbers of applications pending. These pending applications are in areas such as climactic stress tolerance, yield improvement, herbicide tolerance, insect and virus resistance, and other valuable traits.

Unlike in India, China's government-supported research institutions and universities are also important players in biotech seed patents. For example, a review of patents and applications related to Bt cotton, establishes that Chinese research institutes and universities are particularly active, figure 3. The research institutes of CAAS including the Biotechnology Research Institute (BRI), as well as Huazhong Agricultural University, and Central-China Agricultural University all hold multiple patents or applications for Bt-related technologies. The BRI reportedly generated about 15 percent of its income through patents in 2006 and expected to increase that share significantly in the near future (World Bank 2006, 38).[10] By contrast, few domestic Chinese firms hold patents or applications in the Bt technology area. China and India are thus similar in limited patenting activities by domestic companies compared with strong patenting by global firms. They differ in the substantial patenting by Chinese research institutes and universities.

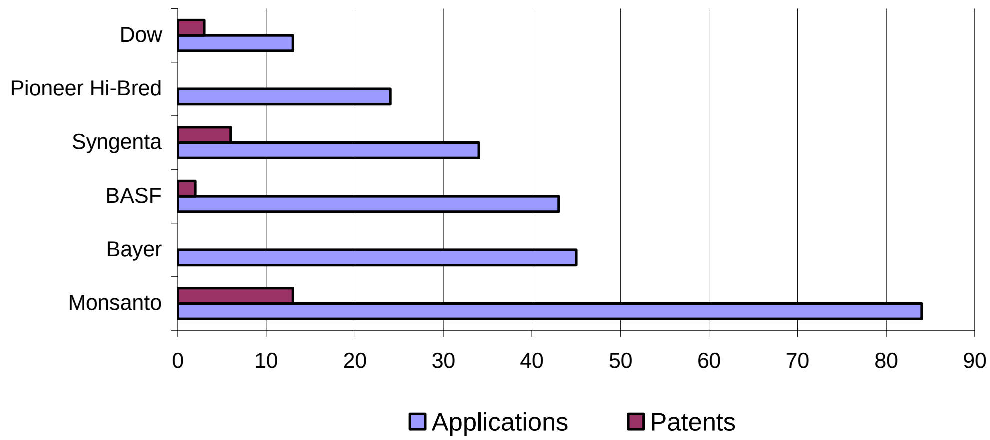
[7] India Big Patents Web site. http://india.bigpatents.org (accessed July 20, 2009).

[8] CSIR patents in the fields of agriculture and biological sciences can be accessed on its patent database, http://www.patestate.com/ (accessed September 8, 2009). See also India Big Patents Web site. http://india.bigpatents.org (accessed July 20, 2009).

[9] Agricultural biotechnology patents were identified by review of patents issued and applications made by the leading global seed firms using the following search terms: seed; plant; bacillus; corn; rice; cotton; or transgenic on the China patent data base, http://search.cnpat.com.cn (accessed August 15, 2009).

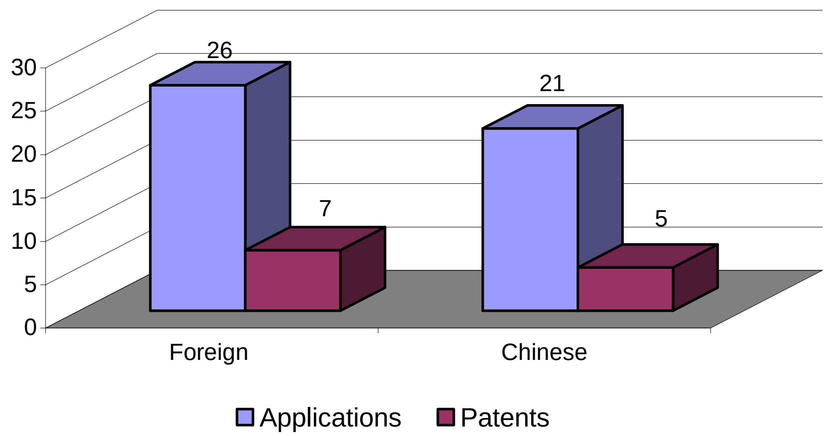
[10] As described in the case study, China's public sector actors have licensed the Bt technologies to firms that market and distribute the seeds.

**FIGURE 2** China: Global Firms' Seed Biotech Patents and Applications, 1984–2009




*Source*: China Patent Database: http://search.cnpat.com.cn.

**FIGURE 3** China: Bt-Related Patents and Applications, 1985–2009




*Source*: China Patent Database: http://search.cnpat.com.cn.

## Plant Variety Protection in India and China

China and India have enacted plant variety protection laws as an alternative to the provision of patent protection for plant varieties. These laws provide marketing rights to developers of new plant varieties that are distinct, uniform, and stable.[11] However, the rights granted contain significant limitations and are generally considered weaker than patent rights, table 1.

China enacted its Plant Variety Protection Act (PVPA) in 1997 and began accepting applications to register new varieties in 1999.[12] India enacted legislation in 2001, the Protection of Plant Varieties and Farmers' Rights Act, 2001 (PPV&FR law), but did not begin accepting applications for the protection of plant varieties until May 2007.[13] Major differences between plant variety protection laws in India, China, and the United States are highlighted below (table 1).[14]

**TABLE 1** Major differences in plant variety protection laws in India, China, and the United States

| | India | China | United States |
|---|---|---|---|
| Length of protection | 18 years for trees and vines; 15 years for other crops and extant varieties | 20 years for vines, fruits, and ornamentals; 15 years for all other crops. | 25 years for trees and vines, 20 years for other crops |
| Coverage | 18 crops eligible. | 73 crops eligible. | No crops excluded. |
| Farmer seed saving and exchange | Seed saving, exchange, sale by farmers broadly permitted. Farmers only prohibited from selling "branded seed." | Farmer seed saving and exchange permitted, if non-commercial. | Seed saving and sole use by the farmer to produce a crop are permitted, subject to the legitimate interests of the breeder. Farmers cannot sell or share seed without the permission of the breeder and payment of royalties. |
| Breeder's exemption | Protected varieties may be used for breeding. | Protected varieties may be used for breeding. | Breeding activities permitted provided that the benefits of new varieties that are "essentially derived" from protected varieties are shared. |

*Sources*: Indian Protection of Plant Varieties and Farmers' Rights Act (2001); U.S. Plant Variety Protection Act, 7 U.S.C. §§ 2321–2582 (2007); Regulations of the People's Republic of China on the Protection of New Varieties of Plants (1999); and World Bank 2006, 7.

[11] A variety is "distinct" if it is clearly distinguishable from another variety; "uniform" if it has relevant characteristics that can be defined for the purpose of protection; and "stable" if its relevant characteristics remain unchanged after repeated propagation. Together, these are known as the DUS criteria. UPOV Web Site. http://www.upov.int/en/about/upov_system.htm#P177_18977 (accessed September 23, 2009).

[12] China, Ministry of Agriculture, Office for the Protection of New Varieties of Plants Web Site. http://www.cnpvp.cn/en/index.html (accessed September 8, 2009).

[13] Government of India, Protection of Plant Varieties and Farmers' Rights Authority Web Site. http://www.plantauthority.gov.in/index.htm (accessed September 8, 2009).

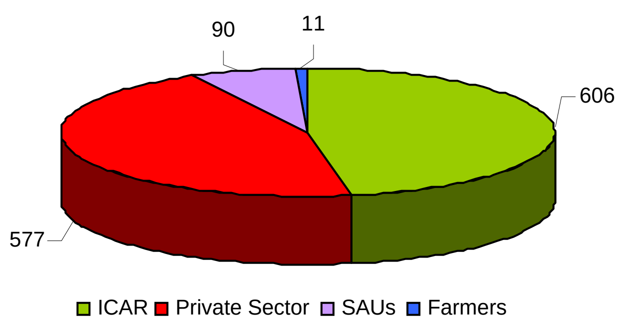
[14] The UPOV Convention, which has undergone several revisions since its enactment in 1961, serves as the model for plant variety protection in China, India, and the United States. The United States follow the latest revision, UPOV 1991, which is the most protective of the rights of plant breeders. China follows an earlier version, UPOV 1978, and India's PPV&FR law, while loosely based on UPOV 1978, contains broad exceptions intended to protect farmers. India's application to join UPOV has not been approved to date, apparently because of deviations from UPOV 1978. Government official, interview by Commission staff, Alexandria, VA, July 20, 2009.

India provides the shortest term of protection for plant varieties, followed by China, and then the United States. China and India are phasing in coverage of the law to include new crops each year; however, because India's law is of recent vintage, relatively few crops are covered. China did not include cotton on the list of crops entitled to PVP until 2005; a delay labeled "strategic" by Keeley (2003, 23) to enable the unrestricted spread of the first generation of biotech cotton technologies.

The most significant difference in PVP laws in the three countries is the breadth of farmers' privileges in India's law. Indian farmers are permitted to save, use, sow, exchange, share, and even sell protected seed. The only limitation is a prohibition on the sale of "branded seed." China's law permits farmer seed saving and informal exchange but prohibits commercial sales. U.S. law is significantly more restrictive; farmers can only save seed under specific conditions and new varieties cannot be "essentially derived" from protected varieties without a sharing of benefits. Global seed firms note that the broad farmers' privileges and breeders' exemptions render plant variety protection of limited commercial value in both India and China.[15]

Unlike in the United States, the dominant users of the plant variety protection systems in India and China are public research institutions and universities, seeking protection for conventional hybrids and OPVs rather than biotech plants. In India, most applications have been filed by the Indian Council of Agricultural Research (ICAR), figure 4. The combined share of ICAR and the state agricultural universities (SAUs) equals 54 percent of all applications. Most of the remaining applications are filed by the private sector, which includes both domestic and foreign firms.

**FIGURE 4** Plant variety protection applications filed in India, 2007–Present




*Source*: Indian PPV&FR Authority.

[15] Industry representative, e-mail messages to Commission staff, June 19, 2009 and August 18, 2009; U.S. government official, telephone interview by Commission staff, July 24, 2009.

Similarly, according to data compiled in China by Hu and others (2006), 66 percent of PVP applications were filed by government research institutes during the period from 1999–2004. This figure actually understates public sector involvement as approximately one half of the applications filed by the private sector were for plants developed by the public research institutions and then licensed to private firms for purposes of the PVP application (Hu et al. 2006, 261, 264). Public sector efforts to protect and commercialize IP are not surprising given that government research institutes in China often are expected to generate a significant portion of their own budgets. Some provincial governments motivate researchers to develop new varieties for commercialization by awarding bonuses or other privileges based on the number of PVP applications filed (Hu et al. 2006, 265).

The public sector dominance of the PVP system in India and China stands in stark contrast to the situation in the United States where the private sector accounts for 75 percent of PVP filings, universities and the government only 15 percent, and foreign applicants the remainder (Strachan 2006, 2). The PVP systems in China and India operate not only to stimulate private sector R&D but, even more importantly based on user statistics, to stimulate public sector involvement in the development of new plants.

## *Regulatory Review*

Biotech seeds cannot be marketed until they have been reviewed and approved for release by the regulatory system. The goals of the Indian and Chinese regulatory systems are wide-ranging. In India, they are to ensure that biotech crops pose no major risk to food safety, environmental safety, or agricultural production, and to ensure that farmers are not adversely affected economically by biotech crops. In China, the objectives of the regulatory system are to promote biotechnology R&D, tighten the safety control of genetic engineering work, guarantee public health, prevent environmental pollution, and to maintain ecological balance. The Indian goal of protecting farmers generally is not part of the regulatory framework in developed countries (Pray et al. 2006, 142-43).

India and China (and the United States) have detailed regulatory frameworks for the review of biotech seeds, encompassing multiple agencies and numerous stages. In China, for example, these stages are intended to take place over multiple years and include laboratory development (variable, 2-4 years), contained field trials (1-2 years), environmental release trials (2-4 years), and pre-production trials (1+ years), followed by the approval or rejection of the product for commercial release (Karplus and Deng 2008, 116; Monsanto 2009, 7). In addition to biosafety review, separate procedures also exist at the state and provincial level for the registration of biotech seeds before they can be marketed in a particular state or province. In China, these procedures can add another 2-3 years to the time to market (Petry and Bugang 2008, 8).[16]

High costs and lengthy procedures can result in products being withdrawn from consideration if the costs of compliance outweigh the benefits the firm can obtain in a particular market. Bayer CropScience, for example, reportedly withdrew its biotech mustard seed from regulatory consideration in

[16] By contrast, regulatory compliance procedures appear to take much less time in the United States. Jaffe (2006, 748) calculated the period of time from the official submission of a regulatory package for a biotech crop to the final agency decision allowing the product to be commercialized. The USDA, which is responsible for assessing the environmental safety of biotech crops and oversees field testing and trials, took on average 8.6 months to issue a final decision during the period from 1994–2005. However, the trend is for review time to increase; the time it took the agency to reach a regulatory decision more than doubled in 2001–2005, when compared to the previous five year period (Jaffe 2006, 748).

India in 2003 after approximately nine years of review and testing and millions of dollars in costs. Bayer reported that the continued costs, uncertainty about whether the product would ever be approved, and the potentially small market size all contributed to the decision not to continue with commercialization of the product in India (Pray, Bengali, and Ramaswami 2005, 273). Moreover, lengthy regulatory proceedings can have the unintended effect of encouraging the growth of illegal seed markets to fill unmet demand during protracted review periods, as occurred in India when illegal versions of Bt cotton reached the market while the legitimate product was still under review.

Both the public and the private sectors in India and China have been conducting field trials of new biotechnology crops since the late 1990s. However, no new biotech crops have been approved in India since Bt cotton in 2002. In China, Bt cotton, approved in 1996, is the only widely planted biotech crop. Table 2 identifies crops undergoing field trials in India. Most of the new biotech crops in the pipeline (24 of the 38 identified products) are from the private sector. China does not regularly publish lists of crops undergoing testing (Petry and Bugang 2008, 4); according to reports, however, stress and herbicide-tolerant rice, disease resistant cotton, insect resistant corn, quality improved corn, herbicide tolerant soybeans, virus resistant wheat, quality improved potato, insect resistant poplar trees and many other crops have entered or even completed trials (Karplus and Deng 2008, 104).

**TABLE 2** India: Biotech crops in field trials, 2006–2009

| Crop | No. of Public/Private Organizations | Trait |
|---|---|---|
| Brinjal | Public (3)<br>Private (3) | Insect resistance |
| Cabbage | Private (2) | Insect resistance |
| Castor | Public (1) | Insect resistance |
| Cauliflower | Private (2) | Insect resistance |
| Corn | Private (3) | Insect resistance, herbicide tolerance |
| Cotton | Public (1)<br>Private (4) | Insect resistance, herbicide tolerance |
| Groundnut | Public (1) | Virus resistance<br>Drought tolerance |
| Okra | Private (4) | Insect resistance |
| Potato | Public (2) | Disease resistance |
| Rice | Public (4)<br>Private (3) | Insect resistance<br>Disease resistance<br>Virus resistance<br>Drought tolerance<br>Fortified food<br>Hybrid improvement |
| Sorghum | Public (1) | Insect resistance |
| Tomato | Public (1)<br>Private (2) | Virus resistance<br>Insect resistance<br>Drought resistance |

*Sources*: Indian GMO Research Information System; James 2008.

A science-based, efficient, and transparent regulatory system is essential for private and public sector firms seeking to introduce new biotech seed technologies on the market, as well as for farmers and the consuming public. In both China and India, regulatory systems reportedly have been used to block market access for global firms and to favor domestic ones. Regulatory review in India has been reported to take into account the manner in which a product will be commercialized, including whether a global firm would have market exclusivity in the event of an approval and thus the ability to charge particularly high prices. Regulatory approval reportedly has been delayed or denied to avoid such a possibility.[17] In China, insect and virus resistant rice has been in development and field trials since the 1990s. Several varieties completed pre-production trials in the early 2000s and have been awaiting approval for commercial release since then, with no articulated biosafety reason for the delay (Karplus and Deng 2008, 102–03).

The products that appear closest to regulatory approval, Bt brinjal in India and phytase maize in China, are those sponsored by domestic firms. Bt brinjal uses technology similar to that in Bt cotton, and was first developed and submitted for approval by Mahyco. Mahyco also has donated its technology to public research institutions in India that are developing OPVs (rather than hybrids) that will be made available to poor farmers for saving and reuse. Mahyco started R&D work on Bt brinjal in 2000 and the product has moved slowly through the regulatory pipeline (Choudhary and Guar 2009, 43-45, 54). Although it was expected to be approved for commercial release in 2009, the Genetic Engineering Approval Committee (GEAC) recently announced the need for a new study of the socioeconomic impact of the product (notwithstanding the free transfer of technology to the public sector), postponing approval for the near future (Indian Express Finance 2009). In China, Origin Agritech has stated that its biotech phytase maize is in the final stage of regulatory approval for use as animal feed. Origin expects to commercialize the product by the end of 2009. According to Origin, the fact that foreign funded companies are restricted to early stage R&D activities provides it with a substantial competitive advantage over global biotech companies (Origin Agritech 2008, 69).

**Illegal Seeds in India and China**

The spread of illegal seeds is a substantial and ongoing problem in China and India. Illegal seeds include those that violate IP laws and those that violate regulatory requirements that biotech products be reviewed and approved before commercial release. Examples of illegal seeds that violate IP laws are those mislabeled to confuse the consumer into believing that he is buying a legitimate product, as well as legitimate products that have been misappropriated. The market for illegal cottonseeds in India is described below, box 1.

[17] Industry representative, telephone interview by Commission staff, June 10, 2009.

**BOX 1** Illegal and counterfeit cottonseeds in India

Illegal cottonseeds reportedly were grown in the Indian state of Gujarat beginning in 1999 and officially discovered in 2001, all while Mahyco-Monsanto Biotech's (MMB) legitimate Bt cotton product was under regulatory review. The illegal seed was identified as NB 151, a variety registered as a conventional hybrid by NavBharat Seeds but containing the Bt genetics developed by MMB.

NavBharat Seeds was banned from the cottonseed business and prosecuted for violating biosafety laws, but the production, distribution, and widespread use of NB 151 reportedly continues. The seed is produced and distributed through a network of seed companies, producers, and agents, many of whom are former contract growers for NavBharat Seeds.

Illegal Bt cottonseed production and sales are thought to be concentrated in Gujarat and, to a lesser extent, in Punjab, Maharashtra, and Andhra Pradesh. According to surveys conducted by Lalitha, Pray, and Ramaswami (2008), the area covered by illegal Bt exceeded the legal Bt area from 2002-03 until 2005-06. The area planted in illegal seeds declined to 34 percent of the total area planted in Bt cotton in 2006-07, and was forecast to further decline to 27 percent in 2007-08. While illegal seeds are still prevalent, price restrictions appear to be having the positive effect of making the legal product more price competitive with illegal Bt cotton.

Counterfeit cottonseeds also are a substantial problem. Dealers label counterfeits with names similar to well-known Bt cotton sources, for example, “Mahaco” rather than “Mahyco.” The counterfeits do not carry the insect-resistant trait of legitimate products. “Brown bagging,” where farmers and others sell repackaged proprietary seed and seed of unknown origin in village markets, is also a common practice, with Bt and non-Bt cottonseeds mixed indiscriminately.

*Sources*: Lalitha, Pray, and Ramaswami (2008); and Herring (2009).

Illegal seeds are also a significant problem in China. With regard to biotech cotton, the problem may be even more prevalent than in India because the genetics were originally inserted into OPVs—which can be saved and reused in subsequent seasons—rather than hybrids. Based on a sample of farmers collected in five provinces in Northern China in 1999–2001, Hu and others (2009) measured the incidence of legitimate and illegitimate versions of domestic Bt cotton (the public sector variety developed by CAAS) and foreign Bt cotton (the Monsanto product marketed by Chinese joint ventures). Illegitimate seed was more prevalent than legitimate seed in Henan (83 percent of sampled households), Shandong (60 percent), and Jiangsu (56 percent) provinces while legitimate seed dominated markets in Hebei and Anhui provinces (where Monsanto's joint ventures had a strong local presence).

The prevalence of illegal seeds reduced benefits from the adoption of Bt cotton. Using regression analysis, Hu and others found that farmers who used legitimate seed used fewer pesticides and obtained higher yields when compared to those who used illegitimate seeds. Moreover, farmers who obtained their seeds from commercial channels rather than from state actors or seed saving and exchange obtained better yields, as did farmers who chose the Monsanto rather than the CAAS varieties (Hu et al. 2009, 801).

These empirical results provide strong support for the conclusion that better IP enforcement and regulatory oversight to ensure that farmers are using legitimate and approved products, as well as reform of the seed industry to permit more foreign participation in China, could significantly improve the production efficiency of cotton and other biotech crops.

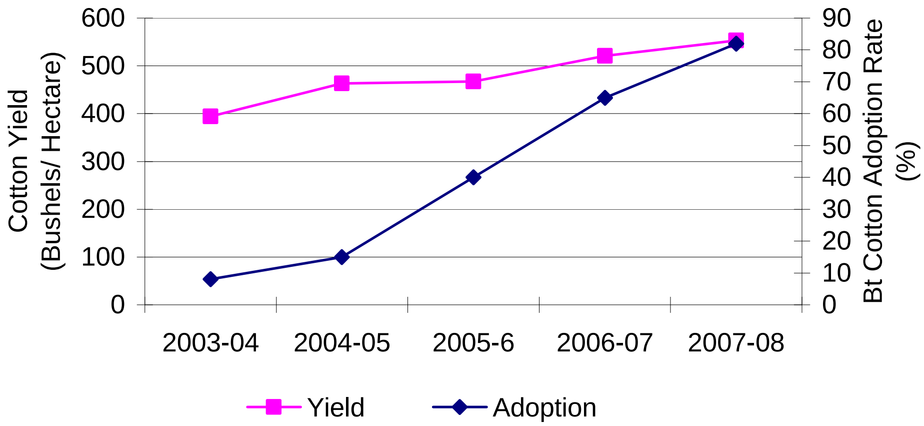
# The Adoption of Bt Cotton in India and China: A Comparative Case Study

Bt cotton has been the first, and only, widely commercialized biotech crop in India and China. While the product has been developed and introduced differently in the two countries, one commonality is notable: the accrual of benefits to farmers in terms of increased profits and yields. We begin with a discussion of these benefits, and then turn to a description of the uptake of Bt cotton in both countries, with a focus on the factors identified as important—market access, IP protection, and regulatory review. The paper concludes with a general assessment of the two countries' policy environments in place to support seed innovation.

## *Benefits from the Adoption of Bt Cotton in India and China*

Bt cotton was approved for commercial release in India in 2002 and farmers grew about 50,000 hectares of it in the first year. Adoption increased rapidly over the next years; by 2008, 7.6 million acres were planted in Bt cotton, representing 82 percent of all cotton planted that year. Increases in yield went hand in hand with increased adoption. Prior to Bt cotton, India had one of the lowest cotton yields in the world, 308 kg per hectare in 2001–02; it is expected to reach 591 kg per hectare in 2008-09, figure 5. India also moved from an importer of cotton in 2002 to a substantial exporter by 2008 (James 2008, 52).

**FIGURE 5** India Cotton Yield and Bt Cotton Adoption Rate, 2003–08

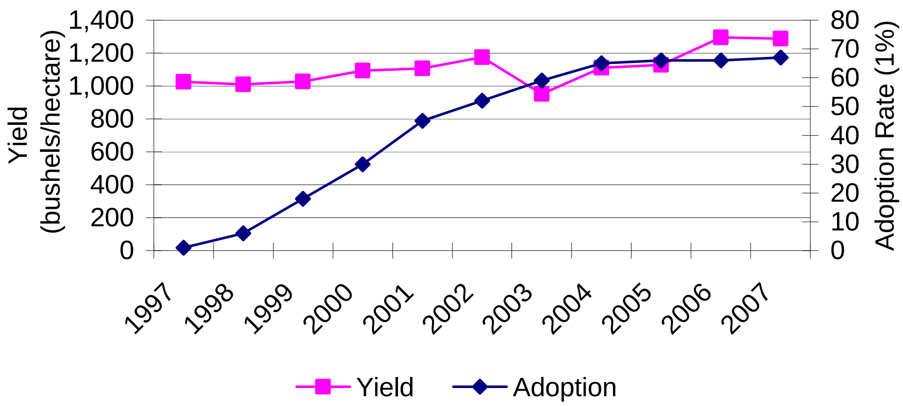



*Source*: Indiastat.com.

The increased use of Bt cotton also has coincided with a significant decrease in pesticide use. Historically, cotton had consumed more insecticides than any other crop in India. The market for insecticides for bollworm (the pest to which Bt cotton is targeted) has declined from $147 million in 1998 to $65 million in 2006, despite the fact that the total area planted in cotton increased. As a result of the increased yields and the decreased use of pesticides, cotton farmers made more money; the adoption of Bt cotton generated economic benefits of $3.2 billion from 2002 to 2007 (James 2008, 43, 51).

In China, Bt cotton was approved for use in 1996, making China one of the six "founder biotech crop countries" that approved biotech crops in the first year of their global commercialization (James 2008, 88). Cotton is primarily grown in the provinces of Hebei, Henan, Shandong, Anhui, Jiangsu, and Shanxi; Bt cotton adoption rates in these provinces generally are above 80 percent. Adoption rates are much lower in Xingjiang province (about 10–15 percent), where the cotton bollworm is not considered to be a major problem (James 2008, 90). Overall, the adoption rate in China has held relatively steady in recent years at about 66 to 69 percent, figure 6.

**FIGURE 6** China cotton yield and Bt cotton adoption rate, 1997–2007




*Source*: CEIC China Database.

China did not start from the same low levels of productivity in cotton as India and thus has not experienced the same dramatic yield increases. Based on studies conducted by the Center for Chinese Agricultural Policy, Bt cotton has increased average yields by 9.6 percent, reduced insecticide use by 60 percent and, at the national level, increased income by approximately $800 million per year (James 2008, 97). The substantial benefits derived from Bt cotton underscore the importance in both countries of getting the policy environment right for innovation in biotech seeds.

## *The Impact of Government Policies on the Adoption of Bt Cotton*

Domestic and foreign firms spearheaded the adoption of Bt cotton in India; the Indian public sector had little involvement in the product's R&D and commercialization. In 1995, after the Indian government's Department of Biotechnology (DBT) rejected an offer from Monsanto to collaborate on biotech crops, Mahyco obtained permission to import Bt cotton technology from Monsanto, table 3. R&D began and in 1998 Monsanto purchased a 26 percent share in Mahyco. The two companies then formed Mahyco-Monsanto Biotech (MMB), a 50:50 joint venture to commercialize biotech products in India. (Scoones 2003, 7).

MMB obtained approval for Bt cotton in 2002, about 6 years after it began field testing of the product. Thereafter, MMB licensed the technology to other domestic and foreign firms for use in their own hybrids. Today, Bt cotton products have been commercialized in India by 30 companies in a total of

274 hybrids. Domestic firms also have obtained approval for two new Bt cotton "events,"[18] including one sourced from the Chinese Agricultural Academy of Science (CAAS). In 2008, the Indian public sector obtained regulatory approval for its Bt cotton event, with genetics inserted into OPVs that can be made available to farmers for them to save and reuse (James 2008, 56).

**TABLE 3** Bt Cotton in India: Chronology of Events

| Date | Events |
|---|---|
| 1990–1993 | Monsanto approaches the Indian government's Department of Biotechnology (DBT) to collaborate on the development and commercialization of Bt technology. Indian government rejects offer. |
| 1995 | Mayhco granted permission to import Bt cotton genetics from Monsanto |
| 1996 | Monsanto's Bt cotton approved for commercial release in the United States. |
| 1996 | Mayhco develops 3 backcrossed lines using Monsanto genetics and its own cotton hybrids and begins biosafety testing |
| 1998 | Monsanto acquires a share of Maycho and they form MMB to jointly develop and commercialize biotech products in India. |
| 1996–2002 | MMB carries out field and biosafety trials to support the regulatory approval of Bt cotton. |
| 2002 | GEAC approves commercial release of MMB's Bt cotton for a 3-year trial period in 6 states. |
| 2006 | GEAC approves Bollgard II, the second generation Monsanto product, and genetic events from JK Agri-Genetics and Nath Seeds. |
| 2006–2008 | GEAC approves a total of 274 Bt cotton hybrids commercialized by 30 different companies. |
| 2008 | GEAC approves Bt cotton genetics developed by public sector and inserted into OPV that can be saved and reused by farmers. |
| 2009 | Monsanto obtains Indian patent for genetics underlying the second generation of its Bt cotton product, Bollgard II. |

*Sources*: Scoones 2003; James 2008.

IP protections did not play a central role in the initial introduction of Bt cotton in India. The MMB Bt cotton events were inserted into hybrids, which have natural, built in protection mechanisms against appropriation by farmers and competitors. Moreover, patent protections were not available for biotech products at the time Bt cotton was introduced, and the plant variety protection system was not put into place until 2007.[19]

The slow-moving regulatory system did give some first mover advantages to the MMB product. Domestic firms with Bt cotton events did not obtain regulatory approval to commercialize their Bt cotton technologies until 2006, 4 years after approval of MMB's first product, Bollgard I. However, delayed approval of the MMB product also fostered a market in illegal seeds to satisfy unmet demand for the technology. Today, Bollgard II is patented in India but illegal seeds are an ongoing problem because of the inadequate enforcement of IP laws and regulatory requirements.

[18] Biotechnologists refer to the transfer of a particular genetic sequence into a plant as an "event."

[19] Patent protection was available for some biotechnology processes rather than products and Monsanto and other firms obtained patents for processes. However, the infringement of process patents generally is more difficult to detect than that of product patents because it requires knowledge of the methods by which a competitor is manufacturing rather than a comparison of the commercially available products.

The public sector has played a much larger role in the development and adoption of Bt cotton in China; the role of foreign firms has been substantially circumscribed, table 4. As in India, Monsanto initially attempted to collaborate with the government on biotech cotton but was turned down (after the technology was shared and field tests conducted). Monsanto and Delta & Pineland (another U.S. firm) then formed a joint venture called Jidai with the Hebei Provincial Seed Company to develop and distribute biotech seeds. The U.S. partners initially held a 67 percent share in the venture. Jidai obtained approval to market the Monsanto variety in 1997. The adoption of the Monsanto varieties was rapid in Hebei and later in Anhui and Shandong provinces (Karpus and Deng 2008, 88-89). In 1997, the Chinese government reduced to 49 percent the stake that a foreign firm could hold in a Chinese seed company, based on concerns that the foreign firms had too much of an upper hand in the Bt cotton collaboration (Keeley 2003, 22).

**TABLE 4** Bt Cotton in China: Chronology of Events

| Date | Events |
|---|---|
| Mid-1990s | Monsanto and the Chinese government's Cotton Research Institute begin a joint research program on biotech cotton. The joint program dissolves in 1995. |
| Mid–1990s | Monsanto and Delta & Pineland form a joint venture with the Hebei Provincial Seed Company and set up a new company, Jidai to test, obtain regulatory approval, and commercialize Bt cotton varieties. CAAS begins field testing and commercialization of its BT cotton varieties. |
| 1996 | Two CAAS Bt cotton varieties approved for commercialization in 9 provinces. |
| 1997 | JiDai obtains approval to market Bt cotton in Hebei province only. Rapid adoption of Monsanto product. Government reduces to 49 percent the maximum foreign ownership in seed companies. |
| 1997–1999 | Slow initial adoption of CAAS products by local seed companies. CAAS sets up Biocentury Transgene Corporation to manage seed sales and licensing. |
| 2002 | CAAS receives marketing approval for its varieties in the Yangtze River Region; Monsanto joint venture turned down. |
| 2002 | FDI guidelines issued to prohibit foreign firms setting up new joint ventures to commercialize biotech seeds. |
| 2004-09 | Bt cotton-related patents issued in China to CAAS, Monsanto, and other public and private sector firms. |

*Sources*: Karplus and Deng 2008; Keeley 2003.

CAAS had its own public sector Bt cotton varieties in development simultaneous with the Monsanto product. The CAAS varieties obtained regulatory approval first and over a wider geographic area. However, CAAS had difficulties with marketing of its products. As a government research institute, it reportedly did not have the distribution networks or relationships needed to quickly bring its varieties to market. CAAS addressed the problem by taking a major stake in Biocentury Transgene Corporation, a company formed to handle the sales of Bt cotton seeds (Karplus and Deng 2008, 88). Biocentury received substantial funding from the 863 program and other government funding programs. As a MOST official stated: "We gave them a title, they are a 'National Development Base of the 863 programme,' not an ordinary company, a national development base, that helps their business" (Keeley 2003, 19). Origin

Agritech acquired a 34 percent stake in Biocentury in 2006, and now markets the CAAS Bt cotton varieties as well (Origin 2008, 45, 48).

The market position of the CAAS varieties has improved significantly in recent years. Today, domestic varieties of Bt cotton are estimated to hold 80 percent of the market, although official data is not available (Sanchez and Lei 2009, 5). Keeley attributes much of the CAAS success to strategic decisions by regulators to deny approval to the Monsanto product in a number of provinces, particularly in the Yangtze River cotton region. Although regulatory authorities justified the decisions on biosafety grounds, industry representatives were skeptical (Keeley 2003, 24). FDI guidelines issued in 2002 prohibiting foreign firms from commercializing biotech products further preserve the market dominance of Chinese firms.

IP protection did not play a central role in the initial introduction of Bt cotton into China. Plant variety protection has been in place since 1997; however, cotton was specifically excluded from coverage until 2005. Patent protection for biotech products was not available at the time of the initial release of the Monsanto and CAAS products. The fact that the Bt cotton events were inserted into OPVs in China rather than hybrids as in India appears to have encouraged even more widespread appropriation of the technologies. Recently, Monsanto, CAAS, and others have obtained patents for their latest Bt cotton technologies. However, enforcement of IPR laws and regulatory requirements is an ongoing problem. While the initial regulatory approval of the Bt cotton technology occurred more quickly in China than in India, at the provincial level the Monsanto product faced regulatory delays and denials that appear to have been unrelated to biosafety issues. These practices undermine confidence in the regulatory system's ability to regulate new biotech seeds in a fair and science-based manner.

# Conclusions

This paper has compared and contrasted government policies in India and China to support innovation in the field of biotech seeds. Both countries have determined that biotech is an important tool for responding to substantial challenges in their agricultural sectors, and have put in place institutions and funding mechanisms to support agricultural biotechnology. India and China also have adopted policies in the areas of market access, IP protection, and regulatory review that have both fostered and discouraged innovation in biotech seeds.

China has established a central role for the public sector in controlling biotech seed innovation. Market access for foreign firms is severely limited. China's public sector takes a leading role in R&D and in the formation and support of firms charged with marketing biotech seeds. China's government research institutions and universities also are leading users of the patent and plant variety IP protection systems. China's apparent strategic use of regulatory review to deny market access to foreign firms has also buttressed the position of the public sector and its affiliated firms.

If judged by the strong market position of domestic varieties of Bt cotton, China's strategy of public sector dominance of biotech seeds has been successful. However, the fact that no other biotech products have been widely commercialized in the 13 years since the approval of Bt cotton, suggests substantial weaknesses in China's approach. China's recent decision to permit FDI in some biotech seed R&D projects is perhaps a recognition that closing the market to foreign participation also shuts off access to valuable technologies needed to address serious agricultural challenges. Improved enforcement of regulatory and IP laws also is critical to ensure that only safe and legitimate products are on the market.

By contrast, India has opened its seed sector to foreign participation on terms equal to those of domestic firms. However, strict price controls at the state level have undermined India's liberal investment environment and negatively impacted the innovative efforts of both foreign and domestic firms. India's public sector has been much less active than China's in R&D and in obtaining IP protection for biotech innovations. The recent focus on the development and commercialization of genetic events for OPVs that will be made available to farmers at a reduced cost is an exception to otherwise lower levels of public sector participation.

The enforcement of IP protections and regulatory requirements also remains a significant problem in India. Delays and decisions that focus on factors other than biosafety undermine regulatory confidence. Timely, science-based review of products that have languished in the regulatory pipeline for years would be an important improvement in India's innovation policy environment.

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Determinants of Diffusion and Downstreaming of Technology-Intensive Products in International Trade[1]

Lauren Deason

University of Maryland and U.S. International Trade Commission

Michael J. Ferrantino

U.S. International Trade Commission

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**Abstract**:

This paper presents and analyzes patterns of trade for a broad category of technology-intensive products, including ATP (advanced technology products), for a group of 15 economies in Asia, Europe, and the United States. Using export data from 1997-2006, we examine the rate of diffusion (distribution of exports over a wider group of economies) and downstreaming (shifting of exports to lower-income economies), by means of index numbers. We find that the degree of downstreaming is highly sector-specific and product-specific; e.g. there has been more downstreaming of electronics than chemicals, of consumer electronics than electronic components, and of certain basic chemicals than specialized products such as photographic film and cosmetics. The exports of many products not normally considered to be ATP continue to be concentrated in high-income economies. We discuss the roles of technology, national and sectoral innovation systems, government policies, and other factors in shaping the degree of diffusion and downstreaming.

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## I. Introduction

The production and export of certain goods normally considered to be "advanced technology" has shifted from higher-income to lower-income economies in recent years. In particular, China's pattern of exports has evolved rapidly, to converge toward that of high-income economies (Schott (2008)). China's trade with the United States in advanced technology products (ATP), as defined by the U.S. Census Bureau, shifted from deficit to surplus in approximately 2001 (Ferrantino, Koopman, Wang and Yinug (2009)). However, many "high-tech" exports are also sourced from other low-income economies, particularly in Asia. Much of the attention has focused on electronics, with the export of personal computers and other consumer electronic goods from China being the most dramatic case.

It has been widely argued that these changes have important consequences for economic development. Some endogenous growth literature, and related empirical work, suggests that the "right" specialization permanently affects long-run growth (Lucas (1988), Young (1991), Grossman and Helpman (1991), Hausman, Hwang, and Rodrik (2007)), thus implying that "leapfrogging" strategies intended to move the geographical location of high-technology products to developing economies. If, as has been argued, the pattern of specialization in modern manufacturing is not closely tied to traditional sources of comparative advantage such as factor abundance, it is indeterminate and thus potentially easy to influence by policy (Rodrik (2006)). Some U.S. observers have argued that China's policies have in fact led to a general leapfrogging in technology, and worried that this poses a major challenge to U.S. commercial and security interests (Preeg (2004), Choate and Miller (2005)).

This paper argues that the recent experience of the electronics industry, and particularly of personal computers, does not generalize widely to other products that are technology-intensive and feature significant innovation. The more normal case is that it is difficult to move comparative advantage in innovative products, once it is achieved. Today's pattern of trade, at least in manufacturing, contains the fossilized economic history of yesterday's technology. It reveals a lot about which goods are hardest to produce, and a fair amount about where the hardest activities were done first, or best. The fossils may be obscured over time, through patterns of erosion or catastrophe, each of which has its own economic logic. But it is the nature of catastrophes that they are unusual. It is, of course, important to ask what may be special about China, or China's policies. But it may be equally important to ask what is special about electronics in general, or about personal computers in particular.

We explore this idea using two trade-based indices of *revealed advanced technology products* (revealed ATP), one of which captures diffusion (geographic de-concentration) and the other capturing downstreaming (the movement of exports to lower-income countries). These are both fairly simple, but they reveal a good deal of indirect information about the relative technological complexity of internationally traded goods, especially those involved in multi-stage production process. This information can lead to a more focused inquiry about the relationships between technology, innovation, the international organization of production, and international trade.

## II. Background

### A. The product cycle[2] – concept and evidence

The idea that there is a logical progression under which newer, more innovative goods are produced in and exported from high-income economies, and later produced in and exported from lower-income economies, is of long standing (Vernon (1966); see also Posner (1961)). In its most idealized form, new goods would be innovated and produced in the most advanced large economies (in the 1960s, the United States), because it had the most innovative capacity and because of "demand-push" innovation to satisfy the tastes of high-income consumers. The good would diffuse, eventually being exported from other economies than the original innovator. When the technology of production became sufficiently mature, the good would be produced in low-wage economies (in our terminology, downstreaming). This pattern was dubbed the "product cycle" by Raymond Vernon. These informal theories developed then there was not a lot of formal theory about the dynamics of comparative advantage, and when empirical work in international trade still faced challenges in testing the static implications of the Heckscher-Ohlin model.

Available tests of the product cycle have shown that it is not the typical pattern for all goods. In fact, patterns of long-run comparative advantage have shown a good deal of persistence, with only occasional downstreaming. For example, Gagnon and Rose (1995) examine exports of six economies disaggregated to SITC4 from 1965-1989. They divide products into 3 categories – surplus, deficit, and balanced trade, using dividing lines at one standard deviation from the mean. Over their period, only about 1 percent of products switch between surplus and deficit, implying only a limited role for product cycles. Similarly, Proudman and Redding (2000) consider 22 broad ISIC-defined manufacturing sectors from 1970-74 to 1990-93, and measure revealed comparative advantage (RCA). For France, Germany, the United Kingdom and the United States, only a couple of categories switch from RCA ∃ 1 to RCA < 1 over the period. Japan, which was still experiencing convergence in per capita income during the period in question, Japan is the most dynamic, losing RCA in "rubber and plastic," "textiles and clothing" and "other manufacturing" and gaining RCA in "non-electrical machinery," "electrical machinery," "motor vehicles" and "computers." Even for Japan, the other 15 industries do not change their status with respect to comparative advantage.

It follows that an appropriate theory of the product cycle should account for the prevalence of such stickiness or persistence of comparative advantage in the usual case, and allow for some criterion as to when diffusion and downstreaming in the product cycle are actually observed.

[2] A word on our use of terminology is in order here. We use "product cycle" in the sense of Vernon (1966) to refer to the geographic relocation of production and exports from one country to another, not in the alternate senses of the time it takes between the development of a new product and its marketing, or the time between generations of new products. Similarly, we use "downstream" ("upstream") to denote a geographical location of production in a low-income (high-income) location, and not in the alternate sense of a stage in a vertical production process closer to the final good (closer to the initial inputs). When we wish to refer to the stages in the production chain, we will do so explicitly.

## B. Predictions of trade theory about the product cycle[3]

In the traditional Heckscher-Ohlin model of international trade, the pattern of trade is determined by relative factor abundance. This implies that patterns of comparative advantage can shift over time only if relative factor abundance is evolving over time. An implication of this is that if some economies have faster-growing capital/labor ratios (or human capital/labor ratios) than others, the production and export of some capital-intensive or human-capital intensive goods will shift to these countries. Since there has been relatively rapid accumulation of physical and human capital in Asia, this by itself would account for product cycles in some goods. This prediction is robust to the addition of increasing returns and product differentiation, as in the first generation of Chamberlin-Heckscher-Ohlin models (Helpman (1981), Helpman and Krugman (1985), as long as scale economies are firm-specific and not nation-specific.

"New trade" theories with a focus on technology often predict that initial conditions drive the pattern of trade, leading to persistence in the pattern of comparative advantage over time. This persistence can come from a technological advantage that operates at the national level. For example, in the case of national, sector-specific economies of scale, if sectoral differences in scale economies outweigh sectoral differences in factor proportions, then the pattern of comparative advantage is determined by initial conditions (Kemp (1969), Markusen and Melvin (1981)). If nation-specific learning-by-doing in sectors is important, initial conditions also determine the pattern of trade (Lucas (1988), Grossman and Helpman (1991, ch. 8).

Such nation-specific, sector-specific technology economies can arise from regional agglomerations at the national or sub-national level (Marshall (1920), Krugman (1991). The characteristic features of a Marshallian industrial district or "Silicon Valley" include an abundance of specific skilled labor, which may move from firm to firm within the district; a similar localized abundance of producers of specialized capital goods and other inputs; and a general culture of knowledge exchange in which the secrets of a particular trade are, in Marshall's phrase, "in the air," and innovations are easily developed through a process of imitation, adaptation, and collaboration.

However, it is at least theoretically possible that certain kinds of knowledge may diffuse rapidly on a global level, leading to global scale economies (Ethier (1979), (1982)) or global knowledge spillovers (Grossman and Helpman (1991, ch. 7)). In the case of global technological dynamics, initial conditions do not matter for the pattern of trade, and one should expect relatively rapid product cycles.

In the actual history of technology and comparative advantage, there is not a single initial condition. Rather, there are initial conditions for new innovations at different times. The observed empirical pattern of regular persistence of comparative advantage, and occasional diffusion and

[3] Much of the argument in this section relies on the discussion in Brasili, Epifani, and Helg (1999).

downstreaming through product cycles, suggests that the extent of nation-specific as opposed to global economies related to technology is an empirical question. In this regard, Keller (2004) has demonstrated that trade-related knowledge spillovers are partly localized and fall with distance. Case studies of learning curves show that they are sometimes nation-specific, e.g. U.S. Navy ships in World War II (Searle (1945)) and sometimes more nearly global, e.g. light-water nuclear reactors (Cowan (1990))

### C. Synthesis

To summarize, the factors tending to preserve historical patterns of comparative advantage in its initial or fossilized form are three-fold:

- Relative factor abundance that changes slowly over time.
- Nation-specific economies of scale
- Nation-specific learning-by-doing

There are also at least three factors that lead to the observance of product cycles (downstreaming and diffusion):

- Relative factor abundance that changes rapidly over time
- Global economies of scale
- Global learning-by-doing

To these may be added two more:

- Foreign direct investment
- Fragmentation or vertical disintegration of the production process.

These two factors are interrelated. Vernon (1977) observed that the increasing prevalence of foreign direct investment meant that multinational firms were increasingly making strategic decisions about the location of production, thus possibly leading to an acceleration of the product cycle. The process of fragmentation or vertical disintegration by its nature alters the geography of production. A combination of reduction in transport costs and economies of scale in executing individual stages of the production process means that it is possible to separate the various stages of production physically according to the comparative advantage associated with deep stage. In the case of China, measures of the "vertical specialization" or "domestic content" of Chinese exports show that the share of imports in the value of Chinese exports is particularly high for electronics and other "high-technology" products (Dean, Fung, and Wang (2007); Koopman, Wang, and Wei (2008). This suggests that fragmentation is also an important driver of more rapid geographic product cycles.

## III. Empirical Strategy and Data Description

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Our main empirical strategy is to derive measures of the product cycle at a high level of disaggregation over a recent period, using a widely used index of concentration or diffusion (the Herfindahl-Hirschman index) and a second index of the level of relative income associated with revealed comparative advantage in the export of a particular good, to capture the concept of downstreaming. Measurement of diffusion and downstreaming correspond to the two phases of the traditional product cycle. Since the measurement of diffusion is also a measure of concentration, it can also be used as an indicator of Marshallian agglomeration economies that may inhibit downstreaming and lead to persistence in comparative advantage.

### A. Main features of the dataset

Export data for 15 economies for the period 1997 – 2006 are obtained from the UN COMTRADE system maintained by the United Nations Statistical Division[4]. This ten-year period is shorter than is often used to test hypotheses relating to the product cycle, but sufficiently long so that disaggregated data can be used without product definitions changing too much.[5] Observations were taken on exports to the world, as reported by the exporting economy, of all HS-6 level subheadings, hereinafter "products." The selected products include all those in 21 HS-2 chapters selected from the 96 regular chapters, as listed in Table 1. Broadly speaking, the product landscape consists of chemicals and allied products; machinery, electronics, and instruments; transportation equipment; and armaments. For comparability over time, the products are defined using the HS 1992 nomenclature. Products for which at least one year in the time period had no exports reported by any of the 15 economies are dropped[6]. In total, this yields 2035 products. The economies included in the dataset are listed in Table 2. They include the six largest OECD economies and nine Asian economies. Together, these 15 economies represent approximately 70 percent of world exports of the products in question, though the percentage

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[4] This database can be accessed at http://comtrade.un.org/db/, accessed Aug 17, 2009. Data for Chinese Taipei were obtained separately from the version of COMTRADE available through the World Integrated Trade Solution (WITS).

[5] We have experimented with a longer dataset over the period 1962-2006, using the older SITC2 product categorization. At this level, products such as cellular phones and personal computers did not exist, and even mainframe computers are only imperfectly identified in the categorization.

[6] This procedure resulted in the dropping of 22 products from the dataset. Additionally, products 846110, 392041, and 850890 were dropped due to an apparent data anomaly wherein several top exporters stopped reporting after 2001.

varies from product to product.. Where available, re-export data is subtracted off of gross exports to yield net export data for the included economies and years.[7]

The HS-2 chapters are selected so as to include all products defined as Advanced Technology Products (ATPs) by the U.S. Census Bureau, as well as chapters which are related to these chapters by type of product. Table 3 presents the categories of ATP products, while Table 4 provides a tabulation of the number of ATP products falling in each HS Chapter. The ATP products, defined at the HTS-10 level[8], are selected based on expert judgment of Census staff regarding the technology intensity of products. The list of products used to construct China's High and New Technology Product Import and Export Statistics Catalogue corresponds closely to the Census ATP list.[9] Because the ATP list represents an independent judgment about technology intensity, it is a useful reference point to compare with inferences about technology intensity drawn from the trade data.

## B. Construction of Indices

Two indices are constructed for each product. In the following definitions, the index i represents a specific product (HS6 subheading), j refers to the economy exporting the product, and t represents the year. Letting $x_{ijt}$ be the value of exports of good I from economy j in year t, the indices are defined as follows.

The first, HHI, is a Herfindahl-Hirschman index measuring the extent to which exports of a given product are concentrated among the economies in our sample. The HHI for each product i and year t pair is given by the following formula:

$$HHI_{it} = \sum_j s_{ijt}^2$$

Where j is the index over economies and

$$s_{ijt} = \frac{x_{ijt}}{\sum_j x_{ijt}}$$

is the export market share of economy j in year t. Thus, an HHI value near 1 indicates that production of the product is concentrated entirely in one of our 15 economies, while low values (0.067 being the lower bound) indicate that exports are diffused throughout these economies.

[7] This results to an adjustment to the data for Hong Kong, the United States, and Thailand. The data for Singapore include re-exports. Thus, Singapore's exports are overstated relative to those of Hong Kong and include some double-counting.
[8] Found at http://www.census.gov/foreign-trade/reference/glossary/a/atp.html, accessed Aug 14, 2009. The concordance based on 2006 US Import HTS10 nomenclature is used. Where products at the HS-6 level corresponded to multiple ATP categories, the ATP category with the most instances of that HS-6 subheading was assigned to the product.
[9] See Ferrantino, Koopman, Wang and Yinug (2009) for details.

The second index we construct, EXPRELY, is a GDP-normalized version of the index PRODY defined by Hausmann, Hwang and Rodrik (2007). EXPRELY is constructed as follows: First, for each economy j in year t, the total exports[10] of economy j in that year are given by:

$$\bar{x}_{jt} = \sum_i x_{ijt}$$

Individual economy GDPs are per capita on a constant year 2000 dollar basis as taken from the World Bank's World Development Indicators.[11] $Y_{jt}$ is then this GDP per capita value normalized by dividing by the GDP per capita of the US in the same year:[12]

$$Y_{jt} = \frac{GDP_{jt}}{GDP_{US,t}}$$

For each product i,

$$EXPRELY_{itT} = \sum_j \frac{x_{ijt}/\bar{x}_{jt}}{\sum_j x_{ijt}/\bar{x}_{jt}} * Y_{jT}$$

Thus, $EXPRELY_{itT}$ is a weighted average of the (normalized) year T GDPs of the economies exporting product i in year t, where the weights are the revealed comparative advantage of the economy. Rather than using $GDP_{jt}$ in this expression, we compute EXPRELY in each year using only the GDP for each economy in a specified year T, in order to allow for cross year comparison of the index. In particular, we fix the level of Y to its 1997 level in all years. Relative incomes change significantly over the period, particularly in the case of China which experiences more rapid growth than average and which has a heavy weight in the calculations. For products whose exports become concentrated in China over time, if Y is allowed to vary by year the calculated values of EXPRELY includes both the movement to China (downstreaming of the product) with the relative position of China in the distribution of per capita income (upstreaming of China itself), making the results difficult to interpret. By fixing the level of per capita income to that of a particular year, we insure that EXPRELY isolates the geographic movement of products "downstream," without conflating this effect with the general dynamics of development.

[10] Note that this is the total value of all exports for country j in year t, rather than the sum of exports of products included in our dataset.
[11] WDI data available at http://www.worldbank.org/. GDP data for Chinese Taipei is not available as part of the WDI data. Purchasing Power Parity GDP per capita data for Chinese Taipei is taken from the University of Pennsylvania's Penn World Table and converted to an exchange rate basis, using benchmark information.
[12] Initially, this procedure was adopted to create an index that would be bounded above by one, however, as later years were incorporated into the sample, the GDP per capita of the US was exceeded by that of Japan, allowing for EXPRELY to exceed one in some cases. The normalization still allows for a useful comparison of the index for a given product to a product exported exclusively by a country with the GDP of the US, which would have an EXPRELY value of 1. Normalized GDPs in benchmark years are given in Table 14. See figure 4 for GDPs over the entire time span 1962-2006.

## IV. Stylized Facts and Anomalies

### A. Relationship between diffusion and down-stream in cross-section and time series

Figure 1 presents a scatter plot of the relationship between HHI (diffusion) and EXPRELY (relative income level of economy with revealed comparative advantage) in 2006. For ease of interpretation, the names of the 15 economies are placed on the horizontal axis approximately at the level of their relative per capita income in 1997, as used to construct the index. A fifth-order polynomial is fitted to the data (see Appendix). The overall pattern is U-shaped. On the right, exports are concentrated in the highest-income economies, the United States and Japan. In the middle, exports are relatively diffused among all the economies, and associated on average with economies in the middle of the income distribution, e.g. Italy and Chinese Taipei. On the left, exports are concentrated in the lowest-income economies. While there are several of these, the left tail is accounted for primarily by concentration in China. For each of the 201 products with HHI > .25 and EXPRELY < .4 in 2006, China accounts for the largest market share. Of the outliers, some are clustered in upward-reaching "fingers" from the main U. These correspond to products that are concentrated in particular middle-income economies.

If taken from right to left, this pattern suggests something like the traditional Vernon product cycle (diffusion followed by downstreaming), followed by a final phase in which exporting is concentrated in China. This impression may be misleading, as Figure 1 represents a cross-section and not a time-series. Time-series behavior may not be the same as cross-section behavior.[13] Thus, we approximate the typical dynamic behavior of HHI and EXPRELY between 1997 and 2006 using flexible second-order polynomial regressions with dHHI and dEXPRELY as the dependent variables (see Appendix).

The resulting dynamics are superimposed over the stylized U in Figure 2. The results suggest on average that during the period in question, exports of many products became both more concentrated and more extreme in terms of the level of relative income they were associated with. Products that in 1997 were associated with a level of EXPRELY above .8 became more concentrated and moved upstream toward either the United States or Japan. Products associated with an upper-middle level of income (France, Germany, Hong Kong, Singapore, United Kingdom) remained about where they were. At somewhat lower incomes (Italy, Chinese Taipei) the typical product downstreamed but remained diffuse, while products associated with income levels equal to that of Korea or lower experienced both downstreaming and concentration (in China). While there are many special cases among the products in question, the overall pattern is one of agglomeration of exports in one of the three largest economies – China, Japan, or the United States – for the products in question.

[13] An analogous problem comes up in relation to the two famous "inverted U" relationships of development economics: the Kuznets curve relating per capita income to income inequality, and the environmental Kuznets curve relating per capita income to pollution.

## B. Sector-specific patterns

### 1. For the product landscape as a whole

Values of HHI and EXPRELY were calculated for both 1997 and 2006 for eleven aggregates of products; the ten ATP technology categories, which together account for 177 of the 2035 products, and for non-ATP products in the product landscape as a single group, accounting for the other 1858 products. The results are portrayed in graphic form in Figure 3. The non-ATP products in the product landscape, represented by group 0, correspond approximately to the middle-level income of Italy, and both diffused and downstreamed moderately during the period. Of the ten ATP categories, there is a marked difference between electronics and information and communications, and all the others. While eight of the ATP categories are both more concentrated and more upstream than the typical products in our landscape, two ATP categories, electronics and information and communications, begin in a position downstream from the average in 1997 and moved further downstream, with the decline in EXPRELY for electronics being especially rapid.

These results highlight the fact that electronics, and to a lesser extent information and communication, represent special cases. One would expect that more technology-intensive products would usually be produced in high-income economies, and that the advantages of agglomeration in fostering innovation would be similarly associated with many of these products. The complex knowledge necessary for innovative success in biotechnology, aerospace, weapons, and nuclear technology keeps these products upstream and concentrated. The largest group of ATP products, "flexible manufacturing," is relatively diffuse, but still exported largely from high-income economies, This category includes advanced machine tools, including multi-planar and digitally controlled machine tools, used in many industries, and related instrumentation. The small category of "advanced materials," which has actually moved further upstream between 1997 and 2006, includes doped wafers for manufacture of semiconductors and optical fibers and cables – both components that are essential for many of the products in the two ATP sectors moving rapidly downstream.

### 2. Machinery, computers, and instruments

We consider a broad subgroup labeled "machinery, computers, and instruments," which includes all products in HS chapters 84, 85, and 90. These amount to 905 products, or nearly half the total in our product landscape. Grouping them together like this enables us to consider computers, classified in HS 84, jointly with electronics in HS 85 and with many electronics-intensive products classified as instruments or measuring devices under HS 90. The grouping also includes a wide variety of capital equipment operating primarily on mechanical rather than electrical or electronic principles.

Table 5 presents a cluster analysis of machinery, computers, and instruments based on the values of HHI and EXPRELY in 2006, reporting the within-cluster means. Consistent with our earlier results, the largest cluster, Cluster 1, contains products that are moderately diffused and relatively upstream. The second largest cluster contains products which are somewhat more diffused and further downstream The third cluster contains 106 products which are both relatively concentrated (HHI = .331) and farthest downstream (EXPRELY = .243). Exports of most of these products are relatively concentrated in China. The smallest cluster contains 53 products which are both highly concentrated (HHI = .544) and, on average, further upstream than the other clusters (EXPRELY = .755).

Also reported is the percentage of products in each cluster categorized as Census ATP. There is a broad correlation between the relative income level associated with a product and the likelihood that it is classified as ATP on technological grounds. 21.3 percent of the products Cluster 4, the furthest "upstream," are ATP products. Moving downstream to Clusters 1, 2, and 3, the percentage declines to 17.1 percent in Cluster 1 (EXPRELY = .669), 12.3 percent in Cluster 2 (EXPRELY = .455), and 6.6 percent in Cluster 3. This suggests that the use of EXPRELY as a proxy for the technological sophistication of a product has some merit, at least for machinery, electronics, and instruments.

This also means that 41 of the 52 products in Cluster 4, or about 79 percent, were *not* classified by Census as ATP. It may be the case that the engineering concepts used by Census for categorizing goods as technology-intensive may not actually capture all of the characteristics of a product that make it difficult to produce, or that prevent its technology from being cheaply or easily diffused. If our indices actually reveal something about the difficulty of technology, or the degree to which technologies experience localized economies of agglomeration, then there ought to be something "advanced" about these 41 products as well. Examples of such "revealed-ATP" products include outboard motors, cylinders for rolling machines, commercial dish washing machines, ski lifts and chair lifts, bulldozer blades, milking machines and parts, brewery machinery, offset printing machinery, dobbies and jacquards for spinning machines and looms, dry-cleaning machines, pneumatic hand tool parts, electron beam machine tools, domestic kitchen waste disposers, and cameras for narrow-gauge film.

While the "upstream" location of some of these products may be explained in part by a trade between rich economies with similar patterns of demand, along the lines of the hypothesis of Linder (1961), there are likely enough to be technology-specific challenges associated with many of them. Moreover, similarity of rich-country demand must be coupled with at least some degree of technological sophistication to prevent easy downstreaming. For example, Christmas lights are exported from China although their pattern of demand is presumably focused on high-income economies. It is likely harder to transfer the technology to produce outboard motors than that for Christmas lights.

It is also interesting to ask whether the ATP products in machinery, electronics and instruments in Cluster 3 (downstreaming and concentration in China) have any particular characteristics. The seven products in question are listed in Table 6. Of these, one is in a basket category that has recently been removed from the ATP list, and another (nuclear reactors) has some data difficulties. Of the remaining five, one has been well-studied. HS 852190, labeled in 1992 as "video recording and reproduction apparatus, nes," is the category which now includes iPods and other MP3 players. The value chain of the iPod has been described by Linden, Kraemer and Dedrick (2007). The iPod is a classic case of coordinated effort organized by a multinational firm (Apple, United States), managing a vertically disintegrated production process. Apple's gross margin makes up about one-quarter of the retail value of the iPod. Components of the iPod are produced in the United States, Japan, Korea, Chinese Taipei and Singapore. Foreign companies also manage the China-based operations of hard drive manufacture (Toshiba, Japan) and insertion, test, and assembly (Inventec, Chinese Taipei). Moreover, although Linden et al. do not say so, the hard drive may have further imported components. Of the others, the category labeled "cash registers" consists mainly of automated point-of-sale equipment such as toll collection devices. The three products in the category of transistors and semiconductors were until recently exported heavily by Japan or Singapore and have moved to the Philippines, suggesting perhaps another FDI story.

Machinery, electronics, and instruments which are both identified as ATP and appear in the upstream/concentrated cluster are identified in Table 7. These include such products as numerically-controlled metal drilling machines (Japan), stereoscopic and diffraction-apparatus microscopes (Germany and Japan), heart pacemakers (United States and France), certain other wood and metal-working machines (Italy and Germany), small turbo-jet engines (United States), and theodolites and tachometers (Japan). It would be useful to be able to identify those features of technology which tend to make them resistant to relocation in search of low-cost labor.

One can also group machinery, electronics and instruments products in terms of the economies that dominate in their export. We identify groups of geographically-focused products by clustering on 2006 market shares and identifying for each economy the cluster for which the market share is maximized. The results of this are presented in Table 8. Of the six clusters, five are associated with a single dominant producer. The largest of these consists of products primarily specialized in by Germany, followed by China (with Thailand), Italy, Japan (with Hong Kong and Korea), and the United States. The role of Italy in exports of so many goods in this category may not be familiar. However, the emergence of Marshallian industrial districts fostering regional specialization in the so-called "Third Italy" during the 1960s and 1970s is well-documented (Lazonick (2005)). The advantage of many of these districts is in a form of decentralized or "putting-out" manufacturing, as opposed to centralized mass production (Brusco (1992)). Italian specialties include machinery for leather-making, printing, food processing and agriculture, specialized wood and metal-making machinery, ski lifts and sunglasses.

## 3. Organic chemicals and allied products

By contrast, we consider a group of chemical products defined primarily by their relation to organic chemistry (HS 29, 30, 32-35, 37-40). Many of these products are chemical precursors (inputs) into other products in the category. This group of 713 products constitutes about 35 percent of the product landscape. In this section we present stylized facts, reserving a more detailed description of some of the technical features of these products until later. For the present, it is appropriate to note that organic chemistry as a whole is more technically challenging than inorganic chemistry.[14] This fact is reflected in Figure 4, in the position of chapter 28 (inorganic chemicals) relative to the various chapters involving organic chemistry mentioned above.

A cluster analysis involving the organic-chemistry chapters is presented in Table 9. Relative to each other, the four groups derived are similar to those presented in Table 9 for machinery, electronics, and instruments. In an absolute sense, the ranges of both HHI and EXPRELY are noticeably higher for the organic-chemistry clusters than for the clusters in machinery, electronics, and instruments, suggesting that these products are on the whole more difficult to produce as well as more subject to specialization. (This can also be observed in Figure 4). Moreover, none of the 24 products in this group classified as ATP is primarily exported from the cluster furthest "downstream." This reinforces the view that the circumstances permitting the production and export of certain electronic products are special cases, and do not in general apply to advanced chemical products.

The tendency for the exports of organic chemicals and allied products to cluster in a few high-income economies is further reinforced by the cluster analysis by country market share presented in Table 10. For comparison with Table 8, we again use six clusters. The most notable difference is that while for machinery, electronics, and instruments, five of the six clusters were dominated by a single economy, in the case of organic chemicals and allied products five clusters are dominated by only four economies. There is a German cluster, a United States cluster and a German-United States cluster, which between them account for nearly half the products in the category. This is a reflection of long-standing historical developments. Germany's advantage in advanced chemistry dates from the work of Justus von Liebig at the University of Giessen in the 1840s, and the subsequent close links between industrial innovation and university research developed at German firms such as BASF (Mokyr (1990), 119-120). Similarly, it was in the United States that the unifying principles involving scaling up of "unit operations" in experimental or batch production to a level providing workable and economic large-scale production processes were codified in the new discipline of chemical engineering, developed at MIT from 1915-1920 (Rosenberg (1998)).

C. Technological difficulty and the production chain

International trade takes place in both intermediate goods as well as final goods. The combined forces of falling costs for logistics, strategic decision-making by multinational corporations, and international fragmentation of the production process

[14] Students that have taken a single chemistry course in high school or college in effect learn inorganic chemistry, because it involves simple molecules of a few atoms each whose equations can be easily worked out. Organic chemistry, involving more complex molecular structures, is generally only studied by students concentrating in chemistry, chemical engineering, or medicine. The basics of inorganic chemistry were reasonably well understood at the industrial level by the latter part of the 18th century (Mokyr (1990), 107-109), and at the theoretical level by the time of John Dalton's *New System of Chemical Philosophy* in 1808. By comparison, significant industrial successes involving applications of organic chemistry were not achieved until the synthesis of artificial dyes in the 1850s and 1860s, with basic practices such as polymerization following in the 1920s and onward (Walsh (1984); Ruttan (2001), 286-315).

mean that there is an increasing amount of trade in intermediate goods, as well as in the embodied services of product design and managerial coordination which are at the core of innovation. Merchandise trade data allow us to track the trade in goods. Are there systematic principles that relate the technological difficulty of earlier stages of the production process to the later ones?

In electronics, the earlier stages of the production process embody greater difficulty than the later ones. Inspection, testing, and final assembly of personal computers, cell phones, MP3 players and other consumer electronic goods is a mature, labor-intensive process which easily gravitates toward low-wage locations. Production of semiconductors and integrated circuits is more difficult and must take place under carefully regulated conditions. Within the semiconductor industry, the most advanced products are designed by so-called "fabless" firms specializing in innovation and contracting production to "front-end" foundries. Front-end production in turn is more skill-intensive than "back-end" testing, assembly and packaging of semiconductors (Yinug (2009)). The technology involved in equipment and inputs for manufacturing semiconductors is sufficiently advanced that economies with a comparative advantage may seek to regulate exports of such equipment for strategic reasons (GAO (2008)).[15].

In organic chemistry, by contrast, the earlier stages of the production process involve refining relatively simple organic chemicals from mineral sources such as petroleum, natural gas, or coal, or, increasingly, from biological sources (e.g., ethanol). Basic chemical precursors are in turn synthesized into intermediate organic chemicals through a variety of chemical processes (e.g., polymerization for plastics). These in turn are used to make final chemical products. At each stage of the production process, the chemistry becomes more complex. The production of photographic film involves the careful combination of many organic chemicals on an emulsion. Exports of film (HS 37) are significantly upstream from exports of cameras (included in HS 90; see Figure 4 and Appendix 3). Cosmetic and perfume products (HS 33) similarly involve difficult formulations of multiple compounds, and mixtures of compounds. This can be confirmed by examining the list of ingredients in an inexpensive bottle of shampoo. As revealed by the income level associated with comparative advantage, cosmetics and perfumes are significantly more challenging or "upstream" than electrical and electronic goods (Figure 4 and Appendix 3).

Thus, the relationship of the earlier or later stages of a vertical production process with the degree of technical complexity varies significantly depending on the nature of innovation in each product category. Figure 5 summarizes the stylized facts presented above. In electronics, the earlier stages of the production process are "high technology," whereas in chemistry, the later stages of the production process are more technology-intensive. Figure 6 shows in more detail some of the linkages in petrochemical production chains.

[15] The point here is not to enter into the debate about whether such controls are effective in their objectives, or appropriate on welfare grounds. The existence of the policy is simply put forth as evidence that the goods in question are recognized to represent technological "high ground."

To see whether the trade data reveal technological complexity, particularly by higher values of EXPRELY and (perhaps) by higher values of HHI, we constructed a number of sub-categories of products. These include both categories designed to correspond roughly to the stages of production portrayed in Figure 5, as well as other categories of interest.[16] We then re-calculated the indices for products aggregated by sub-category. The results of this procedure appear in Table 10.

For petrochemicals and products, the first three categories correspond to the stages of production in Figures 6 and 7. In accordance with our hypothesis, we find that secondary petrochemicals are exported from higher-income economies than are basic petrochemicals, while products of petrochemical-consuming industries are exported from still higher-income economies. This progression is stronger in 2006 than in 1997. In 1997, but not in 2006, we find that the more advanced products are also more regionally agglomerated than the less advanced products. A fourth category of "plastic and rubber articles," including tubes, pipes, and other forms, involves the application of mechanical processes such as molding to the results of chemical processes, and, not surprisingly, reverts to lower-income processes on average.

For pharmaceuticals, the detailed product descriptions in the Harmonized system enable a distinction between bulk medicaments (defined by chemical composition) and medicaments by dosage (made up in pill form). There is significant trade in bulk medicaments which are made up closer to the market of final consumption. (USITC (1994)). Both categories of pharmaceuticals are, on the whole, upstream and concentrated relative to the petrochemical categories. Moreover, medicaments by dosage are upstream and concentrated relative to bulk medicals. Like photographic film and cosmetics, medicaments by dosage often involve mixtures of two or more complex therapeutic compounds. Dosage requirements preferred by local medical practice are also reflected in the production of these goods, as well as features of the product such as texture or "mouth feel" important to the final consumer. It may also be the case that regulation for safety and efficacy is applied more stringently at the level close to the consumer.

The production chain for computers is reflected approximately in the first three categories under "electronics and related products." Here, the dramatic change is in the position of computers. In 1997, inputs to semiconductors (doped wafers and manufacturing machinery) are relatively upstream (EXPRELY = .750) as are computers (EXPRELY = .719), while semiconductors are exported from lower-middle-income economies (EXPRELY = .369).[17] By 2006, computers have "downstreamed" more dramatically than any of the other categories we analyze (EXPRELY = .250), while the positions of inputs to semiconductors and semiconductors/integrated circuits have remained relatively unchanged. This produces the pattern suggested in Figure 5, with

[16] The definitions of these categories are available from the authors on request.

[17] The downstreaming of semiconductors to markets such as Korea, Chinese Taipei, and Malaysia, for export in final assembly of computers in the United States, Japan, and Europe, was already well underway by the late 1980s and early 1990s. This history is recounted in Macher, Mowery and Hodges (1998) and Langlois and Steinmueller (1999).

inputs for semiconductors being the most advanced relative to computers. The position of other electronics-intensive products also indicated that EXPRELY is at least in part an indicator of technology intensity; electro-medical devices are relatively upstream (EXPRELY = .692 in 2006, not much different than in 1997), while cameras (photographic and cinematographic apparatus) are even further downstream than computers and have moved their quickly in recent years (EXPRELY = .324 in 1997 and .140 in 2006).

Not only have electronic goods experienced an unusually intense product cycle relative to other goods, but computers have downstreamed very rapidly relative to other electronic goods. This applies both to desktop computers and to notebook computers. After looking at all of the evidence, it appears less appropriate to view the shift of personal computers to China as paradigmatic of broader changes in the global economy at least in the sense of geographic patterns of production[18], and more appropriate to ask what is so special about personal computers.

Some suggestions as to the technological and managerial peculiarities of personal computers are offered by Dedrick and Kraemer (2009). The strong market positions of Intel in microprocessors and Microsoft in operating systems imply that those two firms may absorb as much as 90 percent of profits in the value chain for personal computers. This may have led to more intense searching for reductions in production costs elsewhere in the supply chain. Another feature of the development of the industry is the "middlement" role of original design manufacturers (ODMs) from Chinese Taipei, such as Quanta, Compal, Wistron, and Inventec. Such firms engaged in design and development of personal computers on behalf of U.S. and Japanese multinationals such as Apple, Dell, HP, IBM, Sharp, Sony, and Toshiba, and accounted for 73 percent of the world's production of notebook computers by 2005. Production of such computers was increasingly outsourced to Chinese Taipei in the 1990s, with design activities following. After taking a leading role in design and development, the ODMs organized production activities in China from about 2000 onward, concentrating notebooks in Shanghai/Suzhou and desktops in Shenzhen/Guangdong, with other concentrations of production in Malaysia, Mexico, the Philippines, Singapore, and elsewhere. The geographical and cultural proximity of Chinese Taipei to Shanghai/Suzhou in particular meant that it was feasible for managers to move to the mainland for extensive stays to organize production networks.

The case of personal computers is an interesting example both of path dependency in the history of innovation and in the adaptation of organizational structure to the needs of the marketplace (Pavitt (2005)). Korean manufacturing firms, which are organized in large, interlocking families, are relatively good at achieving economies of mass production, and have played a significant role in the semiconductor industry, for example in following the mass production strategy of DRAMs originally adopted by the Japanese. The supply of smaller, more agile entrepreneurial firms in Chinese Taipei was better

[18] The fact that personal computers are themselves a general-purpose technology, responsible for increases in productivity and innovation in all industries, and that their production in China has made this technology more abundant and affordable worldwide, is of course of great significance.

suited for the elaborate systems coordination tasks required of ODMs. In an alternate history where Korean firms had succeeded in becoming the dominant players in personal computers in the mid-1990s, it may be wondered whether the further move to China would have been as rapid as it in fact was.

Machinery of the mechanical type is more difficult to categorize as being in the same category as either chemicals, where the final product are relatively technology-intensive, or electronics, where the first inputs are relatively technology-intensive. The Harmonized System contains a large number of “parts” categories that are explicitly mapped to the machines they are included in, and can thus be used to test the hypothesis of relative technology intensity of parts versus final product as revealed by trade. A partial and preliminary test of this hypothesis is presented in Table 11, which considers approximately 40 categories of machinery including agricultural, food-processing, print-making, and construction machinery, as well as engines, pumps, packing and weighing machinery. In general no strong conclusions can be drawn about machinery. Parts tend, on average, to be produced in slightly higher-income economies than final machinery, and to be slightly less concentrated geographically, but there are plenty of special cases. This suggests that the relationship between the stage of production and the intensity of technology for machinery is very case-specific, as well as the implications thereof for international trade.

## V. Conclusions, and topics for further research

The movement of production and exports of electronics (in general) and personal computers (in particular) to Asia (in general) and China (in particular) is sometimes held to be a sign of broad changes in the global economy and a wholesale reconfiguring of comparative advantage. We have shown that such widespread changes in comparative advantage are in fact less common than is often supposed. Many technology-intensive products, as well as many products not often thought of as embodying advanced technology, are in fact technology-intensive, and continue to be exported from high-income countries. The initial conditions under which innovation and production take place may become “fossilized” through patterns of local industrial agglomeration.

This does not mean that the technologies become stagnant. Rather, the advances in technology take place in a localized fashion. In addition to Silicon Valleys, there are likely to be many pharmaceutical valleys, cosmetics valleys, and valleys of pasta-making machinery. These are of comparable importance to the dynamics of comparative advantage as the processes by which electronics has undergone rapid downstreaming and diffusion. In particular, it appears to be harder in general for technologies related to organic chemistry to undergo rapid product cycles. This in turn has implications for a world in which biotechnology is likely to be the source of a significant share of new innovation.

The roles of foreign direct investment and production fragmentation in the product cycle are likely to be important, but we have not directly examined them. There are a number of cases in our data for which market shares change rapidly in a year or two. We suspect a significant share of these cases can be associated with specific acts of direct investment or contract production. Similarly, it should be possible to test directly the hypothesis that the product cycle is more rapid in industries prone to fragmentation and vertical disintegration.

The theoretical framework underlying predictions about the product cycle can be used to interpret the Chinese experience, and perhaps the experience of other countries. China's rapid growth, beginning with the opening-up of the late 1970s, has featured above-average accumulation of both physical and human capital by global standards,. This type of growth, observed elsewhere in Asia, was a precondition for the attraction of certain kinds of goods and the movement of comparative advantage on Heckscher-Ohlin grounds. However, China's recent exports of ATP products have been associated with three types of policy initiatives – encouragement of foreign direct investment, encouragement of the processing trade (importing intermediate goods to use as inputs into exported goods), and the development of a variety of government policy zones associated with further incentives. Each of these policies is associated with a high share of ATP exports, both in general and relative to non-ATP exports (Ferrantino, Koopman, Wang, and Yinug (2009)).

In advance of the adoption of such policies, it would not have been possible to predict which goods would be subject to rapid product cycles. The industrial organization of the personal computer and iPod, as they have developed, were not known in the early 1980s. However, any goods that did undergo diffusion and downstreaming would be more likely to be attracted to places that encouraged foreign direct investment, since multinationals play a key role in reorganizing the production process, and that encouraged processing trade, since this is attractive to goods with fragmented production processes. Thus, when the personal computer came, it would eventually come to China, and to other countries with similar patterns of factor accumulation that adopted particular policies. China's size, as well as the encouragement of regional agglomerations by policy, may also have led to nation-specific, sector-specific economies of scale and learning-by-doing, making it more likely that the products once having moved to China would be likely to stay there.

In conclusion, though the dynamics described in this paper apply to the current state of technology and international trade, it is unknown whether, and for how long, they will continue to do so in the future. Massive changes in the technology and organization of production, from the old vertical disintegration of the pre-industrial putting-out system to the factory system of the Industrial Revolution to today's vertical disintegration, and from mass production driven by large-scale machinery to the dynamic of miniaturization associated with 20th century electronics, can happen suddenly and without warning at any time. Such changes in the future may lead to new patterns of international specialization very unlike those described here.

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Table 1
List of HS-2 Chapters Included in Short-Term Dataset[19]

| HS-2 | Chapter Description |
|---|---|
| 28 | INORGANIC CHEMICALS; ORGANIC OR INORGANIC COMPOUNDS OF PRECIOUS METALS, OF RARE-EARTH METALS, OF RADIOACTIVE ELEMENTS OR OF ISOTOPES |
| 29 | ORGANIC CHEMICALS |
| 30 | PHARMACEUTICAL PRODUCTS |
| 31 | FERTILIZERS |
| 32 | TANNING OR DYEING EXTRACTS; TANNINS AND DERIVATIVES; DYES, PIGMENTS AND OTHER COLORING MATTER; PAINTS AND VARNISHES; PUTTY AND OTHER MASTICS; INKS |
| 33 | ESSENTIAL OILS AND RESINOIDS; PERFUMERY, COSMETIC OR TOILET PREPARATIONS |
| 34 | SOAP ETC.; LUBRICATING PRODUCTS; WAXES, POLISHING OR SCOURING PRODUCTS; CANDLES ETC., MODELING PASTES; DENTAL WAXES AND DENTAL PLASTER PREPARATIONS |
| 35 | ALBUMINOIDAL SUBSTANCES; MODIFIED STARCHES; GLUES; ENZYMES |
| 36 | EXPLOSIVES; PYROTECHNIC PRODUCTS; MATCHES; PYROPHORIC ALLOYS; CERTAIN COMBUSTIBLE PREPARATIONS |
| 37 | PHOTOGRAPHIC OR CINEMATOGRAPHIC GOODS |
| 38 | MISCELLANEOUS CHEMICAL PRODUCTS |
| 39 | PLASTICS AND ARTICLES THEREOF |
| 40 | RUBBER AND ARTICLES THEREOF |
| 84 | NUCLEAR REACTORS, BOILERS, MACHINERY AND MECHANICAL APPLIANCES; PARTS THEREOF |
| 85 | ELECTRICAL MACHINERY AND EQUIPMENT AND PARTS THEREOF; SOUND RECORDERS AND REPRODUCERS, TELEVISION RECORDERS AND REPRODUCERS, PARTS AND ACCESSORIES |
| 86 | RAILWAY OR TRAMWAY LOCOMOTIVES, ROLLING STOCK, TRACK FIXTURES AND FITTINGS, AND PARTS THEREOF; MECHANICAL ETC. TRAFFIC SIGNAL EQUIPMENT OF ALL KINDS |
| 87 | VEHICLES, OTHER THAN RAILWAY OR TRAMWAY ROLLING STOCK, AND PARTS AND ACCESSORIES THEREOF |
| 88 | AIRCRAFT, SPACECRAFT, AND PARTS THEREOF |
| 89 | SHIPS, BOATS AND FLOATING STRUCTURES |
| 90 | OPTICAL, PHOTOGRAPHIC, CINEMATOGRAPHIC, MEASURING, CHECKING, PRECISION, MEDICAL OR SURGICAL INSTRUMENTS AND APPARATUS; PARTS AND ACCESSORIES THEREOF |
| 91 | CLOCKS AND WATCHES AND PARTS THEREOF |
| 93 | ARMS AND AMMUNITION; PARTS AND ACCESSORIES THEREOF |

[19] Chapter Descriptions in this table are complete as taken from the U.S. International Trade Commission website, www.usitc.gov.  All following tables include abbreviated chapter descriptions for presentation purposes.

Table 2
Economies included in the dataset

| Abbreviation | Name |
|---|---|
| CHN | China |
| DEU | Germany |
| FRA | France |
| GBR | United Kingdom |
| HKG | Hong Kong |
| IDN | Indonesia |
| ITA | Italy |
| JPN | Japan |
| KOR | Korea |
| MYS | Malaysia |
| PHL | Philippines |
| SGP | Singapore[20] |
| THA | Thailand |
| TWN | Chinese Taipei |
| USA | United States |

[20] Although Singapore was also one of the five founding members of ASEAN, we have chosen to group it with the "Asian Tiger" countries for data presentation.

Table 3
ATP Categories as defined by the US Census Bureau

| ATP Category | Description |
|---|---|
| 01 | BIOTECHNOLOGY |
| 02 | LIFE SCIENCE |
| 03 | OPTO ELECTRONICS |
| 04 | INFORMATION & COMMUNICATIONS |
| 05 | ELECTRONICS |
| 06 | FLEXIBLE MANUFACTURING |
| 07 | ADVANCED MATERIALS |
| 08 | AEROSPACE |
| 09 | WEAPONS |
| 10 | NUCLEAR TECHNOLOGY |

Table 4
Cross-Tabulation of HS products in each included chapter falling into each ATP Category. HS Chapters containing ATP designated products are highlighted.

| HS2 \ ATP | 0 NonATP | 1 Biotech | 2 LifSci | 3 OptoEl | 4 InfoComm | 5 Elec | 6 FlexMan | 7 AdvMat | 8 Aero | 9 Weap | 10 NucTech | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **28** | 177 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 181 |
| **29** | 271 | 1 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 290 |
| **30** | 25 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| **31** | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 |
| **32** | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| **33** | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 |
| **34** | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |
| **35** | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| **36** | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| **37** | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 |
| **38** | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 55 |
| **39** | 122 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 122 |
| **40** | 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66 |
| **84** | 438 | 0 | 0 | 1 | 3 | 0 | 39 | 0 | 9 | 0 | 4 | 494 |
| **85** | 232 | 0 | 0 | 3 | 12 | 10 | 3 | 1 | 0 | 0 | 0 | 261 |
| **86** | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 |
| **87** | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 76 |
| **88** | 7 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | 0 | 0 | 15 |
| **89** | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| **90** | 98 | 0 | 23 | 9 | 1 | 1 | 8 | 2 | 4 | 3 | 1 | 150 |
| **91** | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 53 |
| **93** | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 17 |
| **TOTAL** | 1858 | 4 | 44 | 13 | 17 | 11 | 50 | 4 | 20 | 7 | 7 | 2035 |

**Figure 1**
**Scatter of HHI and EXPRELY, 2006**

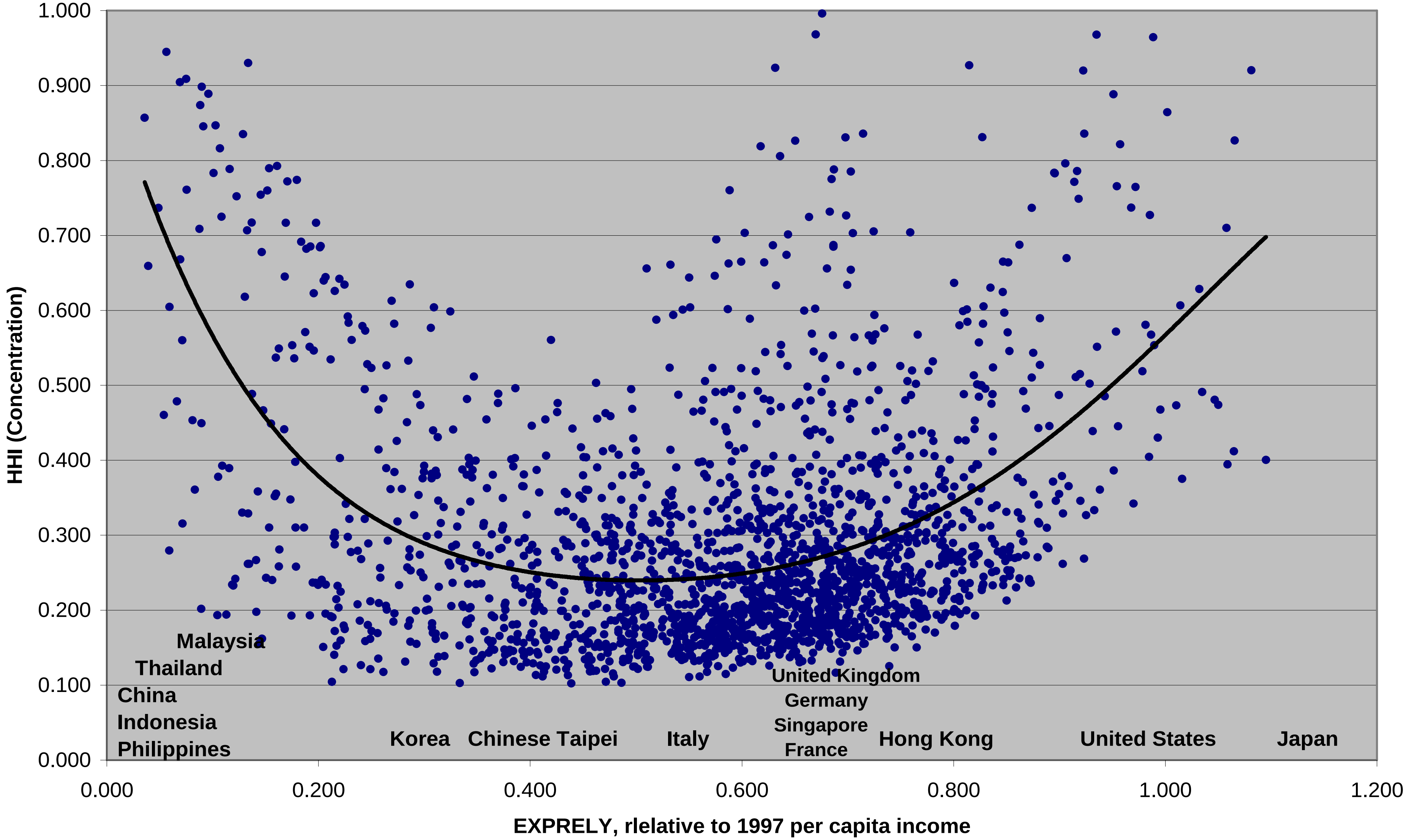
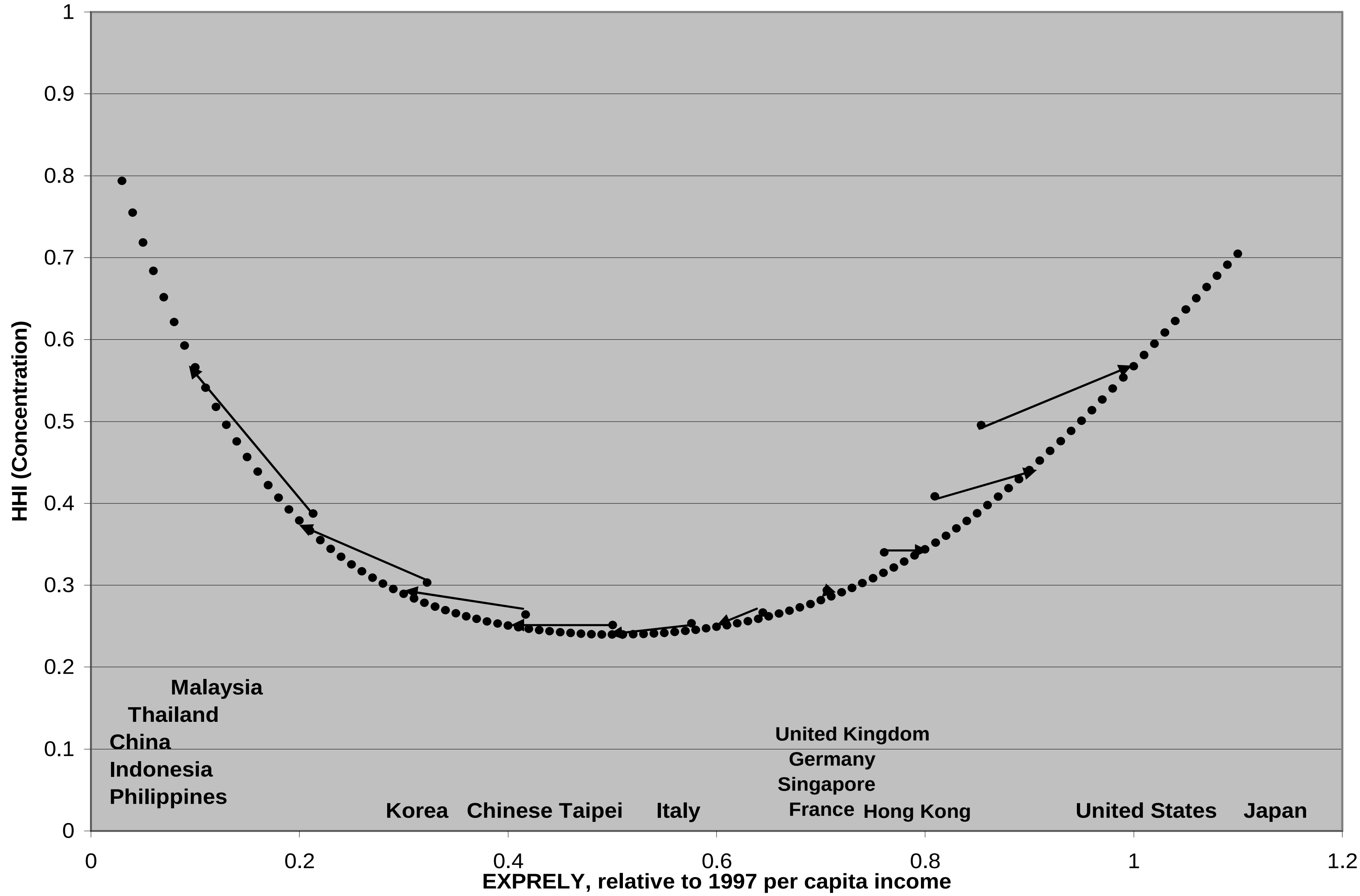
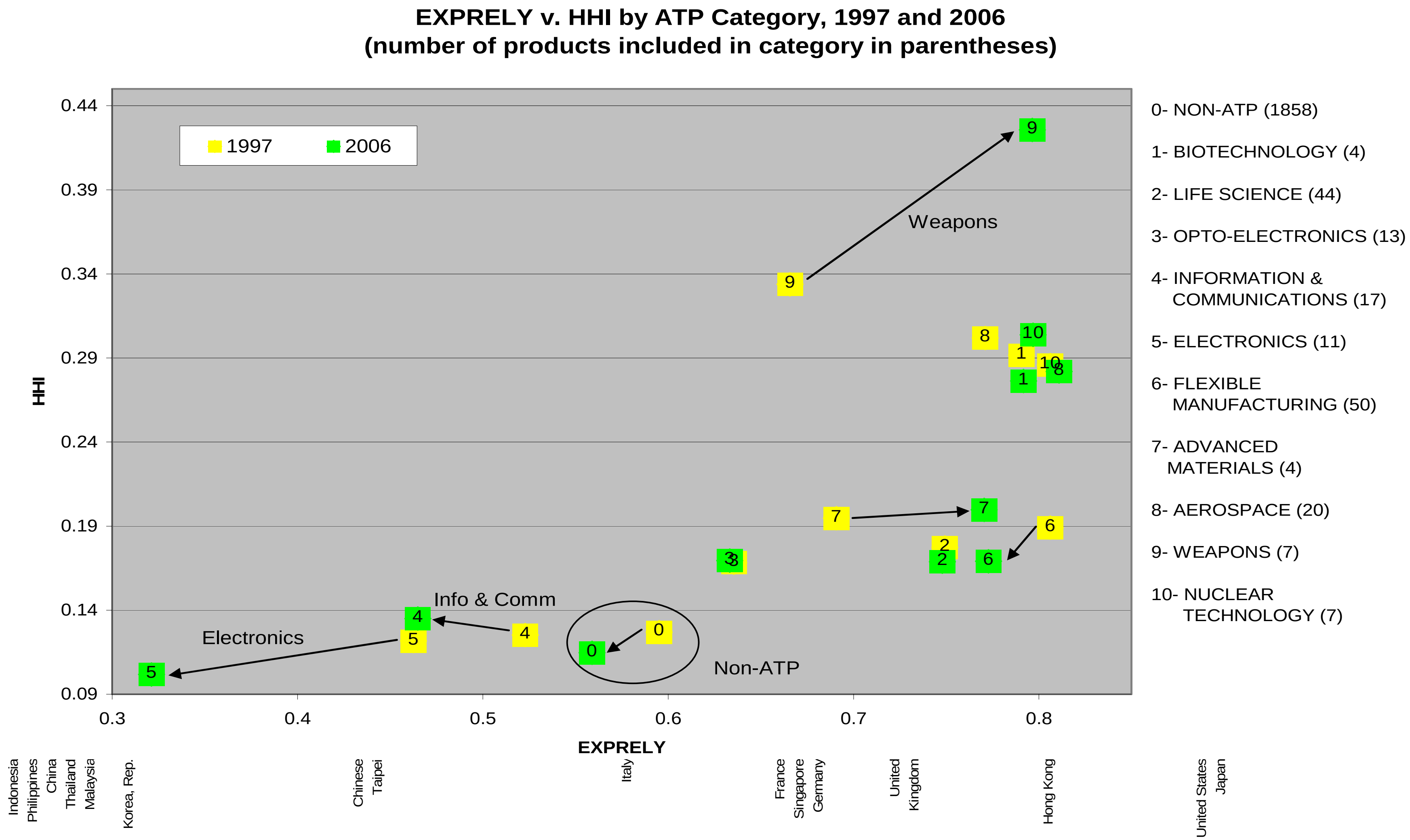


**Figure 2**
**Fitted relationship between HHI and EXPRELY in 2006,showing dynamics from 1997 to 2006**



# Figure 3


EXPRELY v. HHI by ATP Category, 1997 and 2006
(number of products included in category in parentheses)
1997
2006
Weapons
Info & Comm
Electronics
Non-ATP
HHI
EXPRELY
0.44
0.39
0.34
0.29
0.24
0.19
0.14
0.09
0.3
0.4
0.5
0.6
0.7
0.8
0- NON-ATP (1858)
1- BIOTECHNOLOGY (4)
2- LIFE SCIENCE (44)
3- OPTO-ELECTRONICS (13)
4- INFORMATION & COMMUNICATIONS (17)
5- ELECTRONICS (11)
6- FLEXIBLE MANUFACTURING (50)
7- ADVANCED MATERIALS (4)
8- AEROSPACE (20)
9- WEAPONS (7)
10- NUCLEAR TECHNOLOGY (7)
Indonesia
Philippines
China
Thailand
Malaysia
Korea, Rep.
Chinese Taipei
Italy
France
Singapore
Germany
United Kingdom
Hong Kong
United States
Japan

# Figure 4

**EXPRELY v. HHI by HS2 Chapter, 1997 and 2006**
**(number of products included in category in parentheses)**

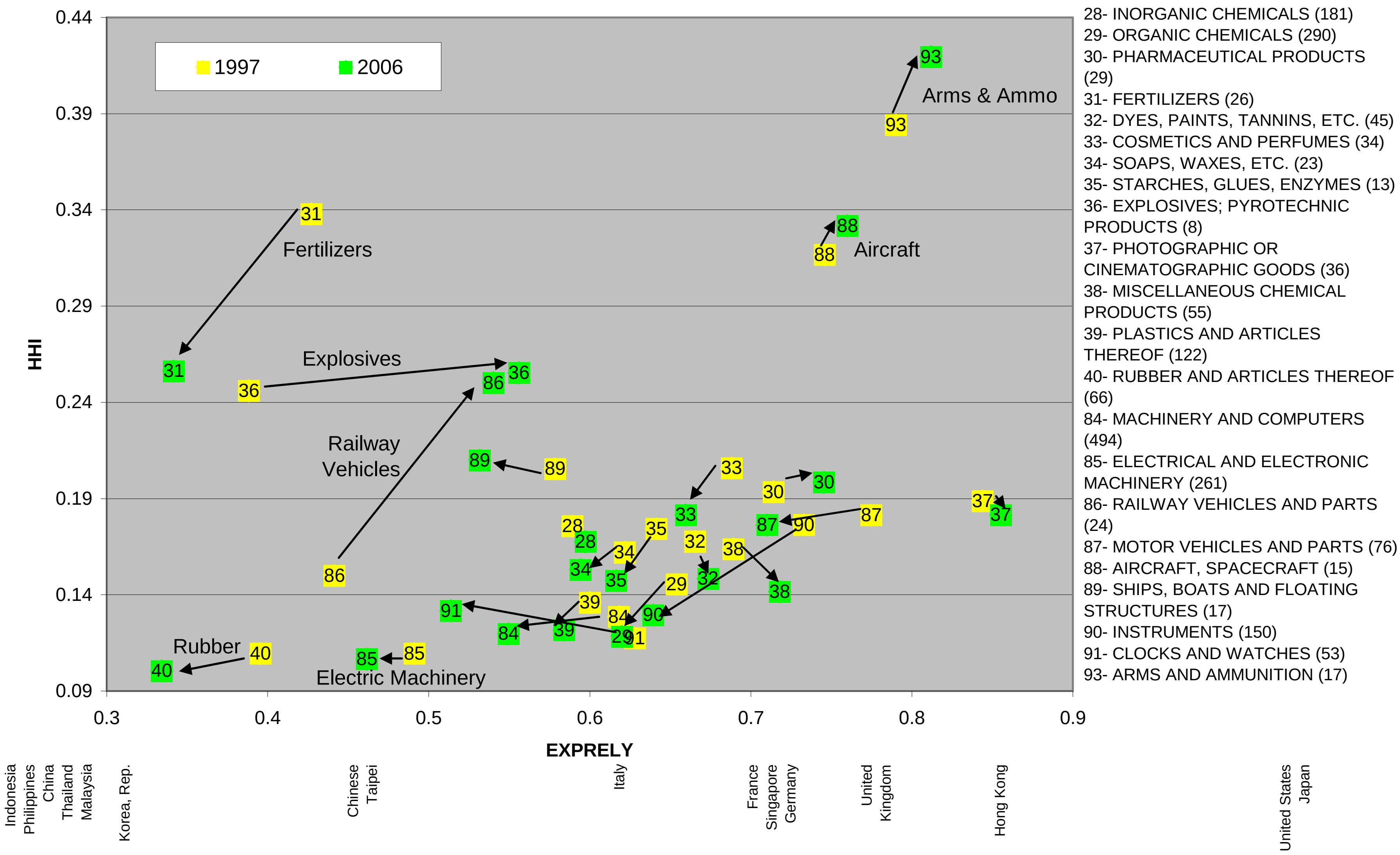


**Table 5**
**Cluster Analysis of Machinery, Electronics and Instruments (HS 84, 85, and 90)**

**Clustering on Indices in 2006:**

| Cluster | _FREQ_ | HHI_06 | EXPRELY_06 | Desc | # of ATP Products | % of Products designated ATP |
|---|---|---|---|---|---|---|
| 1 | 560 | 0.233 | 0.669 | Low HHI; High EXPRELY | 96 | 17.1% |
| 2 | 187 | 0.199 | 0.455 | Low HHI - moderate EXPRELY - diffuse | 23 | 12.3% |
| 3 | 106 | 0.331 | 0.243 | Moderate HHI; LOW EXPRELY – downstreamed | 7 | 6.6% |
| 4 | 52 | 0.544 | 0.755 | High HHI; HIGH EXPRELY – hitech | 11 | 21.2% |

**Table 6**
**ATP products in HS 84, HS 85, and HS 90 falling in Cluster 3 (“Downstreamed”)**

| Product | Product_Name | HHI_06 | EXPRELY_06 | Notes on Market Share |
|---|---|---|---|---|
| 847050 | Cash registers | 0.181 | 0.341 | Was dominated by Japan, China has taken over |
| 840110 | Nuclear reactors | 0.352 | 0.159 | lumpy data |
| 851999 | Sound reproducing apparatus, non-recording, nes | 0.717 | 0.169 | Was dominated by Japan, China has taken over (no longer on ATP list) |
| 852190 | Video record/reproduction apparatus not magnetic tape ***(includes iPODs and MP3 players)*** | 0.537 | 0.160 | Was dominated by Japan, China has taken over |
| 854121 | Transistors, except photosensitive, < 1 watt | 0.162 | 0.147 | Was dominated by Japan, Philippines has taken over |
| 854129 | Transistors, except photosensitive, > 1 watt | 0.193 | 0.105 | Was shared by Japan, Malaysia, Singapore, USA, Philippines has taken over (MS spiked in 2005 – FDI?) |
| 854150 | Semiconductor devices, not light sensitive or emitting | 0.194 | 0.113 | shared largely by Singapore and Philippines, Philippines has taken over |

**Table 7**
**ATP products in HS 84, HS 85 and HS 90 falling in Cluster 4 ("Upstream")**

| Product | Product_Name | HHI_06 | EXPRELY_06 | HS2 | ATP_Code | ATP_Category | Notes on Market Share |
|---|---|---|---|---|---|---|---|
| 845910 | Way-type unit head machines, metal working | 0.601 | 0.587 | 84 | 6 | FLEXIBLE MANUFACTURING | Italy has highest MS over most of period |
| 845921 | Numerically controlled metal working drill machines | 0.491 | 1.035 | 84 | 6 | FLEXIBLE MANUFACTURING | Japan dominates |
| 846510 | Multi-purpose machines for wood etc work | 0.542 | 0.637 | 84 | 6 | FLEXIBLE MANUFACTURING | Germany (followed by ITA, USA) |
| 841111 | Turbo-jet engines of a thrust < 25 KN | 0.469 | 0.868 | 84 | 8 | AEROSPACE | USA (Followed by Germany, GBR) |
| 840120 | Machinery & apparatus for isotopic separation & parts | 0.685 | 0.687 | 84 | 10 | NUCLEAR TECHNOLOGY | Germany (followed by USA, GBR) |
| 900661 | Photographic discharge lamp flashlight apparatus | 0.439 | 0.931 | 90 | 2 | LIFE SCIENCE | Japan (followed by China, Germany) |
| 901210 | Microscopes except optical, diffraction apparatus | 0.405 | 0.985 | 90 | 2 | LIFE SCIENCE | Japan (followed by US, Germany) |
| 902150 | Pacemakers for stimulating heart muscles | 0.476 | 0.706 | 90 | 2 | LIFE SCIENCE | US and France (followed by Germany) |
| 901110 | Stereoscopic microscopes | 0.576 | 0.735 | 90 | 3 | OPTO-ELECTRONICS | Germany (followed by Japan) |
| 901520 | Theodolites and tacheometers | 0.371 | 0.894 | 90 | 3 | OPTO-ELECTRONICS | Japan |
| 901720 | Drawing, marking-out, instruments nes, slide rules | 0.582 | 0.828 | 90 | 4 | INFORMATION & COMMUNICATIONS | USA |

**Table 8**
**Products in HS 84, HS 85 and HS 90 clustered by economy market share in 2006**

| Cluster | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Number of products | 217 | 94 | 113 | 364 | 75 | 42 |
| GER_Market_Share | 43.4% | 17.8% | 13.2% | 15.8% | 13.4% | 8.2% |
| UK_Market_Share | 5.1% | 3.8% | 4.5% | 8.9% | 3.9% | 6.1% |
| FRA_Market_Share | 5.4% | 7.2% | 3.9% | 8.9% | 5.0% | 5.3% |
| ITA_Market_Share | 9.2% | 36.4% | 4.8% | 7.1% | 6.0% | 4.4% |
| HK_Market_Share | 0.0% | 0.1% | 0.0% | 0.1% | 0.3% | 0.2% |
| SNG_Market_Share | 2.1% | 1.5% | 2.5% | 5.1% | 2.0% | 4.6% |
| KOR_Market_Share | 1.8% | 2.8% | 2.9% | 4.0% | 4.1% | 0.5% |
| IDN_Market_Share | 0.2% | 0.4% | 0.8% | 1.5% | 0.4% | 0.3% |
| MYS_Market_Share | 0.9% | 1.2% | 3.4% | 3.7% | 1.5% | 0.7% |
| THA_Market_Share | 0.4% | 1.0% | 2.5% | 2.2% | 0.9% | 0.4% |
| PHL_Market_Share | 0.1% | 0.1% | 0.3% | 1.0% | 0.2% | 0.3% |
| USA_Market_Share | 13.2% | 10.3% | 8.2% | 18.9% | 8.0% | 56.2% |
| CHN_Market_Share | 5.3% | 8.5% | 45.4% | 9.0% | 10.5% | 6.7% |
| JPN_Market_Share | 11.1% | 5.0% | 4.2% | 9.4% | 40.1% | 5.3% |
| TWN_Market_Share | 1.8% | 3.9% | 3.3% | 4.3% | 3.8% | 0.8% |
| # of ATP Prods | 38 | 4 | 8 | 62 | 20 | 5 |
| % of Prods classified as ATP | 17.5% | 4.3% | 7.1% | 17.0% | 26.7% | 11.9% |

**Table 9**
**Cluster Analysis of Organic Chemicals and Allied Products (HS 29, 30, 32-35, 37-40)**

**Clustering on Indices in 2006:**

| Cluster | N | HHI_06 | EXPRELY_06 | Description | # ATP Products | % of Products classified as ATP |
|---|---|---|---|---|---|---|
| 1 | 304 | 0.283 | 0.717 | Low HHI, High EXPRELY -- diffuse, mainly exported from High income Economies | 16 | 5.3% |
| 2 | 59 | 0.609 | 0.819 | High HHI, High EXPRELY - "hitech" | 1 | 1.7% |
| 3 | 241 | 0.216 | 0.543 | Low HHI; Moderate EXPRELY - diffuse, exported from all economies | 7 | 2.9% |
| 4 | 109 | 0.370 | 0.254 | Low/Moderate HHI; Low EXPRELY - "downstreamed" | 0 | 0.0% |

**Table 10**
**Organic Chemicals and Allied Products clustered by economy market share in 2006**

| Cluster | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| _FREQ_ | 136 | 85 | 118 | 32 | 197 | 145 |
| GER_Market_Share | 11.4% | 11.7% | 6.9% | 70.9% | 33.5% | 11.7% |
| UK_Market_Share | 6.6% | 4.0% | 6.6% | 1.8% | 6.2% | 15.6% |
| FRA_Market_Share | 6.6% | 4.6% | 5.3% | 2.2% | 9.3% | 12.3% |
| ITA_Market_Share | 3.6% | 3.5% | 4.2% | 3.0% | 6.0% | 11.0% |
| HK_Market_Share | 0.1% | 0.1% | 0.2% | 0.0% | 0.2% | 0.0% |
| SNG_Market_Share | 2.4% | 3.4% | 4.2% | 1.0% | 2.4% | 6.0% |
| KOR_Market_Share | 2.5% | 4.2% | 2.7% | 0.9% | 2.8% | 4.8% |
| IDN_Market_Share | 1.6% | 0.7% | 0.6% | 0.2% | 0.9% | 2.7% |
| MYS_Market_Share | 0.7% | 1.6% | 0.9% | 0.6% | 1.5% | 3.2% |
| THA_Market_Share | 1.5% | 1.1% | 0.8% | 0.3% | 1.6% | 3.8% |
| PHL_Market_Share | 0.1% | 0.1% | 0.0% | 0.0% | 0.1% | 0.2% |
| USA_Market_Share | 9.5% | 20.9% | 50.9% | 8.8% | 20.0% | 13.2% |
| CHN_Market_Share | 45.2% | 5.7% | 7.9% | 4.7% | 6.0% | 6.9% |
| JPN_Market_Share | 6.1% | 34.4% | 5.7% | 2.3% | 6.3% | 5.8% |
| TWN_Market_Share | 2.0% | 3.9% | 3.1% | 3.3% | 3.1% | 2.9% |
| # of ATP products | 5 | 2 | 2 | 0 | 6 | 9 |
| % of Products which are ATP | 3.7% | 2.4% | 1.7% | 0.0% | 3.0% | 6.2% |

Figure 5
Electronics vs. Chemicals:
Technological Complexity In The Production Chain

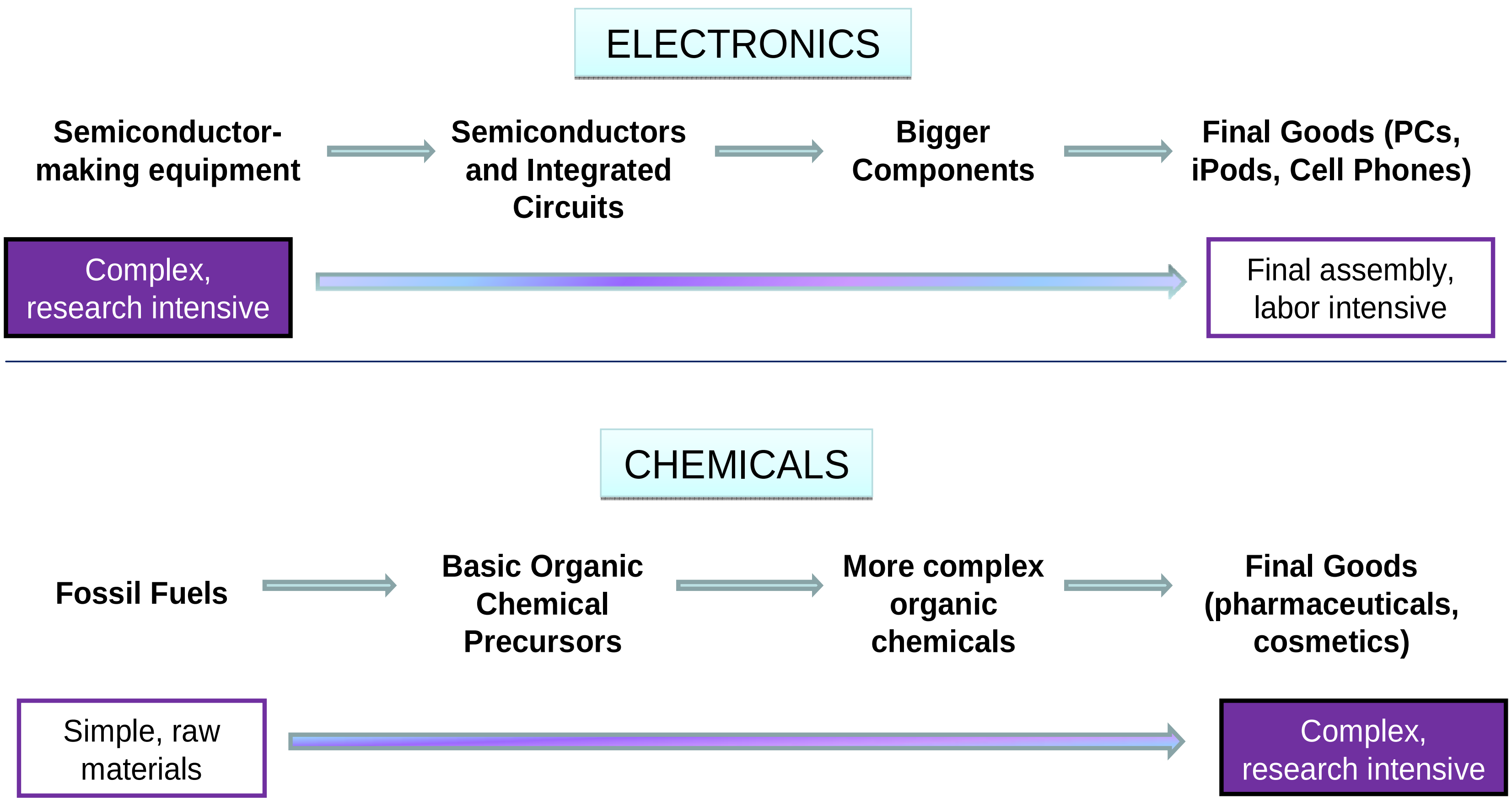
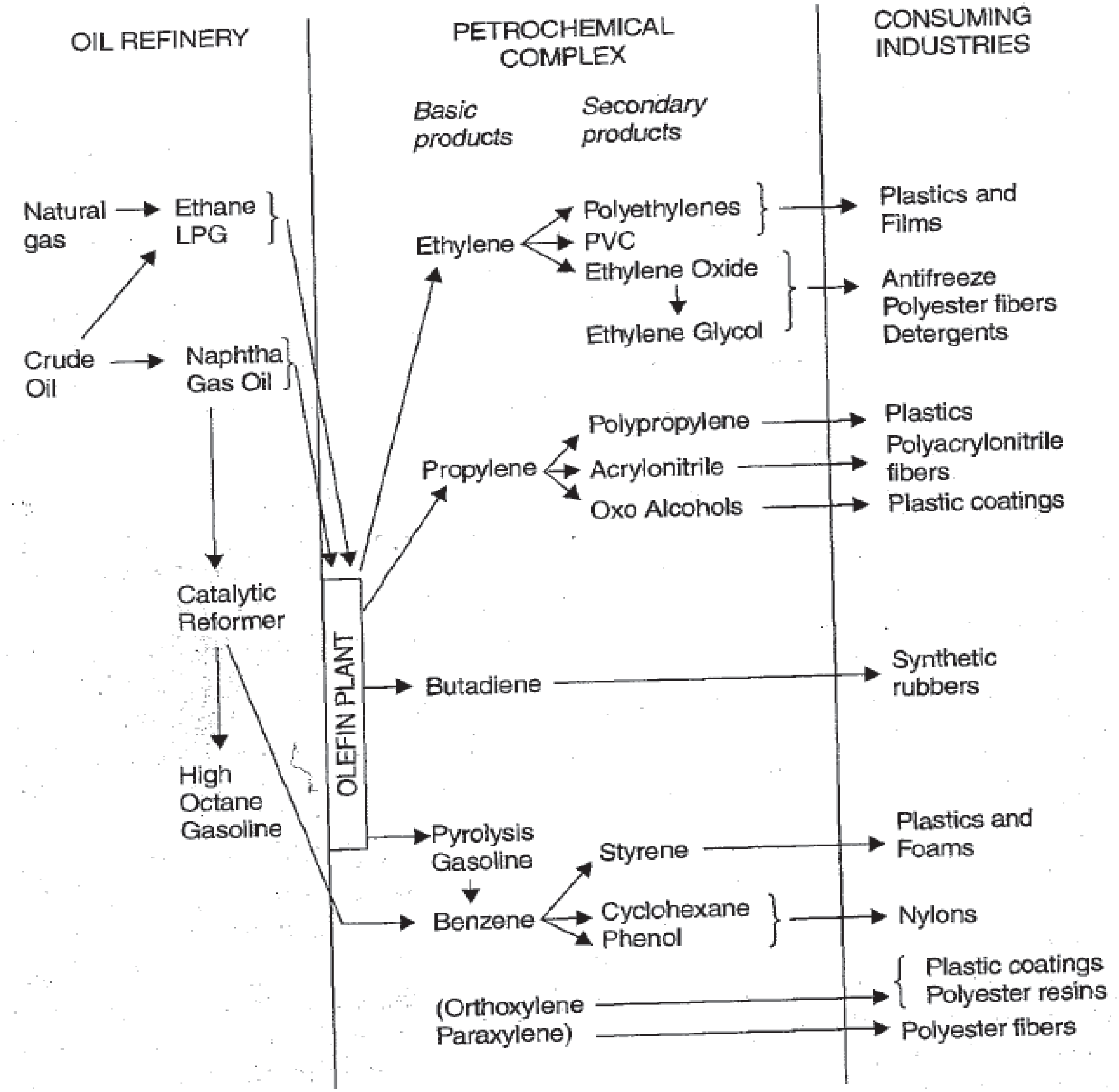


**Figure 6**
**Production Pathways in Chemicals and Products**[21]




[21] Source: Margaret Sharp, "Innovations in the Chemicals Industry." In *The Handbook of Industrial Innovation*, Mark Dodgson and Roy Rothwell, eds., Aldershot, England: Edward Elgar, 1994: 171, as reproduced in Vernon W. Ruttan, *Technology, Growth, and Development: An Induced Innovation Perspective*, Oxford, England: Oxford University Press, 2001, 295.

Table 7

Indices by industry subgroups

| | Relative Income Level EXPRELY | | Concentration HHI | |
|---|---|---|---|---|
| **Petrochemicals and products** | 1997 | 2006 | 1997 | 2006 |
| Basic petrochemicals | 0.556 | 0.479 | 0.135 | 0.128 |
| Secondary petrochemicals | 0.557 | 0.536 | 0.142 | 0.124 |
| Petrochemical-consuming industries | 0.641 | 0.601 | 0.152 | 0.130 |
| Plastic and rubber articles | 0.506 | 0.471 | 0.118 | 0.131 |
| **Pharmaceuticals** | | | | |
| Bulk medicaments | 0.582 | 0.661 | 0.148 | 0.176 |
| Medicaments by dosage | 0.665 | 0.691 | 0.207 | 0.200 |
| **Electronics and related products** | | | | |
| Doped wafers and machinery used in manufacturing semiconductors | 0.750 | 0.753 | 0.221 | 0.194 |
| Semiconductors and integrated circuits | 0.369 | 0.357 | 0.118 | 0.114 |
| Computers | 0.719 | 0.250 | 0.157 | 0.322 |
| Computer input, output, and data storage units | 0.410 | 0.225 | 0.133 | 0.196 |
| Capacitors, resistors, printed circuits, and parts | 0.463 | 0.432 | 0.128 | 0.139 |
| Electrical relays, switches, circuit breakers, etc. | 0.642 | 0.559 | 0.161 | 0.139 |
| Radio, TV, and telecommunications equipment | 0.347 | 0.338 | 0.099 | 0.208 |
| Parts of radio, TV, and telecommunications equipment | 0.523 | 0.419 | 0.112 | 0.168 |
| Transmission equipment for radio, TV, telecom, and TV cameras | 0.636 | 0.489 | 0.169 | 0.186 |
| CRTs and other vacuum tubes | 0.494 | 0.302 | 0.141 | 0.133 |
| Photographic and cinematographic apparatus | 0.324 | 0.140 | 0.126 | 0.127 |
| Electro-medical devices | 0.699 | 0.692 | 0.235 | 0.217 |

Table 11

Relationship between indices for machinery and parts in HS 8401-HS 8443

EXPRELY_06 (Parts) – EXPRELY_06 (Machines):

| Range | Number of categories |
| --- | --- |
| Greater than 0.1 | 6 |
| 0 to 0.1 | 23 |
| -0.1 to 0 | 11 |
| Less than -0.1 | 5 |
| Median | 0.012 |

HHI_06 (Parts) – HHI_06 (Machines)

| Range | Number of categories |
| --- | --- |
| Greater than 0.1 | 2 |
| 0 to 0.1 | 16 |
| -0.1 to 0 | 20 |
| Less than -0.1 | 6 |
| Median | -0.004 |

Appendix 1
Regressions used in Figures 1 and 2

| | HHI_2006 | d EXPRELY | d HHI |
|---|---|---|---|
| Intercept | 0.926<br>(0.065) | -0.204<br>(0.028) | -0.047<br>(0.023) |
| EXPRELY_06 | -4.79<br>(0.028) | -0.079<br>(0.898) | -0.135<br>(0.063) |
| $EXPRELY\_06^2$ | 13.98<br>(4.25) | 0.213<br>(0.065) | 0.091<br>(0.054) |
| HHI_06 | | 0.185<br>(0.079) | 0.376<br>(0.065) |
| $HHI\_06^2$ | | -0.067<br>(0.079) | 0.107<br>(0.061) |
| EXPRELY_06*HHI_06 | | -0.047<br>(0.069) | 0.150<br>(0.047) |
| $EXPRELY\_06^3$ | -21.55<br>(8.96) | | |
| $EXPRELY\_06^4$ | 17.23<br>(8.62) | | |
| $EXPRELY\_06^5$ | -5.21<br>(3.08) | | |
| N | 2035 | 2035 | 2035 |
| $R^2$ | .247 | .184 | .282 |

dHHI = HHI_06 – HHI_97
dEXPRELY = EXPRELY_06 – EXPRELY_97
Standard errors in parentheses

## Appendix 2
## Average HHI Values for HS Chapters, 1997-2006 (annual averages over 10 years)

| HS2 | Chapter Description | Average HHI |
|---|---|---|
| 93 | ARMS AND AMMUNITION; PARTS AND ACCESSORIES THEREOF | 0.399 |
| 88 | AIRCRAFT, SPACECRAFT, AND PARTS THEREOF | 0.330 |
| 31 | FERTILIZERS | 0.291 |
| 36 | EXPLOSIVES; PYROTECHNIC PRODUCTS; MATCHES; PYROPHORIC ALLOYS; CERTAIN COMBUSTIBLE PREPARATIONS | 0.264 |
| 86 | RAILWAY OR TRAMWAY LOCOMOTIVES, ROLLING STOCK, TRACK FIXTURES AND FITTINGS, AND PARTS THEREOF; MECHANICAL ETC. TRAFFIC SIGNAL EQUIPMENT OF ALL KINDS | 0.212 |
| 89 | SHIPS, BOATS AND FLOATING STRUCTURES | 0.208 |
| 33 | ESSENTIAL OILS AND RESINOIDS; PERFUMERY, COSMETIC OR TOILET PREPARATIONS | 0.194 |
| 30 | PHARMACEUTICAL PRODUCTS | 0.194 |
| 87 | VEHICLES, OTHER THAN RAILWAY OR TRAMWAY ROLLING STOCK, AND PARTS AND ACCESSORIES THEREOF | 0.183 |
| 37 | PHOTOGRAPHIC OR CINEMATOGRAPHIC GOODS | 0.180 |
| 28 | INORGANIC CHEMICALS; ORGANIC OR INORGANIC COMPOUNDS OF PRECIOUS METALS, OF RARE-EARTH METALS, OF RADIOACTIVE ELEMENTS OR OF ISOTOPES | 0.167 |
| 90 | OPTICAL, PHOTOGRAPHIC, CINEMATOGRAPHIC, MEASURING, CHECKING, PRECISION, MEDICAL OR SURGICAL INSTRUMENTS AND APPARATUS; PARTS AND ACCESSORIES THEREOF | 0.162 |
| 38 | MISCELLANEOUS CHEMICAL PRODUCTS | 0.156 |
| 34 | SOAP ETC.; LUBRICATING PRODUCTS; WAXES, POLISHING OR SCOURING PRODUCTS; CANDLES ETC., MODELING PASTES; DENTAL WAXES AND DENTAL PLASTER PREPARATIONS | 0.156 |
| 35 | ALBUMINOIDAL SUBSTANCES; MODIFIED STARCHES; GLUES; ENZYMES | 0.156 |
| 32 | TANNING OR DYEING EXTRACTS; TANNINS AND DERIVATIVES; DYES, PIGMENTS AND OTHER COLORING MATTER; PAINTS AND VARNISHES; PUTTY AND OTHER MASTICS; INKS | 0.154 |
| 29 | ORGANIC CHEMICALS | 0.131 |
| 39 | PLASTICS AND ARTICLES THEREOF | 0.130 |
| 91 | CLOCKS AND WATCHES AND PARTS THEREOF | 0.129 |
| 84 | NUCLEAR REACTORS, BOILERS, MACHINERY AND MECHANICAL APPLIANCES; PARTS THEREOF | 0.119 |
| 40 | RUBBER AND ARTICLES THEREOF | 0.110 |
| 85 | ELECTRICAL MACHINERY AND EQUIPMENT AND PARTS THEREOF; SOUND RECORDERS AND REPRODUCERS, TELEVISION RECORDERS AND REPRODUCERS, PARTS AND ACCESSORIES | 0.103 |

Appendix 3

Average EXPRELY Values for HS Chapters, 1997-2006 (annual averages over 10 years)

| HS2 | Chapter Description | Average EXPRELY |
|---|---|---|
| 37 | PHOTOGRAPHIC OR CINEMATOGRAPHIC GOODS | 0.782 |
| 93 | ARMS AND AMMUNITION; PARTS AND ACCESSORIES THEREOF | 0.750 |
| 88 | AIRCRAFT, SPACECRAFT, AND PARTS THEREOF | 0.723 |
| 87 | VEHICLES, OTHER THAN RAILWAY OR TRAMWAY ROLLING STOCK, AND PARTS AND ACCESSORIES THEREOF | 0.694 |
| 30 | PHARMACEUTICAL PRODUCTS | 0.685 |
| 90 | OPTICAL, PHOTOGRAPHIC, CINEMATOGRAPHIC, MEASURING, CHECKING, PRECISION, MEDICAL OR SURGICAL INSTRUMENTS AND APPARATUS; PARTS AND ACCESSORIES THEREOF | 0.659 |
| 38 | MISCELLANEOUS CHEMICAL PRODUCTS | 0.658 |
| 32 | TANNING OR DYEING EXTRACTS; TANNINS AND DERIVATIVES; DYES, PIGMENTS AND OTHER COLORING MATTER; PAINTS AND VARNISHES; PUTTY AND OTHER MASTICS; INKS | 0.620 |
| 33 | ESSENTIAL OILS AND RESINOIDS; PERFUMERY, COSMETIC OR TOILET PREPARATIONS | 0.617 |
| 29 | ORGANIC CHEMICALS | 0.586 |
| 35 | ALBUMINOIDAL SUBSTANCES; MODIFIED STARCHES; GLUES; ENZYMES | 0.573 |
| 28 | INORGANIC CHEMICALS; ORGANIC OR INORGANIC COMPOUNDS OF PRECIOUS METALS, OF RARE-EARTH METALS, OF RADIOACTIVE ELEMENTS OR OF ISOTOPES | 0.552 |
| 34 | SOAP ETC.; LUBRICATING PRODUCTS; WAXES, POLISHING OR SCOURING PRODUCTS; CANDLES ETC., MODELING PASTES; DENTAL WAXES AND DENTAL PLASTER PREPARATIONS | 0.551 |
| 39 | PLASTICS AND ARTICLES THEREOF | 0.532 |
| 84 | NUCLEAR REACTORS, BOILERS, MACHINERY AND MECHANICAL APPLIANCES; PARTS THEREOF | 0.517 |
| 89 | SHIPS, BOATS AND FLOATING STRUCTURES | 0.515 |
| 91 | CLOCKS AND WATCHES AND PARTS THEREOF | 0.497 |
| 86 | RAILWAY OR TRAMWAY LOCOMOTIVES, ROLLING STOCK, TRACK FIXTURES AND FITTINGS, AND PARTS THEREOF; MECHANICAL ETC. TRAFFIC SIGNAL EQUIPMENT OF ALL KINDS | 0.421 |
| 85 | ELECTRICAL MACHINERY AND EQUIPMENT AND PARTS THEREOF; SOUND RECORDERS AND REPRODUCERS, TELEVISION RECORDERS AND REPRODUCERS, PARTS AND ACCESSORIES | 0.415 |
| 36 | EXPLOSIVES; PYROTECHNIC PRODUCTS; MATCHES; PYROPHORIC ALLOYS; CERTAIN COMBUSTIBLE PREPARATIONS | 0.394 |
| 40 | RUBBER AND ARTICLES THEREOF | 0.347 |
| 31 | FERTILIZERS | 0.338 |

# Investment Rate and FDI – a Comparative Analysis of Return to Capital among China, US and Japan

**Sun Wenkai 1, Yang Xiuke 2, Xiao Geng 3**

（**1 Renmin University of China; 2 Peking University; 3 Tsinghua University**）

## Abstract

This paper analyzes why unusual high investment ratio and increasing FDI emerge in China based on the return to capital among China, US and Japan. We also try to investigate into the future investment climate and the change of FDI in China. Over the last decade and a half, FDI-invested Chinese economy is growing at 19.97% a year and the investment rate in the country increases from 25.86% in 1990 to 42.74% in 2006, which are significantly higher than other major economies such as Japan and US. The surging level of FDI and the soaring investment rate in China imply that global capital is pouring into the world’s third largest economy.

In this paper, five important findings are obtained: (1) the reason that China continues to top in the investment rate is because of the high return to capital in the country. During the period with high return to capital in US and Japan, their investment rates are significantly higher than today. The comparatively higher return to capital brings surging FDI into China. (2) The high investment rate and return to capital will sustain for at least 10 years. (3) The return to capital among the three countries doesn’t converge during the last 30 years. This implies that FDI will continuously flows into China. (4) Although the return to capital is significantly affected by the economic cycle, it follows a decreasing trend in the long run. The experiences from Japan and the United States indicate that return to capital decreases in the long run and is likely to remain relatively stable after years of economic development. This implies that the return to capital in China will inevitably decrease in the future. However, it seems that the return to capital in China will continue to be high for a period of time as the labor’s share and capital-output ratio in China are still very low, which means that the high investment rate in China is likely to last for a couple of years. (5) Currently FDI is mainly focusing on manufacturing industries and the ratio of technology-intensive investment rises remarkably in China. The technology-intensive FDI’s growth rate is significantly higher than foreign investment actually utilized after 2000. The major body of technology-intensive product exports is from foreign investment companies. These imply that the high return to capital is not only attractive for low-tech FDI but also for high-tech.

**Keywords:** Return to Capital; Investment Rate; FDI；High-Tech Industry

# 1. Introduction

Over the last decade and a half, China has been maintaining the highest investment rate compared with advanced economies such as Japan and the United States. The investment rate in China, which rises from 25.86% in 1990 to 42.75% in 2006, averages much higher than that of Japan which decreases from 32.32% in 1990 to 23.46% in 2006 and that of the United States which fluctuates around 26% during the period of 1990-2007. In the meantime, the FID-invested Chinese economy is growing at 19.97% a year, sharply rises from $3.5 billion in 1990 to $92.4 billion in 2008.

What has been making China increasingly attractive to investors? Is the high investment rate in China sustainable? How about the sustainability of the flood of FDI into China? To answer those questions that arise from China's high investment rate and the surging level of FDI in the country, a natural metric is to estimate the return to capital in China as well as those of other major countries such as Japan and the United States: If the return to capital in China continues to be high, the high investment rate in the country is likely to last for quite a couple of years; if the return to capital in China is significantly higher than those of other major countries, foreign capital will continue to flow into China. To reveal the sustainability of China's high investment rate and the surging level of FDI in the country, the most intuitive approach is to analyze key factors that affect return to capital and investigate into the changes of the factors.

Scholars and government officials have devoted lengthy and full discussions to the high investment rate[1] and the rapid growing foreign-invested economy in China[2], which conclude that 1) government investment, 2) investment from private sector, and 3) foreign direct investment are typical key factors that contribute to China's high investment rate; while 1) low cost of production factors, 2) huge market demand, and 3) economies of agglomeration are principal elements that attract FDI flows into China. Although many papers have reported estimates of return to capital in China

[1] For example, Development Research Center of the State Council (2005), Li (2006), Hu (2007), and Yu (2008)
[2] For example, Zhao and Lu (2007), Lu and Xu (2008), and Luo (2009)

and concluded that the return to capital is much higher than those of advanced economies and China's emerging peers[3], we are not aware of any study that uses the basic element of the market-oriented economy, the return to capital, to explain the high investment rate and the surging level of FDI. For these considerations, this paper estimates the return to capital in China, Japan and the United States, studies key factors that affect return to capital, and investigates into the changes of the factors, hoping to reveal the trend of return to capital and future investment climate in China, which, we have not noticed any earlier discussions.

Our study of return to capital differs from those earlier estimates in many ways, of which three principal ones are: Firstly, we update China's data reported by China's National Bureau of Statistics (NBS) after the 2007 census, update Japan's data reported by Japan's Statistics Bureau and the American data reported by the Bureau of Economic Analysis (BEA) after the 2008 census. Secondly, by estimating the return to capital in China, Japan and the United States, we investigate into key factors that affect return to capital and analyze the changes of the key factors. Last but not least, we explore the trend of return to capital and future investment climate in China.

Various evidences show that although significantly affected by the economic cycle, return to capital follows a decreasing trend in the long run, which is because return to capital is mainly affected by labor's share and capital-output ratio. At the early stage of economic booms, labor's share and capital-output ratio are always low, however, as the economic development labor's share and capital-output ratio increase, declining return to capital. The reasons that the return to capital in China is higher than that of Japan and that of the United States are precisely because China has a lower labor's share and a lower capital-output ratio. Although labor's share and capital-output ratio in China will inevitably increase as the development of economy, which will decline the return to capital in the country, however, it seems that the return to capital in China will continue to be high for a period of time, and even higher than that of Japan and that of the United States. This is because the labor's share and capital-output ratio

[3] For example, Bai, Hsieh, and Qian (2006), Song (2006)

in the country are still very low, and are not likely to experience remarkable increase in the near future, suggesting that China will be able to sustain the high investment rate and attract more FDI for quite a few years.

Chapter 2 begins this paper with a literature review. Chapter 3 estimates and makes a comparative analysis of the return to capital in China, Japan and the United States. Chapter 4 analyzes key factors that affect return to capital. Chapter 5 explores the trend of return to capital and future investment climate in China, in the meantime discusses the return to capital in high-tech industries. Chapter 6 concludes findings in this paper.

## 2. Literature review

There have been many discussions on China’s high investment rate and the country’s fast growing foreign-invested economy. Development Research Center of the State Council (2005) concludes that the industrialization, the high saving rate, the extensive economy, the low efficiency of investment and the low consumption rate lead to the high investment rate in China. Based upon these conclusions, Li (2006), Hu (2007), Yu (2008) and many other papers further discuss the high investment rate and the low consumption rate in China, while Fan (2009) discusses the same topic based on a comparison between the political system of China and the US, concluding that China’s local governments always pay more attention to the capital’s interests and relatively ignore the labor’s interests, which result in high investment rate and low consumption rate. As for factors that attract FDI flows into China, Shen *et al.* (2002) finds that human capital stock significantly affects FDI’s location choice and investment scale. Xu *et al.* (2002) concludes that FDI is mainly affected by market demand, capital stock, and exchange rate. Li (2004) analyzes that there is a positive correlation between foreign trade and FDI. Huang *et al.* (2006) points out that the transaction cost of foreign trade, technology spillover, and market demand significantly affect FDI’s location choice. Luo (2009) studies the source countries and concludes that the source country market size and the bilateral trade influence on FDI inflow.

In this paper, we use the basic element of the market-oriented economy, the return to capital, to explain the high investment rate and the surging level of FDI, which, we are not aware of any earlier discussions. The earliest estimate of return to capital with large samples originates from Baumol *et al.* (1970), which regresses output on capital invested. Friend and Husic (1973), Brealey *et al*. (1976), and McFetridge (1978), however, challenges Baumol *et al.* (1970) that the regression model omits the scale effect and thus leads to biased estimates of the return to capital that all types of capital almost have the same return. One important thing to be noticed about those pioneer estimates is that all of them are based upon constant prices, rather than market prices. In the 1990s, estimates of the return to capital have developed into market price-based calculation. Mueller and Reardon (1993) serve as the pioneer of using market prices to estimate the return to capital. The methodology is further applied by Mueller and Yurtoglu (2000) and Gugler *et al.* (2003, 2004).

Note that all of the above methodologies measure the return to capital in the capital market, which is a natural way to estimate the aggregate return to capital for a country with well-developed financial market; however, it is inappropriate for estimating the aggregate return to capital of a developing country like China. To estimate the aggregate return to capital in China, Bai, Hsieh, and Qian (2006) calculates the return to capital by using data on capital share, capital-output ratio, depreciation rate, growth rate of investment goods deflator and GDP deflator, considering a decision by a firm, a price-taker, at the margin to purchase a unit of capital. Bai, Hsieh, and Qian (2006) estimate the return to capital in China during the period of 1978-2005, considering different capital concepts and various depreciation rates. By making a comparative study of the regression method, the capital market approach, and the estimation with national account data, it's easy to see that the first one can only estimate the average return to capital during a certain period, however, cannot explain its change over time; the second one cannot be widely used because it's inappropriate for a developing country like China; while the third one, which uses macro data to calculate the aggregate return to capital, is more reasonable for estimating return to capital in different economies, particularly when the System of National Accounts 1993 has been widely used.

Many other papers have also reported estimates of investment efficiency in China[4]. however, we are not aware of any study that research into the trend of return to capital. For these considerations, this paper estimates the return to capital in China, Japan and the United States, studies key factors that affect return to capital, and investigates into the changes of key factors, hoping to reveal the trend of return to capital and future investment climate in China, which, we are not aware of any earlier studies.

[4] For example, Zhang (2005), Qin and Song (2003), Wang and Fan (2000)

# 3. Estimates of Return to Capital

## 3.1 Methodology

As discussed, methods that one could make use to estimate the aggregate return to capital include, firstly, using the return to capital in the capital market to estimate that of the aggregate economy[5], which, however, is only appropriate for a country that with a well-developed capital market and inappropriate for a developing country like China; secondly, regressing output on capital stock, which, however, might omit variables that affect capital stock and aggregate output and thus lead to biased estimates of the return to capital, more importantly, the return to capital estimated from this approach does not change over time.

A third method, which will be employed in this paper, uses the data on labor's share in total income, capital-output ratio where both capital and output are measured at market prices, depreciation rate, growth rate of investment goods deflator, and growth rate of GDP deflator to estimate the aggregate return to capital by considering a transaction by a firm, a price taker, at the margin to purchase a unit of capital[6]. The real return from this transaction is:

$$r(t) = \frac{P_Y(t) MPK_j(t)}{P_{K_j}(t)} - \delta_j - \hat{P}_Y(t) + \hat{P}_{K_j}(t) \quad \ldots\ldots \textbf{(1)}$$

Where,

$r(t)$: The real rate of return to capital;

$P_Y(t)$: The price of the output;

$P_{K_j}(t)$: The price of capital j;

$MPK_j(t)$: The marginal physical product of capital j;

$\delta_j$: The depreciation rate of capital j;

$\hat{P}_Y(t)$: The growth rate of $P_Y(t)$;

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5 Xin, Lin, and Yang (2007) estimates the return to capital investment in China using data of listed companies

6 This methodology originates from the Hall-Jorgenson rental price equation and has been used in Bai, Hsieh, and Qian (2006).

$\hat{P}_{K_j}(t)$ : The growth rate of $P_{K_j}(t)$ .

This methodology is simple and straightforward because it only bases upon one assumption that the firm takes the output price as given. More importantly, the methodology has nothing to do with the economic structure and thus can be used to estimate the return to capital in China, the emerging market economy; those of Japan and the United States, the advanced economic entities. However, it's not likely that one could observe the marginal physical product of capital, which, luckily, can be inferred from data on labor's share. Note that labor's share in total income equals to total wages over aggregate output, thus, the share of capital in total income is:

$$\alpha(t) = 1 - \frac{W(t)L(t)}{P_Y(t)Y(t)} \quad \ldots\ldots \textbf{(2)}$$

Where $W(t)$ is wage and $L(t)$ is employment.

Additionally, the share of payments of capital can be given by:

$$\alpha(t) = \frac{\sum_j P_Y(t)MPK_j(t)K_j(t)}{P_Y(t)Y(t)}$$

$$= \frac{\sum_j \frac{P_Y(t)MPK_j(t)}{P_{K_j}(t)} K_j(t)P_{K_j}(t)}{P_Y(t)Y(t)}$$

Substituting equation (1) into $\alpha(t)$ we get:

$$\alpha(t) = \frac{\sum_j \left( r(t) + \delta_j + \hat{P}_Y(t) - \hat{P}_{K_j}(t) \right) K_j(t)P_{K_j}(t)}{P_Y(t)Y(t)}$$

$$= \frac{\sum_j \left( r(t) + \hat{P}_Y(t) \right) K_j(t)P_{K_j}(t) + \sum_j \left( \delta_j - \hat{P}_{K_j}(t) \right) K_j(t)P_{K_j}(t)}{P_Y(t)Y(t)}$$

$$= \frac{\left( r(t) + \hat{P}_Y(t) \right) K(t)P_K(t) + K(t)P_K(t) \left( \frac{\sum_j \delta_j K_j(t)P_{K_j}(t)}{K(t)P_K(t)} - \frac{\sum_j \hat{P}_{K_j}(t)K_j(t)P_{K_j}(t)}{K(t)P_K(t)} \right)}{P_Y(t)Y(t)}$$

$$= \frac{K(t)P_K(t)\left(r(t) + \hat{P}_Y(t) + \delta(t) - \hat{P}_K(t)\right)}{P_Y(t)Y(t)} \quad \ldots\ldots \textbf{(3)}$$

Where,

$K(t)P_K(t) = \sum_j K_j(t)P_{K_j}(t)$: The aggregate produced assets;

$\hat{P}_K(t) = \sum_j \frac{K_j(t)P_{K_j}(t)}{K(t)P_K(t)} \hat{P}_{K_j}(t)$: The growth rate of the investment goods deflator;

$\delta(t) = \sum_j \frac{K_j(t)P_{K_j}(t)}{K(t)P_K(t)} \delta_j$: The depreciation rate;

From equation (3) we can get the real return to capital as:

$$r(t) = \frac{\alpha(t)}{K(t)P_K(t) \big/ P_Y(t)Y(t)} + \left(\hat{P}_K(t) - \hat{P}_Y(t)\right) - \delta(t) \quad \ldots\ldots \textbf{(4)}$$

Substituting equation (2) into equation (4), we get:

$$r(t) = \frac{1 - \frac{W(t)L(t)}{P_Y(t)Y(t)}}{K(t)P_K(t) \big/ P_Y(t)Y(t)} + \left(\hat{P}_K(t) - \hat{P}_Y(t)\right) - \delta(t) \quad \ldots\ldots \textbf{(5)}$$

Equation (5) is the formula that we will make use to estimate the aggregate return to capital in China, Japan, and the United States. Note that we use the capital stock of produced assets, rather than the capital stock of fixed assets to calculate the capital-output ratio, and the reason is that produced assets, which include tangible fixed assets, inventories, and intangible fixed assets, seem to be better reflecting capital invested.

## 3.2 Data

### 3.2.1 China

For the GDP data in China, we get those for 1978-2006 from Chinese Statistical Yearbook 2007, and those for 1953-1977 from Chinese Statistical Collection

(1949-2004). For the investment goods deflator, China's NBS released price indices for investment in fixed assets since 1990, for those that before 1990, we simply get them from Bai, Hsieh, and Qian (2006)[7]. As for labor's share, theoretically, it should be measured by aggregate compensations to employees over total income. However, the NBS of China only provides data that reveal the basic conditions of China's labor economy in industrial sectors, which does not necessarily reflect the true condition of the aggregate economy; luckily, we can estimate it from the provincial annual data on labor's share, weighted by the share of provincial GDP in the aggregate GDP.

To generate the capital stock in China, we have to use the perpetual inventory method (PIM), of which the formula is:

$$K_t = \sum_{\tau=0}^{d-1} w_\tau * I_{t-\tau} \quad \text{.....} \ \mathbf{(6)}$$

Where,

$K_t$ is the capital stock at time t;

$d$ is the service life of the investment goods;

$I_{t-\tau}$ is the constant value of the investment goods invested $\tau$ years before;

$w_\tau$ is the weight of the investment goods invested $\tau$ years before.

According to the formula, we can easily see that the application of PIM requires estimates and assumptions on three parameters: 1) service life of the investment goods, 2) depreciation method, and 3) constant price of capital invested. For the capital stock in China, we mainly have to consider two kinds of investment goods, including 1) construction and installation and 2) machinery and equipment. According to the estimates in Wang and Wu (2003), the useful life of construction and installation is 38 years and that of machinery and equipment is 12 years. As for depreciation method, this paper employs the declining-balance method of depreciation, which provides gradually decreasing depreciation charges in the service life of the asset and thus might provide a more realistic reflection of the actual depreciation. Therefore, the

[7] Bai, Hsieh, and Qian (2006) assumes that the price of structures from 1978-1989 equals to the deflator of value added in the construction industry, and that of machinery and equipment equals to the output price deflator of the domestic machinery and equipment industry; for that before 1978, Bai, Hsieh, and Qian (2006) assumes it as the growth rate of the aggregate price of fixed capital formation

depreciation rate of construction and installation is 8% and that of machinery and equipment is 24%[8].

In China, the series that being frequently used to measure the annual capital invested is the "investment in fixed assets", which is disaggregated into different types of investment[9]. However, Xu (2000), Bai, Hsieh, and Qian (2006) argue that the widely used statistics might not provide an accurate estimate of the aggregate investment in China because on the one hand, the series include value of purchased land and expenditure on used machinery and preexisting structures, which should not be regarded as part of reproducible capital stock and thus might lead to bias estimates of the change in China's capital stock; on the other hand, the statistics only count large investment projects, which will inevitably underestimate the aggregate investment.

To get around these problems, many researchers recommend another statistics, the "gross fixed capital formation" as an alternative to value the change of capital stock. The reasons are that on the one hand, the statistics has subtracted the value of land sales and the expenditure on preexisting machinery and equipments; on the other hand, the statistics has added expenditure on small-scale investment projects. The main limitation of "gross fixed capital formation" is that it is not disaggregated into different types of investment, to cover this shortage, we assume that the share of the two types of capital in gross fixed capital formation are the same as those for investment in fixed asset[10]. Note that we include inventories in the capital stock because inventories are also important parts of produced assets[11].

### 3.2.2 Japan

The Economic and Social Research Institute (ESRI), which is the producer of the Japanese national account in Japan Statistical Yearbook, publishes several estimates for gross domestic product. The national accounts of Japan Statistical Yearbook 2009

[8] In China, the residual value rate ranges from 3% to 5%, in this paper we use 4% as the residual value rate.
[9] Specifically, it is disaggregated into investment in construction and installation and purchase of equipment and instruments
[10] The data from 1953 to 1977 are from Hsieh and Li (1999), data from 1978 to 2004 are from Bai, Hsieh, and Qian (2006), data from 2005 to 2006 are from China Statistical Yearbook 2007
[11] We initialize the capital stock of 1952 as the ratio of investment in 1953 to the sum of the average growth rate of investment in 1953-1958 and the depreciation rate

provide data on aggregate output for calendar year of 1965-2006, whereas the national accounts of Historical Statistics of Japan provide data on gross domestic products for 1980-2003 under 1993 System of National Accounts (93SNA) and those for 1955-1998 under 1968 System of National Accounts (68SNA). In this paper, we use the data of aggregate output in Japan Statistical Yearbook 2009 for 1965-2006, and the data in Historical Statistics of Japan for 1955-1964. As for the compensation to employees, we use the estimates in the national accounts of Japan Statistical Yearbook 2009 for 2003-2006, the data in the national accounts that under 93SNA for 1980-2002, and those under 68SNA for 1955-1979.

One of the main estimates for capital stock in Japan Statistical Yearbook is net capital stock (NCS), which covers buildings, structures, transport equipment, machinery and etc. Another one is gross capital stock of private enterprises (GCSPE), which covers all fixed assets, excluding residential buildings owned by private corporations and unincorporated enterprises and fixed assets owned by private non-profit institutions. The main limitation with NCS is that it is only disaggregated into six categories for tangible asset, which consists of 1) dwellings, 2) other buildings, 3) other structures, 4) transport equipment, 5) other machinery and equipment, and 6) cultivated assets. As indicated by Erwin Diewert, the current asset classification is too aggregated to fully satisfy research needs as high and low depreciation assets are bundled together in some of the classifications. However, the GCSPE, which is frequently used as the main data source for analysis of production by industry, is not appropriate to be used as a measure of productive capacity because GCSPE does not have asset categories. Moreover, GCSPE only counts the capital stock for private enterprises, which does not provide an appropriate measure for the capital stock of the aggregate economy. Based upon the above analysis, we decide to use NCS as the capital stock of Japan in this paper, adding the inventories.

According to the ESRI, depreciation in NCS is based on geometric method for dwellings, transport equipment, etc. The residual value rate is 50% for cultivated asset and 10% for other assets. We can generate the corresponding depreciation rate as following and compute the aggregate depreciation rate as a weighted average of depreciation rates by types of assets, using the capital stock shares as the weights.

**Table 1: Depreciation Rates Used in Japan Statistical Yearbook (by Types of Assets)**

| | Service Life | Depreciation rate |
|---|---|---|
| Dwellings | 28.0 | 7.9 |
| Other buildings | 37.4 | 6 |
| Other structures | 33.7 | 6.6 |
| Transportation equipment | 7.6 | 26.2 |
| Other machinery and equipment | 10.6 | 12.1 |
| Cultivated assets | 5.4 | 9.9 |

*Source: Koji Nomura and Tadao Futakami (2005)*

### 3.2.2 The United States

In the US Economic Accounts, the US Bureau of Economic Analysis (BEA) provides data for current-dollar and “real” GDP starting from 1929 to 2008. BEA also provides series on compensation to employees for the same period, which includes wages and salary and supplement to wage and salary. The US BEA mainly disaggregates fixed assets into private equipment and software, private nonresidential structures, residential structures, durable goods owned by consumers, and government-owned fixed assets. Like China and Japan, the US used geometric depreciation patterns for most assets types. The US BEA determined the geometric rate for specific types of assets by dividing the appropriate declining-balance rate for each asset by the asset’s assumed service life. The declining-balance rates used by BEA are primarily derived from estimates made by Hulten and Wykoff, who divided assets into three major types: Type A, assets that with extensive data for estimating geometric rates of depreciation; type B, assets that with limited studies or other relevant data to support estimates of the rate of declining balance; and type C, assets that with no data[12]. In this paper, we don’t have to conduct in-depth research into the depreciation rates for different types of assets in the US as the US BEA has provided data series on capital stock as well as depreciation in the National Economic Accounts. To get the average depreciation rate, we simply have to divide the depreciation by the capital stock.

## 3.3 Return to Capital in China, Japan, and the United States

With the above-mentioned data in hand, we can estimate return to capital from

[12] This information is primarily extracted from “BEA Depreciation Estimates” at the BEA website

equation (5). In table 2 we provide our estimates of return to capital in China and list the variables that used to calculate the return to capital in the country, in table 3 we provide our estimates of return to capital in Japan and list the variables that used to calculate the return to capital in the country, and in table 4 we provide our estimates of return to capital in the United States and list the variables that used to calculate the return to capital in the country.

**Table 2: Variables and Return to Capital in China (%)**

| Year | Labor's share | Capital output ratio | Depreciation Rate | Growth of Investment Deflator | Growth of GDP Deflator | Return to Capital |
|---|---|---|---|---|---|---|
| 1978 | 49.67 | 1.39 | 12.10 | 0.93 | 1.92 | 23.17 |
| 1979 | 51.38 | 1.37 | 11.97 | 2.15 | 3.58 | 22.07 |
| 1980 | 51.15 | 1.35 | 11.82 | 4.95 | 3.78 | 25.41 |
| 1981 | 52.68 | 1.44 | 11.43 | 1.78 | 2.25 | 20.98 |
| 1982 | 53.57 | 1.45 | 11.06 | 2.34 | -0.21 | 23.62 |
| 1983 | 53.54 | 1.43 | 10.82 | 3.76 | 1.04 | 24.44 |
| 1984 | 53.68 | 1.33 | 10.67 | 4.80 | 4.96 | 23.92 |
| 1985 | 52.90 | 1.24 | 10.69 | 8.62 | 10.24 | 25.77 |
| 1986 | 52.82 | 1.31 | 10.86 | 7.52 | 4.70 | 27.91 |
| 1987 | 52.53 | 1.33 | 10.81 | 6.98 | 5.17 | 26.60 |
| 1988 | 51.72 | 1.27 | 10.84 | 12.50 | 12.10 | 27.49 |
| 1989 | 51.51 | 1.41 | 10.88 | 9.55 | 8.55 | 24.58 |
| 1990 | 53.36 | 1.48 | 11.00 | 7.31 | 5.80 | 21.96 |
| 1991 | 50.03 | 1.44 | 10.91 | 9.05 | 6.87 | 26.09 |
| 1992 | 50.09 | 1.35 | 10.79 | 15.52 | 8.20 | 33.37 |
| 1993 | 50.37 | 1.31 | 10.72 | 29.35 | 15.16 | 41.47 |
| 1994 | 51.11 | 1.38 | 10.65 | 10.25 | 20.63 | 14.29 |
| 1995 | 52.56 | 1.37 | 10.74 | 4.97 | 13.71 | 15.25 |
| 1996 | 52.80 | 1.39 | 10.71 | 4.51 | 6.43 | 21.42 |
| 1997 | 52.89 | 1.47 | 10.61 | 2.12 | 1.52 | 22.01 |
| 1998 | 53.12 | 1.57 | 10.61 | 0.02 | -0.89 | 20.23 |
| 1999 | 52.42 | 1.64 | 10.59 | -0.15 | -1.27 | 19.59 |
| 2000 | 51.48 | 1.63 | 10.59 | 1.60 | 2.03 | 18.75 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2001 | 51.46 | 1.65 | 10.56 | 0.70 | 2.05 | 17.52 |
| 2002 | 50.92 | 1.67 | 10.55 | 0.37 | 0.60 | 18.62 |
| 2003 | 49.62 | 1.65 | 10.55 | 3.09 | 2.59 | 20.48 |
| 2004 | 45.51 | 1.63 | 10.54 | 6.86 | 6.93 | 22.83 |
| 2005 | 41.40 | 1.71 | 10.53 | 1.42 | 4.14 | 21.00 |
| 2006 | 40.61 | 1.72 | 10.65 | 1.20 | 3.24 | 21.82 |

*Source: China Statistical Yearbook, various years, and author's calculation*

**Table 3: Variables and Return to Capital in Japan (%)**

| Year | Labor's share | Capital output ratio | Depreciation Rate | Growth of Investment Deflator | Growth of GDP Deflator | Return to Capital |
|---|---|---|---|---|---|---|
| 1956 | 41.55 | 1.71 | 10.34 | 14.39 | 6.22 | 31.95 |
| 1957 | 40.81 | 1.54 | 10.00 | 11.59 | 7.16 | 32.79 |
| 1958 | 42.91 | 1.67 | 9.92 | -5.64 | -0.91 | 19.46 |
| 1959 | 42.47 | 1.56 | 9.92 | 1.57 | 5.50 | 23.15 |
| 1960 | 40.48 | 1.29 | 9.76 | 4.95 | 9.48 | 31.76 |
| 1961 | 39.53 | 1.17 | 9.83 | 7.96 | 10.21 | 39.43 |
| 1962 | 41.90 | 1.17 | 9.93 | 0.00 | 5.55 | 34.09 |
| 1963 | 42.34 | 1.24 | 10.10 | 0.00 | 7.18 | 29.03 |
| 1964 | 42.44 | 1.19 | 10.07 | 2.19 | 6.85 | 33.66 |
| 1965 | 44.12 | 1.22 | 10.04 | -0.53 | 13.94 | 21.48 |
| 1966 | 43.96 | 1.21 | 10.00 | 3.76 | 5.34 | 34.86 |
| 1967 | 43.12 | 1.15 | 9.92 | 4.92 | 5.50 | 39.09 |
| 1968 | 42.43 | 1.12 | 9.94 | 2.22 | 5.83 | 37.74 |
| 1969 | 42.51 | 1.13 | 10.11 | 2.66 | 4.93 | 38.59 |
| 1970 | 43.49 | 1.11 | 10.18 | 4.47 | 6.87 | 38.28 |
| 1971 | 46.86 | 1.21 | 10.39 | 1.35 | 5.40 | 29.32 |
| 1972 | 47.65 | 1.31 | 10.52 | 3.56 | 5.60 | 27.44 |
| 1973 | 49.05 | 1.25 | 10.30 | 16.31 | 12.71 | 34.17 |
| 1974 | 52.15 | 1.31 | 10.17 | 24.72 | 20.81 | 30.38 |
| 1975 | 55.00 | 1.64 | 10.16 | 3.85 | 7.18 | 13.94 |
| 1976 | 55.24 | 1.83 | 9.99 | 4.84 | 8.01 | 11.30 |
| 1977 | 55.38 | 1.79 | 9.76 | 4.76 | 6.75 | 13.16 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1978 | 54.34 | 1.86 | 9.60 | 2.85 | 4.60 | 13.23 |
| 1979 | 54.19 | 1.87 | 9.45 | 6.68 | 2.75 | 19.01 |
| 1980 | 53.84 | 1.88 | 9.27 | 8.51 | -1.08 | 24.81 |
| 1981 | 54.13 | 2.04 | 9.35 | 1.74 | 4.52 | 10.33 |
| 1982 | 54.50 | 2.22 | 9.27 | 1.18 | 1.76 | 10.65 |
| 1983 | 55.10 | 2.24 | 9.24 | 0.11 | 1.71 | 9.16 |
| 1984 | 54.62 | 2.22 | 9.22 | 1.16 | 2.48 | 9.94 |
| 1985 | 53.11 | 2.11 | 9.26 | 0.73 | 3.01 | 10.65 |
| 1986 | 52.89 | 2.11 | 9.33 | -0.83 | 1.66 | 10.51 |
| 1987 | 52.57 | 2.09 | 9.37 | -0.73 | -0.36 | 12.92 |
| 1988 | 51.72 | 1.99 | 9.34 | 0.32 | 1.00 | 14.19 |
| 1989 | 51.48 | 1.95 | 9.37 | 1.89 | 2.32 | 15.06 |
| 1990 | 51.68 | 1.92 | 9.38 | 2.89 | 2.99 | 15.62 |
| 1991 | 52.49 | 2.01 | 9.42 | 2.20 | 2.94 | 13.43 |
| 1992 | 52.82 | 2.14 | 9.42 | 1.27 | 1.63 | 12.26 |
| 1993 | 53.55 | 2.28 | 9.42 | -0.19 | 0.53 | 10.27 |
| 1994 | 54.35 | 2.35 | 9.36 | -1.55 | 3.09 | 5.40 |
| 1995 | 54.51 | 2.37 | 9.26 | -1.48 | -0.50 | 8.97 |
| 1996 | 54.22 | 2.36 | 9.25 | -1.18 | -0.57 | 9.52 |
| 1997 | 54.44 | 2.33 | 9.23 | 0.41 | 0.60 | 10.12 |
| 1998 | 55.01 | 2.46 | 9.27 | -1.56 | 0.03 | 7.45 |
| 1999 | 54.88 | 2.57 | 9.27 | -2.14 | -1.29 | 7.44 |
| 2000 | 54.68 | 2.52 | 9.23 | -1.23 | -1.73 | 9.23 |
| 2001 | 54.93 | 2.54 | 9.18 | -2.13 | -1.23 | 7.67 |
| 2002 | 54.30 | 2.60 | 9.15 | -2.05 | -1.55 | 7.94 |
| 2003 | 52.74 | 2.57 | 9.08 | -1.77 | -1.60 | 9.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2004 | 51.44 | 2.51 | 9.00 | -0.21 | -1.08 | 11.25 |
| 2005 | 51.51 | 2.49 | 9.02 | -0.07 | -1.23 | 11.58 |
| 2006 | 51.60 | 2.41 | 9.05 | 0.82 | -0.94 | 12.79 |

*Source: Japan Statistical Yearbook, various years, and author's calculation*

**Table 4: Variables and Return to Capital in the US (%)**

| Year | Labor's share | Capital output ratio | Depreciation Rate | Growth of Investment Deflator | Growth of GDP Deflator | Return to Capital |
|---|---|---|---|---|---|---|
| 1930 | 51.43 | 3.37 | 4.82 | 1.99 | -3.67 | 15.28 |
| 1931 | 52.03 | 3.47 | 4.63 | 0.56 | -10.36 | 20.14 |
| 1932 | 52.98 | 4.16 | 4.53 | -0.77 | -11.80 | 17.81 |
| 1933 | 52.48 | 4.60 | 4.84 | -1.19 | -2.68 | 6.99 |
| 1934 | 51.97 | 4.02 | 4.75 | -0.34 | 5.60 | 1.27 |
| 1935 | 51.02 | 3.67 | 4.79 | 0.37 | 1.98 | 6.94 |
| 1936 | 51.19 | 3.55 | 4.94 | 1.68 | 1.17 | 9.31 |
| 1937 | 52.23 | 3.41 | 4.91 | 1.89 | 4.31 | 6.68 |
| 1938 | 52.26 | 3.67 | 4.60 | 1.11 | -2.97 | 12.50 |
| 1939 | 52.17 | 3.50 | 4.63 | 1.87 | -0.91 | 11.81 |
| 1940 | 51.48 | 3.46 | 4.80 | 2.42 | 1.11 | 10.56 |
| 1941 | 51.14 | 3.16 | 5.57 | 3.88 | 6.69 | 7.10 |
| 1942 | 52.69 | 2.82 | 5.20 | 5.77 | 7.81 | 9.55 |
| 1943 | 55.19 | 2.56 | 5.57 | 5.79 | 5.38 | 12.37 |
| 1944 | 55.19 | 2.47 | 5.79 | 4.59 | 2.37 | 14.57 |
| 1945 | 55.27 | 2.63 | 6.46 | 1.84 | 2.65 | 9.76 |
| 1946 | 53.85 | 3.09 | 6.95 | 0.33 | 11.99 | -3.69 |
| 1947 | 53.24 | 3.26 | 6.88 | 1.58 | 10.89 | -1.82 |
| 1948 | 52.71 | 3.15 | 6.52 | 2.28 | 5.63 | 5.14 |
| 1949 | 53.05 | 3.22 | 5.83 | 2.76 | -0.18 | 11.68 |
| 1950 | 52.83 | 3.28 | 6.11 | 3.90 | 1.09 | 11.08 |
| 1951 | 53.46 | 3.49 | 5.71 | 4.09 | 7.18 | 4.54 |
| 1952 | 54.76 | 3.45 | 5.49 | 3.95 | 1.71 | 9.87 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1953 | 55.40 | 3.37 | 5.47 | 4.31 | 1.24 | 10.84 |
| 1954 | 54.99 | 3.49 | 5.63 | 3.70 | 0.95 | 10.03 |
| 1955 | 54.44 | 3.45 | 5.74 | 4.24 | 1.78 | 9.94 |
| 1956 | 55.91 | 3.54 | 5.87 | 3.65 | 3.46 | 6.77 |
| 1957 | 55.87 | 3.52 | 5.71 | 3.43 | 3.32 | 6.94 |
| 1958 | 55.57 | 3.58 | 5.77 | 2.65 | 2.30 | 6.99 |
| 1959 | 55.49 | 3.43 | 5.69 | 3.58 | 1.23 | 9.64 |
| 1960 | 56.34 | 3.40 | 5.72 | 3.22 | 1.40 | 8.93 |
| 1961 | 56.07 | 3.40 | 5.69 | 3.05 | 1.12 | 9.16 |
| 1962 | 55.87 | 3.30 | 5.69 | 3.54 | 1.36 | 9.86 |
| 1963 | 55.90 | 3.24 | 5.72 | 3.74 | 1.06 | 10.58 |
| 1964 | 55.86 | 3.20 | 5.80 | 4.08 | 1.53 | 10.56 |
| 1965 | 55.56 | 3.15 | 5.79 | 4.46 | 1.83 | 10.96 |
| 1966 | 56.18 | 3.12 | 5.88 | 4.53 | 2.85 | 9.83 |
| 1967 | 57.06 | 3.18 | 5.87 | 4.01 | 3.09 | 8.56 |
| 1968 | 57.62 | 3.19 | 5.99 | 4.10 | 4.27 | 7.14 |
| 1969 | 58.66 | 3.21 | 5.97 | 3.89 | 4.96 | 5.83 |
| 1970 | 59.43 | 3.30 | 5.95 | 3.17 | 5.29 | 4.22 |
| 1971 | 58.46 | 3.34 | 5.95 | 3.28 | 5.00 | 4.77 |
| 1972 | 58.56 | 3.34 | 5.86 | 3.73 | 4.34 | 5.92 |
| 1973 | 58.67 | 3.41 | 5.87 | 4.02 | 5.58 | 4.70 |
| 1974 | 59.35 | 3.72 | 5.92 | 3.10 | 9.03 | -0.93 |
| 1975 | 57.94 | 3.67 | 5.71 | 2.32 | 9.43 | -1.37 |
| 1976 | 58.04 | 3.59 | 5.79 | 2.75 | 5.78 | 2.87 |
| 1977 | 58.13 | 3.61 | 5.91 | 3.26 | 6.35 | 2.60 |
| 1978 | 58.23 | 3.62 | 5.96 | 3.67 | 7.03 | 2.20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1979 | 58.55 | 3.74 | 5.99 | 3.59 | 8.29 | 0.41 |
| 1980 | 59.22 | 3.90 | 5.91 | 2.69 | 9.07 | -1.82 |
| 1981 | 58.37 | 3.81 | 5.83 | 2.54 | 9.39 | -1.76 |
| 1982 | 59.17 | 3.84 | 5.71 | 1.91 | 6.10 | 0.71 |
| 1983 | 57.76 | 3.66 | 5.61 | 2.39 | 3.96 | 4.36 |
| 1984 | 57.35 | 3.49 | 5.74 | 3.29 | 3.75 | 6.03 |
| 1985 | 57.46 | 3.42 | 5.87 | 3.48 | 3.04 | 7.00 |
| 1986 | 57.63 | 3.43 | 5.99 | 3.39 | 2.20 | 7.54 |
| 1987 | 58.06 | 3.43 | 6.01 | 3.14 | 2.73 | 6.62 |
| 1988 | 58.15 | 3.39 | 6.06 | 3.02 | 3.41 | 5.87 |
| 1989 | 57.37 | 3.34 | 6.15 | 2.83 | 3.78 | 5.66 |
| 1990 | 57.56 | 3.31 | 6.12 | 2.52 | 3.86 | 5.37 |
| 1991 | 57.51 | 3.27 | 6.13 | 1.80 | 3.50 | 5.14 |
| 1992 | 57.41 | 3.23 | 6.22 | 1.91 | 2.30 | 6.59 |
| 1993 | 57.15 | 3.23 | 6.21 | 2.21 | 2.31 | 6.97 |
| 1994 | 56.58 | 3.23 | 6.30 | 2.41 | 2.13 | 7.45 |
| 1995 | 56.74 | 3.23 | 6.20 | 2.59 | 2.05 | 7.71 |
| 1996 | 56.22 | 3.20 | 6.19 | 2.88 | 1.90 | 8.46 |
| 1997 | 56.19 | 3.17 | 6.20 | 3.03 | 1.66 | 8.99 |
| 1998 | 57.44 | 3.17 | 6.21 | 3.32 | 1.11 | 9.42 |
| 1999 | 57.86 | 3.19 | 6.27 | 3.52 | 1.45 | 9.04 |
| 2000 | 58.95 | 3.20 | 6.33 | 3.52 | 2.18 | 7.83 |
| 2001 | 58.72 | 3.26 | 6.33 | 2.93 | 2.40 | 6.85 |
| 2002 | 58.23 | 3.30 | 6.13 | 2.62 | 1.75 | 7.39 |
| 2003 | 57.76 | 3.32 | 6.07 | 2.62 | 2.13 | 7.15 |
| 2004 | 57.01 | 3.42 | 6.14 | 2.69 | 2.87 | 6.26 |

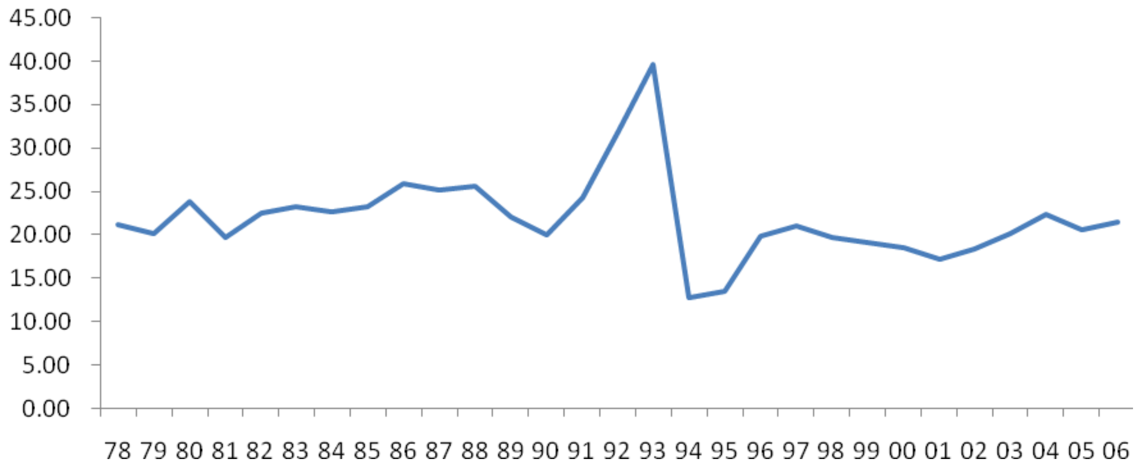
| | | | | | | |
|---|---|---|---|---|---|---|
| 2005 | 56.65 | 3.52 | 6.17 | 2.57 | 3.26 | 5.45 |
| 2006 | 56.46 | 3.57 | 5.71 | 2.71 | 3.22 | 5.99 |
| 2007 | 56.63 | 3.38 | 5.58 | 2.37 | 2.69 | 6.94 |

*Source: National Economic Accounts of the US Bureau of Economic Analysis, and author's calculation*

### 3.3.1 The Return to Capital in China

As shown in Figure 1, the return to capital in China fluctuates from 23.17% in 1978 to 21.82% in 2006, averaging as high as more than 20% during the last three decades, however, there was a drastic fluctuation in the return to capital in China between 1992 and 1994, with a sharp increase in 1993 and a rapid decline in 1994. The reason for the sharp increase in the return to capital in China in 1993 is that there was a sharp increase in the growth rate of investment goods deflator in 1993, which rose from 15.52% in 1992 to 29.35% in 1993; and the reason for the rapid drawdown in the return to capital in China in 1994 is that there was a rapid decline in the growth rate of investment goods deflator in 1994, which decreased from 29.35% in 1993 to 10.25% in 1994. The return to capital remains relatively stable from 1978 to 2006 except the typical fluctuations during 1993 and 1994, and averages at a higher level during 1978-1991 than that of the period after 1994.

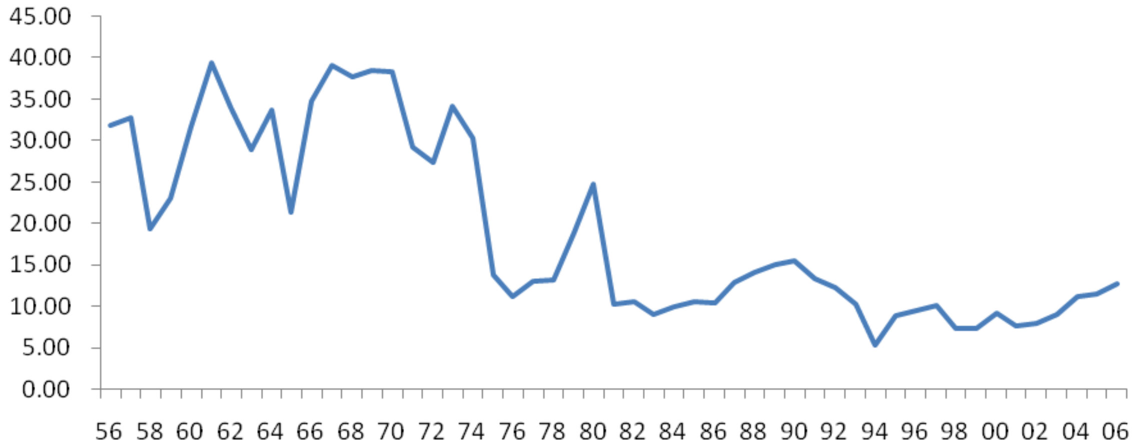
**Figure 1: Return to Capital in China (%)**




### 3.3.2 The Return to Capital in Japan

As shown in Figure 2, the return to capital in Japan was extremely volatile during the period of 1956 to 2006, with the highest return to capital at 39.43% in 1961 and the lowest return to capital at 5.4% in 1994. It's interesting to see that the return to capital in Japan has been significantly affected by the country's economic cycle: During the period of 1956 to 1974, which marks the rebuilding of Japan's lost industrial capacity and the country's economic booms; the return to capital in Japan was at the highest level, with an average return to capital above 31%. In the mid-1970s, Japan faced a severed economic challenge, the world oil crisis in 1973, which shocked the economy that badly depended on foreign petroleum. During this period, the return to capital sharply decreased from 30.38% in 1974 to 13.94% in 1975. Throughout the last five years in the 1970s, the return to capital in Japan fluctuated around 14%; in the mid-1980s, the return to capital in Japan began a period of increase that continued until the country entered a recessionary period in 1992. After the 1990s, the return to capital in Japan remained relatively stable however it was very low, with an average of 9%.

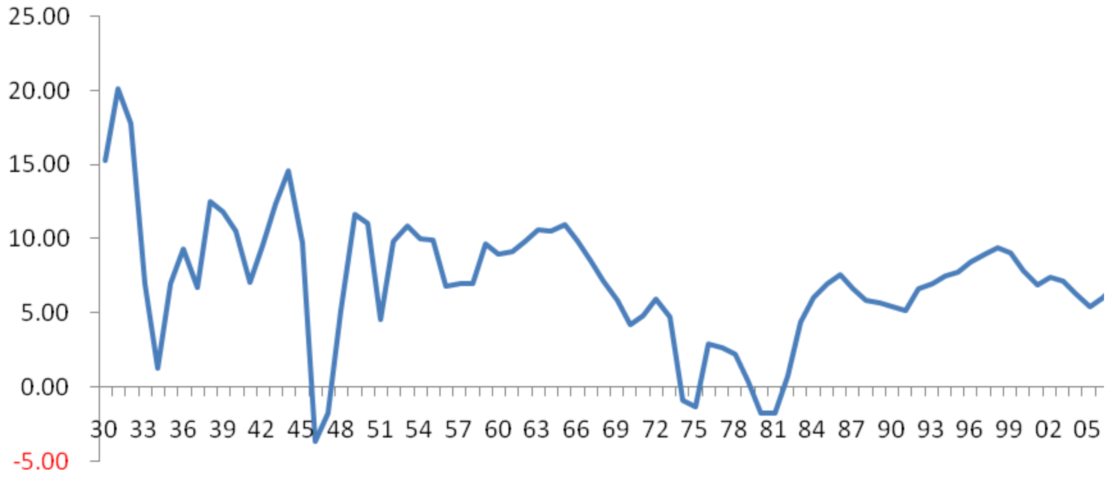
**Figure 2: Return to Capital in Japan (%)**




### 3.3.2 The Return to Capital in the United States

As shown in Figure 3, the return to capital in the United States fluctuates from around 15% after the Second World War to around 5% in the last decade. During late of the 1920s, the United States enjoyed a period of sustained prosperity, which was known as the roaring twenties, even in the first 3 years of the Wall Street Crash of 1929, the United States maintained the return to capital as high as about 15%, which, however, was mainly due to the negative growth rate of the GDP deflator. The Great Depression badly destroyed the economy of the United States and the return to capital in the country dropped to around 6% in the mid-1930s, however, the depression also led to the US government efforts to re-start the economy, and the return to capital during the period of 1935 to 1945 averaged around 10%. During the period of postwar prosperity, which started from 1945 to 1973, the return to capital in the US fluctuated from around 12% to around 4%, with an average around 8%. The oil crisis in 1973, which caused soaring inflation of the 1970s, badly hurt the US economy. The US government quickly response to the oil embargo but of limited effectiveness and the return to capital in the US averaged below 1% for the decade starting from 1974 to 1983. To stimulate the American economy after a recession in the early 1980s, Reagan introduced expansionary fiscal policies, which led to an economic recovery starting from 1983. And the return to capital in the US averaged around 6% continued till the Clinton administration. The six years span of 1994 and 2000 witnessed the emergence of a technology-driven "new economy", and the return to capital in the US during this period averaged above 7%. The US return to capital after 2000 remained relatively stable and averaged around 6%.

**Figure 3: Return to Capital in the US (%)**

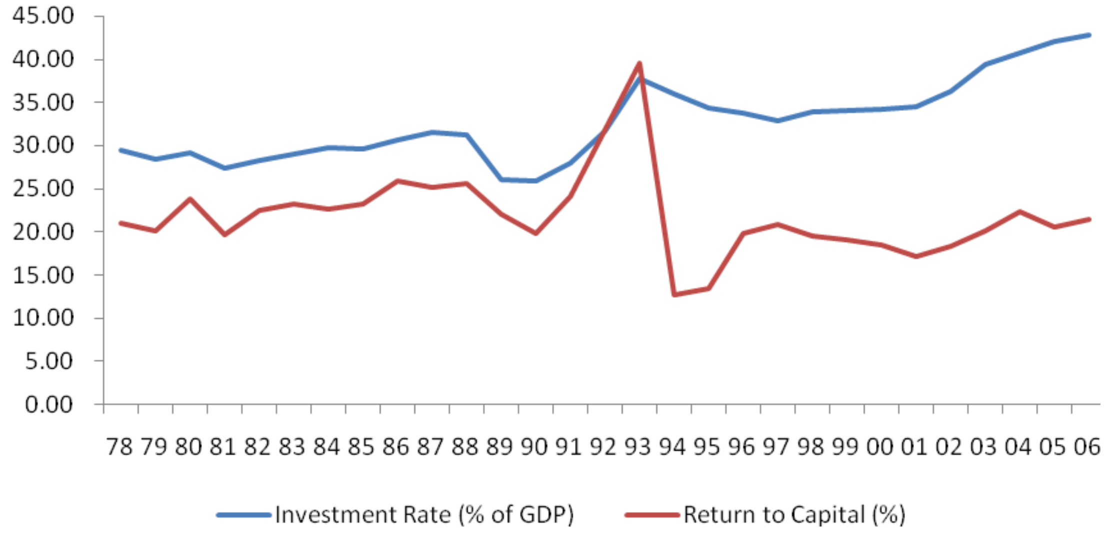



## 3.4 The Impacts of Return to Capital on Investment Rate

### 3.4.1 The Investment Rate in China

Figure 4 shows that investment rate in China increased from 29.46% in 1978 to 42.75% in 2006, in the meantime the return to capital in China fluctuated around as high as 22%. It is thus clear that the correlation between return to capital and investment rate is positive, and the reason that investment rate keep going up in China during the period of 1978 to 2006 is because the return to capital in China is at the highest level in the world, which spurs investors' willingness to invest in the country.

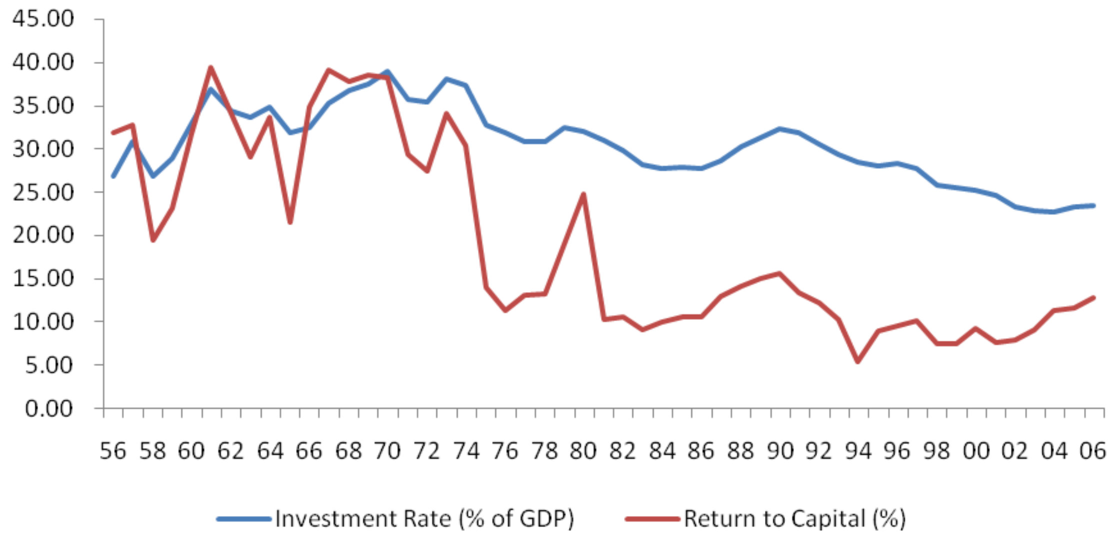
**Figure 4: Investment Rate in China (%)**




### 3.4.2 The Investment Rate in Japan

As show in Figure 5, investment rate in Japan increased from 26.80% in 1956 to 39.02% in 1970 and declined to 23.46% in 2006, with an average at 30.45% during the period of 1956 to 2006. During the period of 1956 to 1970, the return to capital in Japan increased from 31.95% in 1956 to 38.38% in 1970, averaged as high as 32.36%. After 1970, the return to capital in Japan dropped to 12.79% in 2006, averaged as low as 13.62%. The evidence from Japan indicates that investors are willing to invest more when the return to capital is high and invest less when the return to capital is low.

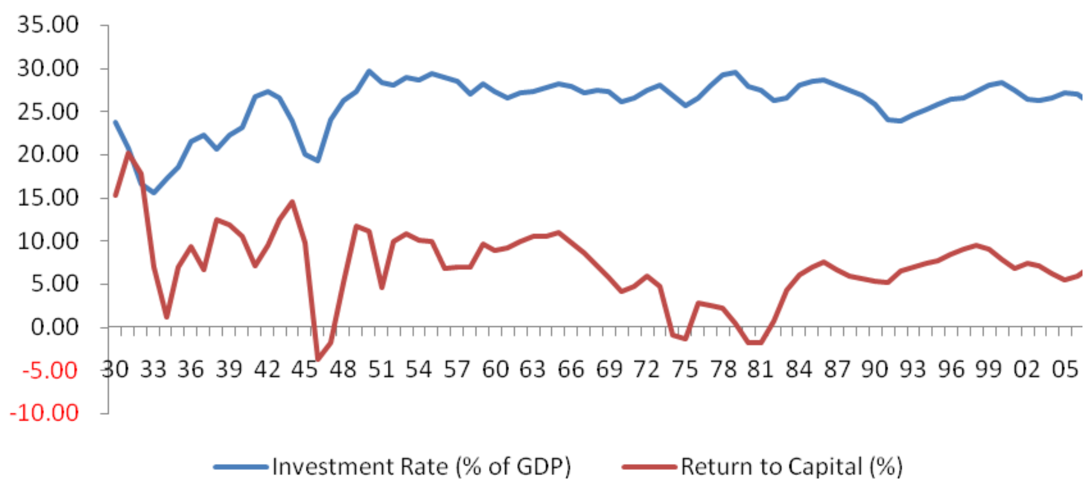
**Figure 5: Investment Rate in Japan (%)**



### 3.4.3 The Investment Rate in the United States

Figure 6 shows that investment rate in the United States experienced sharply decline in the early 1930s, the period that marked the Great Depression, and increased from 15.60% in 1933 to 29.68% in 1950, the year that marked the highest investment rate in the United States during the period of 1930 to 2007. After 1950, the investment rate in the US fluctuated between 24% and 30%, with an average around 27%. The return to capital in the United States, which also suffered a declined during the Great Depression period, increased from 1.27% in 1934 to 11.08% in 1950, with a drawdown in late 1940s just as the investment rate did. After 1950, the return to capital in the US remained relatively stable, however, it experienced a sharp decline in the 1970s because of the oil crisis, from when on it experienced slight increase and remained relatively stable again. It seems that the oil crisis, which badly declined the return to capital in the US, did not affect the investment rate in the country. The possible reason is that during the oil crisis, the government of the US brought many economic stimulus packages into effect, such as Deregulation and Reaganomics, which allowed and stimulated the private sector to invest in such sectors as energy, communications, transportation, and banking. The stimulus packages eventually helped stabilize the investment rate in the country despite the low level of aggregate return to capital.

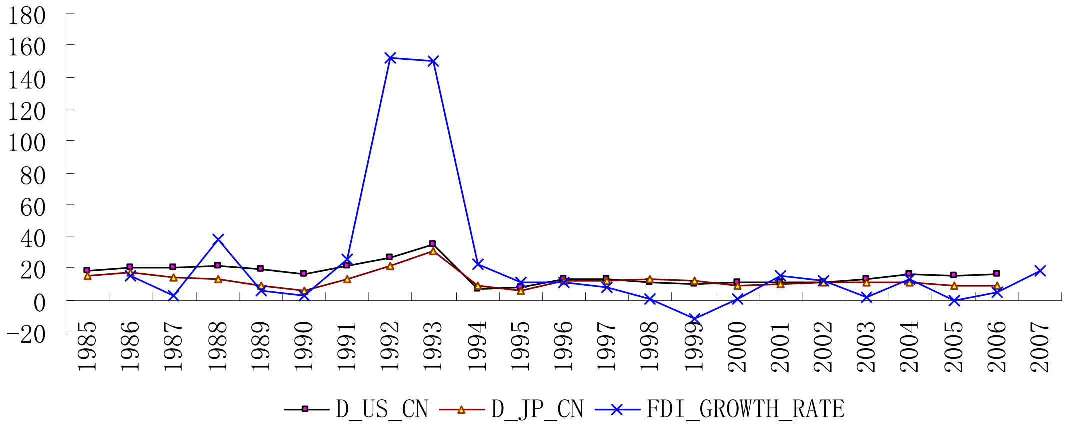
**Figure 6: Investment Rate in the US (%)**



## 3.5 The Impacts of Return to Capital on FDI

FDI plays an important role in the investment of the Chinese economy, and its surging level has contributed to the high investment rate in the country. It's undeniable that one important factor that affects cross boarder capital flow is the discrepancy of return to capital. Figure 7 shows the discrepancies of return to capital among China and the world's two largest capital export countries, Japan and the US, as well as the growth rate of FDI in China. We can see that the growth of FDI in China significantly increases when the discrepancies of return to capital among China, Japan and the US go up, which is especially evident during 1992 to 1993. The correlation coefficient between the growth rate of FDI and the discrepancy between the return to capital in China and Japan is as high as 0.83, much higher than that with the US.

**Figure 7: Discrepancy of Return to Capital and Growth Rate of FDI in China**



# 4. Factors that Affect Return to Capital

## 4.1 Marginal Return

### 4.1.1 Notation and Definition

**Marginal Return (MR):** The marginal return is the change in the aggregate return resulting from a marginal change in an individual factor. The marginal return of factor $i$, $MR_i$, equals,

$$MR_i = \frac{\partial r}{\partial f_i} \text{ ..... } \textbf{(7)}$$

Where,

$MR_i$, marginal return of factor $i$;

$r$, aggregate return;

$f_i$, factor $i$.

### 4.1.2 Estimates of Marginal Return

According to equation (5), we have:

$$r(t) = \frac{1 - \frac{W(t)L(t)}{P_Y(t)Y(t)}}{K(t)P_K(t) \big/ P_Y(t)Y(t)} + \left(\hat{P}_K(t) - \hat{P}_Y(t)\right) - \delta(t)$$

$$\Rightarrow r(t) = \frac{1-\beta(t)}{\varphi(t)} + \left(\hat{P}_K(t) - \hat{P}_Y(t)\right) - \delta(t) \text{ ..... } \textbf{(8)}$$

Where,

$\beta(t) = \frac{W(t)L(t)}{P_Y(t)Y(t)}$, is labor's share

$\varphi(t) = K(t)P_K(t) \big/ P_Y(t)Y(t)$, is capital-output ratio.

By taking partial derivative on return to capital with respect to each of the five factors, we have:

$$dr(t) = \frac{\partial r(t)}{\partial \beta(t)} d\beta(t) + \frac{\partial r(t)}{\partial \varphi(t)} d\varphi(t) + \frac{\partial r(t)}{\partial \hat{P}_K(t)} d\hat{P}_K(t) + \frac{\partial r(t)}{\partial \hat{P}_Y(t)} d\hat{P}_Y(t) + \frac{\partial r(t)}{\partial \delta(t)} d\delta(t) \text{ .. } \textbf{(8)}$$

Where,

$\frac{\partial r(t)}{\partial \beta(t)} = -\frac{1}{\varphi(t)}$, the marginal return of labor's share;

$\frac{\partial r(t)}{\partial \varphi(t)} = -\frac{1-\beta(t)}{\left(\varphi(t)\right)^2}$, the marginal return of capital-output ratio;

$\frac{\partial r(t)}{\partial \hat{P}_K(t)} = 1$, the marginal return of investment goods deflator;

$\frac{\partial r(t)}{\partial \hat{P}_Y(t)} = -1$, the marginal return of GDP deflator;

$\frac{\partial r(t)}{\partial \delta(t)} = -1$, the marginal return of depreciation rate.

$$\Rightarrow dr(t) = -\frac{1}{\varphi(t)} d\beta(t) - \frac{1-\beta(t)}{\left(\varphi(t)\right)^2} d\varphi(t) + d\hat{P}_K(t) - d\hat{P}_Y(t) - d\delta(t) \quad \text{..... } \textbf{(9)}$$

From equation 9, we can see that we only have to estimate marginal returns of labor's share and capital-output ratio in China, Japan, and the US as marginal returns of other factors are constant (1 for investment goods deflator, -1 for GDP deflator and depreciation rate).

As shown in Figure 8, the marginal return of labor's share in Japan decreased from -0.58 in 1956 to -0.9 in 1970, the reason is that the capital-output ratio in Japan during this period declined from 1.71 in 1956 to 1.11 in 1970. During the 1970s and early 1980s, the capital-output ratio in Japan increased from 1.21 in 1970 to 2.24 in 1983, which caused the marginal return of labor's share increased from -0.82 to -0.45. Afterwards, the marginal return of labor's share in Japan fluctuated around -0.44 and remained relatively stable. Compared with Japan, the US enjoyed relatively more stable marginal returns of labor's share during the period of 1930 to 2007. Figure 8 also shows that the marginal return of labor's share in the US averaged at -0.30, and that of Japan averaged at -0.58, while that of China averaged at -0.66.

**Figure 8: Marginal Return of Labor's Share**

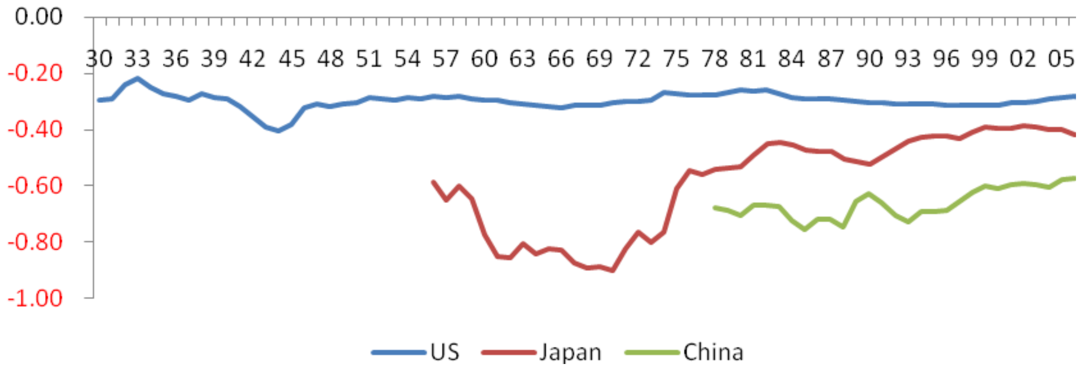



Figure 9 shows that the marginal return of capital-output ratio of Japan had a high volatility during the period of 1958 to the early 1980s, and remained relatively stable after mid-1980s. Compared with that of Japan, the marginal return of capital-output ratio in China and the United States remained relatively stable, however, that of China averaged at -0.22, lower than that of Japan which averaged at -0.19 and that of the United States which averaged at -0.04.

**Figure 9: Marginal Return of Capital-Output Ratio**

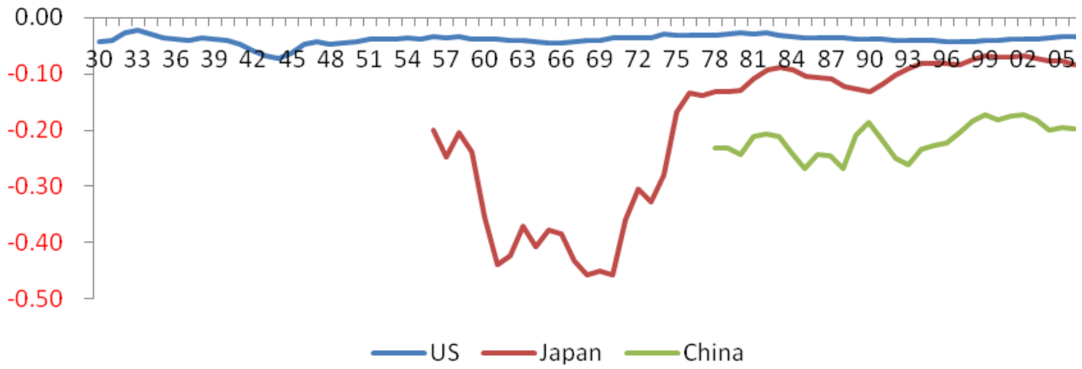



Figure 8 and Figure 9 together show that the marginal returns of labor's share and capital-output ratio are always negative, suggesting that the increase in labor's share and capital-output ratio will lead to a decrease in return to capital. In the long run, however, the marginal returns of labor's share and capital-output ratio on return to capital seem to converge to zero. The return to capital changes significantly when it is at a high level, and changes little when it is at a relatively lower level, this is why return to capital is able to remain stable after a sharp decline. In the short run, the change of marginal return originates from the change of labor's share and capital-output ratio, in the following section we will discuss how these factors change over time and how do they affect return to capital.

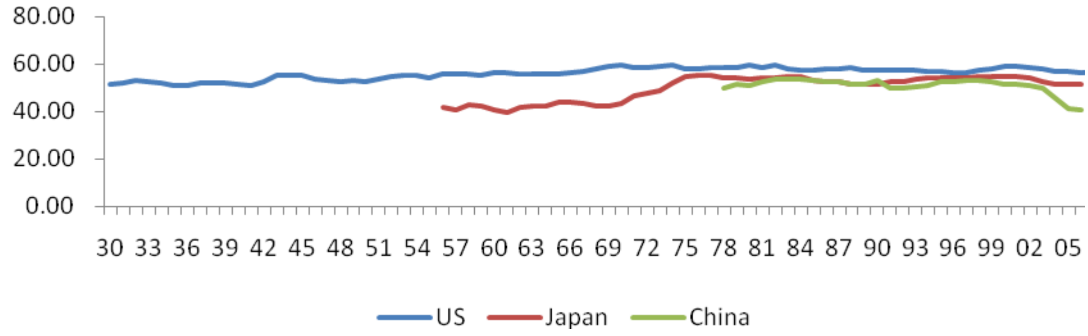
## 4.2 The Changes of Key Factors

### 4.2.1 The Change of Labor's Share

As shown in equation 10, the marginal return of labor's share is always negative, which means that return to capital decreases as labor's share increases. Figure 10 shows that the labor's share in Japan increased from 41.44% in 1956 to 51.6% in 2006, and that of the United States increased from 51.43% in 1930 to 56.63% in 2007, however, the labor's share in China decreased from 49.67% in 1978 to 40.61 in 2006. The labor's share in China is much lower than that of Japan and that of the United States, which is why the country's return to capital is higher than that of Japan and that of the United States. This is very intuitive, when labors get less compensation, capital will get more, which leads to a high return to capital.

The reason that China has a lower labor's share is because China is the manufacturing center, of which the labors get less pay compared with those that work in the service industry. Thanks to the abundant rural migrant workers who provide a steady flow of work force for the world's manufacturing hub, the labor's share in China decreased during the last two decades. In the future the workers in China will inevitably ask for more compensation, which will lead to an increase in labor's share in the country just as Japan and the Unites States did. The increase of labor's share will ultimately decrease the return to capital in the future. However, it seems that the labor's share in China will remain at a lower level for a couple of years compared with Japan and the United States because on the one hand, China is still a manufacturing economy where compensation to employees is naturally low, on the other hand, the bulks of rural migrant workers in the country will continue to provide a steady flow of work force.

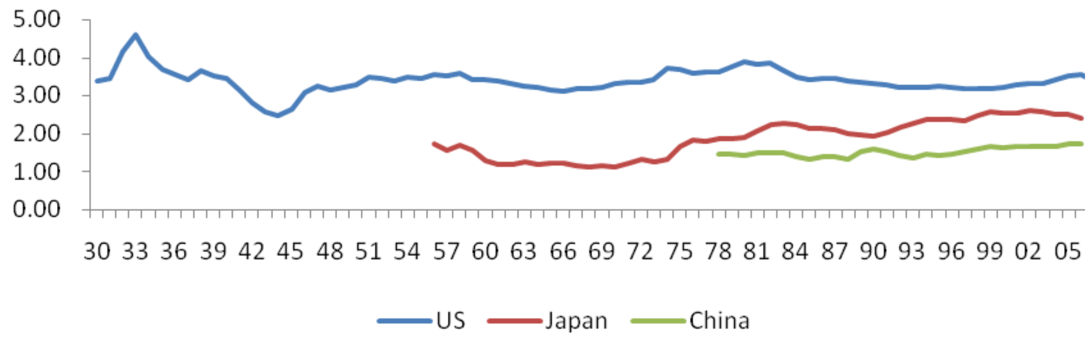
**Figure 10: Labor's Share in China, Japan, and the US (%)**




### 4.2.2 The Change of Capital-Output Ratio

Equation 9 shows that the marginal return of capital-output ratio is always negative, which means that return to capital decreases as capital-output ratio increases. As shown in Figure 11, the United States has the highest capital-output ratio compared with China and Japan, while China has the lowest capital-output ratio among the three countries. The capital-output ratio in the United States, which averaged around 3.4 during the period of 1930 to 2007, is much higher than that of Japan, which averaged around 1.86 during the period of 1956 to 2006. The capital-output ratio in China, which averaged as low as 1.52 during the period of 1978 to 2006, contributes to a relatively higher return to capital in the country compared with that of Japan and that of the United States.

**Figure 11: Capital-output Ratio in China, Japan, and the US (%)**




What is the economic meaning of a high capital-output ratio? Does it mean a low GDP, or imply a high capital stock? In the case of Japan and the United States, which are the two largest economic entities in the world, the answer should be a high capital stock. It's natural that Japan and the United States have attracted major investments during the 20th century, which leads to a high capital stock in the two countries. Figure 11 also shows that capital-output ratio in Japan increased from 1.71 in 1956 to 2.41 in 2006, while that of China just experienced a slight increase from 1.47 in 1978 to 1.74 in 2006. Although the capital-output ratio in the United States did not experience any remarkable change during the period of 1930 to 2007, it remained at a level as high as 3.4, which is much higher than that of China and that of Japan.

From the experience of Japan and the United States we can see that the capital stock in China will inevitably increase in the future, which might lead to an increase in capital-output ratio. The reason is that the high return to capital in China is likely to attract more investment, which will increase the capital stock in the country and lead to a high capital-output ratio. However, it seems that the capital-output ratio in China is not likely to experience significant increase in a short period of time because China has the world's third largest GDP and a fast growing economy. The relatively lower capital-output ratio in China compared with that of Japan and that of the United States will be likely to contribute to the highest return to capital in China among the three countries in the years ahead.

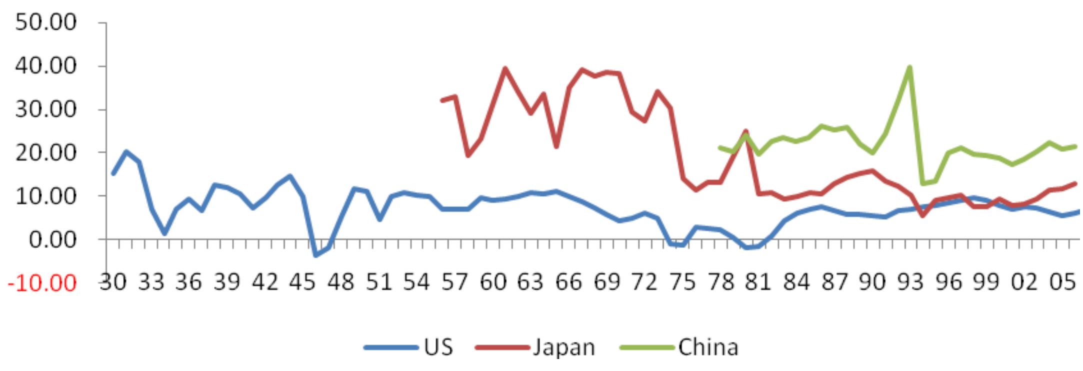
# 5. The Change of Return to Capital and Future Investment Climate in China

## 5.1 The Change of Return to Capital

### 5.1.1 Return to Capital Seems to Decline as the Development of Economy

As shown in Figure 12, the return to capital in Japan decreased from 31.95% in 1956 to 12.79% in 2006, while that of the United States decreased from 15.28% in 1930 to 6.94% in 2007, indicating that return to capital seems to decline from a higher level to a lower level in the long run. The reasons are that labor's share and capital-output ratio seem to increase as the development of economy, which lead to a decline in return to capital. The evidences from Japan and the United States indicate that the return to capital remains at a high level at the early stage of the economic booms, as the economic development, it experiences remarkable declines. This is why during 1965 to 1980, the period that marked the economic booms of Japan, the return to capital in Japan averaged above 28%. It is also why during the period of 1978 to 2006, the period that marked China's opening and reforming, the return to capital in China averaged as high as 21.9%.

**Figure 12: Return to Capital in China, Japan, and the US (%)**




### 5.1.2 The Return to Capital in China will remain higher than that of Japan and that of the United States in Years Ahead

The experiences from major developed countries show that the return to capital in China will inevitably decrease in the future because of the increase of labor's share and capital-output ratio. However, it seems that the return to capital in China will remain higher than that of Japan and that of the United States in years ahead because labor's share and capital-output ratio are still very low and are not likely to experience significant increase in the near future. Considering the experience from Japan, of which the return to capital becomes in line with that of the US after more than 40 years economic development, we can roughly conclude that China will still be able to enjoy a high return to capital for at least 10 years, or even much longer considering scale effect.

## 5.2 The Future Investment Climate in China

Although the return to capital in China averaged as high as 21.9% during the period of 1978-2006, it seems continue to be high for a couple of years because of the low labor's share and capital-output ratio in the country, indicating that the high investment rate in the country is likely to last for quite a few years. In the future, the return to capital in China will inevitably decrease because of the increase of labor's share and capital-output ratio, however, it seems continue to be higher than that of Japan and United States in years ahead because of the relatively lower labor's share and capital-output ratio. As the return to capital in China is significantly higher than those of other major countries, foreign capital will continue to flow into China, especially when China increasingly opens more sectors to foreign investors as part of its commitments to the WTO entry.

To analyze the dynamic relationship between investment rate and return to capital, a natural metric is to use the Vector Auto-Regression model (VAR). However, by using the VAR we found that return to capital goes up with right-handed screw, which does not coincide with the long term fact. A possible reason is that the labor market in China is not in equilibrium, which leads to the fact that when return to capital goes up, investment rate increases. Thus, this paper does not use VAR to study the impact of return to capital on investment rate. Instead, we infer the impacts from the experiences in Japan and the US.

## 5.3 FDI and Return to Capital in High-Tech Industries

The above discussions show that the remarkable discrepancy among return to capital in China, Japan and the United States contributes to the surging level of FDI in China. FDI not only flows into low-tech sectors, but also increasingly pours into high-tech industries, which include Computer & Communication, Life Sciences, Computer Integrated Manufacturing, and etc. According to the Report on Foreign Direct Investment in China (2003-2007), FDI in China increases by 13.3%, -0.5%, and 4.46% respectively in 2004, 2005, and 2006, while FDI in high-tech industries increases by 4.09%, 22.8%, and 32.64% respectively. FDI in high-tech industries accounted for 15% of the total FDI in China in 2003, increases to 21.6% in 2006. In terms of export, the high-tech products exported by foreign invested companies account for 77% of the total high-tech products export in 2003, increases to 88% in 2006, in the meantime, the high-tech products exported by foreign invested companies increase by 64.8%, 57.6%, 32.8%, and 29.1% respectively during 2003 to 2006, while that of total high-tech products export increase by 76%, 38.9%, 31.8%, and 28.9%. From these figures we can easily see that the structure of FDI in China has experienced significant change during 2003-2006, and FDI in high-tech industries also experiences significant increase.

In this paper we also estimate the return to capital of different industries based upon the firm-level data of the industrial enterprises released by NBS. Interestingly, the return to capital in all of the sectors seems to converge during the period of 2003 to 2007, with an average of 20% in 2007. A FDI flow into high-tech industries implies that foreign capitals are more competitive in these sectors.

## 6. Summary and Conclusion

By estimating the aggregate return to capital in China, Japan, and the United States, this paper attempts to study the impacts of return to capital on investment rate, hoping to reveal the unusual high investment rate and surging level of FDI in China. Our findings show that the return to capital in China has maintained at a level as high as 21.9% during the last three decades, even higher than that of Japan and that of the US above 10%. In the meantime, the investment rate in China increases from 29.46% in 1978 to 42.75% in 2006, much higher than that of Japan and that of the US. We also find that investment rate is always high when return to capital is high and low when return to capital is low, indicating that investment rate is significantly affected by return to capital. The reason that China has a higher investment rate during the last thirty years is precisely because China has a higher return to capital.

Our analysis also shows that return to capital remarkably affected by the economic cycle, however, it follows a decreasing trend in the long run because it is affected by labor's share and capital-output ratio. At the early stage of economic booms, labor's share and capital-output ratio are always low, as the development of economy, labor's share and capital-output ratio will increase, leading to a decline in return to capital. The reasons that China has a higher return to capital than that of Japan and that of the United States are because China has a lower labor's share and capital-output ratio. In the long run, the increase of labor's share and capital-output ratio will inevitably decline the return to capital in China, however, our analysis shows that China will continue to top in return to capital because labor's share and capital-output ratio in China are still very low, and are not likely to experience significant increase in the near future. The experiences from developed countries also show that depreciation rate will also decline as the economic development, which will contribute to a higher return to capital.

Through analyzing the return to capital in China, Japan and the United States we find that return to capital doesn't converge during the last 30 years, which implies that the discrepancies among return to capital in China, Japan and the United States will continue to last for a couple of years, indicating that FDI will continuously flows into China, the country that has a higher return to capital.

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**投资率与 FDI——基于中美日三国投资回报率的对比分析**

孙文凯 1 杨秀科 2 肖耿 3

(1 中国人民大学；2 北京大学；3 清华大学)

## 摘 要

本文通过对中国、美国和日本资本回报率及其影响因素的计算，分析中国为何拥有如此之高的国内投资率和快速增长的 FDI，以及今后投资率和 FDI 的可能走势。在过去十几年，中国的投资率一直在增长，吸引 FDI 也以年均高达 19.97%的速度增加，增长速度高于其他大国。FDI 的不断涌入表明国际资本正不断聚集于中国这个世界第三大经济体。

本文有几个发现：（1）中国居高不下的投资率是由于中国具有非常可观的投资回报。在美国和日本总体投资回报率很高的时期，他们的投资率也较高。由于中国投资回报率又显著高于其他大国，因此带来了 FDI 的较快速增长。（2）根据简单的经验判断，中国的高投资率和较高的投资回报率至少还将持续 10 年左右时间，之后可能出现与国际接轨。（3）至少对中国、美国和日本三国而言，资本回报率在过去三十年尚未出现收敛，这意味着 FDI 将会持续涌入中国。（4）分析显示资本回报率虽然严重受到经济周期影响，但是从长期来看，资本回报率遵从一个递减的趋势，日本和美国的经验表明，经过长期的经济发展，资本回报率经历递减之后将会维持在一个相对较低的水平，这意味着中国的资本回报率将不可避免的有所降低。但是，由于中国的劳动者份额及资本-产出比仍处于较低的水平，中国的高资本回报率将会维持一段时间。（5）当前外来投资中制造业占绝对主体，并且在 2000 年以后，高新技术投资占整个 FDI 比重越来越大。外资高新技术产业 FDI 增长率高于中国总的实际利用外资增长率，外商投资企业的高新技术产品出口占中国此类产品出口的绝大部分。这些也意味着，中国的高回报率不但对低技术部门有吸引力，对高技术部门吸引力也在加大。

关键词：资本回报率；投资率；FDI； 高技术行业

## 1. 背景介绍

在过去短短的十几年中，中国的投资率快速上升并超越日本及美国，从1990年的25.86%飚升至2006年的42.74%。在此期间，日本的投资率则从32.32%剧减至23.46%，美国的投资率则在26%左右波动。与此同时，实际利用FDI以年均高达19.97%的增速涌入中国，从1990年的35亿美元增至2008年的924亿美元。FDI的不断涌入以及投资率的持续上升表明资本正不断聚集于中国这个世界第三大经济体。面对这样的经济形势，我们不禁关注几个问题：究竟是什么使得中国对投资者越来越具有吸引力？中国如此之高的投资率具有可持续性吗？中国的 FDI 能否持续增长？要回答这些问题，一个比较直观的方法就是计算中国及其它主要经济体的资本回报率：如果中国的资本回报率持续居高不下，那么中国的高投资率将有可能会持续一段时间；如果中国的资本回报率显著高于其它主要国家的资本回报率，那么FDI将有可能会继续涌入中国。同时，要探寻高投资率及不断上升的FDI是否可以持续，最为直观的方法就是找出影响投资回报率的主要因素，并分析其今后走势。

关于中国的高投资率及不断上升的FDI，许多学者及政府官员都作了深入探讨。他们认为政府投资、私人部门投资以及外商投资等因素的驱动使得中国的投资率居高不下，而廉价的生产要素、巨大的市场需求以及聚集经济等因素的驱动使得 FDI 不断涌入中国。虽然很多学者曾估算过中国的资本回报率并得出中国的资本回报率高于世界主要经济体的结论，但是，我们尚未发现有学者采用资本回报率这个市场经济的基本指标去解释中国不断上升的投资率尤其是FDI。因此，本文估算中国、日本及美国的资本回报率，分析影响资本回报率的主要因素以及这些因素的变化趋势，并基于此探寻资本回报率今后的走势及其对中国未来数十年的投资率的影响。

本文对资本回报率的研究与前期研究主要有两方面的不同。一方面，我们主要比较中国、美国和日本这三个主要的资本大国和投资大国的资料。根据中国国家统计局2007年发布的经济数据更新了中国的数据，根据日本统计署2008年普查结果更新了日本的数据，并根据美国经济分析局2008年普查结果更新了美国的数据。另一方面，通过估算中国、日本及美国的资本回报率，我们深入分析影响资本回报率的主要因素以及这些因素的变化趋势，并基于此分析资本回报率的今后走势及其在未来若干年对中国投资率的影响。

分析显示资本回报率虽然在一定程度上受到经济周期的影响，但从长期来看遵从递减的趋势。这是因为资本回报率主要受到劳动者份额及资本-产出比的影响。在经济发展初期，劳动者份额及资本-产出比往往处于较低的水平，随着经济的发展，劳动者份额及资本-产出比会有所上升，这使得资本回报率会有所下降。而中国的资本回报率之所以高于日本及美国正是因为中国具有较低的劳动者份额及资本-产出比。虽然中国的劳动者份额及资本-产出比将会不可避免的上升，并将导致资本回报率的下降，但是，在未来数年内，中国的资本回报率将会继续维持在较高的水平，并将高于日本及美国。这是因为中国的劳动者份额及资本-产出比尚处于较低的水平，而且短时间内不会经历显著的提升，这意味着中国将在一段时期内维持较高的投资率并吸引更多的FDI流入。

本文的章节安排如下：第二章回顾文献，第三章估算并比较中国、日本及美国的资本回报率，第四章分析影响资本回报率的主要因素以及这些因素的变化趋势，第五章探寻资本回报率的今后走势并分析其对未来投资率的影响，并观察高技术行业资本回报率特点，最后总结全文。

## 2. 相关文献综述

国家发展和改革委员会（2005）认为工业化进程、高储蓄、粗放型经济增长方式、投资效率低下以及较低的消费水平等是造成中国投资率较高的重要原因。在这些分析的基础之上，李如鹏（2007）、胡学勤（2007）、于健（2008）以及其它研究都对中国的高投资率及低消费率作了比较深入的讨论，并进一步指出政府的驱动也是导致中国高投资率的重要因素。而樊明（2009）则基于中美政治制度的比较分析中国高投资率及低消费率的政治因素，并指出中国地方政府更多的重视资本利益而忽视劳动利益，在相当程度上导致了高投资率和低消费率的产生。关于吸引外资流入中国的因素，沈坤荣等（2002）研究认为人力资本存量对FDI在我国的区位选择及投资规模有着重要影响，徐康宁等（2002）分析认为市场需求变化、政策开放性、前期资本存量和汇率水平等严重影响美国对华直接投资。李琴（2004）分析的结果显示，中国的对外贸易与外国直接投资的流人之间存在着长期稳定的正相关关系。黄肖琦等（2006）指出贸易成本、技术外溢、市场规模以及历史 FDI 等传导机制等显著的影响外资的区位选择。罗知（2009）基于 FDI 主要来源国的数据分析 FDI 流入我国的原因，并指出资本来源国的市场规模和双边贸易都是影响 FDI 的重要因素。本研究与前期研究的不同在于我们使用资本回报率这个市场经济的基本指标来解释中国的高投资率及持续飙升的FDI，并基于资本回报率的变化趋势分析今后中国投资率及 FDI 的走势。

最早估算资本回报率的是 Baumol 等（1970），他们采用大量样本对产出及投资资本进行回归从而估算美国的资本回报率。但是这个方法有一定的缺陷，比如 Friend and Husic (1973), Brealey 等(1976)以及 McFetridge (1978)都指出回归方法可能忽视规模等因素从而带来有偏的估计。直至上世纪九十年代，研究者开始才开始从原来的不变价格转而采用市场价格估算资本回报率。其中，Mueller and Reardon（1993）是利用市场价格计算资本回报率的鼻祖，而该方法在 Mueller and Yurtoglu (2000) 以及 Gugler 等(2003, 2004)研究中得以进一步的应用和发展。直到二十一世纪初，对资本回报率的估算才开始从资本市场发展到整体经济，计算整体经济资本回报率的时候，也有学者采用资本市场的回报率来近似，但是这种方法只适用于资本市场较为发达的经济体，而对于一个新兴市场例如中国来说，则不大适用。白重恩等（2006）对中国 1978 至 2005 年间整体经济的资本回报率进行直接估算，该方法采用资本份额、资本-产出比、折旧率、投资平减指数增长率以及 GDP 平减指数增长率等宏观数据直接估算整体经济的资本回报率。对比回归分析方法、资本市场回报率方法和采用国民经济统计账户估计的方法，可以发现，回归分析方法只能发现在一段时间内平均资本回报率，而不能观察其如何随时间变化；资本回报率方法经常不具有代表性；在世界各国国民经济统计法则逐渐趋同的情况下，直接使用宏观指标计算资本回报率是一个方便且便于对比的方法。

此外，还有许多其它文献对中国的投资效率进行了估算和研究，但是我们还没发现关于资本回报率变化趋势及今后走势的分析。有鉴于此，本文估算中国、日本及美国的资本回报率，深入分析影响资本回报率的因素以及这些因素的变化趋势，以期揭示中国资本回报率的今后走势及其未来对中国投资环境的影响。

## 3. 资本回报率的估算

### 3.1 估算方法

如上文所述，可用于估算整体经济资本回报率的方法主要有三种，其一，估算资本市场的回报率并将其近似为整体经济的资本回报率，这种方法对于资本市场极度发达的经济体来说具有一定的适用性，但是对于中国这样的发展中国家来说则不大合适；其二，对产出及资本存量进行回归以估算出资本回报率，这种方法比较容易操作但是有可能忽略一些显著影响资本回报率的因素以致于造成估算偏差，并且其估算出来的资本回报率随时间不变。

第三种方法，也就是本研究所采用的方法，采用整体经济的劳动者份额、资本-产出比（资本及产出都以市场价计价）、折旧率、投资平减指数增长率以及 GDP 平减指数增长率等宏观数据直接估算资本回报率。在该方法中，实际资本回报率可以通过下式计算：

$$r(t)=\frac{P_Y(t)MPK_j(t)}{P_{K_j}(t)}-\delta_j-\hat{P}_Y(t)+\hat{P}_{K_j}(t) \quad \ldots\ldots \textbf{(1)}$$

其中，

$r(t)$：实际资本回报率；

$P_Y(t)$：产出价格；

$P_{K_j}(t)$：资本 j 的价格；

$MPK_j(t)$：资本 j 的实物边际产出；

$\delta_j$：资本 j 的折旧率；

$\hat{P}_Y(t)$：产出价格的增长率；

$\hat{P}_{K_j}(t)$：资本 j 的价格的增长率。

该方法的优点在于：一方面，它非常简单和直观；另一方面，它采用宏观数据直接计算整体经济的资本回报率，因此与经济结构无关，可广泛应用于估算不同经济体的资本回报率：即可用于估算中国这样新兴经济体的资本回报率，又可用于计算日本及美国等发达经济体的资本回报率。但是，资本的实物边际产出不易观察得到，这给利用该方法估算资本回报率带来了一定的难度和挑战。幸运的是，我们可以间接的通过劳动者份额计算出资本的实物边际产出。而总体经济的劳动者份额等于劳动者报酬比上总产出，因此，资本份额可表示为：

$$\alpha(t)=1-\frac{W(t)L(t)}{P_Y(t)Y(t)} \quad \ldots\ldots \textbf{(2)}$$

其中$W(t)$代表工资水平，而$L(t)$代表劳动力数量。

此外，资本份额可表示为：

$$\alpha(t)=\frac{\sum_j P_Y(t)MPK_j(t)K_j(t)}{P_Y(t)Y(t)}$$

$$=\frac{\sum_j \frac{P_Y(t)MPK_j(t)}{P_{K_j}(t)}K_j(t)P_{K_j}(t)}{P_Y(t)Y(t)}$$

把（1）式代入$\alpha(t)$可得：

$$\alpha(t)=\frac{\sum_j\left(r(t)+\delta_j+\hat{P}_Y(t)-\hat{P}_{K_j}(t)\right)K_j(t)P_{K_j}(t)}{P_Y(t)Y(t)}$$

$$=\frac{\sum_j\left(r(t)+\hat{P}_Y(t)\right)K_j(t)P_{K_j}(t)+\sum_j\left(\delta_j-\hat{P}_{K_j}(t)\right)K_j(t)P_{K_j}(t)}{P_Y(t)Y(t)}$$

$$=\frac{\left(r(t)+\hat{P}_Y(t)\right)K(t)P_K(t)+K(t)P_K(t)\left(\frac{\sum_j\delta_jK_j(t)P_{K_j}(t)}{K(t)P_K(t)}-\frac{\sum_j\hat{P}_{K_j}(t)K_j(t)P_{K_j}(t)}{K(t)P_K(t)}\right)}{P_Y(t)Y(t)}$$

$$=\frac{K(t)P_K(t)\left(r(t)+\hat{P}_Y(t)+\delta(t)-\hat{P}_K(t)\right)}{P_Y(t)Y(t)} \quad \ldots\ldots \textbf{(3)}$$

其中，

$K(t)P_K(t)=\sum_j K_j(t)P_{K_j}(t)$：总产出；

$\hat{P}_K(t)=\sum_j\frac{K_j(t)P_{K_j}(t)}{K(t)P_K(t)}\hat{P}_{K_j}(t)$：投资平减指数增长率；

$\delta(t)=\sum_j\frac{K_j(t)P_{K_j}(t)}{K(t)P_K(t)}\delta_j$：折旧率。

从（3）式我们可以得到如下的资本回报率计算公式：

$$r(t)=\frac{\alpha(t)}{K(t)P_K(t)\big/P_Y(t)Y(t)}+\left(\hat{P}_K(t)-\hat{P}_Y(t)\right)-\delta(t) \quad \ldots\ldots \textbf{(4)}$$

把（2）式代入（4）式可得：

$$r(t)=\frac{1-\dfrac{W(t)L(t)}{P_Y(t)Y(t)}}{K(t)P_K(t)\big/P_Y(t)Y(t)}+\left(\hat{P}_K(t)-\hat{P}_Y(t)\right)-\delta(t) \quad \ldots\ldots \textbf{(5)}$$

式（5）正是本文用于估算中国、日本及美国资本回报率的公式。需要注意的是，本文计算资本存量的时候，我们使用的是生产性资产而不是简单的采用固定资产存量，原因在于生产性资产能够更为有效的体现投资资本。

### 3.2 数据说明

#### 3.2.1 中国

已经有很多学者对中国统计数据的准确性进行过深入讨论，本文将不在这方面多费笔墨，而是着重说明各项数据的来源及相应的处理方法。对于中国的 GDP，我们从《中国统计年鉴 2007》获取 1978 至 2006 年的数据，从《新中国 55 年统计年鉴资料汇编（1949-2004）》获取 1953 至 1977 的数据。至于投资平减指数，中国国家统计局提供了 1990 年之后的固定资产投资指数，而 1990 年之前的指数，我们取自白重恩等（2006）。从理论上说，劳动者份

额等于工资总额比上总产出。但是，中国国家统计局仅仅提供工业企业的工资数据，这当然不能全面反映总体经济劳动者份额的真实情况。幸运的是，我们可以通过采用每个省份的劳动者份额，然后加权平均即可估算出总体经济的劳动者份额。

最为常用的计算资本存量的方法是标准永续库存法（PIM），该方法假设当前资本存量为前期所有生命尚未枯竭的投资资本总和，计算公式为：

$$K_t = \sum_{\tau=0}^{d-1} w_\tau * I_{t-\tau} \quad \text{.....} \ \textbf{(6)}$$

其中，

$K_t$：t 时的资本存量；

$d$：投资产品的服务年限；

$I_{t-\tau}$：$\tau$ 年前投资品以不变价格计价的价值；

$w_\tau$：$\tau$ 年前投资品价值的权重。

根据上式不难看出标准永续库存法需要对三个参数进行假设和估算，其一，投资品的服务年限，其二，折旧率及其估算方法，其三，投资品以不变价格计价的价值。至于中国的资本存量，我们主要需要考虑两种投资品的服务年限，它们分别是：1）建筑及构筑物，以及 2）机器及设备。王和吴（2003）曾对不同投资品的服务年限进行估算，他们研究指出建筑及构筑物的服务年限平均为 38 年，而机器及设备的服务年限平均为 12 年。至于折旧率的估算方法，本文计算中国的折旧率采用递减平衡折旧法。在中国，投资品价值的残余率介于 3%及 5%之间，本文采用 4%，即该区间的均值，作为投资品价值的残余率。根据递减平衡折旧法，我们不难得出建筑及构筑物的折旧率为 8%，而机器及设备的折旧率为 24%。

经常用于估算中国资本存量的统计数据是固定资产投资，该统计数据划分为建筑及构筑物的投资、机器及设备的投资两种投资类别。但是，很多学者认为该统计数据并不能全面反映中国的总投资额。原因在于一方面，该统计数据包括了用于购买土地、维修机器设备和构筑物的开支，而这些都不是生产性的支出；另一方面，该统计数据仅仅纳入大型的投资项目，从而不可避免的低估总投资额。为了弥补该统计数据的不足，很多学者和研究人员推荐另外一个统计数据，固定资产形成，用以估算资本存量。一方面，固定资产形成已经扣除土地支出及用于维修既有机器设备的开支；另一方面，该数据已经纳入小型投资项目的投资，因此能够更好的反映实际投资情况。但是，固定资产形成也有一个重要缺陷，该统计数据没有细分为不同的投资类别，为了解决这个问题，我们假设固定资产形成中不同投资类别的比例与固定资产投资相同。

### 3.2.2 日本

日本经济社会研究所在《日本统计年鉴》中披露日本的 GDP 等数据，其中，《日本统计年鉴 2009》发布 1965 至 2006 年的 GDP 数据，《日本历史统计年鉴》发布 1980 至 2003 年的 GDP 数据（基于 93SNA 规范）以及 1955 至 1998 年的 GDP 数据（基于 68SNA 规范）。本文采用《日本统计年鉴 2009》中的 GDP 数据作为 1965 至 2006 年的数据，采用《日本历史统计年鉴》中基于 68SNA 规范的 GDP 数据作为 1955 至 1964 年的数据。至于劳动者报酬，我们采用《日本统计年鉴 2009》中的劳动者报酬作为 2003 至 2006 年的数据，并采用《日本历史统计年鉴》中的劳动者报酬作为 1955 至 2002 年的数据（其中 1980 至 2002 是基于 93SNA 规范，1955 至 1979 基于 68SNA 规范）。

关于日本资本存量，日本经济社会研究所提供的一个重要的统计数据是净资本存量，该统计数据包括建筑、构筑物、交通设备及其他机器等，另外一个是私有部门资本存量，该统计数据包括私有部门的所有固定资产，但是不包括私有部门的住宅建筑及私有非盈利部门的固定资产。私有部门资本存量虽然经常用于估算不同行业的资本存量，并不适用于估算日本总体经济的资本存量，一方面在于该统计数据没有具体的分类，另外一方面在于该统计数

据仅仅计入私有部门的资本存量，因此不能完全反应总体经济的实际资本存量。基于上述分析，本文采用净资本存量估算日本的资本存量，同时，我们也把生产库存纳入资本存量中。

根据日本经济及社会研究所披露的资料，日本采用几何折旧法计算住宅、交通工具等的折旧率。至于残存率，育成资产的为 50%，而其它资产则为 10%。因此，我们很容易就能采用加权法计算出日本的总体折旧率。

**表 1：日本不同资产类别的折旧率**

| | 服务年限 | 折旧率 |
|---|---|---|
| 住宅 | 28.0 | 7.9 |
| 其它建筑 | 37.4 | 6 |
| 其它构筑物 | 33.7 | 6.6 |
| 交通工具 | 7.6 | 26.2 |
| 其它机器设备 | 10.6 | 12.1 |
| 育成资产 | 5.4 | 9.9 |

*资料来源：Koji Nomura and Tadao Futakami (2005)*

#### 3.2.2 美国

美国经济分析局在美国经济账户中提供自 1929 年至 2008 年的统计数据，包括以现价计价的 GDP 数据、以不变价格计价的 GDP 数据以及劳动者报酬等。我们通过以现价计价的 GDP 数据及以不变价格计价的 GDP 数据计算 GDP 平减指数的增长率，并通过劳动者报酬及以现价计价的 GDP 数据计算劳动者份额。此外，美国经济分析局还直接提供投资平减指数及资本存量数据，并把资本存量细分为私有部门的机器设备、软件、私有部门分住宅构筑物、住宅建筑、耐用品及公共部门固定资产等。与中国及日本一样，美国所采取的折旧方法也是几何折旧法。但在本文中，我们并不需要估算美国不同资产的折旧率，因为美国经济分析局已经提供资本存量及折旧的统计数据。因此，我们仅需要通过折旧除以资本存量便可计算出美国的折旧率。

### 3.3 中国、日本及美国的资本回报率

有了上述数据，我们可以通过式（5）估算中国、日本及美国的资本回报率。表 2 罗列了用于计算中国资本回报率的变量及数据，同时提供了中国资本回报率的估算结果；表 3 罗列了用于计算日本资本回报率的变量及数据，同时提供了日本资本回报率的估算结果；表 4 罗列了用于计算美国资本回报率的变量及数据，同时提供了美国资本回报率的估算结果。

表 2: 中国的资本回报率

| 年份 | 劳动者份额（%） | 资本-产出比 | 折旧率（%） | 投资平减指数增长率（%） | GDP 平减指数增长率（%） | 资本回报率（%） |
|---|---|---|---|---|---|---|
| 1978 | 49.67 | 1.39 | 12.10 | 0.93 | 1.92 | 23.17 |
| 1979 | 51.38 | 1.37 | 11.97 | 2.15 | 3.58 | 22.07 |
| 1980 | 51.15 | 1.35 | 11.82 | 4.95 | 3.78 | 25.41 |
| 1981 | 52.68 | 1.44 | 11.43 | 1.78 | 2.25 | 20.98 |
| 1982 | 53.57 | 1.45 | 11.06 | 2.34 | -0.21 | 23.62 |
| 1983 | 53.54 | 1.43 | 10.82 | 3.76 | 1.04 | 24.44 |
| 1984 | 53.68 | 1.33 | 10.67 | 4.80 | 4.96 | 23.92 |
| 1985 | 52.90 | 1.24 | 10.69 | 8.62 | 10.24 | 25.77 |
| 1986 | 52.82 | 1.31 | 10.86 | 7.52 | 4.70 | 27.91 |
| 1987 | 52.53 | 1.33 | 10.81 | 6.98 | 5.17 | 26.60 |
| 1988 | 51.72 | 1.27 | 10.84 | 12.50 | 12.10 | 27.49 |
| 1989 | 51.51 | 1.41 | 10.88 | 9.55 | 8.55 | 24.58 |
| 1990 | 53.36 | 1.48 | 11.00 | 7.31 | 5.80 | 21.96 |
| 1991 | 50.03 | 1.44 | 10.91 | 9.05 | 6.87 | 26.09 |
| 1992 | 50.09 | 1.35 | 10.79 | 15.52 | 8.20 | 33.37 |
| 1993 | 50.37 | 1.31 | 10.72 | 29.35 | 15.16 | 41.47 |
| 1994 | 51.11 | 1.38 | 10.65 | 10.25 | 20.63 | 14.29 |
| 1995 | 52.56 | 1.37 | 10.74 | 4.97 | 13.71 | 15.25 |
| 1996 | 52.80 | 1.39 | 10.71 | 4.51 | 6.43 | 21.42 |
| 1997 | 52.89 | 1.47 | 10.61 | 2.12 | 1.52 | 22.01 |
| 1998 | 53.12 | 1.57 | 10.61 | 0.02 | -0.89 | 20.23 |
| 1999 | 52.42 | 1.64 | 10.59 | -0.15 | -1.27 | 19.59 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2000 | 51.48 | 1.63 | 10.59 | 1.60 | 2.03 | 18.75 |
| 2001 | 51.46 | 1.65 | 10.56 | 0.70 | 2.05 | 17.52 |
| 2002 | 50.92 | 1.67 | 10.55 | 0.37 | 0.60 | 18.62 |
| 2003 | 49.62 | 1.65 | 10.55 | 3.09 | 2.59 | 20.48 |
| 2004 | 45.51 | 1.63 | 10.54 | 6.86 | 6.93 | 22.83 |
| 2005 | 41.40 | 1.71 | 10.53 | 1.42 | 4.14 | 21.00 |
| 2006 | 40.61 | 1.72 | 10.65 | 1.20 | 3.24 | 21.82 |

*资料来源:《中国统计年鉴》及作者的计算*

**表 3:** 日本的资本回报率

| 年份 | 劳动者份额（%） | 资本-产出比 | 折旧率（%） | 投资平减指数增长率（%） | GDP 平减指数增长率(%） | 资本回报率（%） |
|---|---|---|---|---|---|---|
| 1956 | 41.55 | 1.71 | 10.34 | 14.39 | 6.22 | 31.95 |
| 1957 | 40.81 | 1.54 | 10.00 | 11.59 | 7.16 | 32.79 |
| 1958 | 42.91 | 1.67 | 9.92 | -5.64 | -0.91 | 19.46 |
| 1959 | 42.47 | 1.56 | 9.92 | 1.57 | 5.50 | 23.15 |
| 1960 | 40.48 | 1.29 | 9.76 | 4.95 | 9.48 | 31.76 |
| 1961 | 39.53 | 1.17 | 9.83 | 7.96 | 10.21 | 39.43 |
| 1962 | 41.90 | 1.17 | 9.93 | 0.00 | 5.55 | 34.09 |
| 1963 | 42.34 | 1.24 | 10.10 | 0.00 | 7.18 | 29.03 |
| 1964 | 42.44 | 1.19 | 10.07 | 2.19 | 6.85 | 33.66 |
| 1965 | 44.12 | 1.22 | 10.04 | -0.53 | 13.94 | 21.48 |
| 1966 | 43.96 | 1.21 | 10.00 | 3.76 | 5.34 | 34.86 |
| 1967 | 43.12 | 1.15 | 9.92 | 4.92 | 5.50 | 39.09 |
| 1968 | 42.43 | 1.12 | 9.94 | 2.22 | 5.83 | 37.74 |
| 1969 | 42.51 | 1.13 | 10.11 | 2.66 | 4.93 | 38.59 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1970 | 43.49 | 1.11 | 10.18 | 4.47 | 6.87 | 38.28 |
| 1971 | 46.86 | 1.21 | 10.39 | 1.35 | 5.40 | 29.32 |
| 1972 | 47.65 | 1.31 | 10.52 | 3.56 | 5.60 | 27.44 |
| 1973 | 49.05 | 1.25 | 10.30 | 16.31 | 12.71 | 34.17 |
| 1974 | 52.15 | 1.31 | 10.17 | 24.72 | 20.81 | 30.38 |
| 1975 | 55.00 | 1.64 | 10.16 | 3.85 | 7.18 | 13.94 |
| 1976 | 55.24 | 1.83 | 9.99 | 4.84 | 8.01 | 11.30 |
| 1977 | 55.38 | 1.79 | 9.76 | 4.76 | 6.75 | 13.16 |
| 1978 | 54.34 | 1.86 | 9.60 | 2.85 | 4.60 | 13.23 |
| 1979 | 54.19 | 1.87 | 9.45 | 6.68 | 2.75 | 19.01 |
| 1980 | 53.84 | 1.88 | 9.27 | 8.51 | -1.08 | 24.81 |
| 1981 | 54.13 | 2.04 | 9.35 | 1.74 | 4.52 | 10.33 |
| 1982 | 54.50 | 2.22 | 9.27 | 1.18 | 1.76 | 10.65 |
| 1983 | 55.10 | 2.24 | 9.24 | 0.11 | 1.71 | 9.16 |
| 1984 | 54.62 | 2.22 | 9.22 | 1.16 | 2.48 | 9.94 |
| 1985 | 53.11 | 2.11 | 9.26 | 0.73 | 3.01 | 10.65 |
| 1986 | 52.89 | 2.11 | 9.33 | -0.83 | 1.66 | 10.51 |
| 1987 | 52.57 | 2.09 | 9.37 | -0.73 | -0.36 | 12.92 |
| 1988 | 51.72 | 1.99 | 9.34 | 0.32 | 1.00 | 14.19 |
| 1989 | 51.48 | 1.95 | 9.37 | 1.89 | 2.32 | 15.06 |
| 1990 | 51.68 | 1.92 | 9.38 | 2.89 | 2.99 | 15.62 |
| 1991 | 52.49 | 2.01 | 9.42 | 2.20 | 2.94 | 13.43 |
| 1992 | 52.82 | 2.14 | 9.42 | 1.27 | 1.63 | 12.26 |
| 1993 | 53.55 | 2.28 | 9.42 | -0.19 | 0.53 | 10.27 |
| 1994 | 54.35 | 2.35 | 9.36 | -1.55 | 3.09 | 5.40 |
| 1995 | 54.51 | 2.37 | 9.26 | -1.48 | -0.50 | 8.97 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1996 | 54.22 | 2.36 | 9.25 | -1.18 | -0.57 | 9.52 |
| 1997 | 54.44 | 2.33 | 9.23 | 0.41 | 0.60 | 10.12 |
| 1998 | 55.01 | 2.46 | 9.27 | -1.56 | 0.03 | 7.45 |
| 1999 | 54.88 | 2.57 | 9.27 | -2.14 | -1.29 | 7.44 |
| 2000 | 54.68 | 2.52 | 9.23 | -1.23 | -1.73 | 9.23 |
| 2001 | 54.93 | 2.54 | 9.18 | -2.13 | -1.23 | 7.67 |
| 2002 | 54.30 | 2.60 | 9.15 | -2.05 | -1.55 | 7.94 |
| 2003 | 52.74 | 2.57 | 9.08 | -1.77 | -1.60 | 9.12 |
| 2004 | 51.44 | 2.51 | 9.00 | -0.21 | -1.08 | 11.25 |
| 2005 | 51.51 | 2.49 | 9.02 | -0.07 | -1.23 | 11.58 |
| 2006 | 51.60 | 2.41 | 9.05 | 0.82 | -0.94 | 12.79 |

*资料来源:《日本统计年鉴》及作者的计算*

**表 4: 美国的资本回报率**

| 年份 | 劳动者份额(%) | 资本-产出比 | 折旧率(%) | 投资平减指数增长率(%) | GDP 平减指数增长率(%) | 资本回报率(%) |
|---|---|---|---|---|---|---|
| 1930 | 51.43 | 3.37 | 4.82 | 1.99 | -3.67 | 15.28 |
| 1931 | 52.03 | 3.47 | 4.63 | 0.56 | -10.36 | 20.14 |
| 1932 | 52.98 | 4.16 | 4.53 | -0.77 | -11.80 | 17.81 |
| 1933 | 52.48 | 4.60 | 4.84 | -1.19 | -2.68 | 6.99 |
| 1934 | 51.97 | 4.02 | 4.75 | -0.34 | 5.60 | 1.27 |
| 1935 | 51.02 | 3.67 | 4.79 | 0.37 | 1.98 | 6.94 |
| 1936 | 51.19 | 3.55 | 4.94 | 1.68 | 1.17 | 9.31 |
| 1937 | 52.23 | 3.41 | 4.91 | 1.89 | 4.31 | 6.68 |
| 1938 | 52.26 | 3.67 | 4.60 | 1.11 | -2.97 | 12.50 |
| 1939 | 52.17 | 3.50 | 4.63 | 1.87 | -0.91 | 11.81 |
| 1940 | 51.48 | 3.46 | 4.80 | 2.42 | 1.11 | 10.56 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1941 | 51.14 | 3.16 | 5.57 | 3.88 | 6.69 | 7.10 |
| 1942 | 52.69 | 2.82 | 5.20 | 5.77 | 7.81 | 9.55 |
| 1943 | 55.19 | 2.56 | 5.57 | 5.79 | 5.38 | 12.37 |
| 1944 | 55.19 | 2.47 | 5.79 | 4.59 | 2.37 | 14.57 |
| 1945 | 55.27 | 2.63 | 6.46 | 1.84 | 2.65 | 9.76 |
| 1946 | 53.85 | 3.09 | 6.95 | 0.33 | 11.99 | -3.69 |
| 1947 | 53.24 | 3.26 | 6.88 | 1.58 | 10.89 | -1.82 |
| 1948 | 52.71 | 3.15 | 6.52 | 2.28 | 5.63 | 5.14 |
| 1949 | 53.05 | 3.22 | 5.83 | 2.76 | -0.18 | 11.68 |
| 1950 | 52.83 | 3.28 | 6.11 | 3.90 | 1.09 | 11.08 |
| 1951 | 53.46 | 3.49 | 5.71 | 4.09 | 7.18 | 4.54 |
| 1952 | 54.76 | 3.45 | 5.49 | 3.95 | 1.71 | 9.87 |
| 1953 | 55.40 | 3.37 | 5.47 | 4.31 | 1.24 | 10.84 |
| 1954 | 54.99 | 3.49 | 5.63 | 3.70 | 0.95 | 10.03 |
| 1955 | 54.44 | 3.45 | 5.74 | 4.24 | 1.78 | 9.94 |
| 1956 | 55.91 | 3.54 | 5.87 | 3.65 | 3.46 | 6.77 |
| 1957 | 55.87 | 3.52 | 5.71 | 3.43 | 3.32 | 6.94 |
| 1958 | 55.57 | 3.58 | 5.77 | 2.65 | 2.30 | 6.99 |
| 1959 | 55.49 | 3.43 | 5.69 | 3.58 | 1.23 | 9.64 |
| 1960 | 56.34 | 3.40 | 5.72 | 3.22 | 1.40 | 8.93 |
| 1961 | 56.07 | 3.40 | 5.69 | 3.05 | 1.12 | 9.16 |
| 1962 | 55.87 | 3.30 | 5.69 | 3.54 | 1.36 | 9.86 |
| 1963 | 55.90 | 3.24 | 5.72 | 3.74 | 1.06 | 10.58 |
| 1964 | 55.86 | 3.20 | 5.80 | 4.08 | 1.53 | 10.56 |
| 1965 | 55.56 | 3.15 | 5.79 | 4.46 | 1.83 | 10.96 |
| 1966 | 56.18 | 3.12 | 5.88 | 4.53 | 2.85 | 9.83 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1967 | 57.06 | 3.18 | 5.87 | 4.01 | 3.09 | 8.56 |
| 1968 | 57.62 | 3.19 | 5.99 | 4.10 | 4.27 | 7.14 |
| 1969 | 58.66 | 3.21 | 5.97 | 3.89 | 4.96 | 5.83 |
| 1970 | 59.43 | 3.30 | 5.95 | 3.17 | 5.29 | 4.22 |
| 1971 | 58.46 | 3.34 | 5.95 | 3.28 | 5.00 | 4.77 |
| 1972 | 58.56 | 3.34 | 5.86 | 3.73 | 4.34 | 5.92 |
| 1973 | 58.67 | 3.41 | 5.87 | 4.02 | 5.58 | 4.70 |
| 1974 | 59.35 | 3.72 | 5.92 | 3.10 | 9.03 | -0.93 |
| 1975 | 57.94 | 3.67 | 5.71 | 2.32 | 9.43 | -1.37 |
| 1976 | 58.04 | 3.59 | 5.79 | 2.75 | 5.78 | 2.87 |
| 1977 | 58.13 | 3.61 | 5.91 | 3.26 | 6.35 | 2.60 |
| 1978 | 58.23 | 3.62 | 5.96 | 3.67 | 7.03 | 2.20 |
| 1979 | 58.55 | 3.74 | 5.99 | 3.59 | 8.29 | 0.41 |
| 1980 | 59.22 | 3.90 | 5.91 | 2.69 | 9.07 | -1.82 |
| 1981 | 58.37 | 3.81 | 5.83 | 2.54 | 9.39 | -1.76 |
| 1982 | 59.17 | 3.84 | 5.71 | 1.91 | 6.10 | 0.71 |
| 1983 | 57.76 | 3.66 | 5.61 | 2.39 | 3.96 | 4.36 |
| 1984 | 57.35 | 3.49 | 5.74 | 3.29 | 3.75 | 6.03 |
| 1985 | 57.46 | 3.42 | 5.87 | 3.48 | 3.04 | 7.00 |
| 1986 | 57.63 | 3.43 | 5.99 | 3.39 | 2.20 | 7.54 |
| 1987 | 58.06 | 3.43 | 6.01 | 3.14 | 2.73 | 6.62 |
| 1988 | 58.15 | 3.39 | 6.06 | 3.02 | 3.41 | 5.87 |
| 1989 | 57.37 | 3.34 | 6.15 | 2.83 | 3.78 | 5.66 |
| 1990 | 57.56 | 3.31 | 6.12 | 2.52 | 3.86 | 5.37 |
| 1991 | 57.51 | 3.27 | 6.13 | 1.80 | 3.50 | 5.14 |
| 1992 | 57.41 | 3.23 | 6.22 | 1.91 | 2.30 | 6.59 |

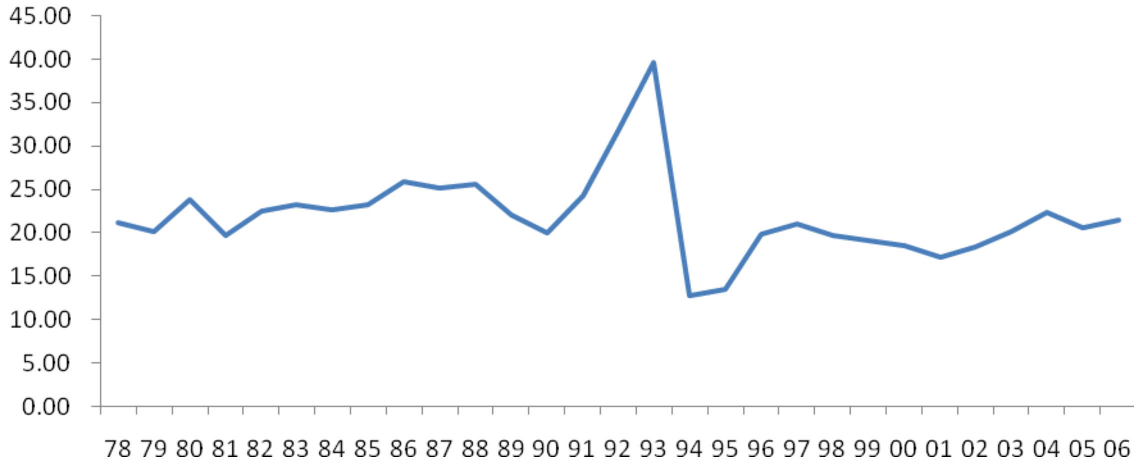
| | | | | | | |
|---|---|---|---|---|---|---|
| 1993 | 57.15 | 3.23 | 6.21 | 2.21 | 2.31 | 6.97 |
| 1994 | 56.58 | 3.23 | 6.30 | 2.41 | 2.13 | 7.45 |
| 1995 | 56.74 | 3.23 | 6.20 | 2.59 | 2.05 | 7.71 |
| 1996 | 56.22 | 3.20 | 6.19 | 2.88 | 1.90 | 8.46 |
| 1997 | 56.19 | 3.17 | 6.20 | 3.03 | 1.66 | 8.99 |
| 1998 | 57.44 | 3.17 | 6.21 | 3.32 | 1.11 | 9.42 |
| 1999 | 57.86 | 3.19 | 6.27 | 3.52 | 1.45 | 9.04 |
| 2000 | 58.95 | 3.20 | 6.33 | 3.52 | 2.18 | 7.83 |
| 2001 | 58.72 | 3.26 | 6.33 | 2.93 | 2.40 | 6.85 |
| 2002 | 58.23 | 3.30 | 6.13 | 2.62 | 1.75 | 7.39 |
| 2003 | 57.76 | 3.32 | 6.07 | 2.62 | 2.13 | 7.15 |
| 2004 | 57.01 | 3.42 | 6.14 | 2.69 | 2.87 | 6.26 |
| 2005 | 56.65 | 3.52 | 6.17 | 2.57 | 3.26 | 5.45 |
| 2006 | 56.46 | 3.57 | 5.71 | 2.71 | 3.22 | 5.99 |
| 2007 | 56.63 | 3.38 | 5.58 | 2.37 | 2.69 | 6.94 |

*资料来源：美国经济分析局及作者的计算*

### 3.3.1 中国的资本回报率

如图 1 所示，中国的资本回报率在 1978 年的 23.17%与 2006 年的 21.82%间波动，在过去的三十年中平均超过 20%。但是，在 1992 年至 1994 年间中国的资本回报率曾出现剧烈的波动，分别于 1993 年剧增又于 1994 年骤减。中国的投资平减指数在 1992 年至 1993 年间剧增，从 15.52%升至 29.35%，使得资本回报率飙升，同时，投资平减指数于 1993 年至 1994 年间骤减，从 29.35%降至 10.25%，使得中国的资本回报率出现大幅降低。除了 1991-1994 年这一典型的经济波动区间之外，中国的资本回报率始终比较稳定。平均而言，在 1991 年之前，平均资本回报率较高，1994 年之后，平均回报率较低。

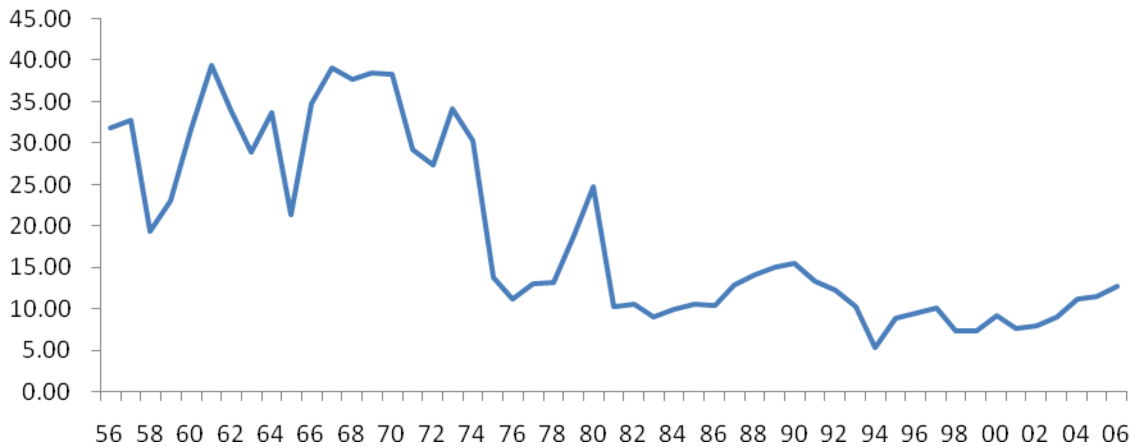
**图 1：中国的资本回报率（%）**




### 3.3.2 日本的资本回报率

如图 2 所示，日本的资本回报率在 1956 年至 2006 年期间波动性非常强，其中最高为 1961 年的 39.43%，最低为 1994 年的 5.4%。有趣的是，我们发现日本的资本回报率严重受到该国经济周期的影响：在 1956 年至 1974 年期间，日本的经济处于战后重建及飞速发展时期，日本的资本回报率处于历史最好的水平，平均高达 31%。在 20 世纪 70 年代中期，由于受到石油危机的影响，日本经济遭受重创，其资本回报率从 1974 年的 30.78%迅速跌落降至 1975 年的 13.94%。在 20 世纪 70 年代的最后五年中，日本的资本回报率在 14%左右波动，而在 20 世纪 80 年代中期，日本的资本回报率开始有所回升，但是 1992 年该国经济又一次陷入衰退，其资本回报率也经历剧减。20 世纪 90 年代之后，日本的资本回报率逐步趋于稳定，但是资本回报率处于一个比较低的水平，平均约 9%。

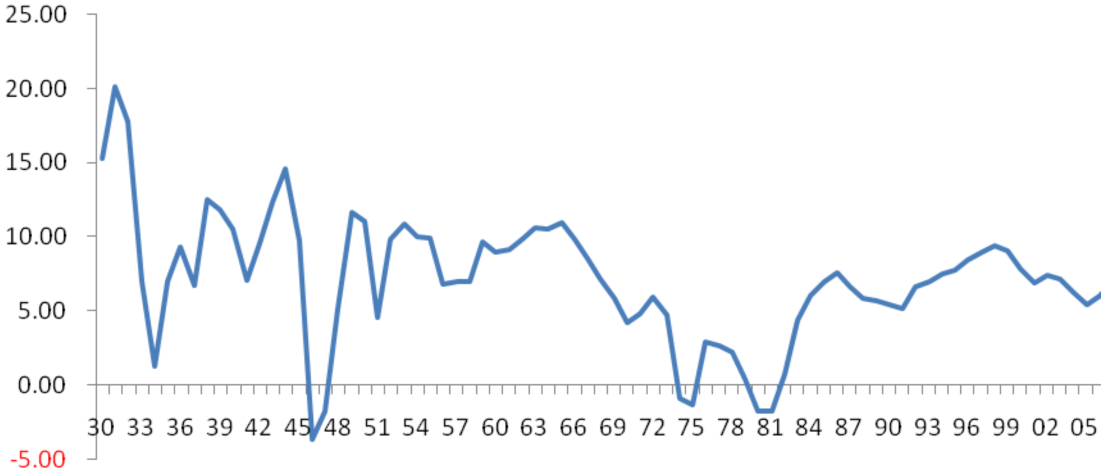
**图 2：日本的资本回报率（%）**




### 3.3.3 美国的资本回报率

如图 3 所示，美国的资本回报率在 1929 年至 2007 年间经历了剧烈的波动。在 20 世纪初期，美国经济经历了一个“喧嚣的二十年代”，享有一个持续的繁荣，甚至在 1929 年经济大萧条之后的三年，美国的资本回报率都处于一个比较高的水平，约达 15%。但是，分析发现，该时期美国的资本回报率之所以比较高，主要得益于该时期负的 GDP 平减指数增长率。大萧条重创美国经济，同时使得美国的资本回报率急剧下降，跌至 1934 年的 1.27%。所幸的是，经济大萧条促使美国政府采取更为积极的财政及货币政策重启经济，从而使得美国经济有所复苏，而其资本回报率亦于 1935 年至 1945 年间恢复至 10%的水平。在战后的繁荣期，即 1945 年至 1973 年期间，美国的资本回报率平均约为 8%。1973 年的石油危机使得美国通货膨胀不断上升，并重创美国经济，虽然美国政府迅速对此做出反应，但是效果极其有限，美国的资本回报率在 1974 年至 1983 年间平均低于 1%。为了刺激美国经济发展，里根政府的一系列政策，使得美国经济自 1983 年开始恢复。同时，美国的资本回报率亦回升至 6%的平均水平。1994 年至 2000 年见证了美国科技驱动的“新经济”，该时期美国的资本回报率平均超过 7%。2000 年之后美国的资本回报率趋于平稳，平均约 6%。

**图 3：美国的资本回报率（%）**

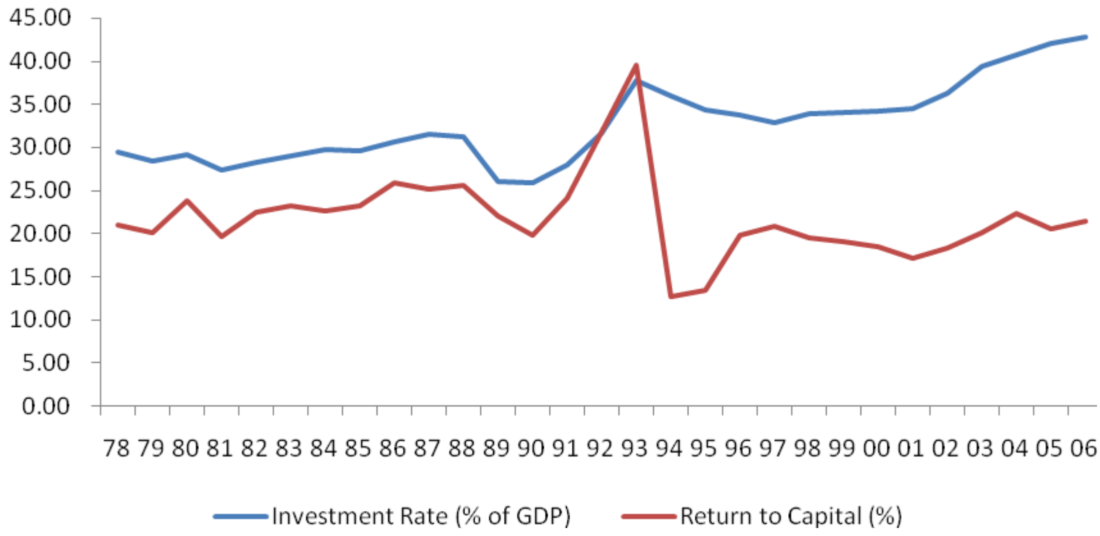


### 3.4 资本回报率对投资率的影响

#### 3.4.1 中国的投资率

如图 4 所示，中国的投资率从 1978 年的 29.46%上升至 2006 年的 42.75%，在这期间中国的资本回报率在高达 22%的水平波动。并且，投资率变动和投资回报率变动趋势明显正相关。可见，中国投资率在 1978 年至 2006 年期间持续上升的一个重要因素是因为中国具有最高的资本回报率，这促使投资者对中国这个经济体具有更高的投资意愿。

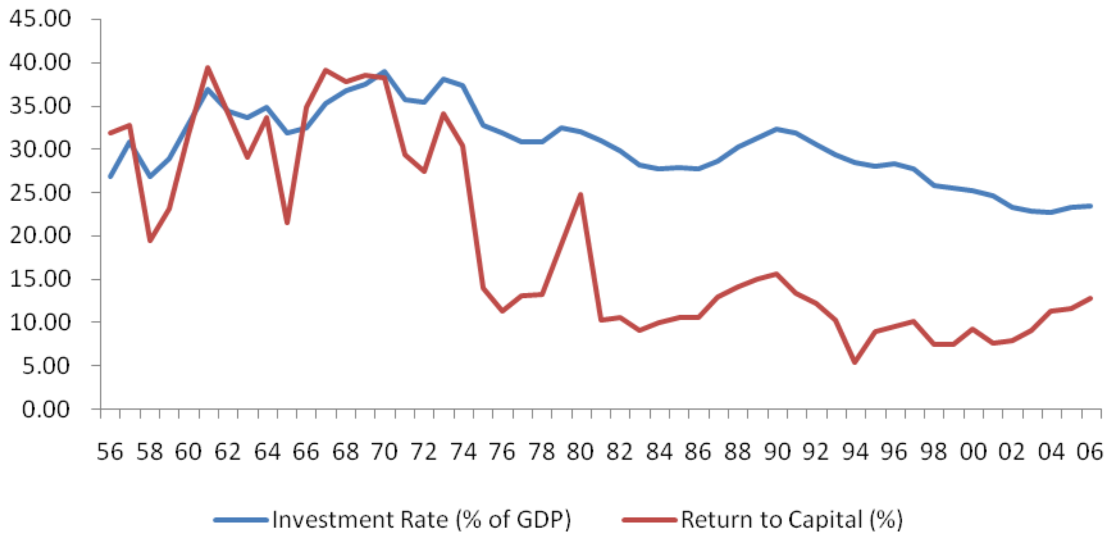
**图 4：中国的投资率（%）**




#### 3.4.2 日本的投资率

如图 5 所示，在 1956 年至 1970 年期间，日本的投资率从 1956 年的 26.80%上升至 1970 年的 39.02%，与此同时，日本的资本回报率从 1956 年的 31.95%升至 1970 年的 38.38%，平均高达 32.36%。1970 年后，日本的投资率降低至 2006 年的 23.46%，在此期间，日本的资本回报率下降至 2006 年的 12.79%。日本的经验表明投资者在资本回报率较高时的投资意愿往往也较高，而在资本回报率较低时投资意愿往往也较低。

**图 5：日本的投资率（%）**

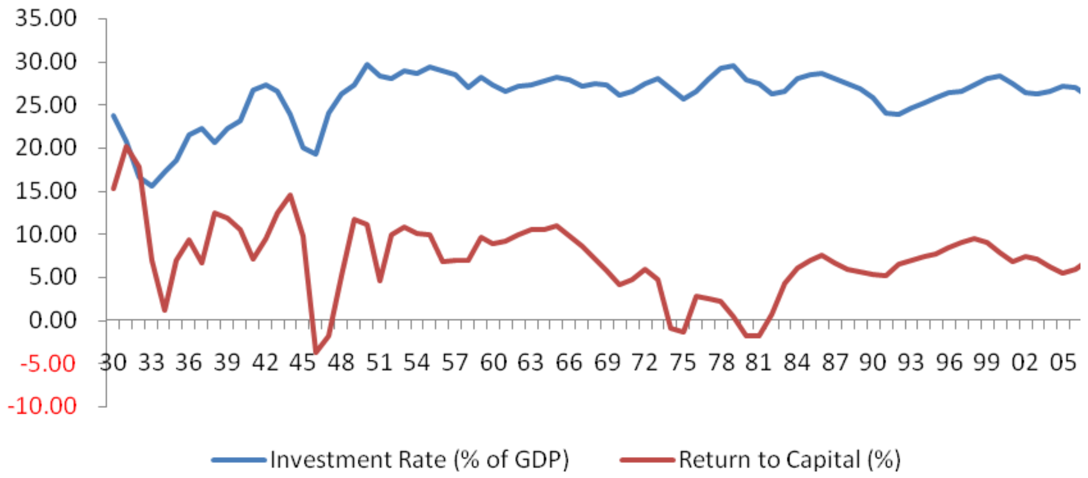



#### 3.4.3 美国的资本回报率

如图 6 所示，在 20 世纪三十年代初期，美国的投资率经历了大幅度的下降，而这段时

间正好是美国经济大萧条的时期。此后美国投资率从 1933 年的 15.60%增加至 1950 年的 29.68%，达到美国历史上最高的投资率水平，在此期间，美国的资本回报率从 1.27%飞速上升至 11.08%。1950 年之后，美国的投资率在 24%与 30%之间波动，平均约为 27%，维持在一个相对较为稳定的水平。在 1950 年至 1970 年期间，美国的资本回报率也基本维持稳定。在 20 世纪 70 年代，由于石油危机，美国的资本回报率经历了剧烈的递减，之后才缓慢上升并维持相对稳定。但是石油危机似乎并没有影响美国的投资率，一个可能的原因是在石油危机期间，美国政府推出很多经济刺激政策，例如解除管制及里根经济学，这促使美国私有部门可以投资于能源、通信、交通及银行等领域，使得美国的投资率维持在一个较为稳定的水平。

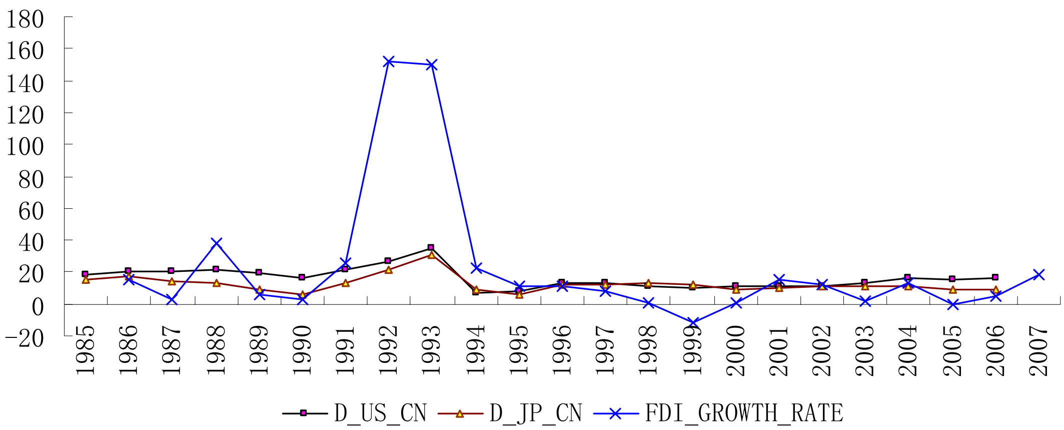
**图 6：美国的投资率（%）**




### 3.5 资本回报率差异与 FDI

外国直接投资是构成投资的一个重要部分，其近年不断增长也是推高中国国内投资率的一个原因。毫无疑问，影响资本跨国流动的一个重要因素是跨国资本回报率差异。图 7 列示了 1985 年至 2007 年中国实际利用 FDI 增长率和中国与两大资本输出国美国、日本资本回报率差异间的关系。可以直观地看到，当中国资本回报率与美日的回报率差提高时，FDI 增长率显著提高，这在 1992-1993 年间尤为显著。中国的实际利用 FDI 增长率与中国和日本资本回报率差间相关关系更明显，相关系数为 0.83，高于与美国差异间的相关关系。

**图 7 资本回报率差异与中国 FDI 增长率**



## 4. 影响资本回报率的重要因素

### 4.1 边际回报率

#### 4.1.1 符号及定义

**边际回报率（MR）**：我们定义的边际回报率是当单个因素发生单位变动时投资回报率的变化量，因此，因素 i 的边际回报率，$MR_i$，可表示为：

$$MR_i = \frac{\partial r}{\partial f_i} \text{……} \textbf{(7)}$$

其中，

$r$：资本回报率；

$f_i$：因素 $i$。

#### 4.1.2 边际回报率的估算

根据式（5），我们可得：

$$r(t) = \frac{1 - \dfrac{W(t)L(t)}{P_Y(t)Y(t)}}{K(t)P_K(t) \big/ P_Y(t)Y(t)} + \left(\hat{P}_K(t) - \hat{P}_Y(t)\right) - \delta(t)$$

$$\Rightarrow r(t) = \frac{1-\beta(t)}{\varphi(t)} + \left(\hat{P}_K(t) - \hat{P}_Y(t)\right) - \delta(t) \text{…..} \textbf{(8)}$$

其中，

$\beta(t) = \dfrac{W(t)L(t)}{P_Y(t)Y(t)}$：劳动者份额；

$\varphi(t) = K(t)P_K(t) \big/ P_Y(t)Y(t)$：资本-产出比。

通过分别对上述五个变量求偏导，我们可得：

$$dr(t) = \frac{\partial r(t)}{\partial \beta(t)} d\beta(t) + \frac{\partial r(t)}{\partial \varphi(t)} d\varphi(t) + \frac{\partial r(t)}{\partial \hat{P}_K(t)} d\hat{P}_K(t) + \frac{\partial r(t)}{\partial \hat{P}_Y(t)} d\hat{P}_Y(t) + \frac{\partial r(t)}{\partial \delta(t)} d\delta(t) \text{..} \textbf{(9)}$$

其中，

$\dfrac{\partial r(t)}{\partial \beta(t)} = -\dfrac{1}{\varphi(t)}$：劳动者份额的边际回报率；

$\dfrac{\partial r(t)}{\partial \varphi(t)} = -\dfrac{1-\beta(t)}{\left(\varphi(t)\right)^2}$：资本-产出比的边际回报率；

$\dfrac{\partial r(t)}{\partial \hat{P}_K(t)} = 1$：投资平减指数的边际回报率；

$\dfrac{\partial r(t)}{\partial \hat{P}_Y(t)} = -1$：GDP 平减指数的边际回报率；

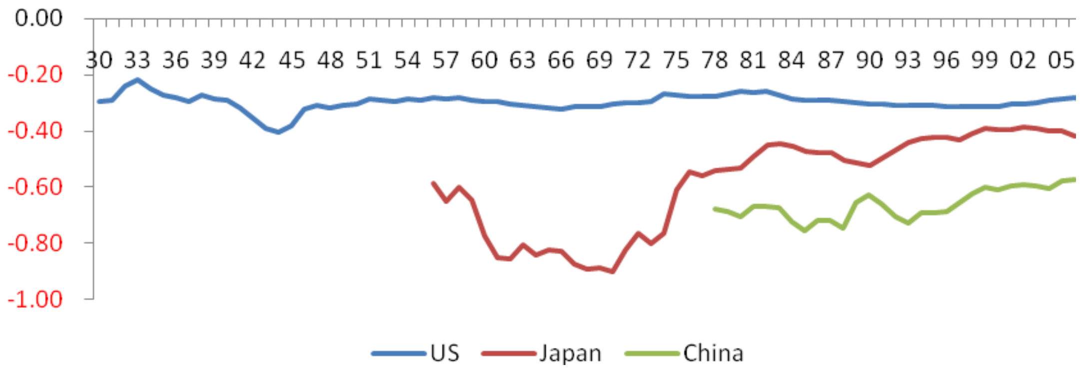
$\dfrac{\partial r(t)}{\partial \delta(t)} = -1$：折旧率的边际回报率。

从式 9 可以看出，我们仅仅需要估算劳动者份额及资本-产出比的边际回报率，而其它因素的边际回报率都是常数（投资平减指数增长率的边际回报率为 1，GDP 平减指数增长率和折旧率的边际回报率为-1）。同时，我们也可以看出劳动者份额及资本-产出比的边际回报率都是负的，意味着资本回报率随着劳动者份额及资本-产出比的增加而递减。

如图 8 所示，日本的劳动者份额边际回报率从 1956 年的-0.58 逐渐减至 1970 年的-0.9，

原因在于日本在这段时间内的资本-产出比从 1956 年的 1.71 减少至 1970 年的 1.11。在 20 世纪 70 年代至 80 年代初期，日本的资本-产出比从 1970 年的 1.21 增加至 1983 年的 2.24，使得劳动者份额的边际回报率从-0.82 增至-0.45。此后，日本的劳动者份额边际回报率在-0.44 左右波动，并维持在一个较为稳定的水平。与日本相比，美国的劳动者份额边际回报率较为平稳。如图 8 所示，美国在 1930 年至 1970 年期间的劳动者份额边际回报率平均约-0.3，而日本则平均约-0.58。图 8 也显示了中国的劳动者份额边际回报率平均为-0.66，低于日本及美国的平均值。

**图 8：劳动者份额的边际回报率**




如图 9 所示，日本的资本-产出比边际回报率在 1958 年至 20 世纪 80 年代初期间的波动性比较强，而 20 世纪 80 年代中期之后维持一个相对稳定的水平。与日本相比，中国和美国的资本-产出比边际回报率较为平稳，但是，中国的资本-产出比边际回报率平均为-0.22，低于日本的均值-0.19 以及美国的均值-0.04。

**图 9：资本-产出比的边际回报**

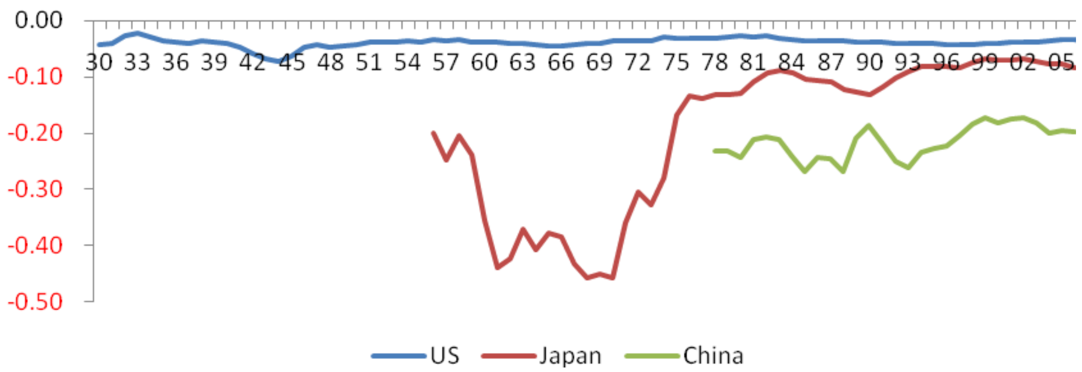



图 8 和图 9 显示，劳动者份额及资本-产出比的边际回报率通常都是负的，意味着资本回报率随着劳动者份额及资本产出比的增加而递减。从长期来看，劳动者份额及资本-产出比的边际回报率都会趋于稳定。资本回报率在其处于较高水平的时候变动比较大，而在其处于较低水平的时候变动比较小，资本回报率能够在经历一定时期的递减之后变得相对稳定。在短期，资本回报率的变动源于劳动者份额及资本-产出比的变动，以及折旧率、投资平减指数、GDP 平减指数的变动。下面我们将逐一讨论这些因素的变化趋势以及这些变化如何影响资本回报率的今后走势。

### 4.2 主要因素的变动趋势

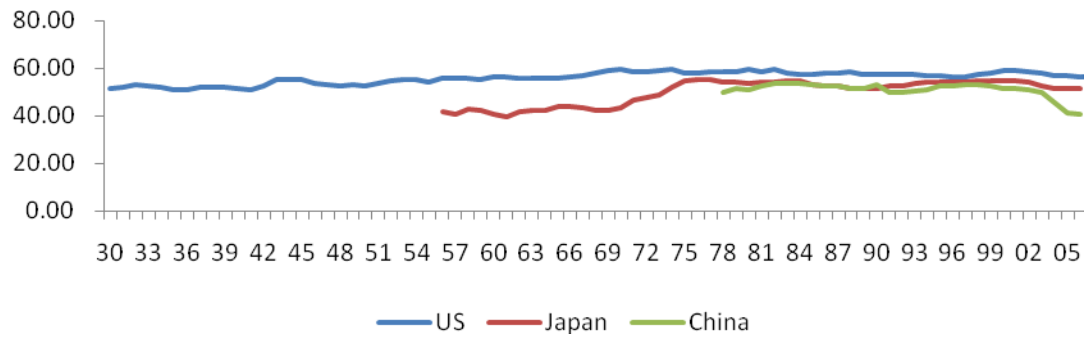
#### 4.2.1 劳动者份额的变化趋势

由式（5）不难看出，资本回报率随着劳动者份额的增加而减少。如图 10 所示，日本的劳动者份额从 1956 年的 41.44%上升至 2006 年的 51.6%，美国从 1930 年的 51.43%上升至

2007 年的 56.63%，但是中国的劳动者份额却从 1978 年的 49.57%降至 2006 年的 40.61%。可见，中国的劳动者份额比日本和美国的都低，较低的且在不断降低的劳动者份额使得中国的资本回报率比日本及美国都要高。这是非常直观的经济现象：当劳动者报酬比较低的时候，资本所得就会相对较高，从而使得资本回报率处于较高的水平。

中国劳动者份额相对较低的主要原因在于中国是以制造业为主的经济，而制造业本身的性质使其劳动者报酬相对服务业的劳动者报酬要低。此外，由于中国农村的劳动力源源不断的往城市输送，使得中国的在过去三十年中具有非常富余的廉价劳动力，甚至使得劳动者份额在过去三十年不断降低。随着经济的不断发展以及就业的不断充分，中国的劳动者将会不可避免的要求提升劳动者报酬，从而使得劳动者份额有所上升，并最终降低资本回报率。但是，在未来一段时期内，中国的劳动者份额不大可能有显著快速的提升，而且相对日本及美国来说仍然会处于较低水平。原因在于，一方面，中国在相当长时间内仍然是以制造业为主，经济转型不会快速完成；另一方面，中国仍然有大量的农村劳动力需要往城市转移。

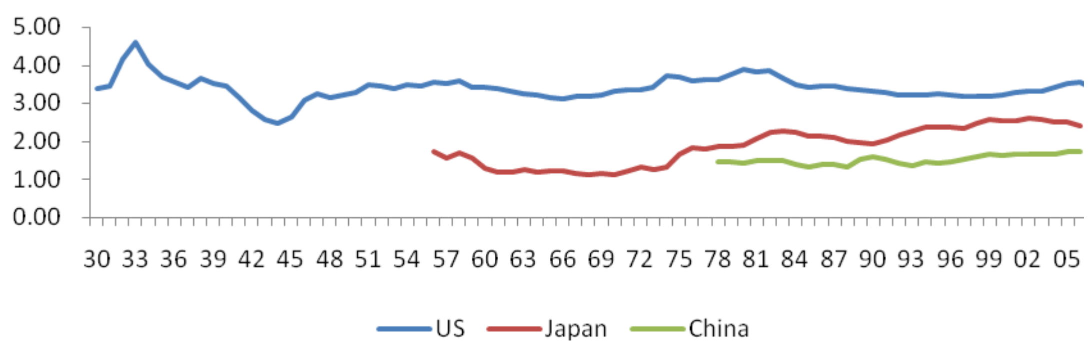
**图 10：中国、日本及美国的劳动者份额（%）**




**4.2.2 资本-产出比的变化趋势**

与劳动者份额一样，资本-产出比的边际回报率也是负值，意味着资本回报率是资本-产出比的减函数。如图 11 所示，美国的资本-产出比相对于中国和日本的要高，而中国的资本-产出比是这三个国家当中最低的。美国的资本-产出比在 1930 年至 2007 年期间平均约 3.4，高于日本在 1956 年至 2006 年期间的平均水平 1.86。中国的资本-产出比在 1978 年至 2006 年期间平均约 1.52，比日本及美国的平均水平都低，这使得中国的资本回报率高于日本及美国的资本回报率。

**图 7：中国、日本及美国的资本-产出比**




一个较高的资本-产出比具有什么样的经济学含义呢？它是意味着一个较低的 GDP 水平，还是一个较高的资本存量？对于日本及美国这两个世界上最大的经济体的来说，较高的资本-产出比意味着较高的资本存量。上个世纪日本及美国吸引了大量投资，这是很自然的事情，因为这两个国家在上个世纪具有较高的资本回报率，经济也经历了飞速的发展，而正是这些投资使得两国都具有较高的资本存量。图 11 显示了日本的资本-产出比从 1956 年的 1.71 上升至 2006 年的 2.41，而中国的资本-产出比只从 1978 年的 1.47 轻微上升至 2006 年的 1.74。虽然美国的资本-产出比在 1930 年至 2007 年期间没有经历显著的变化，但是它基

本维持在高达 3.4 的水平，这比中国及日本的资本-产出比要高。

从美国及日本的经验我们可以看出随着投资的不断增加，中国的资本-产出比将会不可避免的会上升，原因在于目前中国的高资本回报率会吸引更多的投资，而这将会增加中国的资本存量并提升资本-产出比。但是，与劳动者份额一样，在短期内中国的资本-产出比似乎不会经历显著变化，原因在于中国是世界第三大的经济体，具有非常庞大的 GDP，同时中国的 GDP 还具有非常高的增速。而中国相对较低的资本-产出比将会在未来数年内使其资本回报率高于日本及美国。

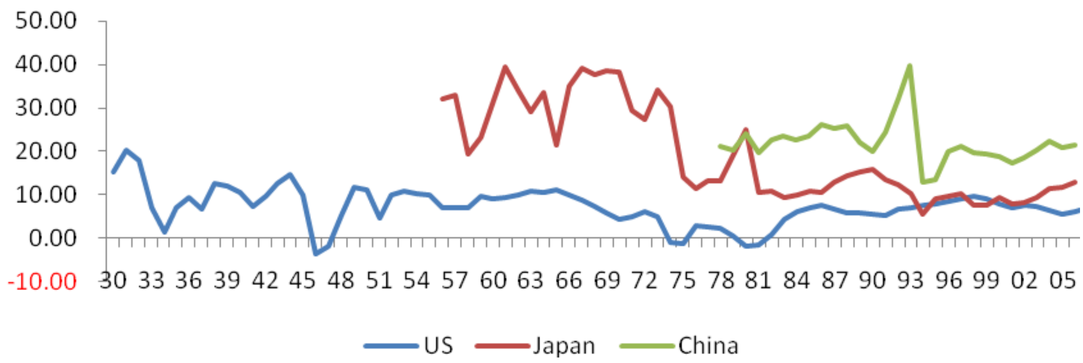
## 5. 资本回报率和投资率的今后走势分析

### 5.1 资本回报率的变化趋势

#### 5.1.1 资本回报率从长期来看遵从递减的趋势

如图 12 所示，日本的资本回报率从 1956 年的 31.95%降至 2006 年的 12.79%，而美国的资本回报率则从 1930 年的 15.28%降低至 2007 年的 6.94%，这意味着从长期来看，资本回报率遵从一个递减的趋势。原因在于在经济发展的初期，劳动者份额及资本-产出比往往处于较低的水平，而随着经济的发展，劳动者份额及资本-产出比会有所上升，这使得资本回报率有所下降。日本的劳动者份额从 1956 年的 41.44%上升至 2006 年的 51.6%，而美国则从 1930 年的 51.43%上升至 2007 年的 56.63%，与此同时，日本及美国的资本-产出比也有不同程度的上升。美国和日本的经验表明在经济飞速发展的初期，资本回报率处于较高的水平，随着经济的发展，资本回报率会经历显著下降，并在下降一定时间和幅度之后波动在一个较低的水平。这就是为什么在 1965 年至 1980 年日本经济飞速发展的时期，日本的资本回报率平均高达 28%，而在 1978 年至 2006 年中国经济飞速发展时期，中国的资本回报率平均高达 21.9%。

**图 8：中国、日本及美国的资本回报率（%）**




#### 5.1.2 未来数年中国的资本回报率将会继续维持在较高水平

随着劳动者份额及资本-产出比的提高，中国的资本回报率将会不可避免的降低，这也是世界各主要发达国家的经验。但是，由于较低的劳动者报酬份额及较低的资本产出比绝对水平，这些因素难以快速提高，加上折旧率不断下降的趋势，未来数年中国的资本回报率将会继续维持在较高水平，并且高于日本和美国。考虑日本追赶美国的趋势，在战后经济高速发展约 40 年，日本的资本回报率开始与美国相当。简单类比，中国至少还有十年左右的时间可以维持相对较高的资本回报率。如果考虑规模因素，这个时间要更长。

### 5.2 中国未来数年的投资环境

中国的资本回报率尽管在 1978 至 2006 年间平均高达 21.9%，但是分析显示，由于较低

的劳动者份额及资本-产出比，在未来数年内中国的资本回报率将会继续维持在较高的水平，意味着中国将会继续维持一个较高的投资率并吸引更多的 FDI 流入。随着经济的发展，劳动者份额及资本-产出比将会不可避免的上升，这将使得资本回报率难免有所下降，但是在未来数年内，由于较低的劳动者份额及资本-产出比，中国的资本回报率将会继续高于日本及美国，并且随着 WTO 规定可投资领域不断放开，都将使得 FDI 继续加速流入中国。

要分析投资回报率和投资率的动态影响关系，向量自回归（Vector Auto-Regression, VAR）模型是一个简单有效的办法。它考察了几个内生变量间滞后项与水平项的相互影响关系。然而，当我们使用 VAR 模型估计的时候，发现了投资回报率的正螺旋向上结果，和长期事实并不相符。可能的原因是，我国的劳动力市场尚未达到均衡水平，使得资本回报率和投资率间的动态负向影响关系不显著，即投资率提高，但资本回报率也在提高。因此，本文没有用这种计量模型加以估计，而更多的采用定性观察的办法。

### 5.3 高技术产业 FDI 及资本回报率特点

如上所述，较大的跨国资本回报率差异带来了较高的 FDI 流入中国速度。这些 FDI 的流入不止限于低技术行业，高新技术产业跨国投资也不断增多。这里所说的高新技术产业，包括计算机与通信、生命科学、电子、计算机集成制造、航空航天、光电、生物、材料等。根据商务部《中国外商投资报告 2003-2007》的统计，2004-2006 年实际利用 FDI 总额增速分别为 13.3%、-0.5%和 4.46%，而高新技术 FDI 增速分别达到 4.09%、22.80%和 32.64%。高新技术投资占全部 FDI 比重从 2003 年的 15.0%增加到 2006 年的 21.6%。其中电子及通讯设备制造业额度最大。在出口中，外商投资企业高新技术产品出口额占全国高新技术产品出口总额的比重从 2003 年的 77%增加到 2006 年的 88%，占全部外资企业出口额的比重从 2003 年的 38%增加到 2006 年的 44%。同时，外商投资企业高新技术产品出口额增速在 2003-2006 年分别为：64.8%、57.6%、32.8%和 29.1%，而全国高新技术产品出口总额增速分别为 76.0%、38.9%、31.8%和 28.9%，外商投资企业出口总额增速分别为 41.4%、40.88%、31.2%和 26.9%。通过这些数字都可以看到，在中国吸引的 FDI 投资中，结构也在不断发生变化，高技术产业规模在不断扩大。

本文也通过统计局提供的工业企业数据库对不同行业资本回报率做了估算，发现从 2003-2007 年，各个行业回报率在趋向收敛，2007 年约为 20%。而高技术部门投资增多，可能说明外资在这方面更具有比较优势。

## 6. 总结

本文通过估算中国、美国和日本资本回报率，分析中国为何拥有如此之高的国内投资率和 FDI，以及今后投资率和 FDI 的可能走势。结果显示，中国的资本回报率在过去三十年内维持在较高的水平，平均高达 21.9%，甚至高出日本及美国 10 多个 百分点。与此同时，中国的投资率从 1978 年的 29.46%上升至 2006 年的 42.75%，远远高出日本及美国。同时我们还分析发现，当资本回报率比较高的时候，投资率往往也处于较高的水平，当资本回报率比较低的时候，投资率往往也处于较低的水平。这说明中国之所以在过去三十年拥有较高的投资率正是因为中国具有非常可观的资本回报率。投资回报率与投资率高度相关，说明其对投资率解释力度很强，可能是影响中国高投资率的最重要因素。

通过对资本回报率的分析，我们发现资本回报率在一定程度上受到经济周期的影响，但从长期来看，资本回报率遵从递减的趋势。这是因为资本回报率主要受到劳动者份额及资本-产出比的影响。在经济发展初期，劳动者份额及资本-产出比往往处于较低的水平，随着经济的发展，劳动者份额及资本-产出比会有所上升，这使得资本回报率难免有所下降。中国的资本回报率之所以高于日本及美国正是因为中国具有较低的劳动者份额及资本-产出比。当然从长期来看，中国的劳动者份额及资本-产出比将会不可避免的上升，并将导致资本回报率的下降，但是，在未来数年内，中国的资本回报率将会继续维持在较高的水平，并将高于日本及美国。这是因为中国的劳动者份额及资本-产出比尚处于较低的水平，而且短

时间内不会经历显著的提升。并且，根据发达国家经验，折旧率也将经历显著下降的过程，这些都使得投资回报率较高。

同时，通过对日本及美国的资本回报率分析发现，过去三十年资本回报率并未出现收敛，这意味着中国与日本及美国资本回报率的差异将会继续存在，使得 FDI 将会继续涌入中国这个资本回报率相对较高的经济体。

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# 中国医药产业价值链及国际分工研究

李大伟　杨长湧　杜琼

本文运用价值链分析和 GL 指数、投入产出模型等工具，对医药产业价值链的特征以及中国在全球医药产业价值链中的位置进行了研究。研究结果表明，在全球医药价值链中，专利药的价值链完全属于生产者驱动型，其核心增值主要来自研发投入；而非专利药的价值链中则存在着相对独立，与研发关系较弱的原料药生产环节。在此基础上，本文对中国在全球医药产业价值链的位置进行了实证研究。结果表明，中国目前在全球医药产业国际分工中主要处于微笑曲线最低端的非专利药生产这一位置，是医药产业垂直专门化分工的组成部分。本文据此计算了中国医药产业的 VS 指数，并将医药产业和计算机产业参与全球垂直专门化分工的状况进行了对比。最后，本文对中国在医药产业研发环节的国际分工中的地位也进行了探讨

关键词：价值链分析，GL 指数，产业内贸易，垂直专门化分工

## 第一节　前言

国际分工是世界上各国（地区）之间的劳动分工，是各国生产者通过世界市场形成的劳动联系，是国际贸易和各国（地区）经济联系的基础。近年来，在全球价值链理论框架下的国际分工理论立足于一个全球国际生产网络的视角，对在全球化程度不断加深的背景下出现的产业内分工、垂直专业化分工等现象作出了有效的解释，已逐渐成为目前研究各行业国际分工的主流理论之一。

医药产业作为为广大消费者提供健康医疗用品的重要行业，不但能够直接拉动经济增长，而且具有极强的正向外部性。正如全球最大的制药行业组织美国药物生产和研发协会(PHRMA)所宣称的那样，医药产业最大的价值在于为人类提供更长的寿命和更好的健康、其次才是拉动经济增长。同时，医药产业是典型的技术密集型行业，研发环节在医药产业中具有重要位置。据 PHRMA 统计，2008 年美国医药行业 R&D 投入就高达 652 亿美元。我国作为世界上人口最多的国家，医药产业健康发展不但有利于劳动经济增长和提升我国整体的科研能力和国际竞争力，而且对改善我国居民的医疗福利具有非常重要的意义。

加入 WTO 以来，我国医药产业迅速发展。据笔者测算（计算方法见正文），2008 年我国医药产业对外贸易额高达 122.8 亿美元，较 2002 年约上升了 2.6 倍。因此，运用现代价值链理论和国际分工理论对我国医药产业在全球价值链和国际分工中的地位进行分析，对我国医药产业的健康快速发展有着非常重要的意义。

本文在全球价值链理论框架下对我国医药产业的价值链和国际分工状况进行研究。正文主要分以下四个部分。第二部分是文献综述，阐述本文的研究背景及运用的相关理论工具。第三部分将对医药产业价值链的自身特点进行阐述，并在此基础上分析中国在全球医药产业价值链中的相对优势环节。第四部分将基于前文的分析对中国医药产业的国际分工地位进行实证研究。最后是一些政策建议。

## 第二节 文献综述

一、价值链理论的相关文献

价值链(Value Chain)一词最早由迈克尔·波特在 1985 年提出。波特将企业的生产经营流程解构为一系列的价值创造过程，这一系列流程的连结既是价值链。波特认为，绝大多数

产品的价值链均有共通性，即包含主要生产环节和支持环节两类，前者主要为生产该产品主要的生产与销售程序，后者则包括为主要生产环节提供支持的相关环节，如基础建设、研发、人力资源管理等等。

Gereffi(1999)则从产品特征角度将价值链分为生产者驱动型和消费者驱动型。他认为，生产者驱动型价值链主要处于资本和技术密集型行业中，少数大制造商是整体生产网络布局的决定者。而消费者驱动型价值链的生产网络则非常分散，整体生产网络布局则由大量的零售商、分销商和小生产商共同组成，多存在于劳动密集型行业中。Kaplinsky and Morris(2000)进一步将价值链分为简单价值链（simple value chain）和扩展价值链(extended value chain)。他们指出，大多数价值链均可以简化为研发、生产、营销和消费及再利用四个环节，且四个环节相互影响。但具体产品的价值链则要较上述描述复杂的多，往往涉及多个企业和行业，从而形成一个大的价值链网络。Gereffi(2005)进一步提出了全球价值链的概念，将整个行业上游的研发、设计，中游的零部件制造和组装、下游的营销、品牌和服务等整合成一个国际性的生产网络，为分析全球化背景下各国在国际分工中的位置提供了新的视角。

二、国际分工理论的相关文献

最早的国际分工理论可以追溯到亚当·斯密的绝对优势理论。在其著名作品《国富论》中，斯密阐述了当一国所消耗的劳动成本绝对低于另一国时，该国则会生产并出口该种产品。随后大卫·李嘉图进一步发展了斯密的学说，提出了相对优势理论。赫克歇尔和俄林则进一步提出了资源禀赋学说，将产品分为劳动密集型产品、资本密集型产品和技术密集型产品等部类。

上个世纪后半叶以来，随着国际分工的进一步深化，产业内贸易占全球贸易的比重逐渐增加，针对产业内分工的研究逐渐成为了国际分工的研究主流。Verdoorn(1960)最早提出了国际贸易标准体系分类（SITC）项下同一产品组类而非不同产品组间贸易增长的现象。Balassa(1963)对欧共体的研究也证明了这一观点。而 Gray(1979)和 Krugman(1981)等学者进一步完善的产业内贸易的概念。Grubel&Lloyd(1975)提出了将产业内贸易分为水平型产业内贸易和垂直型产业内贸易的方法，并被大多数学者所采用。

近年来，随着跨国公司在全球范围内全面布局不同的价值链环节，国际垂直专业化分工成为了产业内分工的新形式。国际垂直专业化分工是指同一产业内同一产品的不同生产阶段（生产环节）之间的国际分工，既可在跨国公司内部实现，也可以通过市场在不同国家间的非关联企业间完成。Hummels, Ishii and Yi(2001)所建立的 VS（vertical specialization）指数，为垂直专门化的定量分工提供了条件。目前已经有大量的学者针对的各国的垂直专门化分工状况进行了深入研究和定量测算。该理论与全球价值链理论有着近似的理论基础，逐渐成为目前研究各产业国际分工的主流理论之一。

三、关于我国整体和产业价值链和国际分工的相关文献

目前，已有相当多的学者针对我国整体或个别产业的价值链和国际分工研究。如刘遵义和陈锡康运用2002年非竞争型投入占用产出表对我国41大部类的出口的国内增值率进行了测算；平新乔所带领的北京大学经济研究中心课题组对中国各行业出口的垂直专门化指数进行了测算；喻志军（2008）对我国产业内贸易的整体状况进行了测算；胡昭玲（2006）对产业内贸易和垂直专业化分工进行比较，说明垂直专业化分工是产业内贸易的一种新形式；王建华等专门对中国纺织服装业的垂直专业化分工进行了测算；黄先海等（2007）对中国制造业出口垂直专业化程度进行了测算；闫逢柱等（2008）针对我国装备制造业产业内贸易进行了测算。

但目前上述研究仍然存在以下两方面的不足：第一，没有将不同产业的价值链特征和其国际分工特点进行对比，因此对不同产业产业内贸易和垂直专业化贸易的程度很难给出有说服力的解释；第二，目前从国际分工和全球价值链视角对我国医药产业进行分析的研究很少。

本文将首先基于价值链理论对医药产业价值链的自身特点分析，并在此基础上论证我国在全球医药产业价值链中的优势环节，并据此对我国在全球医药产业国际分工中的地位进行实证研究。

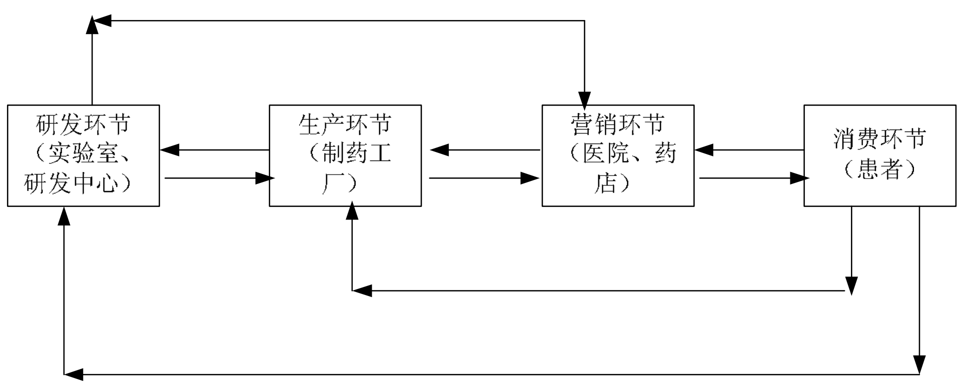
## 第三节　医药产业价值链结构研究

一、医药产业价值链的特殊性

价值链分析（Value Chain Analysis）这一方法最早起源于迈克尔·波特。他将企业的生产经营流程解构为一系列的价值创造过程，并这一系列流程的连结称作价值链（Value Chain）。而 Gereffi(1999)则进一步从产品特征角度将价值链分为生产者驱动型和消费者驱动型，并给出了两类价值链的判别特征。Kaplinsky and Morris(2000)在前人研究基础上对价值链分析框架进行了总结，并提出了将价值链分为简单价值链（simple value chain）和扩展价值链(extended value chain)的分析模式。他们认为，大多数产品的价值链均可以用研发、生产、营销和消费四个环节的模型来描述。但不同类产品的扩展价值链却较为复杂，并以木材产业为例给出了一个扩展价值链的流程图。

本文主要按照这一分析模式对药物产业的价值链进行分解。根据美国罗氏、辉瑞公司所提供的药物生产流程和江苏省金陵药业公司的实地调研结果，发现和其它制成品类似，医药产业的简单价值链符合 Kaplinsky(2000)所提出的模型，如图 1 所示。

图 1　医药产业简单价值链示意图




然而，药品的扩展价值链则具有非常明显的特殊性，主要体现在以下几个方面：

第一，不同类型药品的扩展价值链存在明显的差异。国际上对药品的分类有多种形式，如按照生产流程分为医药分为化学药品、生物药品（我国还有中药）；以专利保护为标准分为专利药和非专利药等等。在汽车、计算机等产业中，不同型号的最终产品的生产环节具有高度的相似性。但上述各类药品虽然同为最终产品，但其生产环节分工却呈现出明显的不一致性。

第二，医药产品价值链的产品模块化程度相对较低。模块化（modularization）是指将整个生产工序自顶向下划分成若干模块的过程。每个模块完成一个特定的子功能，所有的模块按某种方法组装起来，成为一个整体，完成整个系统所要求的功能，是目前现代跨国公司的主要生产模式。

在计算机、汽车等大多数资本和技术密集型产业中，模块化的程度相当高。如个人电脑可以拆分为显示器、CPU、键盘、主板等多个子模块，各个模块均有明确的功

能定义，必须组合成一个整体才能发挥出系统要求的功能。但药品的功能完全体现在其主要药物成分方面，基本上很难将药物分解为多个子模块，因此模块化程度要远远低于其它资本和技术密集型工业产品。

目前可以将一部分药物的生产划分为原料药（Raw material）生产和制剂(preparation)生产两大模块。原料药是指由化学合成、植物提取或生物技术所制备的不能由病人直接服用的物质。而制剂则是根据原料药加工所得到直接服用的给药形式。一般原料药视品种不同，需要通过化工、生物技术和植物提取等做法生成，往往是一个化学过程或生物过程；而制剂生产则是指按照固定的配方主要是对药物进行包装、鸦片、制膏等物理变化。

第三，药物行业研发环节较为复杂，且模块化程度较高。药物行业研发的一个显著特点在于，由于其产品直接作用于人体，因此产品的实际效果在研发之前往往有较大的不可测性。因此，为保证药品的疗效和安全性，药物行业研发环节中有着极其复杂的动物实验和临床试验环节，且各类实验又可划分多个子环节。这一现象是药物行业的特殊性，在绝大多数行业中均无法对应。

这一现象早就了制药行业研发投入高、风险大、周期长的特点。以计算机为例，其核心处理器（CPU）的新产品推出一般只需要一年左右的时间，但根据美国创新药物委员会公布的数据，研发一种新药需要 10-15 年的时间， 2006 年美国一种新药的研发成本高达 13 亿美元。用于研发的投入占平均总销售额的 20.3%。从表 1 中可以看出，美国医药企业的辉瑞公司的研发投入规模、研发投入比和利润率均要明显高于 IT 行业的龙头企业 Intel 公司。

表 1： IT 产业和医药产业代表性跨国公司 2008 年部分财务指标（前三个指标单位为百万美元）

| | 辉瑞 | | | 英特尔 | | |
|---|---|---|---|---|---|---|
| 年份 | 2008 | 2007 | 2006 | 2008 | 2007 | 2006 |
| 营业收入 | 48296 | 48418 | 48371 | 37586 | 38334 | 35382 |
| 研发投入 | 7945 | 8089 | 7599 | 5722 | 5755 | 5873 |
| 净利润 | 8104 | 8144 | 19337 | 5292 | 6976 | 5044 |
| 每股收益 | 1.2 | 1.17 | 2.66 | 0.92 | 1.18 | 0.86 |
| 研发收入比 | 16.45% | 16.71% | 15.71% | 15.22% | 15.01% | 16.60% |
| 主营业务利润率 | 16.78% | 16.82% | 39.98% | 14.08% | 18.20% | 14.26% |

数据来源：美国辉瑞公司、Intel 公司年报

本文针对制药行业的上述特点，分别按照专利药和非专利药、原料药和制剂、化学制药、生物制药和中药两种分类方式对各子产品的扩展价值链进行了分析。

二、专利药和非专利药扩展价值链比较研究

专利药和非专利药扩展价值链比较。专利药（国内也称原研药）是指原创性的新药，在研发成功之前基本无法人工合成或从生物中提取，其疗效也并不为业界所知。这类药物多用于治疗各种尚无有效药物的疾病，其研发过程极其复杂。据美国辉瑞公司介绍，一种专利药的研发要经历发现药物成分、临床前开发、新药临床前申请(IND)、新药临床试验 I 期、新药临床试验 II 期、新药临床试验III期等多个环节，进行多年的临床试验后才能够进入市场。而非专利药则是指当，某种专利药的专利保护期到期后，对其进行模仿生产的代用品。显然，专利药和非专利药的研发环节有明显差异。非专利药的生产无需前期的发现药物成分、临床前开发等环节，而临床试验的成功率也要远远高于专利药。

图 2 给出了专利药生产的扩展价值链。其研发环节包含五个子环节：第一个环节是发

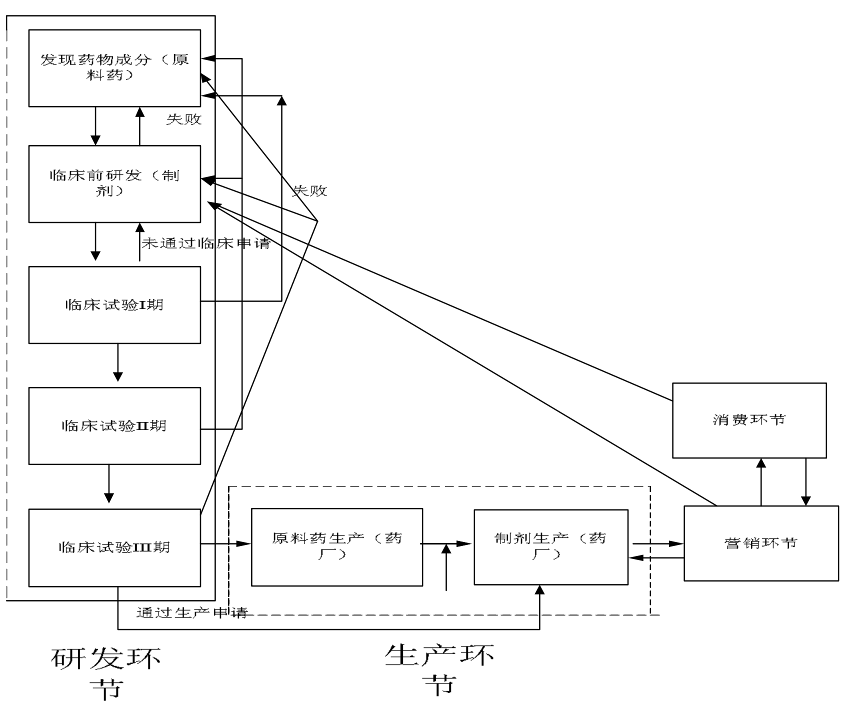
现主要药物成分。这种主要药物成分可以体现为化学分子式（化学制药，包括植物药），也可以体现为某种基因和病毒（生物制药），甚至体现为某种配方（如中药）。这个环节的研发带有明显的基础研究性质，在 R&D 分类中大部分可归入基础研究范畴；第二个子环节主要是临床前开发，即将原始的主要药物成分转化为直接被人体服用的药品，如研究不同药品配比、不同剂型对药效和副作用影响，该部分研究在 R&D 分类中大部分归入应用研究和试验发展范畴。第三至第五个环节主要是临床试验。主要通过大量的实验对药品的疗效进行实证，并将数据结果返回给上两个环节，基本上属于试验发展范畴。而当临床试验失败之后，必须返回到临床前研发，甚至发展主要药物成分环节重新开始。

这种独有的研发模式是专利药研发周期长、耗资高和风险大的主要原因。统计数据显示临床试验的成功率不到五分之一，基本上研发成功一次新药要重复几十、几百次的上述各项研发环节，从而大大延长了专利药研发的时间和增加了研发成本。

因此，专利药的生产决定了其研发和生产的核心价值链环节均被跨国公司垄断。其原因在于，在专利保护期内，只有专利所有者能够生产该项专利药，该产品的市场属于完全垄断市场，从而保证了专利所有者所获得的巨额利润。事实上，发达国家的大型跨国医药公司的高额利润往往主要来自几个专利药品种。

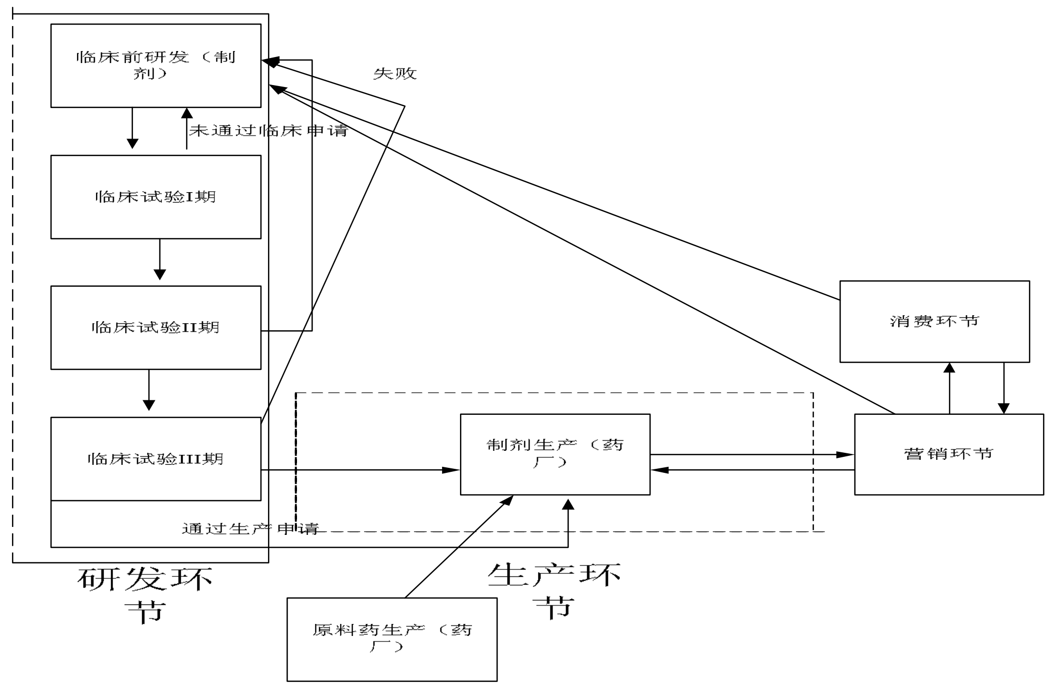
根据以上的分析，我们对专利药价值链各部分环节的增值率进行判断。首先，研发环节是专利药价值链的主要增值环节，保证了专利所有者垄断生产该项产品的地位。其次，研发环节中的前两个环节是主要增值环节，主要从事创新性工作，而临床试验环节则是为辅助环节，为前两个环节提供数据支持。再次，专利药的生产环节（包括原料药生产和制剂生产）实际上是研发环节的辅助环节，主要发挥实现利润的功能。最后，由于跨国公司在该市场上近似处于完全垄断地位，因此营销环节所实现的增值要远远低于研发环节。

图 2：　专利药扩展价值链示意图



而非专利药（国内又称仿制药）的扩展价值链则与专利药有明显差别。首先，非专利药价值链基本上不存在发现药物成分的环节。非专利药的主要药物成分和配方基本上来自于专利药，无需在这一环节投入过多的资金进行研发。其次，非专利药的临床前研发环节投入规模要明显小于专利药。一般而言，专利药的制剂配方是通过大量的临床研究数据得出的，具有良好的预后效果，为非专利药的临床前研发提供了良好的基础。因此，非专利药可以通过较少的研发投入得到符合其特定医疗要求的制剂产品。最后，非专利药的原料药生产与研发链关系不大。由于原料药的生产流程和工艺主要来自第一个研发环节，因此非专利药的原料药生产并不需要前面的研发环节就可以进行，因此原料药生产存在独立参与国际分工的可行性。图 4 给出了非专利药的扩展价值链。

图 3：　非专利药的扩展价值链




对比图 2 和图 3 可以看出，非专利药的价值链与专利药相比存在以下差别：

1．非专利药的整体增值率要明显低于专利药。因为非专利药较专利药相比，缺少了发现药物成分这一环节，而这一环节位于微笑曲线的左上端，其增值率最高。因此非专利药的增值率一般要明显低于专利药。

2．非专利药制剂生产是研发环节的具体实现环节，也是其主要的增值环节。从图 4 中可以看出，非专利药原料药的生产是脱离于价值链主链条之外的，与前面的研发环节没有明显关系，而只有非专利药制剂生产才直接与前面的研发环节发生直接联系。

3．非专利药市场的竞争程度要明显高于专利药，从而增加了营销环节的增值。由于非专利药的生产门槛明显低于专利药，因此非专利药生产并不限于极少数大型跨国公司，发达国家，乃至发展中国家的中小型医药企业均可以从事生产，因此市场竞争程度要较专利药高的多。这种市场结构提高了营销环节的增值率。

4．非专利药原料药生产的竞争程度最高。对于大多数药物而言，生产原料药的门槛主要在于其生产工艺和流程。在生产工艺和流程基本公开的情况下，非专利药原料药的生产的门槛要远远低于非专利药制剂，其市场的竞争性最强。而由于大量企业生产的

原料药产品基本可以互相替代，因此该环节的增值率最低，容易出现低价竞争现象。

但专利药和非专利药在研发环节中均存在临床试验环节。与前期的发现主要药物成分等环节不同，临床试验环节主要起到为前期研究提供大量数据支持的作用。因此，临床试验环节不但需要高素质的科研人才，而且需要大量的患者参与。这也导致临床试验的成本与所在地的居民收入水平有一定关系。而且临床试验环节的功能和输入输出均较为明确，具有明显的模块化特点。因此，医药产业除在生产环节存在模块化外，在研发环节同样存在明显的模块化。

在此基础上，本文按照 Gereffi（1999）的方法对专利药和非专利药价值链进行归类。Gereffi 认为，可以从表 2 中所示的指标体系对医药产品价值链的特征进行判定。

表 2：　产品价值链判断标准表

| 指标 | 生产者驱动型 | 消费者驱动型 |
|---|---|---|
| 动力根源 | 研发 | 营销 |
| 进入壁垒 | 企业规模 | 市场范围 |
| 主导企业 | 跨国公司 | 本地企业 |
| 主要产业联系 | 以投资为主线 | 以贸易为主线 |
| 代表产品 | 计算机 | 玩具 |

根据前文的分析，可以对专利药、非专利原料药和非专利制剂的价值链进行判定。专利药的核心竞争力主要在于研发，对生产企业的资金和技术投入要求非常高，主要由大型跨国公司主导。因此属于生产者驱动型；而营销环节和生产环节对非专利药制剂的核心竞争力均有明显提升作用，其参与企业既有跨国公司，也有本地中小型企业，因此兼具生产者驱动型和消费者驱动型的特征；而非专利药原料药的核心则基本上完全来自营销环节，其生产门槛非常低，本地企业所占比重相对较高，因此基本属于消费者驱动型价值链。

需要特别说明的是，虽然近年来非专利药市场发展迅速，但全球专利药市场仍远远大于非专利药市场。由于每年都有大量的专利药物转变为非专利药物，因此全球专利药市场和非专利药市场的规模和贸易量很难准确测算。根据著名国际医药信息发布企业 IMS Health 等对全球医药零售市场和非专利药零售市场的规模的估算结果，2008 年全球非专利药零售市场份额约为 800 亿美元，仅占全球市场份额的 13%左右。但也有研究机构认为这一数字较为保守，非专利药所占市场份额可能超过 15%。因此，专利药的全球价值链目前仍然是全球医药制造业的主要价值链。

## 二、 我国医药产业价值链的特征分析

本文同样采取 Gereffi(1999)的方法对我国本土医药产业价值链的特点。

我国医药产业行业分散度较高，并不存在大型的跨国公司。本文根据《中国高新技术统计年鉴》提供的数据计算了我国大型企业增加值占全行业增加值的比重。计算结果表明。2007 年我国大型企业增加值仅占医药企业总增加值的 22..3%。而据美国创新药物委员会公布的数据，美国最大的 30 家跨国企业药物销售额占其药物总销售额的 76.9%。这说明我国医药产业基本不存在大型的跨国公司，而是由大量中小型企业所主导。

第一，我国医药产业的研发投入较低。一方面，我国医药产业的研发投入总规模非常低。据统计，2007 年我国医药产业的科技活动研发投入总额仅为 63 亿元人民币左右，而美国辉瑞公司 2008 年的 R&D 投入则高达 87 亿美元。另一方面，我国医药产业的研发强度（以

研发销售比计算）也很低。下表给出了我国和发达国家医药制造业的研发强度。

表 3 ：我国和发达国家医药制造业的研发强度对比

| | 中国（2007） | 美国（2006） | 日本（2006） | 德国（2006） | 法国（2006） | 英国（2006） | 韩国（2006） |
|---|---|---|---|---|---|---|---|
| 制造业 | 3.5 | 10.2 | 11.0 | 7.6 | 9.9 | 7.0 | 9.3 |
| 高技术产业 | 6.0 | 39.8 | 28.9 | 21.5 | 31.9 | 26.6 | 21.3 |
| 医药制造业 | 4.7 | 46.2 | 37.1 | 23.9 | 33.4 | 42.3 | 6.3 |

数据来源：科技部

从中可以看出，中国的医药制造业的研发强度仅略高于制造业的平均水平，不但远远低于发达国家，而且低于我国高技术产业的平均水平。因此，研发环节在我国医药制造业并不占据主导地位。

根据上述两点特征，可以判断我国的医药产业价值链属于消费者驱动型。这意味着我国在参与全球医药产业国际分工时，更偏向参与那些消费者驱动型的环节，如非专利原料药的生产等。下文将在对全球医药产业国际分工状况进行梳理的基础上，对我国在全球国际分工中的地位进行实证研究。

## 第四节 全球医药产业国际分工状况实证研究

根据上文分析的全球医药产业价值链的特点，我们对全球医药产业的国际分工状况作出如下假设：

假设 1：发达国家之间的产业内分工是全球医药产业国际分工的主要形式。现代国际分工理论将国际分工划分为产业间国际分工和产业内国际分工。一般认为，产业间国际分工主要在发达国家和发展中国家之间进行，而产业内国际分工则主要在发达国家之间进行。近年来的垂直专门化分工理论进一步对产业内分工理论进行了拓展。

从上文的分析中可以看出，药品，特别是最终产品制剂生产的价值链具有典型的技术密集型特征，基本不存在劳动密集型的环节。而发达国家在高技术领域较发展中国家具有明显优势，因此可以推断发达国家之间的产业内分工是全球医药产业分工的主要形式。

本文计算了 2008 年全球药品贸易的国别结构。相关数据来自联合国商品贸易数据库，统计口径见附录 1 所示。2008 年发达国家和发展中国家相关指标的计算结果如表 5 所示。而发达国家将价值链低端环节转移到发展中国家的垂直化分工运作也很少出现。上述种种原因决定了发展中国家参与全球医药市场国际分工的程度相对较低。这必然使得发达国家的大型跨国公司是全球医药产品的主要提供者。

按照上述统计口径，本文对全球药品贸易的分布情况进行了测算，计算结果如下表所示。

表 4： 2008 年全球药品贸易的国别结构

| | 出口占全球比重 | 进口占全球比重 |
|---|---|---|
| 发达国家： | 90.55% | 80.15% |
| 欧洲发达国家 | 80.02% | 56.85% |
| 美国 | 7.98% | 15.73% |
| 加拿大 | 1.53% | 2.84% |
| 澳大利亚 | 0.86% | 1.84% |
| 日本 | 0.89% | 2.90% |
| 其它国家： | 9.45% | 19.85% |
| 印度 | 1.51% | 0.53% |
| 中国 | 1.81% | 1.45% |

注：本表中的欧洲发达国家包括欧盟 15 个核心成员国和瑞士。本表数据根据联合国世界贸易统计数据库提供的数据计算，网址为"http://comtrade.un.org/db/"。

计算结果表明，全球药品贸易基本上主要在欧美发达国家间进行，20 个发达国家提供了全球 91%的药物出口和 80%的药物进口。而法国、德国等欧洲发达国家是全球药品的主要提供者，美国既是重要的药品出口国，也是全球第一大药品进口国。印度、中国等发展中国家虽然近年来加快了参与全球药物产业国际分工的步伐，但目前在全球药品贸易中所占比重仍然非常低。

在此基础上，本文运用 Grubel&Lloyd(1975)提出的 GL 指数来判断发达国家参与医药行业国际分工的形式。GL 指数的计算方法如下：

假定某产业 j 下有 N 种贸易品，则该产业的 GL 指数为：

$$GL_j = \frac{\sum_{i=1}^{N}(X_i + M_i) - \sum_{i=1}^{N}(|X_i - M_i|)}{\sum_{i=1}^{N}(X_i + M_i)} \times 100$$

其中$X_i$为第$i$种产品的出口，$M_i$为第$i$种产品的进口。

GL 指数的理论基础在于：产业内贸易是产业贸易总额减去该产业中进出口差额后的余额部分。如某国某个商品只有出口没有进口，或者只有进口没有出口，则该商品的 GL 指数为零，说明某国是某个商品的净进口或出口国，不存在产业内分工；而如国某国某个商品的进出口数相同，其 GL 指数则为 100，说明该商品完全是产业内贸易，产业内分工程度非常高。

本文根据医药产品的数据，对美国、英国、瑞士、法国和德国 2004 年和 2008 年医药产品、原料药的 GL 指数进行了计算。计算结果表明，各国的 GL 指数均超过 0.5，且多呈现明显的上升趋势，说明发达国家产业内分工是医药产品国际分工的主要形式。而从产品结构看，作为中间产品的原料药 GL 指数相对较低，而主要贸易品种——制剂的 GL 指数相对较高。

表 5:　　发达国家医药产品的 GL 指数计算

| | 年份 | 医药产品 GL 指数 | 原料药 GL 指数 | 制剂 GL 指数 |
|---|---|---|---|---|
| 法国 | 2004 | 73.25 | 48.98 | 76.78 |
| | 2008 | 78.54 | 60.77 | 80.19 |
| 德国 | 2004 | 59.20 | 57.80 | 59.33 |

| | 2008 | 61.34 | 40.41 | 63.08 |
|---|---|---|---|---|
| 瑞士 | 2004 | 66.87 | 46.66 | 70.03 |
| | 2008 | 57.26 | 51.70 | 57.82 |
| 英国 | 2004 | 77.97 | 57.48 | 79.36 |
| | 2008 | 75.80 | 80.06 | 75.60 |
| 美国 | 2004 | 69.58 | 77.66 | 67.96 |
| | 2008 | 63.00 | 65.91 | 62.51 |

假设 2：最终产品贸易是全球医药产品贸易的主要形式，中间产品贸易所占比重较低。产业内分工既可以是最终产品的专业化分工，也可以是中间产品的专业化分工。前者体现在产业内最终产品贸易，后者体现在中间产品贸易。国际贸易理论表明，中间产品贸易在很大程度上依赖于以下两点：第一，产品生产过程中的生产工序在空间上具有可分性；第二，不同生产工序的生产要素禀赋存在差异。在计算机、汽车等制造业等模块化程度较高的行业，其价值链均存在着有明显的劳动密集型特征的环节，因此跨国公司可以将这类环节转移到劳动力成本相对较低的发展中国家以提高生产效率，从而产生了大量的中间产品贸易，而医药药品的价值链则与上述行业显著不同。可以发现，在全球市场中占据主导地位的专利药物的生产工序可分性很弱，从而使得最终产品贸易成为全球医药产品分工的主导型式。

下文将对这一结论进行实证。根据上文的分析，根据上文的分析，可以将化学原料药、生物原料作为全球医药行业的中间产品，而将各种制剂作为最终产品。附录 1 给出了这一测算方法的统计口径。

在此基础上，本文分别计算了 2008 年全球药品贸易中消费品和中间品的比重，如下表所示。计算结果证明，假设 2 成立，全球药品国际分工主要通过最终产品贸易来进行。

表 6： 2008 年全球原料药和制剂所占贸易比重

| | 原料药（中间产品） | 制剂（最终产品） |
|---|---|---|
| 出口所占比重 | 90.40% | 9.60% |
| 进口所占比重 | 90.59% | 9.41% |

注：本表数据根据联合国世界贸易统计数据库提供的数据计算，网址为”http://comtrade.un.org/db/”。

假设 3：在医药行业，发达国家之间的贸易多为水平型异质产业内贸易。现代国际分工理论将产业内国际分工又划分为水平异质的产业内国际分工、垂直异质的产业内国际分工两种形式。一般认为，发达国家彼此之间具有相似的资源禀赋，其分工多体现为水平型产业内分工形式，既发达国家之间的贸易多属于同一产业内同类异质的产品之间的贸易。由于发达国家在全球医药产业贸易中占据绝对优势地位，因此可以推测水平型异质产业内分工是发达国家参于医药行业国际分工的主要形式。

产业内贸易又可分为水平异质型产业内贸易（HIIT）和垂直异质型产业内贸易（VIIT）。前者主要指在技术水平相差较小的商品之间的贸易，后者则是指在技术水平相差较大的商品之间的贸易。Fukao&Ishido(2003)在假设某类商品技术质量差异可以以进出口单位价值的差异来判定的基础上，给出了将双边贸易的三类划分标准，具体如下：

当$\frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \le 0.1$时，认为是单向贸易（包括单项进口和出口）；

当$0.1 \le \frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \le 10$且$0.8 \le \frac{P_{kk'j}}{P_{k'kj}} \le 1.25$时，认为是水平型产业内贸易；

当$0.1 \le \frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \le 10$且$0.8 \le \frac{P_{kk'j}}{P_{k'kj}} \ge 1.25$或$\frac{P_{kk'j}}{P_{k'kj}} \le 0.8$时，认为是垂直型产业内贸易。

其中$M_{kk'j}$表示k国对k'国的j商品出口额，$P_{kk'j}$则表示出口价格，反之亦然。0.1、1.25和0.8为常用的阈值。

、

本文按照 Fukao 和 Ishido（2004）的方法，对全球主要医药产品出口国——法国、德国和主要医药产品进口国美国之间的双边医药产品的各类贸易所占比重进行了测算，结果如下表所示。

表 7：　德国和法国与美国之间的双边医药产品贸易分类计算

| | 单向贸易所占比重 | 垂直型产业内贸易所占比重 | 水平型产业内贸易所占比重 |
|---|---|---|---|
| 德国 | 20.89% | 30.11% | 49.01% |
| 法国 | 16.28% | 10.97% | 72.75% |

计算结果表明，德国、法国等发达国家和美国之间的贸易中，水平型产业间贸易所占比重要明显高于单向贸易和垂直型产业内贸易。因此，假设 3 同样成立。

# 第五节 中国医药产业国际分工实证研究

一、我国医药产业整体国际分工实证研究

本节将对我国医药产业在全球医药产业价值链中所处的位置进行实证研究。

如前所述，由于医药产业价值链在生产环节相对较为简单，一般仅划分为原料药生产和制剂生产两大环节，因此可以通过对我国在原料药和制剂两大类产品的竞争优势指数来判断我国医药产业在国际分工生产环节中所处的位置。

本文计算了我国和印度医药产品、原料药和制剂 2004 年以来的竞争优势指数（Trade Special Coefficient），如表 8 和表 9 所示。

表 10：　中国对美国和全球竞争优势指数计算

| 年份 | 中美 TC 指数 | 中国 TC 指数 | 印美 TC 指数 | 印度 TC 指数 |
|---|---|---|---|---|
| 2004 | 0.52 | 0.19 | 0.72 | 0.55 |
| 2005 | 0.45 | 0.17 | 0.60 | 0.50 |
| 2006 | 0.26 | 0.17 | 0.66 | 0.49 |
| 2007 | 0.17 | 0.15 | 0.72 | 0.47 |
| 2008 | 0.27 | 0.13 | 0.70 | 0.52 |

数据来源：同上。

表 10：　中国和印度两类产品对外贸易情况

| 年份 | 原料药（中间产品） | 制剂（最终产品） |
|---|---|---|

| | 中美 TC 指数 | 中国 TC 指数 | 印美 TC 指数 | 印度 TC 指数 | 中美 TC 指数 | 中国 TC 指数 | 印美 TC 指数 | 印度 TC 指数 |
|---|---|---|---|---|---|---|---|---|
| 2004 | $0.87 | $0.73 | $0.08 | ($0.01) | ($0.70) | ($0.56) | $0.87 | $0.76 |
| 2005 | $0.88 | $0.74 | $0.09 | ($0.11) | ($0.84) | ($0.56) | $0.74 | $0.74 |
| 2006 | $0.92 | $0.78 | $0.10 | ($0.15) | ($0.89) | ($0.58) | $0.73 | $0.70 |
| 2007 | $0.95 | $0.79 | ($0.08) | ($0.13) | ($0.88) | ($0.58) | $0.81 | $0.70 |
| 2008 | $0.92 | $0.80 | $0.08 | ($0.06) | ($0.73) | ($0.60) | $0.77 | $0.71 |

从中可以看出，中国和印度虽然整体医药产业均具有一定的竞争力，但其竞争力的来源却存在很大差异。在原料药方面，中国的 TC 指数非常高，近似处于绝对比较优势地位；而印度则处于相对比较劣势地位。但在制剂领域，中国却处于绝对比较劣势地位，且 TC 指数有进一步下降的趋势；而印度却具有显著的比较优势。据此可以断定 2004 年以来，我国在全球医药产业价值链生产环节中主要处于生产原料药的环节，而印度则处于生产制剂的环节位置。

采用前文所提到的产业内贸易的研究方法也可以得出相同的结论。表 11 和表 12 分别对 2004-2008 年中国和印度的 GL 指数以及 2008 年中国和印度医药产品贸易中单向贸易、垂直型产业内贸易和水平型产业内贸易所占的比重进行了测算。

表 11：　中国参与全球医药产业 GL 指数计算

| 年份 | 中美双边 GL 指数 | 中国 GL 指数 | 印美双边 GL 指数 | 印度 GL 指数 |
|---|---|---|---|---|
| 2004 | 16.95 | 34.45 | 13.21 | 38.26 |
| 2005 | 12.98 | 33.76 | 24.29 | 39.10 |
| 2006 | 9.46 | 31.16 | 21.22 | 40.04 |
| 2007 | 7.68 | 30.62 | 17.44 | 42.40 |
| 2008 | 13.89 | 29.32 | 17.74 | 40.11 |

表 12：　2008 年中国和印度医药产品贸易分类情况

| | | 单向贸易（进口） | 单向贸易（出口） | 垂直型产业内贸易 | 水平型产业内贸易 |
|---|---|---|---|---|---|
| 中国 | 医药整体 | 34.03% | 53.12% | 12.85% | 0.00% |
| | 制剂 | 87.95% | 0.00% | 12.05% | 0.00% |
| | 原料药 | 0.00% | 85.92% | 14.08% | 0.00% |
| 印度 | 医药整体 | 8.96% | 0.00% | 89.86% | 1.18% |
| | 制剂 | 0.00% | 0.00% | 95.19% | 4.81% |
| | 原料药 | 0.00% | 12.74% | 87.26% | 0.00% |

从中可以看出，印度医药产品的对外贸易的产业内贸易程度要明显高于我国，离欧美发达国家的距离更近；而按照 Fukao&Ishido(2003)的方法测算的结果也表明，中国虽然在原料药领域则完全处于单向出口。但在医药产业的主导产业——制剂产业却基本处于完全进口状态，基本不参加产业内分工；而印度在制剂和原料药领域基本上均属于垂直型产业内贸易，参与产业内分工的程度明显高于我国。

我国在全球医药产业价值链中主要位于原料药这一环节的现象对我国医药产业的发展是不利的。如前所述，在非专利药领域，原料药生产和价值链的核心环节——研发环节的关联度较弱，而制剂生产与研发环节的关联度则较强，因此原料药生产是非专利药价值链中最低端的环节。而制剂研发和生产则是相对高端的环节。因此，可以认为我国在全球医药产业国际分工中主要处于生产非专利原料药这一微笑曲线最低端的环节，而印度则处在微笑曲线相对高端的环节。

为验证这一观点，我们根据美国国际贸易委员会提供的数据对 2008 年中美贸易相关商品的数据进行了测算。测算结果如下表所示。

表 13： 2008 年中美贸易中原料药价格对比（单位：美元/公斤）

| | 中国从美国进口价格 | 中国对美国出口价格 |
| --- | --- | --- |
| 非专利抗生素原料药 | 127.54 | 31.15 |
| 非专利药原料药 | 23.30 | 14.2 |

注：考虑运输和关税等因素，已按 15%的比率将进口价格从到岸价格转化为离岸价格。

从中可以看出，在同样的非专利药原料药领域，中国生产的成本仅为美国的一半，而在非专利药原料药的重点领域——抗生素领域，中国的生产成本仅为美国的四分之一。一次，我国原料药出口主要依靠成本优势，其增值率相对较低。这说明我国在全球医药产业价值链中确实处于最低端的环节。

由于原料药生产是最终产品制剂生产环节的一个子环节，因此我国参与全球医药产业国际分工带有一定的垂直专业化特征。垂直专业化分工是指同一产业内同一产品的不同生产阶段（生产环节）之间的国际分工，是垂直型产业内分工的一种新形式，也是发达国家和发展中国家在产业内分工的主要形式之一。显然，将原料药生产这一低增加值环节转移到我国是跨国公司通过垂直专业化分工提高生产效率的体现。

但医药产业的垂直专业化分工和计算机等模块化较高的行业仍然存在很大差别。一方面，医药产业的原料药生产环节虽然和医药产业的核心研发环节的关联度很弱，但仍属于资本密集型环节，对技术和资本的要求要明显高于计算机等行业的加工组装环节。这就使得虽然我国虽然在全球医药产业价值链中位于最低端，但其增值率可能要高于计算机等行业的加工组装环节。另一方面，计算机产业的加工组装环节位于其价值链生产环节的末端，其产品直接用于销售。而原料药行业则位于医药产业价值链生产环节的前端，将这一部分外包出去虽然能够在一定程度上降低成本，但也会使后端高增值环节生产面临更多不确定因素，可能会扩大生产风险。因此，我国医药产业的垂直专业化分工程度很可能要远远低于计算机等模块化程度较高的产业。最后，这种垂直专业化分工和加工贸易的关系要弱于计算机等制造业。

为验证这一假设，本文运用陈锡康和祝坤福等（2008）编制的考虑加工贸易的 2002 年非竞争型投入占用产出表对我国医药产业的 VS 指数和本地增值率进行了计算。计算过程如下：

第一步，由于原有的非竞争型投入占用产出表中只有 42 部门，并没有将医药制造业单独分类，因此需要运用 2002 年 123 部门的投入产出表和 2002 年医药产业的对外贸易数据编制出新的含有医药制造业的 2002 年考虑加工贸易的 43 部门非竞争型投入占用产出表。具体调整方法如下：

首先，根据海关数据，对医药的贸易数据进行归并统计，得到医药制品业的加工贸易和一般贸易（除加工贸易）的进出口数据。

其次，将 2002 年 122 部门投入产出表归并为 43 部门表，即将统计局公布的 42 部门中

化学工业分成化学工业和医药制造业。在 43 部门投入产出表的化学工业和医药制造业投入（列）与产出（行）保留，其他项设为零，得到化学工业和医药制造业的直接消耗系数（包括增加值系数）和直接分配系数（包括最终使用结构系数）。注意中间交叉数使用消耗系数（经验表明：消耗系数比分配系数更稳定），分配系数做相应调整。

最后，利用这两组系数把 2002 年反映加工贸易的非竞争型投入产出表从 42 部门扩展到反映医药贸易的 43 部门非竞争型投入产出表（初表）。利用医药制品业的加工贸易和一般贸易（除加工贸易）的进出口数据，对初表进行数学平衡，由于只调整两个部门，此处只用了 RAS 进行行列平衡调整，得到 2002 年反映医药贸易的 43 部门非竞争型投入产出表（终表）。

第二步，根据祝坤福（2008）所推导的根据非竞争型投入占用产出表的计算方法，对各行业（包括医药制造业）的 VS 指数和本地增值率进行计算，所有的公式推导见附录 2。其中制造业各子行业的垂直专业化率见表 15（其它行业数据暂略）

表 14： 2002 年医药行业垂直专业化率测算

| | 直接垂直专业化率 | | | 完全垂直专业化率 | | |
|---|---|---|---|---|---|---|
| | 一般贸易 | 加工贸易 | 整体 | 一般贸易 | 加工贸易 | 整体 |
| **食品制造和烟草加工业** | 0.0013 | 0.5075 | 0.1115 | 0.0081 | 0.5664 | 0.1900 |
| **纺织业** | 0.0025 | 0.6389 | 0.1991 | 0.0124 | 0.6977 | 0.2730 |
| **服装皮革羽绒及其制品制造业** | 0.0022 | 0.5929 | 0.1980 | 0.0113 | 0.6616 | 0.2829 |
| **木材加工及家具制造业** | 0.0025 | 0.5831 | 0.1798 | 0.0130 | 0.6514 | 0.3175 |
| **造纸印刷及文教用品业** | 0.0030 | 0.5399 | 0.2059 | 0.0127 | 0.6147 | 0.3410 |
| **石油加工、炼焦及核燃料加工业** | 0.0546 | 0.7302 | 0.6840 | 0.0705 | 0.7755 | 0.7326 |
| **化学工业** | **0.0071** | **0.6416** | **0.3592** | **0.0237** | **0.7267** | **0.5303** |
| 医药制品业 | **0.0042** | **0.5253** | **0.2732** | **0.0129** | **0.5937** | **0.3816** |
| **非金属矿物制品业** | 0.0045 | 0.5512 | 0.2482 | 0.0175 | 0.6280 | 0.3962 |
| **金属冶炼及压延加工业** | 0.0061 | 0.6917 | 0.2810 | 0.0224 | 0.7370 | 0.4715 |
| **金属制品业** | 0.0034 | 0.7382 | 0.2323 | 0.0189 | 0.7760 | 0.4589 |
| **通用、专用设备制造业** | 0.0072 | 0.6944 | 0.3709 | 0.0213 | 0.7466 | 0.5284 |
| **交通运输设备制造业** | 0.0066 | 0.6905 | 0.3257 | 0.0214 | 0.7552 | 0.5369 |
| **电气机械及器材制造业** | 0.0079 | 0.7239 | 0.3443 | 0.0227 | 0.7723 | 0.5189 |
| **通信设备、计算机及其他电子设备制造业** | **0.0058** | **0.8221** | **0.5112** | **0.0201** | **0.8419** | **0.6210** |
| **仪器仪表及文化办公用机械制造业** | 0.0489 | 0.6062 | 0.3626 | 0.0629 | 0.6408 | 0.5103 |

同样，根据祝坤福（2008）提供的方法，可以计算出 2002 年医药产业的国内直接增加值率和完全增加值率。

表 15：2002 年医药产业的国内增加值率计算

| | 直接国内增加值率 | | | 完全国内增加值率 | | |
|---|---|---|---|---|---|---|
| | 一般贸易 | 加工贸易 | 整体 | 一般贸易 | 加工贸易 | 整体 |
| **食品制造和烟草加工业** | 0.3403 | 0.1701 | 0.2132 | 0.9919 | 0.4336 | 0.8100 |
| **纺织业** | 0.2896 | 0.1357 | 0.1761 | 0.9876 | 0.3023 | 0.7270 |
| **服装皮革羽绒及其制品制造业** | 0.3233 | 0.1346 | 0.1857 | 0.9887 | 0.3384 | 0.7171 |
| **木材加工及家具制造业** | 0.3148 | 0.1494 | 0.1923 | 0.9870 | 0.3486 | 0.6825 |
| **造纸印刷及文教用品业** | 0.3772 | 0.1843 | 0.2409 | 0.9873 | 0.3853 | 0.6590 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 石油加工、炼焦及核燃料加工业 | 0.1835 | 0.0942 | 0.1177 | 0.9295 | 0.2245 | 0.2674 |
| **化学工业** | **0.2754** | **0.1355** | **0.1735** | **0.9763** | **0.2733** | **0.4697** |
| 医药制品业 | **0.4148** | **0.2397** | **0.2827** | **0.9871** | **0.4063** | **0.6184** |
| 非金属矿物制品业 | 0.3550 | 0.1801 | 0.2254 | 0.9825 | 0.3720 | 0.6038 |
| 金属冶炼及压延加工业 | 0.2596 | 0.1336 | 0.1671 | 0.9776 | 0.2630 | 0.5285 |
| 金属制品业 | 0.2665 | 0.1296 | 0.1678 | 0.9811 | 0.2240 | 0.5411 |
| 通用、专用设备制造业 | 0.3140 | 0.1538 | 0.1948 | 0.9787 | 0.2534 | 0.4716 |
| 交通运输设备制造业 | 0.2880 | 0.1436 | 0.1815 | 0.9786 | 0.2448 | 0.4631 |
| 电气机械及器材制造业 | 0.2817 | 0.1322 | 0.1818 | 0.9773 | 0.2277 | 0.4811 |
| **通信设备、计算机及其他电子设备制造业** | **0.2655** | **0.1151** | **0.1749** | **0.9799** | **0.1581** | **0.3790** |
| 仪器仪表及文化办公用机械制造业 | 0.1883 | 0.2888 | 0.0891 | 0.9371 | 0.3592 | 0.4897 |

计算结果证明了我们的假设。我国医药制品业的 TVS 值为 0.38，加工贸易 TVS 值为 0.59，仅高于食品、纺织等部分轻工业，远远低于计算机、交通运输设备等行业。因此，我国医药制品业的本地增值率是相当高的，其完全国内增值率达到 0.618，说明我国出口 1000 美元的医药产品能够带来 618 美元的国内增加值收益，是通信设备、计算机及其他电子设备制造业的 1.63 倍。这说明，虽然我国医药产业在国际分工中同样处于产业链的最低端环节，但医药产业的本地增值率仍然要明显高于计算机制造业。

其他一些数据也能够对这一结论进行佐证。最主要的间接证据来自我国医药产业的加工贸易状况。我国参与垂直专业化分工的主要方式是加工贸易。然而加工贸易在我国医药产品对外贸易中的地位相对较低。根据美国国际贸易委员会提供的数据，本文对 2006-2008 年中国对美国药物类产品出口中加工贸易出口和一般贸易出口所占比重进行了测算，结果如下表所示。

表 16：　2008 年中国对美出口医药产品贸易分类情况

| | | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| 所有药品 | 一般贸易出口比重 | 81.95% | 87.42% | 81.09% |
| | 加工贸易出口比重 | 11.25% | 11.64% | 16.60% |
| 原料药 | 一般贸易出口比重 | 81.45% | 87.11% | 80.93% |
| | 加工贸易出口比重 | 18.02% | 12.08% | 16.81% |
| 制剂 | 一般贸易出口比重 | 98.53% | 95.07% | 82.77% |
| | 加工贸易出口比重 | 0.53% | 0.52% | 14.32% |

可以看出，药物行业我国对美国的加工贸易出口比重一直在 15%左右波动。远远低于我国对美国出口中加工贸易出口的平均水平。

另外一个证据来自我国医药产品出口的企业结构。跨国公司在我国医药出口中的比重要远远低于计算机等行业。据测算，2008 年我国对美出口医药产品中只有 33.1%。是由外资企业出口，其它全部是由本土企业出口。甚至在加工贸易出口中，我国本土企业也占有优势地位，2008 年我国医药产业加工贸易对美出口中本土企业所占比重达到了 68%。而我国整体加工贸易出口中外资企业比重一直超过 80%。

这一结论说明，我国医药产业虽然也在一定程度上参与全球的垂直专业化分工，但这种参与并不是由外资企业主导，而是本土企业为谋求利益最大化主动参与全球分工的结果。

上文主要分析了我国在全球医药产业价值链生产环节所处的位置。而在研发环节，跨国公司同样有将研发环节中的临床试验环节向我国转移的趋势。如前所述，前期研发环节中

的临床试验环节具有明显的模块化特征。与前两个环节不同，临床试验环节既需要投入高素质的科技人才，也需要投入大量的资金从各种试验体取得试验数据。因此，我国在临床试验领域具有一定的比较优势。一方面，由于发达国家的居民收入水平远高于我国，且有各种动物保护组织限制动物实验的进行，因此跨国公司在发达国家进行临床试验的成本要远远高于我国。另一方面，在研发环节中，临床试验环节的作用主要为前面的研发提供数据支持，因此其技术溢出效应要低于其它两个环节，对跨国公司的技术垄断地位影响较小。因此，以临床试验外包为主体的研发环节外包（CRO）近年来得到了迅速发展。

为对这一结论进行实证，我们依据全球最大的临床试验注册数据库”cliniclatrials.gov”和《中国高新技术统计年鉴》提供的数据，对跨国公司在我国开展临床试验和开展制药企业的数据进行了统计，如表 3 所示。计算结果表明，2007 年跨国公司在我国所开展的临床试验较 2005 年增长了 74%，高于同期跨国公司增加值的增长率（57%）。

表 17： 跨国公司在我国开展临床试验和制药的情况对比

| 年份 | 临床试验数 | 跨国公司数量 | 跨国公司增加值（亿元） |
|---|---|---|---|
| 2005 | 79 | 707 | 364.05 |
| 2006 | 123 | 739 | 432.9 |
| 2007 | 137 | 797 | 570.12 |

因此，我们认为假设 4 同样成立。我国在临床试验领域确实具有一定的比较优势。

## 第六节 总结

本文在对医药产业价值链特点进行分析的基础上，对我国医药产业在全球国际分工中所处的位置进行了实证研究，得到了以下重要的结论：

1. 相比其他制造业，医药行业价值链具有研发环节复杂度高、制造环节模块化程度低的特点，这些特点导致发达国家之间的水平产业内分工是医药行业国际分工的主要形式；

2. 专利药和非专利药价值链具有明显的差异，非专利化学制药价值链的模块化程度要高于专利药，存在着研发强度较低的原料药生产环节，使得医药行业存在着一定程度的垂直专门化分工；

3. 医药行业研发环节中独有的临床试验环节具有模块化较强、技术溢出效应低、劳动力成本所占比重较大的特点，使得临床试验外包成为了医药行业研发环节外包的主要形式；

5. 我国医药产业研发强度低、企业规模小的特点决定了我国主要在非专利药原料药生产环节参与国际分工，该环节是医药行业各环节中增值率最低的环节，实证结果也证明了这一结论；

6. 在研发环节，我国较低的临床试验成本使得跨国公司有将临床试验环节转移到我国的倾向，相关统计数据也能够对此提供支持；

7. 由于医药行业价值链的特点所限，我国仅在非专利原料药生产领域参与垂直专门化国际分工，且参与程度明显低于计算机等行业，对 VS 指数的测算结果也验证了这一结论。

8. 由于垂直专业化程度低，加工贸易由本土企业主导等特点，我国医药产业的本地增值率要高于 IT 等行业。

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附录 1：各类医药产品贸易数据的统计口径

目前对各大类药品类型对外贸易的统计口径尚未完全达成一致。考虑到数据的限制，在调研的基础上，本文按照如下规则对全球药品贸易的数据进行统计：HS 商品编码体系中 2935（磺胺原料药），2936（维生素原料药），2937（激素原料药），2939（生物碱原料药），2941（抗生素原料药）以及 3001-3004 下的各种商品。其中 2935-2941 涵盖了 95%以上的以化学工艺生产的原料药；3001 基本涵盖了全部生物原料药；3002 基本涵盖了目前的大部分生物制剂；3003-3004 基本涵盖了全部化学制剂、植物药制剂、中成药制剂和一部分生物制剂。本文并不将并非用于药用，而是用于医疗服务的绷带、夹板以及医疗箱等产品列入制药产品范畴。

附录 2：VS 指数的计算方法

**1．相关直接消耗系数的定义**

从扩展的非竞争型投入占用产出表的水平方向看， D、P、N 和进口（M）的如下平衡关系方程组：

$$X^{DD}m+X^{DP}m+X^{DN}m+F^{D}=X^{D} \tag{1.1}$$

$$F^{P}=X^{P} \tag{1.2}$$

$$X^{ND}m+X^{NP}m+X^{NN}m+F^{N}=X^{N} \tag{1.3}$$

$$X^{MD}m+X^{MP}m+X^{MN}m+F^{M}=X^{M} \tag{1.4}$$

由垂直方向我们可以得到如下方程：

$$mX^{DD}+mX^{ND}+mX^{MD}+V^{D}=(X^{D})^{T} \tag{1.5}$$

$$mX^{DP}+mX^{NP}+mX^{MP}+V^{P}=(X^{P})^{T} \tag{1.6}$$

$$mX^{DN}+mX^{NN}+mX^{MN}+V^{N}=(X^{N})^{T} \tag{1.7}$$

其中， $m=(1,1,\ldots,1)$ 。

考虑直接消耗系数，不妨定义

$$a_{ij}^{DD}=X_{ij}^{DD}/X_{j}^{D}, i,j=1,2,\ldots,n \tag{1.8}$$

则 $a_{ij}^{DD}$ 表示第 $j$ 个部门生产单位用于国内需求的产品对第 $i$ 个部门用于国内需求产品的直接消耗量。则国内需求产品对国内需求产品的直接消耗系数矩阵可表示为：

$$A^{DD}=(a_{ij}^{DD})=(X_{ij}^{DD}/X_{j}^{D}) \tag{1.9}$$

同理可以定义其他各类生产的直接消耗系数矩阵：

$$A^{DP}=(a_{ij}^{DP})=(X_{ij}^{DP}/X_j^P),A^{DN}=(a_{ij}^{DN})=(X_{ij}^{DN}/X_j^N)$$
$$A^{ND}=(a_{ij}^{ND})=(X_{ij}^{ND}/X_j^D),A^{NP}=(a_{ij}^{NP})=(X_{ij}^{NP}/X_j^P)$$
$$A^{NN}=(a_{ij}^{NN})=(X_{ij}^{NN}/X_j^N),A^{MD}=(a_{ij}^{MD})=(X_{ij}^{MD}/X_j^D) \quad （1.10）$$
$$A^{MP}=(a_{ij}^{MP})=(X_{ij}^{MP}/X_j^P),A^{MN}=(a_{ij}^{MN})=(X_{ij}^{MN}/X_j^N)$$

把（1.10）、（1.9）式代入(1.1)、(1.2)、(1.3)和(1.4)式可得：

$$A^{DD}X^D+A^{DP}X^P+A^{DN}X^N+F^D=X^D$$
$$F^P=X^P \quad (1.11)$$
$$A^{ND}X^D+A^{NP}X^P+A^{NN}X^N+F^N=X^N$$
$$A^{MD}X^D+A^{MP}X^P+A^{MN}X^N+F^M=X^M$$

综上，为了清晰表示，此处将 D、P 和 N 的各类直接消耗系数和进口、增加值、就业直接系数分别加以汇总为如下矩阵公式表（附表 1）。

附表 1： 各类直接消耗系数矩阵公式表

| | $D$ | $P$ | $N$ |
|---|---|---|---|
| $D$ | $A^{DD}$ | $A^{DP}$ | $A^{DN}$ |
| $P$ | $A^{PD}=0$ | $A^{PP}=0$ | $A^{PN}=0$ |
| $N$ | $A^{ND}$ | $A^{NP}$ | $A^{NN}$ |
| $M$ (进口产品作为中间投入) | $A^{MD}$ | $A^{MP}$ | $A^{MN}$ |
| $V$ (增加值) | $A_V^D$ | $A_V^P$ | $A_V^N$ |
| $L$ (就业) | $A_L^D$ | $A_L^P$ | $A_L^N$ |

2.完全需要系数的计算方法

式(1.11)可以写成以下形式：

$$\begin{bmatrix}(I-A^{DD}) & -A^{DP} & -A^{DN}\\ 0 & I & 0\\ -A^{ND} & -A^{NP} & (I-A^{NN})\end{bmatrix}\begin{bmatrix}X^D\\X^P\\X^N\end{bmatrix}=\begin{bmatrix}F^D\\F^P\\F^N\end{bmatrix}$$

这样我们可以得到：

$$\begin{bmatrix}X^D\\X^P\\X^N\end{bmatrix}=\begin{bmatrix}(I-A^{DD}) & -A^{DP} & -A^{DN}\\ 0 & I & 0\\ -A^{ND} & -A^{NP} & (I-A^{NN})\end{bmatrix}^{-1}\begin{bmatrix}F^D\\F^P\\F^N\end{bmatrix}$$

上面方程可以写成：

$$\bar{X}=(I-\bar{A})^{-1}\bar{F} \quad (1.12)$$

$$\bar{X}=\bar{B}\bar{F} \quad (1.13)$$

这里，

$$\bar{X}=\begin{bmatrix}X^D\\X^P\\X^N\end{bmatrix},\ \bar{A}=\begin{bmatrix}A^{DD} & A^{DP} & A^{DN}\\0 & 0 & 0\\A^{ND} & A^{NP} & A^{NN}\end{bmatrix},\ \bar{F}=\begin{bmatrix}F^D\\F^P\\F^N\end{bmatrix}$$

这就是扩展的投入产出模型，其中

$\bar{B}=(I-\bar{A})^{-1}=\begin{bmatrix}(I-A^{DD}) & -A^{DP} & -A^{DN}\\0 & I & 0\\-A^{ND} & -A^{NP} & (I-A^{NN})\end{bmatrix}^{-1}$是扩展的里昂惕夫逆，或者说是扩展的完全需要系数矩阵。

将其分块矩阵记为

$$\begin{bmatrix}(I-A^{DD}) & -A^{DP} & -A^{DN}\\0 & I & 0\\-A^{ND} & -A^{NP} & (I-A^{NN})\end{bmatrix}^{-1}=\begin{bmatrix}B^{DD} & B^{DP} & B^{DN}\\B^{PD} & B^{PP} & B^{PN}\\B^{ND} & B^{NP} & B^{NN}\end{bmatrix}$$

根据矩阵运算法则得：

$$B^{DD}=(I-A^{DD})^{-1}+(I-A^{DD})^{-1}A^{DN}B^{NN}A^{ND}(I-A^{DD})^{-1}$$
$$B^{DP}=(I-A^{DD})^{-1}A^{DP}+(I-A^{DD})^{-1}A^{DN}B^{NN}[A^{NP}+A^{ND}(I-A^{DD})^{-1}A^{DP}]$$
$$B^{DN}=(I-A^{DD})^{-1}A^{DN}B^{NN}$$
$$B^{PD}=0,\quad B^{PP}=I\quad,\quad B^{PN}=0$$
$$B^{ND}=B^{NN}A^{ND}(I-A^{DD})^{-1}$$
$$B^{NP}=B^{NN}[A^{NP}+A^{ND}(I-A^{DD})^{-1}A^{DP}]^{-1}$$
$$B^{NN}=[I-A^{NN}-A^{ND}(I-A^{DD})^{-1}A^{DN}]^{-1}$$

(1.14)

其中，$B^{DD}$、$B^{DP}$和$B^{DN}$分别表示 D、P 和 N 的单位最终需求对 D 的完全需要系数矩阵；$B^{PD}$、$B^{PP}$和$B^{PN}$分别表示 D、P 和 N 的单位最终需求对 P 的完全需要系数矩阵；$B^{ND}$、$B^{NP}$和$B^{NN}$分别表示 D、P 和 N 的单位最终需求对 N 的完全需要系数矩阵。

**3.VS 系数的计算方法**

根据 Hummels 等（2001）的方法，可以得到 VS 计算的公式：

$$VS_i=(\frac{X_i^M}{X_i})X_i^E=(\frac{X_i^E}{X_i})X_i^M \qquad （1.15）$$

其中$VS_i$、$X_i$、$X_i^E$和$X_i^M$分别表示第$i$部门出口的垂直专业化值、总产出、出口和第$i$部门生产所使用的进口品总值。在 Hummels 的文中，假设了出口生产与满足国内需求生产的生产结构是无差异的，这样上述公式即可计算出口生产所使用的垂直专业化值，即 VS。

但是在中国出口中，Hummels 的关于不同贸易方式生产结构相同假设是不

成立的。原因有二：一是中国对外贸易中，加工贸易占了很大的比例，其生产与一般生产完全不同；二是由于长期国内外市场对商品的要求标准不一样，一般出口品的质量和生产技术和内销商品不同。因此在计算中国出口的垂直专业化数值时，必须直接根据定义，公式如下：

$$VS_i = X_i^{MP} + X_i^{MN} = \sum_j A_{ji}^{MP} X_j^P + \sum_j A_{ji}^{MN} X_j^N \qquad (1.16)$$

其中 $X_i^{MP}$ 、$X_i^{MN}$ 分别表示第 $i$ 部门加工出口生产消耗的进口批总值、非加工出口生产消耗的进口批总值。矩阵表示各部门垂直专业化公式为：

$$VS = mX^{MP} + mX^{MN} = mA^{MP}X^P + mA^{MN}X^N \qquad (1.17)$$

将第 $i$ 部门出口的垂直专业化值比该部门出口值，得到第 $i$ 部门出口的垂直专业化率，计算公式如下：

$$VSSH_i = \frac{VS_i}{X_i^E} = \frac{X_i^{MP}}{X_i^E} + \frac{X_i^{MN}}{X_i^E} = \frac{\sum_j A_{ji}^{MP} X_j^P + \sum_j A_{ji}^{MN} X_j^N}{X_i^P + X_i^N} \qquad (1.18)$$

设 $W_i^P = \frac{X_i^P}{X_i^E}$，$W_i^N = \frac{X_i^N}{X_i^E}$；则 1.18 式可以整理如下：

$$VSSH_i == \frac{\sum_j (A_{ji}^{MP} W_j^P + A_{ji}^{MN} W_j^N) X_i^E}{X_i^E} = \sum_j (A_{ji}^{MP} W_j^P + A_{ji}^{MN} W_j^N) \qquad (1.19)$$

其中 $W_i^P + W_i^N = 1$。

根据公式 1.19，各部门出口的垂直专业化比率可以矩阵表示为：

$$VSSH = m(A^{MP}W^P) + m(A^{MN}W^N) \qquad (1.20)$$

其中 $W^P = (W_1^P, W_2^P, ..., W_n^P)$ 和 $W^N = (W_1^N, W_2^N, ..., W_n^N)$。

以上计算的是直接垂直专业化比率。相应的，完全垂直专业化比率计算公式为：

$$TVSSH = m(B^{MP}W^P) + m(B^{MN}W^N) \qquad (1.21)$$

其中 $B^{MP}$ 和 $B^{MN}$ 分别为加工出口（P）生产和非加工出口（N）生产对进口产品（M）的完全拉动作用，即 P 和 N 的对 M 完全需要系数矩阵。可以通过以下方法计算 $B^{MP}$ 和 $B^{MN}$ 。

首先，由（1.13）式可以得到：

$$\overline{B^M} = \overline{A^M}(I - \bar{A})^{-1} = \overline{A^M}\bar{B} \qquad (1.22)$$

其中 $\overline{B^M}=[B^{MD}\quad B^{MP}\quad B^{MN}],\overline{A^M}=[A^{MD}\quad A^{MP}\quad A^{MN}]$。

那么

$$(B^{MD},B^{MP},B^{MN})=(A^{MD},A^{MP},A^{MN})(I-\bar{A})^{-1}$$
$$=(A^{MD},A^{MP},A^{MN})\begin{bmatrix} B^{DD} & B^{DP} & B^{DN} \\ 0 & I & 0 \\ B^{ND} & B^{NP} & B^{NN} \end{bmatrix}$$

从以上公式，我们可以得到：

$$\begin{aligned} B^{MP} &= A^{MD}B^{DP}+A^{MP}+A^{MN}B^{NP} \\ B^{MN} &= A^{MD}B^{DN}+A^{MN}B^{NN} \end{aligned} \tag{1.23}$$

利用公式 1.20 和 1.21，就可以计算各部门出口的垂直专业率。其中投入产出表相关系数由不同年份反映加工贸易的非竞争型投入占用产出表数据计算获得，因此不同的投入产出表计算的相关直接进口系数和完全进口系数也不同；$W^P$ 和 $W^N$ 有当年各部门加工出口和非加工出口值计算得到，显然不同年份和不同出口目的地的 $W^P$ 和 $W^N$ 都不同。

根据加工出口生产和非加工出口生产的进口系数。可得各部门加工出口生产和非加工出口生产的直接垂直专业化率为：

$$\begin{aligned} VSSH_j^P &= \sum_{i=1}^{n} a_{ij}^{MP},\ j=1,2,\mathbf{L},n \\ VSSH_j^N &= \sum_{i=1}^{n} a_{ij}^{MN},\ j=1,2,\mathbf{L},n \end{aligned} \tag{1.24}$$

同样得到各部门加工出口生产和非加工出口生产的完全垂直专业化率公式如下：

$$\begin{aligned} TVSSH_j^P &= \sum_{i=1}^{n} b_{ij}^{MP},\ j=1,2,\mathbf{L},n \\ TVSSH_j^N &= \sum_{i=1}^{n} b_{ij}^{MN},\ j=1,2,\mathbf{L},n \end{aligned} \tag{1.25}$$

# On the value chain and international specialization of China’s pharmaceutical industry

**Abstract:** This article make the study of the character of medicine industry value chain and China's position in the world medicine industry value chain, using the tools of value chain analysis, GL index as well as input-output model. The research shows that proprietary medicine's value chain,which in the world medicine value chain, is totally belongs to the producer-driven type, and the core added value is mainly from the input of R&D; while in the non-proprietary medicine's value chain, the raw medicine is comparably independent and has a weak relation with the R& D link. This article is based on this reason and make a concrete study on China's position in the world medicine industry value chain, and the result shows that, China now stands at the lowest point of “smile curve” which is located at non-proprietary medicine production, demonstrating the vertical specialization division of the world medicine industry value chain, hereby work out the VS Index and local appreciation rate of Chinese medicine industry. In the end, the author analyse that China's position in R&D link of the world medicine value chain, and consider that Chinese cheaper labour cost is the main reason why multinational company move the clinical trail in China.

Key word: Value Chain Analysis, GL Index, Intra-industry trade, Vertical Specialization, Clinic trial

## Part 1 Preface

Since China entering WTO, our medicine industry has experienced a rraw medicined progress. According to the statistics, the foreign trade volumes of Chinese medicine industry in 2008 has reached up to 12.28billion dollar, almost 2.6 times of the volume in 2002. Therefor, it is very important to use the modern value chain theory and international specialization theory to analyse our medicine industry's position in the world value chain and international specialization, and it plays a very important role in maintain a healthy and rraw medicined development of China's medicine industry.

This article make the study of the value chain of Chinese medicine industry and the status of international specialization under the frame of world value chain, there are six parts in this article, Part 2 is reference, illustrating the research background and the related methodology we used in this article. Part 3 is focused on the character of Medicine industry value chain; Part 4 is the ratified research on international specialization of world medicine industry; while Part 5 is the ratified study of the position of Chinese medicine industry in international specialization.Part 6 is conclusions.

## Part 2 References

**References on theory of Value chain**

Value Chain was firstly put forward by Michael E.Porter in 1985.He deconstructed the production link as a series of value creattion, and thus the connection of this link is called Value Chain. Porter think that most of the Value Chain share the same character, which contains both production and supporting link, the former mainly contains production and marketing link in producing link, the latter mainly contains the related supporting link to the production link. E.g. Construction、R&D、Human Resources, etc.

Gereffi(1999) divides Value Chain into producer-driven and buyer-driven from the perspective of product character.. Kaplinsky and Morris(2000) further divide value chain into simple value chain and extended value chain. They pointed out that most of the value chain can be simplified as R&D.production,sales, consumption and the four link are interacted. While the detailed value chain is much more complicated than the mentioned above, normally related to several lines of business or industry, thus form a bigger value chain network. Gereffi(2005) further put forward the world value chain concept, which composing the entire R&D,design link of the upper course, spare parts manufacture and assembly of the middle course, as well as sales,,brand and service of the lower course into world production networking, providing a new perspective for analyzing every country's position in the international specialization under the world globalization.

### References to International specialization

The earliest concept of international specialization can be traced back to Adam Smith's Absolute Advantage Theory , David Ricardo's Relative Advantage Theory, as well as Resource Endowment by Heckscher and Ohlin..

Since the latter of the last century, as long as the deepening development of international specialization, the share of intra-industry trade increased gradually and become the main stream of international specialization. Verdoom(1960) firstly put forward the phenomenon of increase of trade of the same product but not the different product under SITC. Balassa(1963) also proved the same viewpoint by research of EC.While Gray (1979)and Krugman(1981) also complete the concept of intra-industry trade. Grubel&Lloyd(1975) also put forward the concept of dividing intra-industry trade into horizontal and vertical trade , and already been adopted by most of the scholars.

In recent years, as long as the multinational company distribute various value chain link worldwide, vertical specialization becomes the new type of intra-industry division. Vertical Specialization refers to the international specialization in different production period in the same industry. This can be completed not only in in the multinational company but also in non-related company in different country by market regulation. VS index proposed by Hummels, Ishii and Yi （2001）provide condition for rationing division in vertical specialization. Now there are many scholars have conducted deep research and rationed measurement on every country's vertical specification status. This theory share the same theoretical base as the world value chain, and will gradually become one of the main stream of international specialization of every industry.

### References on China's overrall value chain and international specialization

Till now, many scholars have studied the value chain and international specialization of china's overall or individual industry.: Liu Zunyi and Chen xikang(2007) had taken measurement and calculation on export’s total value-added rate in 41 sectors using non-competitive input-output table. And the research team which is leaded by Ping xinqiao(2005) calculated the VS index in the trade between China and USA.But because only the input-output table which include 123 sector can analyze the medicine industry, so there is no research on the TVA and VS index of medicine industry until now.

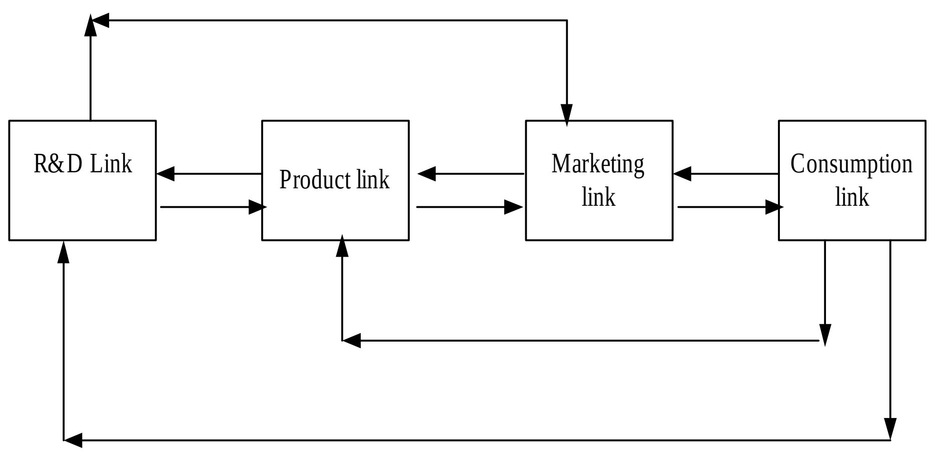
# Part3 Study on medicine industry value chain structure

**Particularity of medicine industry value chain**

Kaplinsky and Morris(2000) make a conclusion on value chain structure and put forward that value chain can be divided into simple value chain and extended value chain. They maintain that most of the value chain can be described by four link model:R&D, production, sales and consumption. But the extended value chain of different product are more complicated, and they illustrate an extended value chain link chart taking the timber industry as an example.

According to the investigation results on six medical company such as Jin Ling Meical company in Jiangsu Province and the medicine production link which is issued on the website of Roche Company and Pfizer Company, we find that the simply value chain is similar to other finished product and agree with the model of Kaplinsky(2000), as illustrated in Figure 1.

Figure 1: Four links in a simple value chain




However, the extended value chain of the medicine has some very visible particularities, which can be shown as follows:

First, there exists clear difference between different medicine's value chain.And there are various catalogue of medicine worldwide, such as proprietary medicine and non-proprietary medicine, which is divided by standards of intellectual protection. In automobile and IT industry, different type of final products' production link share the high similarities .Though the above medicine are all final product, the production link's division shows visible inconsistency.

Second,Modularization degree of medicine's value chain is relatively low. Currently there are two modularization in the production link of medicine value chain, which is raw medicine production and preparation production. The former is a chemical link, while the latter is a physical link.

Third, It is more complicated in R&D link of medicine industry, and modularization degree is comparably high. According to Pfizer company, The R&D link of oneproprietary medicine will undergo many link, for example, finding the ingredients,clinic trial development, new medicine clinic trial Phase I, II and III. Etc.  So after many years of clinic trial, this new medicine will not have the access to the market if no many years of clinic trial.

There are different character in different R&D link in medicine industry, clinic trial is the most representative.In above link, the clinic trial is the core link in medicine industry, and also very special link. The main function of this link is to put the trial medicine from the former R&D link into human body, according a certain rules, and give the feedback to the former R&D link. Therefor, this link require not only high-tech talents, but also need to recruit large amount of patients to attend this trial, thus greatly increase the cost of the entire R&D link.

**Study of Extended value chain ofproprietary medicine and non-proprietary medicine**

But the extended value chain in propreitary medicine and non-propreitary medicine is different. Figure 2 shows the extended value chain of proprietary medicine production. You can see there is a very long period of R&D link in proprietary medicine, which is a very indispensable link for the follow-up link. It result in such characteristics of proprietary madicine production as high risk, high input and high value-added rate. According to PHRMA's statistics, R&D input of every proprietary medicine in 2006 demand for 1.3 billion dollars. Such high input determined that R&D and production link of proprietary medicine is monopolized by multinational company.

Based on the above analysis, We make an judgement on the added value of various value chain of the proprietary medicine/ Firstly, R&D link is the main value-added link in proprietary medicine value chain, ensuring the position of patent owner's monopoly right. Secondly, the former two sub link in the R&D link are the main value added link, while clinic trial only assistant link which providing data support to the former two link. Thirdly, the production link actually also the auxiliary link to the R&D link, functioning as realizing profit. Finally, Due to almost complete monopoly of the multinational company, the added value from marketing link is far lower than R&D link.

Figure 2:  the extended value chain of the proprietary medicine

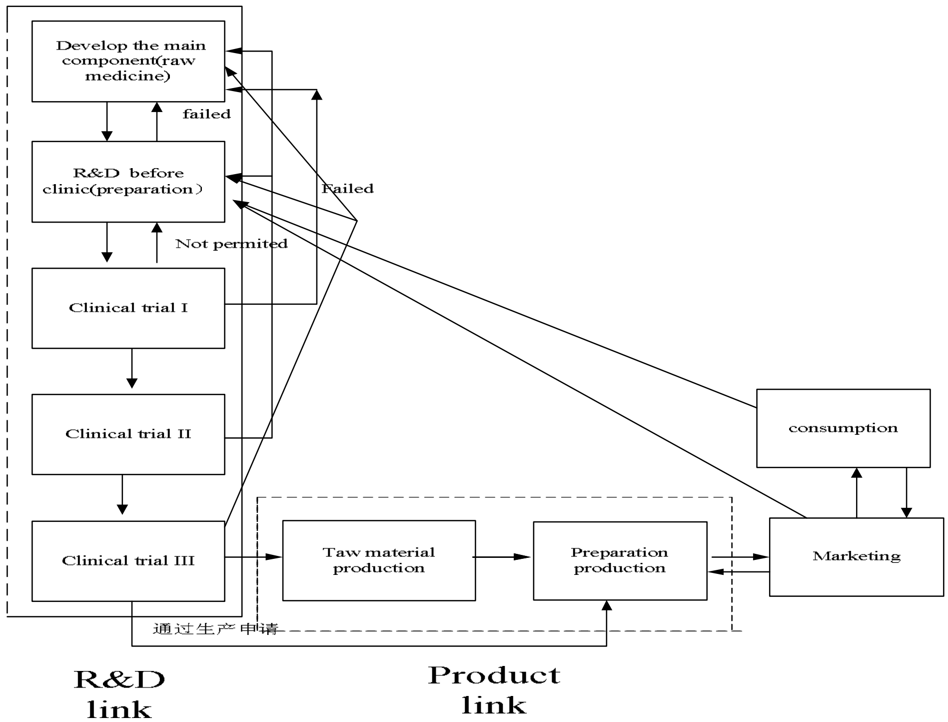
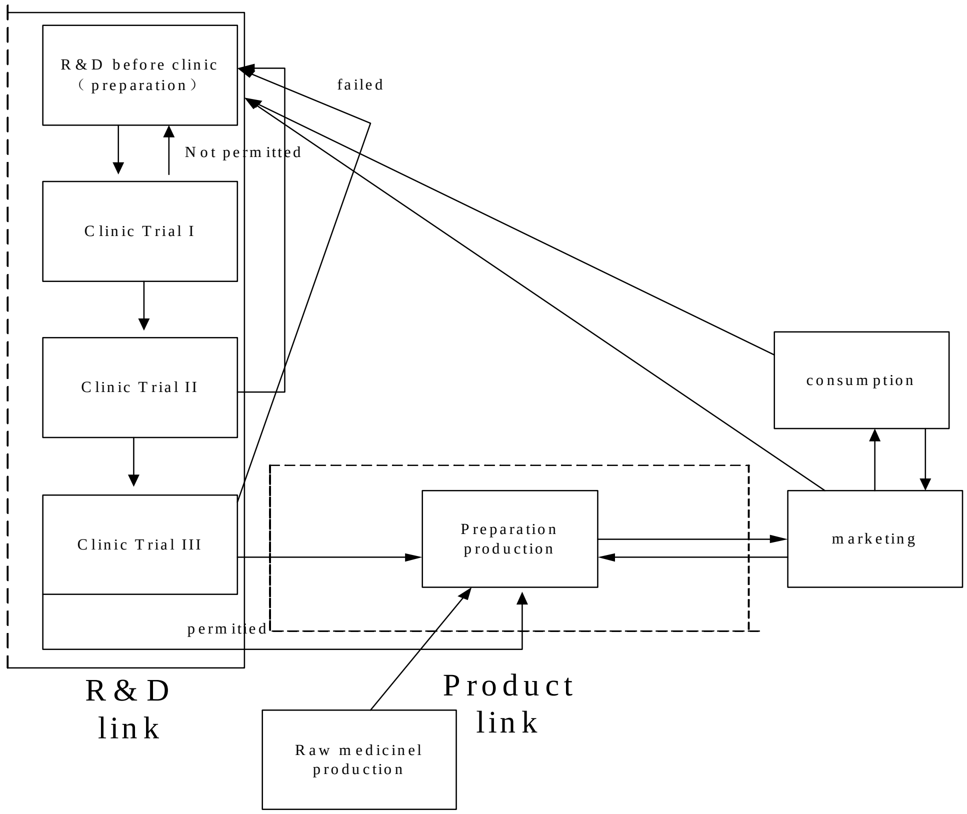



Figure 3 shows the non-proprietary medicine's extended value chain. Compared with Figure 2 and Figure 3, non-proprietary medicine's value chain has the differences fromproprietary medicine as follows:

Figure 3: the extended value chain of the non-proprietary medicine




First, The total value added ratio of non-proprietary medicine is clearly lower than proprietary medicine. The reason is that non-proprietary medicine has no link of finding components compared to proprietary medicine, while this link is just located on the upper left top of "smile curve", and that is the maximum value added link. Thus the value added ratio of non-proprietary medicine is clearly lower thanproprietary medicine.

Second, non-proprietary medicine production is the link which is called R&D before clinic, and also the main value added link. From Chart 4, we can see that the production of raw medicine for non-proprietary medicine is out of the main value chain,and has no clear relation with the former R&D link, while the non-proprietary medicine pharmaceutical production has a direct connection with R&D link. In fact, some non-proprietary medicine's pharmaceutical formulation is the same as that of the proprietary medicine, so there is also no the second sub link of the R&D link in their value chain.

Second, there is more competition in non-proprietary medicine market than proprietary medicine market, thus adding more value to the marketing link. Due to lower threshold of non-proprietary medicine than proprietary medicine, non-proprietary medicine production are not limited to fewer multinational companies, but also widely seen in most companies in developed countries, even some middle to small sized pharmaceutical manufactures in developing countries,thus more degree of competition than proprietary medicine. The above market structure increase the value added ratio of marketing link.

Last, The degree of non-proprietary medicine production competition is the utmost. For most of the medicine, the threshold of raw medicine production lie in its production technology. When the production technology is publicized, the threshold of non-proprietary medicine's raw medicine is far lower than non-proprietary medicine preparation manufacture, which has a strongest competitive edge than others.Due to the alternative character of raw medicine among many companies, the value added ratio of this link is the lowest and it is very easy to have low price competition.

Based on above, This article make an judgement on the characteristics of proprietary medicine and non-proprietary medicine's value chain according to Gereffi's method (1999). Gereffi hold that value chain can be judged by the system in Table 1.

Table 1: Producer-driven and Buyer-Driven value chains

| | Producer-Driven Commodity Chains | Buyer-Driven Commodity Chains |
|---|---|---|
| Drivers of Global Commodity Chains | Industrial Craw medicinetal | Commercial Craw medicinetal |
| Core Competencies | R&D;Production | Marketing;Design |
| Barriers | Economies of Scale | Economies of Scope |
| Typical Industries | Automobiles; Computers; Aircraft | Apparel;Footwear; Toys |
| Ownership of Manufacturing Firms | Transnational Firms | Local Firms, predominantly in developing countries |
| Main Network Links | Investment-based | Trade-based |

Source: Gereffi,1999b.

According to the above analysis, we can make an judgement on the value chain ofproprietary medicine, non-proprietary medicine raw medicine and non-proprietary medicine pharmaceutical preparation.proprietary medicine's core competition edge is mainly in R&D,and have a high demand of investment and technical input which mainly manipulated by multinational company. Therefor belongs to producer-driven; while marketing link and production link have clearly upgrade the core competition edge on non-proprietary medicine pharmaceutical preparation, which are attended by multinational company and local middle to small sized company, thus shares both character of producer-driven and buyer-driven; Non-proprietary medicine raw medicine mainly come from marketing link and it has a very low threshold, therefor local company have a higher proportion, and belongs to buyer-driven value chain.

**Analysis on character of Chinese medicine industry value chain**

Chinese medicine industry has two important characters:

First, Our medicine industry has a high dispersion degree, no multinational company is existing. According to Chinese High-Tech Statistic Yearbook, the article give an calculation of the proportion of Chinese Multinational company's added value on whole industry's added value. The calculation shows that the proportion is 22..3% in 2007. According to the statistics released by US creation new medicine committee, 30 biggest multinational company's sales volume is up to 76.9% of it total medicine sales.This demonstrate that our medicine industry is actually led by small to middle sized company while no multinational company existing in China.

Second, The R&D input in Chinese medicine industry is low, on one side, our medicine industry's R&D input scale is very low. According to statistics, the input of science activities in medicine industry is up to 6.3billion yuan in 2007.while Phifzer company had input 8.7 billion dollar in R&D in 2008. On the other side, our medicine industry's R&D indensity is low, the following table shows the differences in R&D indensity between our country and developed countries in pharmaceutical manufacture.

Table 2: The comparation of the R&D indensity in China and some developed countries

| | China | USA | Japan | Germany | France | England | Korea |
|---|---|---|---|---|---|---|---|
| | 2007 | 2006 | 2006 | 2006 | 2006 | 2006 | 2006 |
| Manufacture | 3.5 | 10.2 | 11 | 7.6 | 9.9 | 7 | 9.3 |
| High-tech industry | 6 | 39.8 | 28.9 | 21.5 | 31.9 | 26.6 | 21.3 |
| medical industry | 4.7 | 46.2 | 37.1 | 23.9 | 33.4 | 42.3 | 6.3 |

Source: ministry of Science and Technology of the People's Republic of China

We can see that the R&D indensity of Chinese medicine manufacture is just little bit higher than the average level of manufacture industry, which is not only far lower than developed countries,but also lower than the average level of Chinese high-tech industry, Thus, R&D link is not the leading place in medicine manufacture industry.

Based on the above character and the above theories, we can conclude that our medicine industry's value chain is buyer-driven.

# Part4 Empirical research on international specialization of World medicine industry

According to the analysis of world medicine industry value chain,we can make the assumption of international specialization status of world medicine industry:

Assumption 1: the intra-industry division in developed countries are the main type of international specialization of world medicine industry.

Therefor, we can predict that the medicine, especially final product value chain has a typical character of technology intensive, while no labour intensive link there. Developed countries have a very visible advantage in high tech field than developing countries, Thus, we can predict that the intra-industry division among developed countries is the main type of world medicine industry division.

The article give the calculation of world medicine trade breakdown by countries. Related data are from United States Commodity Trade Database and the statistical standards are shown in Appendix I. According to the above statistical standards, the article give an calculation on the distribution of world medicine trade and the result is in Table 3.

Table 3: the distribution of world medicine trade

| | Proportion of Export | Proportion of Import |
|---|---|---|
| | 2008 | 2008 |
| Developed Countries: | 90.55% | 80.15% |
| EU15 and Switzerland | 80.02% | 56.85% |
| USA | 7.98% | 15.73% |
| Canada | 1.53% | 2.84% |
| Australia | 0.86% | 1.84% |
| Japan | 0.89% | 2.90% |
| Other Countries： | 9.45% | 19.85% |
| India | 1.51% | 0.53% |
| China | 1.81% | 1.45% |

Source: calculated by the data from U.N. commodity trade statistics.

The result show that most of the world medicine trade are operated among developed countries,about 91 precent of medicine export and 80 percent of the medicine import supply are in 20 developed countries. Developing countries like China and India, though quicken their steps in international specialization of world medicine, occupy very small portion of world medicine trade.

On this base, the article gives us an judgement of how developed countries conduct international specialization in medicine industry, using GL Index by Grubel&Lloyd(1975).

The GL index is defiinited as follows:

$$GL_j = \frac{\sum_{i=1}^{N}(X_i + M_i) - \sum_{i=1}^{N}(|X_i - M_i|)}{\sum_{i=1}^{N}(X_i + M_i)} \times 100$$

$X_i$,export of the i product; $M_i$,import of the i product

According to the statistics of the medicine product, the article calculate the GL index of medicine product, raw medicine of US, UK, Switzerland, France and German in 2004 and 2008. The result is in table 4. It shows that every countries' GL index is over 0.5 and is in obvious rising trend. This proves that the intra-industry division in developed countries are the main type of international specialization of world medicine industry. From the perspective of product structure, we can see that the GL index of raw medicine as intermediate product is comparatively low, while the GL index of main trade product--pharmaceutical preparation is comparatively high.

Table4: The GL index of medicial trade in five developed country

| | Year | GL index of the total medical trade | GL index of the raw medicine | GL index of the preparation trade |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| France | 2004 | 73.25 | 48.98 | 76.78 |
| | 2008 | 78.54 | 60.77 | 80.19 |
| Germany | 2004 | 59.2 | 57.8 | 59.33 |
| | 2008 | 61.34 | 40.41 | 63.08 |
| Switzerland | 2004 | 66.87 | 46.66 | 70.03 |
| | 2008 | 57.26 | 51.7 | 57.82 |
| England | 2004 | 77.97 | 57.48 | 79.36 |
| | 2008 | 75.8 | 80.06 | 75.6 |
| USA | 2004 | 69.58 | 77.66 | 67.96 |
| | 2008 | 63 | 65.91 | 62.51 |

Source: calculated by the data from U.N. commodity trade statistics.

Assumption2: The final product trading is the main type of world medicine trade, the intermediate product occupies smaller proportion. International trade theory shows that the trading of intermediate product greatly rely on two points: first, the separability when producing in space; second, different factor endowment in different producing link. We can speculate that the separability degree of producing link inproprietary medicine which are dominant in world market share is weak, thus the final product trade will be the dominant type of the world medicine product division.

The following paragraph will positive study the result. According to analysis above, we take raw medicine as intermediate product in world medicine industry, while take all kinds of preparations as final product. Appendix 1 shows the statistic standard of the calculation.

Based on that, the article calculate separately the ratio of consuming product and intermediate product in world medicine trade in 2008, shown in following table. The result demonstrate that Assumption 2 is correct, and the international specialization is mainly conducted by final product trade.

Table 5: the proportion of the intermediate product trade and the final product trade

| | preparation trade(2008) | Raw medicine trade(2008) |
|---|---|---|
| | (intermediate product) | (final product) |
| proportion of export | 90.40% | 9.60% |
| proportion of import | 90.59% | 9.41% |

Source: calculated by the data from U.N. commodity trade statistics.

Assumption3: most of the trade between the develped countries is horizontal intra-industry trade. Intra-industry trade can be divided in two parts: horizontal intra-industry trade(HIIT) and vertical intra-industry trade(VIIT). HIIT means the technological level of import and export is similar, while VIIT means the technological level is different. Fukao&Ishido(2004)gives the criteria to judge whether the trade is HIIT or VIIT. The method is as follows:

$\frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \le 0.1$; unilateral trade;

$0.1 \le \frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \le 10$且$0.8 \le \frac{P_{kk'j}}{P_{k'kj}} \le 1.25$时，horizontal inter-industry trade;

$0.1 \le \frac{Min(M_{kk'j}, M_{k'kj})}{Max(M_{kk'j}, M_{k'kj})} \le 10$且$0.8 \le \frac{P_{kk'j}}{P_{k'kj}} \ge 1.25$或$\frac{P_{kk'j}}{P_{k'kj}} \le 0.8$时，vertical inter-industry trade

$M_{kk'j}$:country k export to country k' in commodity j, $P_{kk'j}$: the price, 0.1、1.25 and 0.8为threshold

Based on that, the article calculate separately the proportiong of unilateral trade, HIIT and VIIT in the trade between France, Germany and USA, shown in following table. The result demonstrate that Assumption 3 is correct,

Table 6: the proportion of unliateral trade,VIIT and HIIT

| | proportion of unilateral trade(2008) | proportion of vertical intra-industry trade(2008) | proportion of horizontal intra-industry trade(2008) |
|---|---|---|---|
| Germany and USA | 20.89% | 30.11% | 49.01% |
| France and USA | 16.28% | 10.97% | 72.75% |

Source: calculated by the data from U.N. commodity trade statistics.

## Part5 Empirical Study on Chinese Medicine Industry Division

Medicine industry value chain is relatively simple in production link, and is divided into raw medicine production and preparation production. We can judge the position of Chinese Medicine industry in the international specialization according to Trade Special Coefficient of Chinese RAW MEDICINE and Preparation.

The article gives an calculation on Chinese and Indian medicine product, RAW MEDICINE and Preparation's Trade Special Coefficient since 2004, as shown in table 8&9.

We can see from the chart that China and India both have a certain degree of overall competitiveness in medicine industry, but the origin of the competitiveness differs greatly. In the respects of raw medicine, Chinese TC index is very high, near to the absolute comparative advantage position; while India locate at a relative low position. In the preparation field, China locates low position and TC index has a falling trend; while India has an remarkable advantage. Thus we can infer that since 2004, In the world medicine value chain production link, China is mainly positioned on RAW MEDICINE producing link while India locates in Preparation link.

Table 8: the TC index of China and India medicine trade

| Year | TC index of China | TC index of India |
|---|---|---|

| | | |
|---|---|---|
| 2004 | 0.19 | 0.55 |
| 2005 | 0.17 | 0.5 |
| 2006 | 0.17 | 0.49 |
| 2007 | 0.15 | 0.47 |
| 2008 | 0.13 | 0.52 |

Source: calculated by the data from U.N. commodity trade statistics and China customs.

Table 9: the TC index of China and India intermediate product trade and prepraation product trade

| Year | Intermediate products | | Preparation products | |
|---|---|---|---|---|
| | TC index of China | TC index of India | TC index of China | TC index of India |
| 2004 | 0.73 | -0.01 | -0.56 | 0.76 |
| 2005 | 0.74 | -0.11 | -0.56 | 0.74 |
| 2006 | 0.78 | -0.15 | -0.58 | 0.7 |
| 2007 | 0.79 | -0.13 | -0.58 | 0.7 |
| 2008 | 0.8 | -0.06 | -0.6 | 0.71 |

Source: calculated by the data from U.N. commodity trade statistics and China customs.

We can get the same conclusion using intra-industry trade analysis method. table 10 and 11 give an calculation on GL index of China and India in 2004-2008 as well as both countries' bilateral trade, vertical inner trade and horizontal trade ratio in medicine trade.

Table 10: the GL index of China and India medicine trade

| Year | GL index of China | GL index of India |
|---|---|---|
| 2004 | 34.45 | 38.26 |
| 2005 | 33.76 | 39.1 |
| 2006 | 31.16 | 40.04 |
| 2007 | 30.62 | 42.4 |
| 2008 | 29.32 | 40.11 |

Source: calculated by the data from U.N. commodity trade statistics and China customs.

Table 11: the proportion of unilateral trade, VIIT and HIIT in China and India

| | | Unilateral trade(import) | Unliateral trade(export) | VIIT | HIIT |
|---|---|---|---|---|---|
| China | Total medical trade | 34.03% | 53.12% | 12.85% | 0.00% |
| | Preparation trade | 87.95% | 0.00% | 12.05% | 0.00% |

| | | | | | |
|---|---|---|---|---|---|
| | raw medicine trade | 0.00% | 85.92% | 14.08% | 0.00% |
| India | Total medical trade | 8.96% | 0.00% | 89.86% | 1.18% |
| | Preparation trade | 0.00% | 0.00% | 95.19% | 4.81% |
| | raw medicine trade | 0.00% | 12.74% | 87.26% | 0.00% |

Source: calculated by the data from U.N. commodity trade statistics and China customs.

Thus we can see, The degree of intra-industry trade of Indian foreign trade on medicine product is obviously higher than China, and closer to developed countries in Europe and United States.; We can also see from the method of Fukao&Ishido(2003) that China's raw medicine is on bilateral export status, while the leading industry--Preparations are basically on import status and not attending the intra-industry division;India basically on vertical intra-industry trade both in raw medicine and Preparations, and the degree of attending the intra-industry division is much more higher than China.

China's statue of raw medicine in world medicine value chain is not a good sign for the development of our medicine industry. As described above, in non-proprietary medicine field, raw medicine production has a weak connection with core link of value chain---R&D link, while Preparation production has a closer connection with R&D link, Thus raw medicine production is the lowest end link in non-proprietary medicine value chain. While R&D and production in Preparations are the relative high end. So we can regard China's position in international specialization of its non-proprietary medicine is on the lowest end of “smile curve”, while India located on a relative high end of it.

Because the raw medicine production is one of the link of final product of Preparations, our country has the characteristics of vertical specialization when attending the international specialization of world medicine industry. Vertical specialization refers to the international specialization of different production link of the same product in same industry, a new type of vertical industry division, and also the main type of intra-industry division between developed countries and developing country, Clearly, raw medicine production in China embodies the higher efficiency by multinational company's vertical specialization.

But there is great difference between vertical specialization of medicine industry and IT industry. On the one hand, though there is weak connection between raw medicine production and core R&D link, raw medicine production still belongs to craw medicinetal intensive industry link, and have higher requirements on technical and craw medicinetal than assembly link of IT industry. Therefor, though China is now located on the lowest end on world medicine value chain, but the added value is much higher than the assembly link of IT industry. On the other hand, the assembly link of IT industry is located at the end of its value chain, and the product are directly for sales. While raw medicine is located at the front part of production chain in medicine value chain, if outsourcing this part can lower down the cost in some degree, it will produce more uncertainty for the latter high value added link, and may enlarge the production risk. Thus, the degree of vertical specialization of Chinese medicine industry maybe far lower than hthe IT industry. At last, the relation of the vertical specialization and processing trade is weaker than the manufacture industry like IT industry.

We used the Input-Holding-Output Model of the Non-Competitive Imports Type Capturing China’s Processing Exports by Chen Xikang and Zhu Kunfu(2008) to calculate the VS index and domestic value-added ratio. With their help, we constructed the Input-Holding –Output Models which includes 43 sectors in 2002. This process used the 42 sector input-Holding –Output Models ,the 123 sector Input-Holding-Output Models, and the processing trade of Chinese medicine. All the data is in 2002.

So we can caluculate the VS index and domestic value-added ratio by the method in Chen Xikang and Zhukunfu(2008). The result is in table 12 and table 13.

Table 12: the VS index in medicine industry in 2002

| | Direct VS index | | | Total VS Index | | |
|---|---|---|---|---|---|---|
| | General Trade | Processing Trade | Total | General Trade | Processing Trade | Total |
| Manufacture of food products and tobacco processing | 0.0013 | 0.5075 | 0.1115 | 0.0081 | 0.5664 | 0.19 |
| Textile goods | 0.0025 | 0.6389 | 0.1991 | 0.0124 | 0.6977 | 0.273 |
| Wearing apparel, leather, furs, down and related products | 0.0022 | 0.5929 | 0.198 | 0.0113 | 0.6616 | 0.2829 |
| Sawmills and furniture | 0.0025 | 0.5831 | 0.1798 | 0.013 | 0.6514 | 0.3175 |
| Paper and products, printing and record medium reproduction | 0.003 | 0.5399 | 0.2059 | 0.0127 | 0.6147 | 0.341 |
| Petroleum processing, coking and nuclear fuel processing | 0.0546 | 0.7302 | 0.684 | 0.0705 | 0.7755 | 0.7326 |
| Chemicals | **0.0071** | **0.6416** | **0.3592** | **0.0237** | **0.7267** | **0.5303** |
| Medicine industry | **0.0042** | **0.5253** | **0.2732** | **0.0129** | **0.5937** | **0.3816** |
| Nonmetal mineral products | 0.0045 | 0.5512 | 0.2482 | 0.0175 | 0.628 | 0.3962 |
| Metals smelting and pressing | 0.0061 | 0.6917 | 0.281 | 0.0224 | 0.737 | 0.4715 |
| Metal products | 0.0034 | 0.7382 | 0.2323 | 0.0189 | 0.776 | 0.4589 |
| Common and special equipment | 0.0072 | 0.6944 | 0.3709 | 0.0213 | 0.7466 | 0.5284 |
| Transport equipment | 0.0066 | 0.6905 | 0.3257 | 0.0214 | 0.7552 | 0.5369 |
| Electric equipment and machinery | 0.0079 | 0.7239 | 0.3443 | 0.0227 | 0.7723 | 0.5189 |
| Telecommunication equipment, computer and other electronic equipment | **0.0058** | **0.8221** | **0.5112** | **0.0201** | **0.8419** | **0.621** |
| Instruments, meters, cultural and office machinery | 0.0489 | 0.6062 | 0.3626 | 0.0629 | 0.6408 | 0.5103 |

Table 13: the domestic value-added ratio in medicine industry in 2002

| | DVA | | | TVA | | |
|---|---|---|---|---|---|---|
| | General Trade | Processing Trade | Total | General Trade | Processing Trade | Total |
| Manufacture of food products and tobacco processing | 0.3403 | 0.1701 | 0.2132 | 0.9919 | 0.4336 | 0.81 |
| Textile goods | 0.2896 | 0.1357 | 0.1761 | 0.9876 | 0.3023 | 0.727 |
| Wearing apparel, leather, furs, down and related products | 0.3233 | 0.1346 | 0.1857 | 0.9887 | 0.3384 | 0.7171 |
| Sawmills and furniture | 0.3148 | 0.1494 | 0.1923 | 0.987 | 0.3486 | 0.6825 |
| Paper and products, printing and record medium reproduction | 0.3772 | 0.1843 | 0.2409 | 0.9873 | 0.3853 | 0.659 |
| Petroleum processing, coking and nuclear fuel processing | 0.1835 | 0.0942 | 0.1177 | 0.9295 | 0.2245 | 0.2674 |
| Chemicals | **0.2754** | **0.1355** | **0.1735** | **0.9763** | **0.2733** | **0.4697** |
| Medicine industry | **0.4148** | **0.2397** | **0.2827** | **0.9871** | **0.4063** | **0.6184** |
| Nonmetal mineral products | 0.355 | 0.1801 | 0.2254 | 0.9825 | 0.372 | 0.6038 |
| Metals smelting and pressing | 0.2596 | 0.1336 | 0.1671 | 0.9776 | 0.263 | 0.5285 |
| Metal products | 0.2665 | 0.1296 | 0.1678 | 0.9811 | 0.224 | 0.5411 |
| Common and special equipment | 0.314 | 0.1538 | 0.1948 | 0.9787 | 0.2534 | 0.4716 |
| Transport equipment | 0.288 | 0.1436 | 0.1815 | 0.9786 | 0.2448 | 0.4631 |
| Electric equipment and machinery | 0.2817 | 0.1322 | 0.1818 | 0.9773 | 0.2277 | 0.4811 |
| Telecommunication equipment, computer and other electronic equipment | **0.2655** | **0.1151** | **0.1749** | **0.9799** | **0.1581** | **0.379** |
| Instruments, meters, cultural and office machinery | 0.1883 | 0.2888 | 0.0891 | 0.9371 | 0.3592 | 0.4897 |

The result proves our assumption is right. TVS value of our medicine industry is 0.38, the processing trade‘sTVS value is 0.59, just higher than some light industry like food and textile, and far lower than IT industry and transport equipment industry. Therefore, the domestic value added of Chinese medicine production is very high, which has reach to 0.618 in regarding to its domestic value added ratio, this shows that exporting 1000dollars medicine product can bring us 618 dollar domestic value added earning, 1.63 times of communication equipment, computer and other electronics equipment. All this demonstrate that the local added value of domestic medicine industry is much higher than IT industry though ithey both locate at the lowest end of the value chain.

Other data can also support this conclusion. The main indirect proof comes from the processing trade statue of our medicine industry. The main way of attending vertical specialization is by linking trade. But the position of linking trade is comparatively low in foreign trade. According to the statistics provided by United States International Trade Commission,this article compares the ratio of linking trade with general trade export between China and US, the result is as follows:

Table 14: the Proportion of General trade and Processing trade between China and US in medicine industry

| | | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Total | Proportion of General trade | 81.95% | 87.42% | 81.09% |
| | Proportion of Processing trade | 11.25% | 11.64% | 16.60% |
| Raw medicine | Proportion of General trade | 81.45% | 87.11% | 80.93% |
| | Proportion of Processing trade | 18.02% | 12.08% | 16.81% |
| Preparation | Proportion of General trade | 98.53% | 95.07% | 82.77% |
| | Proportion of Processing trade | 0.53% | 0.52% | 14.32% |

Source: calculated by the data from China customs.

We can see that the export ratio of linking trade of medicine industry is floating around 15%,far lower than the average level of linking trade export.

Another proof comes from the company structure of our medicine export. Multinational company occupies less ratio in Chinese medicine export than IT industry. It is estimated that only 33.1% of the export medicine to US are operated by foreign invested company, others are all local company. Even in linking trade, Chinese local company take a advantage position. In 2008, Chinese local company's export to US in medicine linking trade is up to 68% . The proportion of Foreign invested company is over 80% in overall linking trade export.

This result shows that our medicine industry, though attending world vertical specialization in some degree, is not led by foreign invested company, and it is the result of local company's seeking to maximize the benefits and actively attending the international specialization.

The above article mainly analyse the position in world medicine industry value chain. In R&D link, multinational company has the intention to move the clinic trial to China. As described above,The R&D trial link is different from the former two link, which need not only high tech talents but also large amount of craw medicinetal.to get the experiment data from all kinds of experiment. Therefore, our country has a relative advantage in clinic trial. On the one hand, because the clinic trial cost is much higher in developed countries than China due to their high resident income; on the other hand,Clinic trial's function is mainly offering database support, thus the technical spillovers effect is far lower than the other link and give less influence on multinational country's technical monopoly .

In order to give evidence to this conclusion, we do some statistics on multinational company's clinic trial and pharmaceutical company's data based on the biggest clinic trial registered database"clinicaltrials.gov" and the data from China's High-tech Statistical Yearbook, shown in table 16. The result shows that in 2007 multinational company's clinic trial in China increase 74% of that in 2005. Higher than the ratio of value added 57% of the same period.

Table 16: Clinic trials in China

| **Year** | **Clinic trial number by TNE** | **TNE number** | **Value-added by TNE (100 MRMB)** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 2005 | 79 | 707 | 364.05 |
| 2006 | 123 | 739 | 432.9 |
| 2007 | 137 | 797 | 570.12 |

Due to the increasing demand for clinic trial candidates for I -II(from tens of candidates in Phase I to thousands in Phase IV), therefore, In Phase III&Phase IV, more expenditures on collecting sample data in clinic trial cost than the former link, Thus, we can prove the cost advantage in Chinese clinic trial by analysing the structure of multinational company's clinic trial in China. The result is in table 17.

Table 17: Clinic trials I-IV in China and Total world by TNEs

| Year | TNE in China | | | | TNE in total Wrold | | | |
|---|---|---|---|---|---|---|---|---|
| | Phase I | Phase II | Phase III | Phase IV | Phase I | Phase II | Phase III | Phase IV |
| 2005 | 2.56% | 16.67% | 55.13% | 25.64% | 8.66% | 32.14% | 38.78% | 20.41% |
| 2006 | 5.79% | 9.92% | 69.42% | 14.88% | 15.04% | 32.52% | 34.68% | 17.76% |
| 2007 | 5.69% | 17.89% | 55.28% | 21.14% | 20.46% | 35.33% | 27.59% | 16.61% |
| 2008 | 8.21% | 9.70% | 53.73% | 28.36% | 25.07% | 32.77% | 25.94% | 16.22% |

Thus we can see that in clinic trial in China by multinational company, the labour cost proportions higher in Phase III&IV than average level. We can conclude that the main reason for conducting clinical trail in China is because we have a lower labour cost.

# Part6 Conclusion

On the analysis of medicine industry value chain, we can have an empirical study on Chinese medicine industry position in international specialization and make the conclusion as follows:

First, Comparing to other manufacture business, medicine industry value chain has the character of complicated R&D link, lower modularizationdegree of production link, and these characters makes the main type of medicine industry division is the horizontal intra-industry division among developed countries.

Second, .proprietary medicine and non-proprietary medicine has clear differences in their value chain. The modularizationdegree of non patent chemicals Preparations value chain is higher thanproprietary medicine, and Nonproprietary medicine has less demand for R&D in RAW MEDICINE medicine production link , which makes the medicine industry has some degree of vertical specialization.

Third, The unique clinic trial in R&D link in medicine industry have the character of strong modular, technical spillovers lower, greater portion of labour intensive,which makes outsourcing becomes the main type of vertical specialization in R&D link. Experimental results show that the lower cost of clinic trial make the multinational company intend to transfer the clinic trial to China

Fourth,The character of lower degree of R&D, small scaled enterprises determined that China mainly attend vertical specialization in non-proprietary medicine RAW MEDICINE medicine production, and less active than IT industry, This link is the lowest end of world value chain in medicine product.

Last, VS index and vertical specialization ratio shows that linking trade is dominant by local company, due to it low level of vertical specialization. Though medicine industry and IT industry are both in the lowest end of value chain, the local value added ratio of medicine industry is higher than IT industry.

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Appendix I : Statistical standards of Various medicine product

Nowadays there is still no agreement on statistical standards of various medicine's foreign trade. In respective of the limit of data, this article do some data statistic on global medicine trade by the rules as follows: in HS product code 2935,2936,2937,2939,2941 and 3001-3004, 2935-2941 covers 95% chemical RAW MEDICINE medicine; 3003-3004 covers almost all the chemical Preparations,Plant preparations, chinese medicine preparations and part of Bio preparations, This article does not list the general medical supplies like bandage, medical splint and medical box into preparations product category.

## OFFICE OF INDUSTRIES WORKING PAPER

## U.S. International Trade Commission

# The Information Technology Agreement: An Assessment of World Trade in Information Technology Products

DRAFT: NOT FOR DISTRIBUTION

**Michael Anderson and Jacob Mohs**
**Office of Industries**
**U.S. International Trade Commission**

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***ADDRESS CORRESPONDENCE TO*:**
**OFFICE OF INDUSTRIES**
**U.S. INTERNATIONAL TRADE COMMISSION**
**WASHINGTON, DC 20436 USA**

**Michael Anderson and Jacob Mohs**[1]
**U.S. International Trade Commission**

## ABSTRACT

The Information Technology Agreement (ITA), a plurilateral agreement emerging from the Uruguay Round, eliminates tariffs on specific technology and telecommunications products for ascribed member countries. Primary goals of the ITA are increased trade and competition through trade liberalization for information technology (IT) products, and the global diffusion of information technology. The ITA went into effect in 1997 with 29 WTO member countries and now includes 72 WTO members. The Agreement covers over 95 percent of total world trade in IT products, currently estimated at $4 trillion. The emergence of complex global supply chains for IT products, rapid deployment of new technologies, and technology convergence since the ITA's inception, shine new light on the role of the ITA in global trade. This paper provides an overview of the ITA, the level of tariff liberalization associated with membership, and discusses the changing composition of ITA membership. The paper further examines ITA trade between 1996 and 2008, highlighting the changing composition of trade by leading exporting and importing nations and profiles ITA trade by product segment, focusing on computers, semiconductors, and telecommunications equipment. The paper finds a significant shift in ITA trade to Asia, particularly China, and to a lesser extent Eastern Europe. Increasing diversification of ITA members' trade and economic profiles and the expanding trade participation by developing countries are significant developments in global ITA trade.

[1] This paper represents solely the views of the author and is not meant to represent the views of the U.S. International Trade Commission or any of its commissioners. The invaluable assistance of Monica Reed is gratefully acknowledged. Please direct all correspondence to Michael Anderson, Office of Industries, U.S. International Trade Commission, 500 E Street, SW, Washington, DC 20436, telephone: 202-205-3249, fax: 202-205-2018, email: michael.anderson@usitc.gov.

# Introduction

The Information Technology Agreement (ITA or Agreement), a plurilateral agreement emerging from the Uruguay Round, eliminates tariffs on specific technology and telecommunications products by ascribed member countries. Based on the Most Favored Nation (MFN) principle, the benefits of ITA tariff liberalization are extended to all WTO members. Primary goals of the ITA are increased trade, global diffusion of information technology, and enhanced global economic growth and welfare through trade liberalization for information technology (IT) products. The ITA was concluded in late 1996 with 29 WTO member countries and now includes 72 WTO members. This paper provides a historical perspective of ITA product trade, examining global trade flows and accession of new member countries during the 12 years of the Agreement. Trade patterns for ITA products are examined in the context of increased trade and competition and diffusion of information technology as envisioned in the Agreement. Beginning with an overview of the ITA and the level of tariff liberalization associated with membership, the changing composition of ITA membership is discussed. The paper then examines ITA trade between 1996 and 2008, highlighting the changing composition of leading exporting and importing countries and profiles ITA trade by product segment, focusing on computers, semiconductors, and telecommunications equipment. World trade in ITA products increased three-fold, expanding nearly $3 trillion since 1996, facilitated by aggressive tariff liberalization and broadening membership in the Agreement. This paper finds a significant shift in ITA trade to Asia (particularly China), and to a lesser extent Eastern Europe. Further, this shift is evident in the displacement of traditional producers and exporters of computers and telecommunications equipment by rising Asian ITA members. Other key findings include the increasing diversification of ITA members in terms of trade and economic profiles, and the expanding trade participation by developing countries.

## The Agreement

At the WTO‘s Singapore Ministerial Conference, the Ministerial Declaration on Trade in Information Technology Products (Declaration)[1] was concluded by 29 signatory countries in December 1996. Activation of the provisions in the Declaration was contingent on membership comprising countries accounting for 90 percent of world trade in IT products by a deadline 4 months later (April 1, 1997). The original signatories' trade coverage was only 83 percent. Through additional negotiations, several other countries ascribed to the Declaration, bridging the gap in trade coverage stipulated in the Declaration. With the ITA in effect on April 1, 1997, participants soon after commenced a schedule of phased duty reductions with all duties slated for elimination by 2000.[2] Because the commitments under the ITA are on a MFN basis, the bound zero duty rates for ITA products apply to all WTO members, including non-ITA members.

At the outset, the stated goals of raising living standards, enhancing global economic growth and welfare, and facilitating increased trade for information technology products rested on aggressive tariff liberalization. In accordance with the ITA, member countries agreed to "bind and eliminate all custom duties and other duties and charges" for IT products specified in the agreement.[3] While ITA provisions

[1] WTO, Ministerial Declaration on Trade in Information Technology Products (WT/MIN/96)/16, December 13, 1996).

[2] Several developing countries, including Costa Rica, India, Indonesia, South Korea, and Chinese Taipei, implemented extended duty staging to 2005 on a product-by-product basis as permitted in the Declaration.

[3] WTO, Ministerial Declaration on Trade in Information Technology Products (WT/MIN/96)/16, December 13, 1996).

call for periodic review and consultations on non-tariff barriers, the only commitments in the ITA are for tariff elimination.

## Tariff Rates

A primary objective of the Declaration was to improve market access and promote global trade through elimination of bound duties on IT products on an MFN basis. Initial participants agreed to a series of four equal tariff reductions between 1997 and 2000, with certain exceptions granted to developing countries. While many developed countries maintained fairly low tariffs on IT goods prior to the Singapore Ministerial, tariff elimination on an MFN basis was central to achieving the trade and economic benefits envisioned in the ITA. Bora and Liu (2006) calculate that simple average tariffs over all ITA products was 3.6 percent for ITA members compared with 11.2 percent for non-members. According to the WTO, average bound tariff rates for ITA products for developed countries were reduced from 4.9 percent to zero (WTO 2008, 15). These initial rates ranged from 12.1 percent to 1 percent, which compared with 66.4 percent to 1.2 percent for developing countries.[4] Because of considerably higher bound rates, several developing countries implemented significant tariff liberalization to achieve duty free trade under the ITA. The largest concessions based on pre-ITA bound rates were by India (66.4 percent), Thailand (30.9 percent), and Turkey (24.9 percent). Similarly for applied tariff rates, developing countries' pre-ITA tariffs were generally higher than the average 2.7 percent for developed countries. Notable average applied tariff reductions for developing countries included India (from 36.3 percent), China (from 12.7 percent), and Egypt (from 12.1 percent).

## Expanding Membership

Since the inception of the ITA with 29 original signatories,[5] ITA membership has steadily expanded, reaching 72 members in 2009,[6] with increasing participation from developing countries. Developed countries accounted for nearly all of the original signatories, with Indonesia and Turkey the only developing countries formally adopting the Singapore Ministerial Declaration (table 1).[7] Following the Singapore Ministerial in 1996, 11 additional countries ascribed to the Declaration triggering the 90 percent trade criteria and the ITA entered into force April 1, 1997. In total, 14 members, more than half of them developing countries, joined the ITA in 1997 raising total membership to 43 countries. Between 1998 and 2008, the continued shift toward greater participation by developing countries accounted for 20 of the 29 new participants (68.9 percent). Consequently, developing countries' participation expanded from 2 to 30 countries or from 6.9 percent to 41.7 percent of ITA members (figure 1). While the present composition of ITA members, based on economic status, differs from that of the WTO (41.7 percent versus nearly two-thirds are developing countries), the steady increase in participation by developing

[4] Exceptions included Macao, China, and Hong Kong, China, which already maintained duty free status for ITA products. WTO, World Trade Report 2007, 15.

[5] The European Communities (e.g EU-15) treated as individual members, with Switzerland and Lichtenstein a single customs union.

[6] WTO, Status of Implementation (G/IT/1/Rev.41), 23 October 2008. Peru, the latest member entering the ITA, submitted its ITA schedule to participants for verification and approval in 2008. USTR Web site, http://www.ustr.gov/trade-topics/industry-manufacturing/industry-initiatives/information-technology (accessed September 18, 2009).

[7] Developing countries include middle income and low income countries based on World Bank income classifications. World Bank Web site, http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20421402~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html#Low_income (accessed August 10, 2009).

countries is a significant achievement considering IT products trade was highly concentrated between developed countries prior to the ITA (Mann and Liu, 4).[8]

**TABLE 1** ITA member countries by economic status, 1996–2008

| Year Joined ITA | Developed countries | Developing Countries | | |
|---|---|---|---|---|
| | Economic status[a] | | | |
| | High Income | Upper Middle Income | Lower middle income | Low income |
| 1996 | Australia, *Austria, Belgium*, Canada, *Denmark*, *Finland*, *France*, *Germany*, *Greece*, Hong Kong, Iceland, *Ireland*, *Italy*, Japan, South Korea, Liechtenstein, *Luxembourg*, *Netherlands*, Norway, *Portugal*, Singapore, *Spain Sweden*, Switzerland, Chinese Taipei, *United Kingdom*, United States | Turkey | Indonesia | |
| 1997 | *Czech Republic*, *Estonia*, Israel, Macao, New Zealand, *Slovak Republic* | Costa Rica, Malaysia, *Poland*, *Romania* | El Salvador, India, Philippines, Thailand | |
| 1998 | | Panama | | |
| 1999 | Croatia | *Latvia*, *Lithuania*, Mauritius | Albania, Georgia, Jordan | Kyrgyz Republic |
| 2000 | *Cyprus*, Oman, *Slovenia* | | | |
| 2001 | | *Bulgaria* | Moldova | |
| 2003 | Bahrain | | China, Egypt, Morocco | |
| 2004 | *Hungary*, *Malta* | | | |
| 2005 | | | Nicaragua | |
| 2006 | Saudi Arabia | Dominican Republic | Guatemala, Honduras | |
| 2007 | United Arab Emirates | | | Vietnam |
| 2008 | | Peru | Ukraine | |

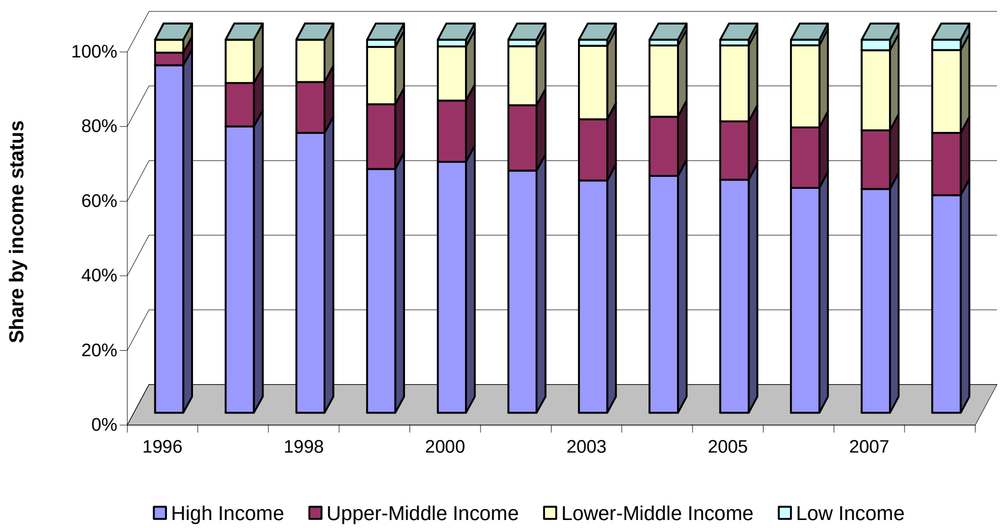
*Source*: Compiled by USITC staff.

*Note*: EU members in italics.

[a] Based on World Bank income classification.

[8] Mann and Liu report that in 1990 Japan, Europe, and the U.S. accounted for nearly two-thirds (68 percent) of the global export market for IT products.

**FIGURE 1** ITA membership composition, share by income status,[a] 1996-2008




[a]Based on World Bank income classification.

The ITA participants that joined subsequent to the original signatory members also presented diverse trade and economic profiles, consistent with the increasing participation of developing countries after 1996. The diversification of membership profiles illustrates increasing interest in liberalized ITA trade. Utilizing total ITA trade (exports and imports) and per capita gross domestic product (GDP)[9] as indicators of trade activity and economic station, a diffuse pattern emerges among the post-1996 entrants. For example, Bahrain and China entered the ITA in 2003 with highly divergent economic and ITA trade profiles. Bahrain, in accordance with its developed country status, exhibited relatively high GDP ($13,726), but lower ITA trade activity ($273 million) compared to China's lower GDP ($1,270) and higher ITA trade activity ($250.2 billion) (table 2 and figure 2). Even within high income, middle income, and low income groups, the economic and trade profile of countries upon ITA entrance varied considerably. Among the high income countries Hungary, Israel, and United Arab Emirates displayed relatively higher GDP and ITA trade activity compared with Estonia and Croatia. Within the middle income group of developing countries, Malaysia and China entered the ITA with relatively strong GDP and ITA trade activity compared with Georgia and Moldova with lower GDP and nascent ITA trade activity. Despite its developing income status China's total ITA trade was $250.2 billion in 2003, exceeding the ITA trade level of Japan in 1996 ($153.6 billion). Notably, China was a leading manufacturer and trader of IT products prior to joining the ITA and deeply engaged in the global IT production chain even prior to tariff liberalization.

[9] IMF statistics , World Economic Outlook Database, April 2009 (accessed August 18, 2009).

**TABLE 2** ITA membership countries by economic status, 1997–2008

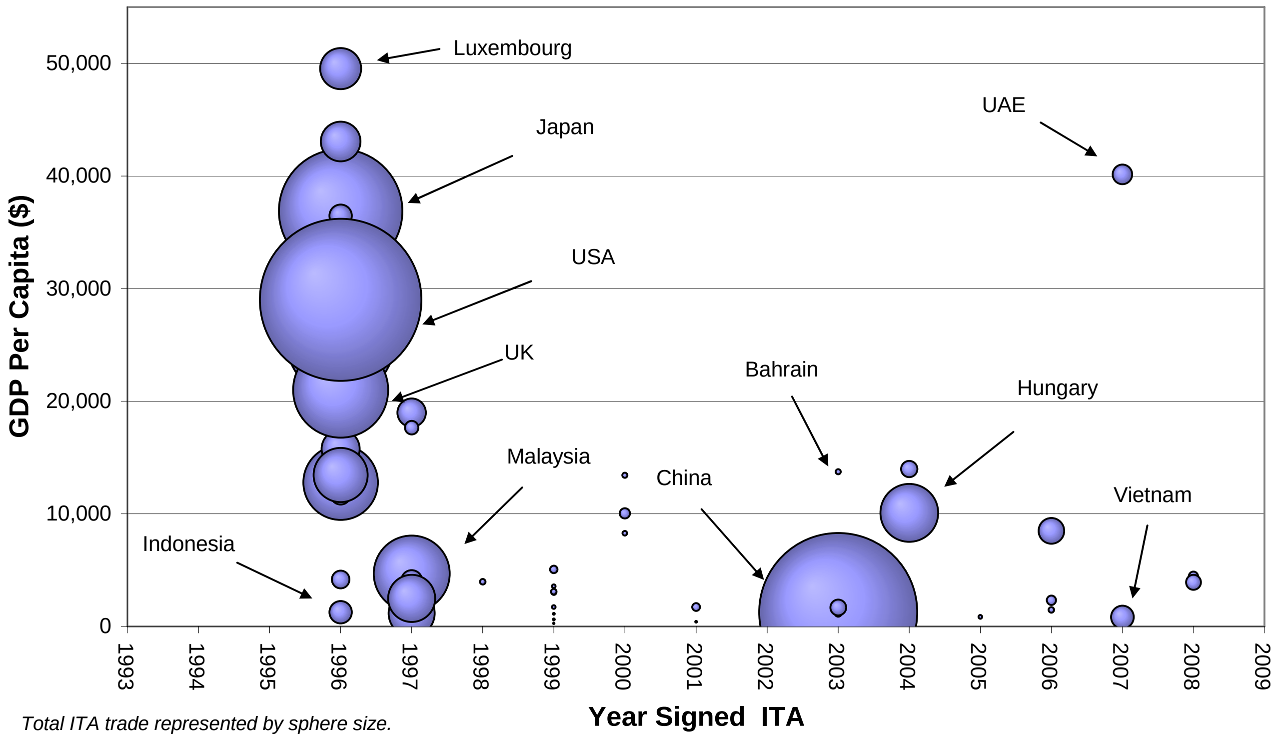
| Country | Year joined ITA | Economic status[a] | GDP per capita | Total ITA trade |
|---|---|---|---|---|
| | | | Dollar | Million $ |
| Hungary | 2004 | High Income | 10,090 | 33,673 |
| Israel | 1997 | High Income | 18,993 | 8,169 |
| Saudi Arabia | 2006 | High Income | 8,490 | 6,600 |
| Czech Republic | 1997 | High Income | 5,545 | 5,885 |
| United Arab Emirates | 2007 | High Income | 40,147 | 4,000 |
| Malta | 2004 | High Income | 13,987 | 2,770 |
| New Zealand | 1997 | High Income | 17,656 | 1,942 |
| Slovak Republic | 1997 | High Income | 3,984 | 1,406 |
| Slovenia | 2000 | High Income | 10,045 | 1,148 |
| Estonia | 1997 | High Income | 3,581 | 788 |
| Croatia | 1999 | High Income | 5,058 | 617 |
| Cyprus | 2000 | High Income | 13,425 | 278 |
| Bahrain | 2003 | High Income | 13,726 | 273 |
| Oman | 2000 | High Income | 8,271 | 255 |
| Malaysia | 1997 | Upper Middle Income | 4,693 | 58,416 |
| Poland | 1997 | Upper Middle Income | 4,064 | 4,542 |
| Romania | 1997 | Upper Middle Income | 1,567 | 948 |
| Peru | 2008 | Upper Middle Income | 4,453 | 948 |
| Bulgaria | 2001 | Upper Middle Income | 1,712 | 654 |
| Costa Rica | 1997 | Upper Middle Income | 3,508 | 629 |
| Lithuania | 1999 | Upper Middle Income | 3,098 | 361 |
| Panama | 1998 | Upper Middle Income | 3,954 | 316 |
| Latvia | 1999 | Upper Middle Income | 3,038 | 275 |
| Mauritius | 1999 | Upper Middle Income | 3,571 | 144 |
| China | 2003 | Lower Middle Income | 1,270 | 250,202 |
| Thailand | 1997 | Lower Middle Income | 2,496 | 22,368 |
| Philippines | 1997 | Lower Middle Income | 1,170 | 21,460 |
| India | 1997 | Lower Middle Income | 410 | 3,077 |
| Morocco | 2003 | Lower Middle Income | 1,688 | 2,664 |
| Ukraine | 2008 | Lower Middle Income | 3,920 | 2,338 |
| Guatemala | 2006 | Lower Middle Income | 2,325 | 941 |
| Egypt | 2003 | Lower Middle Income | 1,197 | 625 |
| Honduras | 2006 | Lower Middle Income | 1,474 | 361 |
| Nicaragua | 2005 | Lower Middle Income | 843 | 173 |
| Jordan | 1999 | Lower Middle Income | 1,720 | 169 |
| Moldova | 2001 | Lower Middle Income | 407 | 46 |
| Georgia | 1999 | Lower Middle Income | 627 | 38 |
| Albania | 1999 | Lower Middle Income | 1,130 | 37 |
| El Salvador | 1997 | Lower Middle Income | 2,077 | 0 |
| Vietnam | 2007 | Low Income | 835 | 5,375 |
| Kyrgyz Republic | 1999 | Low Income | 260 | 26 |

*Source*: Compiled by USITC staff.

*Note*: EU members in italics

[a]Based on World Bank income classification.

**FIGURE 2** Profiles of ITA members, by income and trade levels




*Total ITA trade represented by sphere size.*
*Source*: Compiled by USITC staff from UN Comtrade

## ITA Products

Recognizing the positive social and economic benefits derived from liberalized trade and diffusion of information technology products,[10] drafters of the Ministerial Declaration identified specific products for which duties and other charges would be eliminated. Participants agreed to implement binding duty eliminations through a schedule of concessions covering products in categories such as computers, software, telecommunications, semiconductors, semiconductor manufacturing equipment, scientific and measuring equipment, and related parts. Explicit product coverage under the ITA is comprised of two annexes to the Declaration, commonly referred to as Attachments A and B.[11] Attachment A is a positive list of items at the 6-digit Harmonized Schedule (HS) separated into two sections (A1 and A2). Attachment B includes product descriptions with no corresponding HS code, regardless of their inclusion in Attachment A. The descriptive approach in the Attachment B list is designed to cover products regardless of specific HS codes (Mann and Liu, 8) and to address divergent

[10] WTO, Ministerial Declaration on Trade in Information Technology Products (WT/MIN/96)/16, December 13, 1996).
[11] Ibid, Annex.

national positions in coverage of complex, multifunction products (Dreyer and Hindley, 4). Common products under Attachments A1, A2, and B with their initial number of 6-digit HS codes are noted in table 3. Notable IT products outside the scope of the ITA, mainly consumer electronic products, include CRT television sets, video cameras, and certain photocopiers.[12]

**TABLE 3** Representative ITA products and number of HS codes, by attachment

| | Number of HS codes | Sample Products |
|---|---|---|
| Attachment A1 | 112 | **Computers and Computer Peripherals**; Personal computers, laptops, work stations, monitors, keyboards, hard drives, CD-ROM drives, smart cards, printers, scanners and other input/output units<br><br>**Telecommunications Equipment**; telephone sets, cordless phones, mobile handsets, pagers, answering machines, switches, routers, hubs, modems, fiber optic cables<br><br>**Semiconductors**; micro processors, integrated circuits, printed circuits, diodes, resistors<br><br>**Software**; magnetic tapes, unrecorded media<br><br>**Office Equipment;** certain photocopy machines, fax machines, cash registers, adding machines, calculators, automatic teller machines (ATM)<br><br>**Scientific and Measuring Devices;** spectrometers, chromatographs, flow meters, gauges, optical radiation devices<br><br>**Other;** Loudspeakers, still digital cameras, parts |
| Attachment A2 | 78 | **Semiconductor manufacturing equipment (SME)**; etching and stripping apparatus, vapor deposition devices, sawing and dicing machines for wafers, spinners, ion implanters, wafer transport, handling and storage machines, injection molds, optical instruments, parts and accessories |
| Attachment B | 13[a] | Computers, electric amplifiers, flat panel displays, network equipment, monitors, pagers, CD and DVD drives, plotters, printed circuit assemblies, removable storage devices, and set top boxes |

[a] Attachment B products are covered regardless of where they are classified in the HS system. ITA Committee members have made attempts to narrow divergences in the customs classification of some Attachment B products (WTO G/IT/W6/Rev.3) though there is no agreed upon list. This paper uses such codes as a proxy.

*Source:* WTO and compiled by Commission staff.

# ITA Trade[13]

Global IT trade has grown substantially under the ITA. Beginning in 1996 through 2008 total ITA products trade (imports and exports) expanded 10.1 percent annually, albeit unevenly, from $1.2

[12] For details on ITA negotiating history, including product coverage see Fleiss and Sauve, *Of Chips, Floppy Disks and Great Timing: Assessing the WTO Information Technology Agreement*, 1997, paper prepared for Institut francais des relations internationales and Tokyo Club Foundation.

[13] Trade data based on appropriate HS nomenclature for each year. See box 1 for further details regarding the dataset and attendant complexities.

trillion to $4.0 trillion. The strong growth in ITA trade exceeded that of manufactures trade, which expanded 7.1 percent annually during the same period (figure 4). ITA trade expansion was steepest between 1996 and 2000, growing 17.5 percent, but declined between 2000 and 2002 (-2.8 percent) as the internet boom of the 1990's abruptly reversed, adversely affecting IT spending and investment (Goldman Sachs, 4).[14] In 2002, however, ITA products trade growth resumed, but at a lower trajectory (10.4 percent).

**BOX 1** Data challenges and changing classifications

Changes to the HS system resulting from several factors including technological developments impede attempts at pinpointing precise values in ITA trade. The HS system underwent nomenclature revisions in 2002 and more significantly in 2007, complicating the construction of a consistent times series for ITA product trade. As noted by the WTO, "The ITA committee has already started to discuss how to update the products list into the new nomenclatures, but it proved very difficult to reach an agreement due to the complexity of HS amendments and the remaining classification problems under the old nomenclature (HS1996)."[a] Quantifying trade in Attachment B products is additionally challenging because each country has provided their own list of tariff codes (usually at the national line level (i.e. 8- or 10-digit level)) where these products may be classified and some countries have not provided a list.

Because no WTO approved ITA product list exists for HS 2007, estimates were constructed for this analysis. For example, 6-digit codes provided in the ITA for Attachments A1 and A2 reflect World Customs Organization (WCO) transpositions as a proxy. However, many such products are breakouts (i.e. ex-outs) at the 6-digit level and ITA members have identified specific national tariff lines within these subheadings to cover these products. In our estimation, the HS 2007 system includes 354 sets of changes, 70 impacting the ITA. In Attachment A1, 54 of 111 subheadings are impacted, and 53 of 58 subheadings in Attachment A1. For Attachment B, while there is no agreed upon list, it is estimated that approximately 51 of 72 subheadings are impacted for products where a code was listed. Consequently, the integrity of ITA trade data in 2007 and 2008 likely reflects transposition challenges with HS 2007. For example, uneven 2007-2008 trade in office equipment stems in part from significant classification changes. Despite the challenges attendant with the HS 2007 nomenclature, utilizing the HS 2002 list after 2006 may significantly understate trade, as several ITA products are not captured starting in 2007.[b] To mitigate this, a constructed data set was employed, using the nomenclature appropriate for each year.[c] The data set also segregates products covered in both Attachments A and B to avoid possible duplication.[d] Finally, ITA product segments (e.g. computers, semiconductors, etc.) are based on HTS product descriptions, and in instances where products are covered in both Attachments and their use may span multiple segments (e.g. printed circuit assemblies), segmentation relied on USITC product digests.[e] Therefore this paper present a conservative approximation of the aggregate ITA trade data. Using this dataset, changes in trade patterns, product composition, country market share, are examined as the new members ascribe to tariff liberalization embodied in the ITA.

[a] http://www.wto.org/english/thewto_e/coher_e/wto_wco_e.htm.

[b] For example, cellular telephones, classified in HS 2002 under 8525.20, are classified under 8517.12 in HS 2007, a new 6-digit subheading not contained in HS 2002.

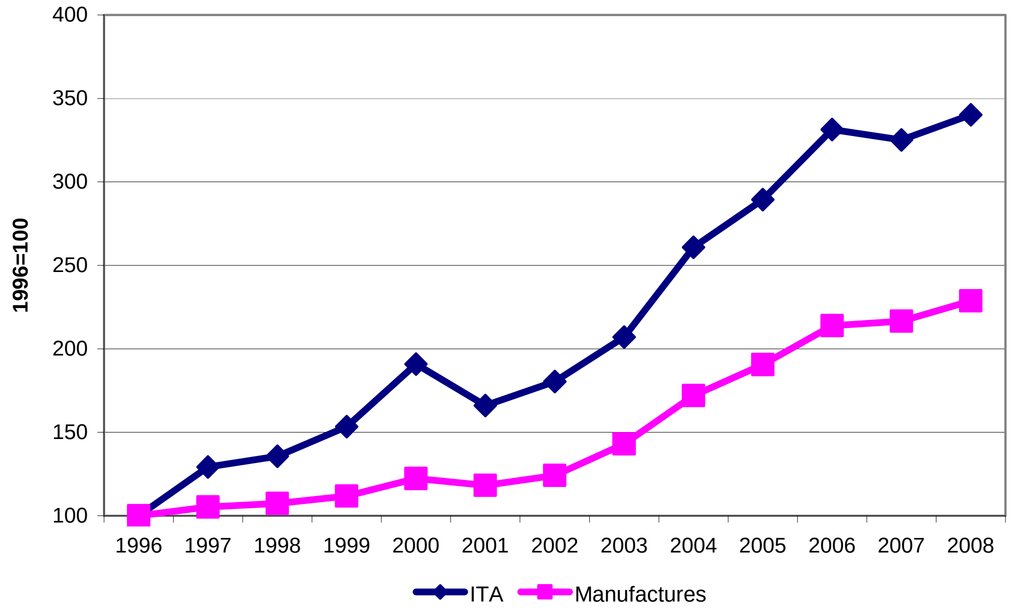
[c] The data for 1996–2001calculates the total base on the 1996 Ministerial Declaration, the list from 2002-2006 calculates the total based on the WTO's transposition into HS 2002. For 2007–2008, the total is calculated using a list transposed into HS 2007. While imperfect and likely understating trade for certain ITA products, using the HS 2007 produces a more representative dataset.

[d] Appendix A illustrates ITA total trade by segregated Attachment lists during 1996–2008.

[e] See USITC publication 4089, "Shifts in U.S. Merchandise Trade 2008," Investigation No. 332-345. http://www.usitc.gov/research_and_analysis/trade_shifts.htm.

[14] U.S. technology investment was down 7 percent in 2001 and 9 percent in 2002, reacting sharply to excesses associated with the tech bubble (Goldman Sachs, "Independent Insight: IT Spending Survey", November 2008).

**FIGURE 3** ITA and manufactures total trade, 1996–2008




*Source* : Compiled by USITC staff from UN Comtrade database.

As a share of global trade, ITA product trade peaked in 2001 at 18.4 percent. While ITA's share declined slightly to 15.2 percent in 2008, it remains above the 1996 level of 13.8 percent (table 4). This share, however, likely understates the economic significance of this product group. Since the inception of the ITA, prices of technology products have trended downwards (WTO 2008, 16),[15] masking the increasing level of ITA trade.

**TABLE 4** ITA trade compared with manufactures trade, share and growth rates, selected years

| | Share of total trade | Compound annual growth rate | | |
|---|---|---|---|---|
| | 2008 | 1996–2008 | 1996–2000 | 2001–2008 |
| | | Percent | | |
| ITA Total Trade | 15.2 | 10.7 | 17.5 | 10.8 |
| Manufactures Total Trade | 65.5 | 7.1 | 5.2 | 9.9 |

*Source:* Compiled by USITC staff from UN Comtrade database.

[15] Based on U.S. import values between 1996 and 2005, average unit prices for IT products declined 6 percent annually compared with a 1 percent increase for all other manufactured goods (WTO World Trade Report 2008, 16).

**TABLE 5** ITA exports, top 30 countries and growth rates, selected years

| Number | Exporter | Exports 2008 | Share of total 2008 | Compound annual growth rates 1996-2008 [a] | 1996-2000 [a] | 2001-2008 |
|---|---|---|---|---|---|---|
| | | Thousand $ | Percent | | | |
| 1 | China | 463,685,179 | 24.6 | 33.5 | 29.2 | 38.1 |
| 2 | Japan | 173,712,915 | 9.2 | 4.3 | 7.9 | 7.2 |
| 3 | Singapore | 146,781,694 | 7.8 | 7.1 | 5.6 | 11.8 |
| 4 | Germany | 142,524,685 | 7.8 | 9.0 | 7.2 | 11.2 |
| 5 | United States | 142,470,901 | 7.6 | 1.9 | 10.2 | 1.0 |
| 6 | Korea, South | 124,747,772 | 6.6 | 13.1 | 18.1 | 17.0 |
| 7 | Netherlands | 80,490,648 | 4.3 | 9.8 | 13.4 | 11.5 |
| 8 | Mexico | 64,610,222 | 3.4 | 13.1 | 19.2 | 10.2 |
| 9 | Chinese Taipei | 53,435,374 | 2.8 | 9.8 | 39.5 | 0.0 |
| 10 | Malaysia | 43,475,140 | 2.3 | 3.0 | 11.9 | 0.6 |
| 11 | France | 42,985,486 | 2.3 | 3.9 | 7.5 | 4.9 |
| 12 | United Kingdom | 39,170,154 | 2.1 | -0.8 | 7.7 | -4.8 |
| 13 | Thailand | 37,657,450 | 2.0 | 10.7 | 13.3 | 13.2 |
| 14 | Czech Republic | 27,529,537 | 1.5 | 28.5 | 18.1 | 34.8 |
| 15 | Hungary | 27,516,996 | 1.5 | 37.2 | 81.8 | 22.8 |
| 16 | Ireland | 24,606,914 | 1.3 | 3.0 | 16.0 | -4.3 |
| 17 | Italy | 23,684,093 | 1.3 | 2.1 | -0.7 | 3.9 |
| 18 | Sweden | 22,399,212 | 1.2 | 4.7 | 8.0 | 11.0 |
| 19 | Belgium | 18,559,404 | 1.0 | 7.6 | 8.5 | 6.8 |
| 20 | Finland | 17,743,663 | 0.9 | 9.2 | 18.2 | 8.8 |
| 21 | Austria | 15,885,611 | 0.8 | 10.8 | 9.4 | 12.2 |
| 22 | Philippines | 15,582,762 | 0.8 | 11.0 | 56.6 | -4.6 |
| 23 | Canada | 14,746,829 | 0.8 | -0.5 | 12.7 | -2.1 |
| 24 | Switzerland | 14,619,955 | 0.8 | 5.6 | 4.2 | 8.5 |
| 25 | Slovak Republic | 13,060,477 | 0.6 | 36.8 | 10.1 | 60.1 |
| 26 | Poland | 11,851,929 | 0.6 | 29.3 | 13.3 | 43.1 |
| 27 | Spain | 11,034,632 | 0.6 | 7.7 | 6.7 | 9.5 |
| 28 | Israel | 7,317,840 | 0.4 | 6.1 | 22.4 | 1.0 |
| 29 | Denmark | 6,967,475 | 0.4 | 6.9 | 9.0 | 7.3 |
| 30 | Norway | 4,568,130 | 0.2 | 10.0 | 3.4 | 15.6 |
| | World | 1,882,022,074 | | 10.6 | 17.7 | 10.7 |
| | EU 15 | 440,673,667 | 23.4 | 6.0 | 8.9 | 6.2 |
| | EU External only | 199,487,510 | 10.6 | | | 9.4 |

*Source*: Compiled by USITC staff from UN Comtrade database.
[a] Data starts in 1997 for Singapore, Malaysia, Russia, Brazil, Slovak Republic, and Philippines. Data starts in 1998 for Thailand. *Note*: Belgian data in 1996 includes Luxembourg.

**TABLE 6** ITA imports, top 30 countries and growth rates, selected years

| Number | Importer | Imports 2008 | Share of total 2008 | Compound annual growth rates 1996-2008[a] | 1996-2000[a] | 2001-2008 |
|---|---|---|---|---|---|---|
| | | Thousand $ | Percent | | | |
| 1 | United States | 305,082,078 | 14.3 | 6.2 | 12.1 | 7.4 |
| 2 | China | 279,582,232 | 13.1 | 24.4 | 25.2 | 25.3 |
| 3 | Hong Kong, China | 183,994,486 | 8.6 | 14.3 | 12.7 | 17.7 |
| 4 | Germany | 135,253,735 | 6.3 | 8.5 | 8.7 | 9.3 |
| 5 | Singapore | 106,436,489 | 5.0 | 6.2 | 5.8 | 11.1 |
| 6 | Japan | 95,821,222 | 4.5 | 5.7 | 9.5 | 6.8 |
| 7 | Korea, South | 77,368,758 | 3.6 | 9.0 | 12.4 | 12.7 |
| 8 | Netherlands | 75,045,283 | 3.5 | 9.7 | 14.9 | 10.7 |
| 9 | Mexico | 71,774,690 | 3.4 | 13.5 | 24.3 | 9.7 |
| 10 | United Kingdom | 69,048,943 | 3.2 | 3.1 | 9.5 | 3.4 |
| 11 | France | 60,873,645 | 2.5 | 6.0 | 8.2 | 8.1 |
| 12 | Malaysia | 52,919,855 | 2.5 | 5.5 | 8.6 | 7.2 |
| 13 | Canada | 40,083,796 | 1.9 | 4.1 | 10.8 | 4.7 |
| 14 | Italy | 39,840,656 | 1.9 | 6.3 | 7.6 | 7.9 |
| 15 | Spain | 38,107,998 | 1.8 | 11.6 | 8.8 | 16.2 |
| 16 | Thailand | 33,837,547 | 1.6 | 9.6 | 9.2 | 11.9 |
| 17 | Czech Republic | 26,957,270 | 1.3 | 19.3 | 9.1 | 25.1 |
| 18 | Russian Federation | 25,146,828 | 1.2 | 17.9 | -15.7 | 38.7 |
| 19 | Hungary | 24,583,846 | 1.2 | 25.4 | 46.7 | 17.8 |
| 20 | Philippines | 24,463,013 | 1.1 | 3.1 | -0.6 | 5.9 |
| 21 | Chinese Taipei | 24,036,619 | 1.1 | 6.0 | 48.9 | -7.6 |
| 22 | Belgium | 22,902,964 | 1.1 | 7.8 | 8.4 | 7.2 |
| 23 | Brazil | 22,173,634 | 1.0 | 8.1 | 2.5 | 13.5 |
| 24 | Australia | 21,238,066 | 1.0 | 6.7 | 4.7 | 12.9 |
| 25 | Sweden | 19,934,993 | 0.9 | 6.0 | 7.0 | 10.8 |
| 26 | Switzerland | 17,058,388 | 0.8 | 6.0 | 6.5 | 8.3 |
| 27 | Austria | 16,699,116 | 0.8 | 9.4 | 9.6 | 10.9 |
| 28 | Ireland | 16,230,409 | 0.8 | 3.9 | 16.3 | -2.8 |
| 29 | Slovak Republic | 12,877,092 | 0.6 | 22.7 | -1.3 | 38.5 |
| 30 | Finland | 12,678,786 | 0.6 | 9.3 | 12.5 | 11.0 |
| | World | 2,131,461,652 | | 10.9 | 17.4 | 10.9 |
| | EU 15 | 472,359,584 | 22.2 | 7.2 | 9.9 | 8.1 |
| | EU 15 External | 302,642,656 | 14.2 | | | 10.5 |

*Source*: Compiled by USITC staff from UN Comtrade database.
[a] Data starts in 1997 for Singapore, Malaysia, Russia, Brazil, Slovak Republic, and Philippines. Data starts in 1998 for Thailand. *Note*: Belgian data in 1996 includes Luxembourg.

## *Shifting Trade Patterns*

Twelve years of duty-free trade in ITA products triggered substantial changes in trade patterns and market shares for ITA member countries. A prominent feature of expanding ITA trade is the broadening participation of Asian countries, particularly China, and an increasingly important role for other developing countries. While especially high growth rates[16] of ITA trade are observed throughout Asian countries, some ITA member countries benefited more than others. Among Asian and developing countries the rapidly expanding role of China stands out; China has emerged to become the largest single player in the global ITA market. Outside of Asia, several Eastern European countries experienced an upsurge in ITA trade.

### Broader Asia Shifts

Asia's role in ITA trade grew extensively during the last decade. While not all countries within Asia gained equally, several Asian ITA countries are now leading exporters and importers and centers for global production networks for ITA products.

Asian ITA exports grew rapidly between 1996 and 2008, led principally by China and to a lesser extent Singapore, South Korea, and Thailand. Annual export growth rates were strongest for China (33.5 percent),[17] South Korea (13.1 percent), Chinese Taipei (9.8 percent), and Philippines (11.0 percent) (table 5).[18] Similarly, import growth rates were strong, led by China (24.4 percent),[19] and also Thailand (9.6 percent), South Korea (9.0 percent), Singapore (6.2 percent), and Japan (5.7 percent) (table 6). Asian ITA members now represent 5 of the 10 largest exporters and importers of ITA products.

Japan, formerly the leading exporter of ITA products, is now the second largest Asian exporter behind China, ceding market share due to sharper growth in exports by other Asian countries. Japan's export market share fell from a 1996 high of 18.6 percent to only 9.2 percent in 2008. Despite the decline in ITA export shares in Japan, the robust increase in ITA market share for several other Asian countries, punctuated by China, indicates a significant shift in manufacturing capabilities for ITA products towards Asian countries, particularly developing countries.

Shifting ITA trade patterns in Asia are consistent with the increasingly fragmented production of goods across the Asian region. Diversified production chains allow producers to benefit from an individual country's comparative advantages (Capannelli, 3). Moreover, products covered by the ITA are conducive to this production model, and therefore play a major role in global production networks (Slaughter 2003, 27). Fragmentation based specialization has become a key component of the economic landscape in Asia (Athukorola, 15), with much of the change taking place since the inception of the ITA.

### China

China's rise to preeminence in the global ITA market is the most significant shift in ITA trade in Asia, and the world. When the original member countries concluded the ITA in 1996, China accounted for 3 percent of total ITA trade. By 2008, China accounted for nearly 19 percent of total ITA trade, surpassing the U.S., the next largest trader at 11.2 percent. During this period, China's total ITA trade

[16] Growth rates are compound annual growth rates unless otherwise indicated.
[17] ITA exports from Hong Kong, China grew 13.0 percent annually.
[18] Malaysia's ITA trade grew at an annual rate of 10.2 percent from 1997-2006, then declined sharply, due largely to incomplete data reporting for HS 2007.
[19] ITA imports from Hong Kong, China increased 14.3 percent annually.

value grew at a remarkable annual rate of 29.0 percent, more than twice the global average of 10.7 percent. Presently, China is the largest exporter and second largest importer of ITA products (tables 5 and 6). Through its WTO accession and commitment to join the ITA,[20] China gained MFN access to major markets, and became an increasingly attractive location for export orientated foreign direct investment (FDI) (Fung, Korhonen, Li, and Ng, 9),[21] contributing to China's rapidly growing export and import share in the ITA market. Indeed, China's ITA trade accelerated subsequent to its WTO commitments to reduce trade impediments, including tariff elimination for ITA products. In 2001 for example, global ITA exports declined 13.0 percent, but Chinese exports of ITA products grew 19.9 percent. By 2003, when China entered the ITA, it was already the third largest exporter, and the fourth largest importer of ITA products. In 2004, China expanded its market share becoming the world's largest exporter of ITA products. In 2005, China surpassed both the EU and the U.S. to become the largest country in terms of overall ITA trade.

Increased FDI had a major role in China's accelerating ITA exports, as multinational corporations sought to reduce costs by directly adding capacity in China (WTO 2008, 18). Once China joined the WTO, products exported from China were guaranteed MFN access to other countries, providing strong incentives for multinational corporations to establish production and assembly operations in China.

The ITA further improved China's export capabilities by lowering the cost of intermediate ITA goods through tariff elimination. China recognized that tariffs acted as a tax for Chinese firms seeking to enhance participation in global production networks (Borrus and Cohen, 12-14). One example of China's expansion into global production networks is the Pearl River delta which has become the largest location in the world for electronics contract manufacturing (Luthje, 1). Consequently, China has become a critical hub in global production networks for ITA goods, and has emerged as the fastest growing supplier to the world of many ITA products including computers, telecommunications equipments, and associated ITA parts.[22]

The rise of China and other developing ITA members in Asia represent a major shift in ITA trade, but not the only shift. The increasing export shares of Eastern European countries are also significant and reflect similar characteristics to the rise of Asia.

## Eastern Europe

Eastern European countries are rapidly expanding their share of ITA trade. Four countries, all ITA members, stand out: Hungary, Slovak Republic, Czech Republic, and Poland. Between 1996 and 2008, total ITA trade grew by 30.0 percent for Hungary, 27.5 percent for the Slovak Republic, 22.9 percent for the Czech Republic, and 15.4 percent for Poland.

For each of these four countries, exports expanded faster than imports. For example, the Slovak Republic's annual export growth was 60.1 percent between 2001 and 2008, whereas import growth was 38.5 percent over the same period. The Slovak Republic, Czech Republic, Hungary, and Poland combined, account for barely 4 percent of global ITA trade, yet their export growth rate is remarkable and worth noting.

The rise of Eastern European countries in ITA trade reflects continued restructuring of production networks in the information technology industry (OECD 2008, 107). This region is a critical hub in global supply networks of ITA products, with corporations making export oriented investments, setting up factories to export to western Europe and the world. For example, according to Radosevic (14), FDI

[20] China's accession to the WTO in 2001 included a commitment to join the ITA, which occurred in 2003.

[21] According to Fung, Korhonen, Li, and Ng, China's WTO accession was the catalyst for a new surge in FDI inflows, focused on manufacturing, during a time when worldwide FDI was declining.

[22] See section *"Shifting Trade in Product Segments"* herein.

was the primary vehicle for the integration of Eastern European electronics firms into global supply networks, and "EU demand is a strong focal point" in new production networks. ITA countries in Eastern Europe provide advantages of geographic proximity and cultural ties (Fung, Korhonen, Li, and Ng, 7), and therefore have benefited from the location decisions of EU and multinational corporations, particularly following tariff liberalization under the ITA.

In addition to tariff liberalization, the EU integration process also helped to drive the expansion of ITA trade in Eastern Europe (WTO 2008, 18). According to the European Commission, large flows of FDI from traditional EU members have increased the technological content of new EU member countries'[23] export baskets (EU 2009, 53).

These shifting trade patterns towards Asia, China, and Eastern Europe illustrate the rise of developing countries and geographic diversification in global trade of ITA products.

### *Comparison of Developed and Developing Members*

Since the launch of the ITA, developing countries have gradually gained market share from developed trading countries. Developed countries still account for 67.1 percent of world ITA exports, but have expanded at a much slower rate, gradually ceding market share to developing countries, China in particular (figure 4). Developing country ITA members comprised 3.4 percent of total ITA exports in 1996, but climbed rapidly to 32.9 percent of total exports by 2008.

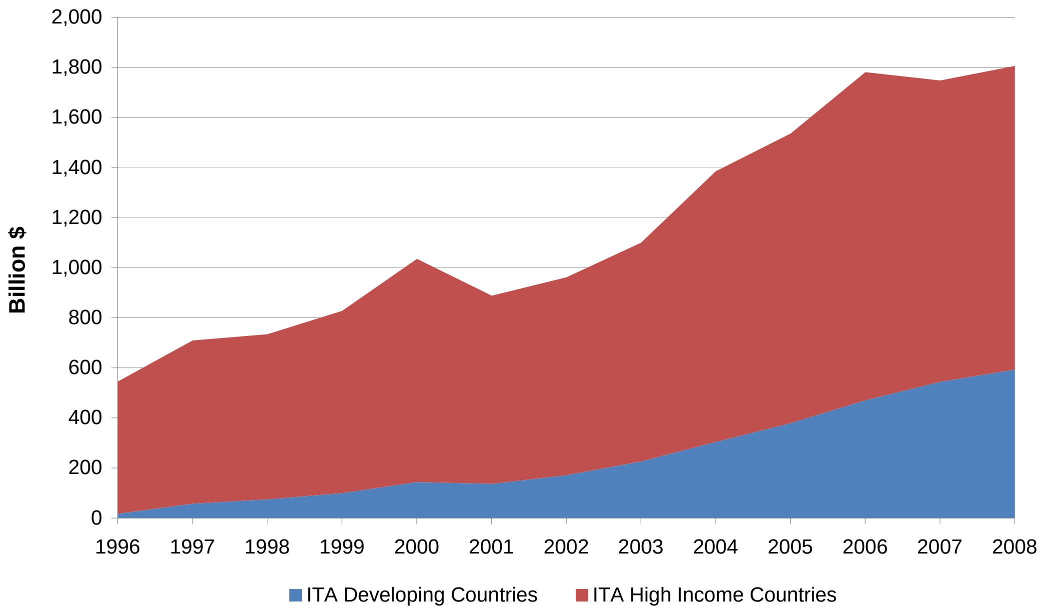
Between 1996 and 2008, developing countries' exports expanded at an annual growth rate of 33.6 percent, compared to 7.2 percent for developed countries. Although some of the early growth for developing countries reflects improved consistency in reporting of export data, from 2001-08, developing country ITA exports still expanded more than three times as fast as developed country ITA exports.

Based on year-over-year measurements of export growth, developing country trade expanded faster between 1996 and 2000, and declined less sharply during 2000-02. Developing country ITA exports expanded at 33.3 percent in 1999 and 43.6 percent in 2000. In contrast, developed country ITA exports expanded at 10.3 percent in 1999 and 22.5 percent in 2000. Following the peak in the technology boom, developing country exports declined at a slower rate, 5.4 percent year-over-year compared to a 15.6 percent decline for developed countries.[24] Broadening participation and increasing market share of developing countries in the ITA trade represents another major shift in ITA trade patterns.

[23] Hungary, Slovak Republic, Czech Republic, and Poland each joined the EU as part of the 2004 expansion.

[24] It should be noted that these calculations include countries not yet signed onto the ITA in the given years; the MFN nature of the ITA provides all WTO members tariff duty free access to all markets for ITA member countries.

**FIGURE 4** Developing and developed (high income) ITA exports 1996–2008




*Note:* Includes only ITA members
*Source* : Compiled by USITC staff from UN Comtrade database.

## *Role of non-ITA countries*

ITA member countries account for the vast majority of total ITA trade, with a few non-ITA member countries expanding their share of ITA trade. In 2008, non-ITA countries accounted for only 6 percent of total ITA trade, yet several non-ITA countries have a significant and growing foothold. Despite non-member status, Mexico, Russia, Brazil, and South Africa, have demonstrated strong ITA trade since 1996. In particular, Mexico's export role and Russia's import growth are both noteworthy.

Mexico is the only non-ITA member in the top 30 ITA exporters, ranking 8$^{th}$ in 2008 (table 5). As a WTO member, its exporters benefit from the MFN nature of the Agreement. Additionally, on the import side, Mexico unilaterally instituted "ITA plus" which eliminates duties on a wide variety of critical inputs, machinery, and finished products in the electronics and IT sectors (Padiema-Peralta, 1). These lower cost inputs provide a competitive price advantage to Mexican producers and exporters. Moreover, due to the NAFTA, there is established ITA production networks linking Mexico with the U.S. and Canada; in 2008, 87 percent of Mexico's ITA exports went to either Canada or the U.S.

Russia is rapidly increasing imports of ITA products despite being outside the WTO and the ITA. While the rest of the world benefited from the technology boom of 1996-2000, Russia's ITA imports declined by 15.7 percent, with the country suffering from a severe financial crisis in 1998. Yet, since 2001, Russian imports of ITA products have grown annually by 38.7 percent (table 6), albeit from a relatively small base. Russia is primarily an importer of ITA products, rather than an exporter. They are a major exporter of information and communication services (OECD 2008, 91). The ITA does not cover services, but Russia's strong position in the related services industry may explain its demand for products covered by the ITA. Russia's main sources of ITA imports are China, Germany, and Hungary.

## Product Segment Profiles

While many ITA products are readily identifiable, others are parts or intermediary products with functions across multiple broad categories. In examining the growth and composition of ITA products the covered goods are grouped into eight general product segments as noted in table 1, namely: computers and peripherals (computers) office equipment, scientific and measuring devices (scientific devices), semiconductors, semiconductor manufacturing equipment (SME), software, telecommunications equipment, and other ITA products and parts (other).[25] While annualized growth rates for most product segments exceeded 10 percent, import and export growth rates were strongest for other products (other ITA products and parts), office machines,[26] semiconductors, and telecommunications during 1996-2008. Rapidly rising trade in other products is consistent with the proliferation of intermediary goods and parts trade fueled by expanding global product networks (Athukorala, 7). Strong growth rates in semiconductors and telecommunication segments, in part, reflects expanding uses of semiconductors in IT products and advances in cellular communications.

The composition of ITA trade during the past twelve years was dominated by semiconductors and computer trade, despite ceding market share to other fast growing products including telecommunications and other products. The internet boom of the 1990's and declining prices for personal computers and semiconductors (Aizcorbe, Flamm, and Khurshid, 12) spurred increasing demand and trade flows for these products.

### *Product Segment Growth Rates*

Across all ITA product segments total trade increased by 10.7 percent annually between 1996 and 2008. Annualized growth of ITA trade was strongest at 17.5 percent during 1996–2000, then slowed to 10.8 percent between 2001 and 2008 reflecting, in part, the sharp decline in IT spending following the internet boom in the late 1990's. Import growth was led by other products and parts (17.0 percent), with expansion in global imports of office equipment, semiconductors, and telecommunications ranging between 15.5 percent and 13.1 percent (table 7). Similar product growth patterns emerge in global exports, with office machines and other ITA products and parts exhibiting the strongest annual growth rates (16.4 percent and 16.0 percent, respectively). Increasing trade in parts is indicative of the increasing fragmentation of the global electronics and IT supply chains. Additionally, significant technology developments surrounding the internet and mobile communications were important drivers behind the rapid trade expansion for telecommunications and office machines.[27] [28] Further, trade in office machines and other ITA products and parts at the inception of the ITA was relatively low compared with computers and semiconductors, which accounted for the majority of IT trade and of considerable focus in the negotiations leading up to the Singapore Ministerial (Fleis and Sauve, 29–32).

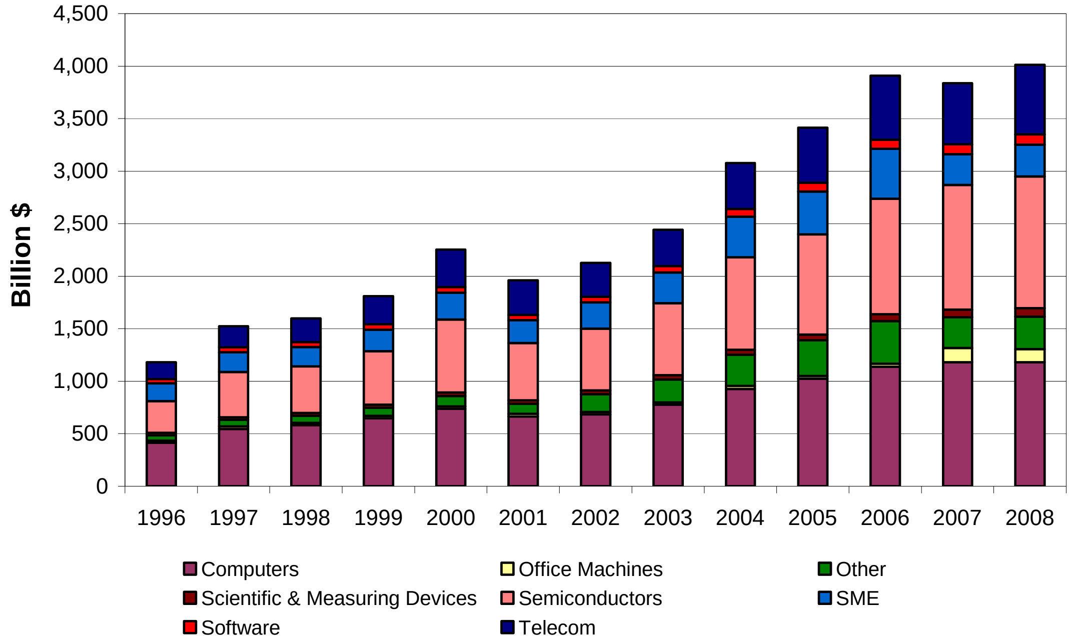
[25] Segmented according to 6-digit HS in accordance with USITC product classifications.

[26] Difficulties in reconciling trade data associated with complex HS 2007 nomenclature changes may account for some of the increase in office machine trade after 2006.

[27] Examples of technology developments include rapid adoption of cellular phones and increased popularity of multifunction printing machines. Indeed, cell phones, and printing parts and accessories accounted for 35 percent and 88 percent of total imports for their respective product segments in 2008.

[28] Uneven 2007-2008 trade in office equipment stems in part from significant HS classification changes.

**FIGURE 5** ITA total trade by product, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

**TABLE 7** ITA import and export, growth rates, by product category, selected years

| Category | Flow | 1996 | 2000 | 2001 | 2008 | Annual growth 1996–2008 | Annual growth 1996–2000 | Annual growth 2001–2008 |
|---|---|---|---|---|---|---|---|---|
| | | | Thousands$ | | | | Percent | |
| Other | Import | 25,755,884 | 54,044,287 | 50,593,669 | 170,142,725 | 17.0 | 20.4 | 18.9 |
| Office Machines | Import | 11,716,868 | 12,508,909 | 12,395,073 | 66,056,407[a] | 15.5[a] | 1.6[a] | 27.0[a] |
| Semiconductors | Import | 159,153,497 | 369,531,817 | 297,379,179 | 713,043,592 | 13.3 | 23.4 | 13.3 |
| Telecom | Import | 78,072,743 | 180,851,150 | 168,551,206 | 340,914,187 | 13.1 | 23.4 | 10.6 |
| Scientific Devices | Import | 12,064,397 | 16,580,565 | 17,895,020 | 40,171,254 | 10.5 | 8.3 | 12.2 |
| Software | Import | 19,430,181 | 25,569,836 | 25,045,653 | 52,362,180 | 8.6 | 7.1 | 11.1 |
| Computers | Import | 231,691,768 | 387,107,292 | 350,008,651 | 601,158,386 | 8.3 | 13.7 | 8.0 |
| SME | Import | 80,899,512 | 130,178,132 | 111,159,562 | 147,612,922 | 5.1 | 12.6 | 4.1 |
| Office Machines | Export | 9,673,615 | 11,207,972 | 10,864,082 | 60,086,400[a] | 16.4[a] | 3.7[a] | 27.7[a] |
| Other | Export | 23,385,248 | 46,501,635 | 44,323,728 | 138,769,407 | 16.0 | 18.7 | 17.7 |
| Telecom | Export | 79,823,837 | 175,432,546 | 159,056,944 | 321,572,875 | 12.3 | 21.8 | 10.6 |
| Semiconductors | Export | 143,321,320 | 323,924,248 | 247,443,755 | 541,211,042 | 11.7 | 22.6 | 11.8 |
| Scientific Devices | Export | 12,246,914 | 14,981,935 | 16,264,111 | 39,121,240 | 10.2 | 5.2 | 13.4 |
| Computers | Export | 182,684,635 | 349,687,303 | 316,379,366 | 579,872,049 | 10.1 | 17.6 | 9.0 |
| Software | Export | 22,403,227 | 26,097,693 | 25,469,977 | 46,382,620 | 6.3 | 3.9 | 8.9 |
| SME | Export | 87,203,921 | 127,583,670 | 106,186,643 | 155,006,442 | 4.9 | 10.0 | 5.6 |
| TOTAL TRADE | | 1,179,527,569 | 2,251,788,989 | 1,959,016,618 | 4,013,483,726 | 10.7 | 17.5 | 10.8 |

[a] Difficulties in reconciling trade data associated with complex HS 2007 nomenclature changes may account for some of the increase in office machines trade, and some of the SME trade decrease after 2006.

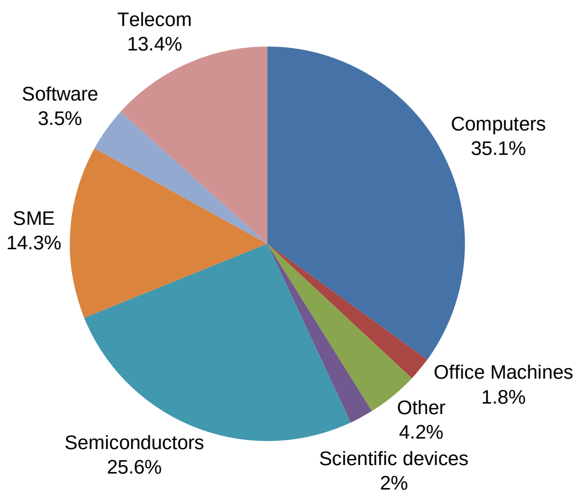
*Source*: Compiled by USITC staff from UN Comtrade database.

## *Shifting Trade in Products Segments*

Computers and semiconductors dominate trade in ITA products despite rising telecommunications and parts trade. The composition of total trade in ITA products was heavily weighted to computers and semiconductors (60.7 percent in 2008) though the share of computers declined and semiconductors increased during 1996-2008 (figures 6-7). In addition to computers, which declined 6 percentage points, the share of SME total trade declined from 14.3 percent to 7.5 percent. Telecom and other products (other ITA products and parts) collectively represent 24.2 percent of 2008 trade, up from 17.6 percent in 1996.

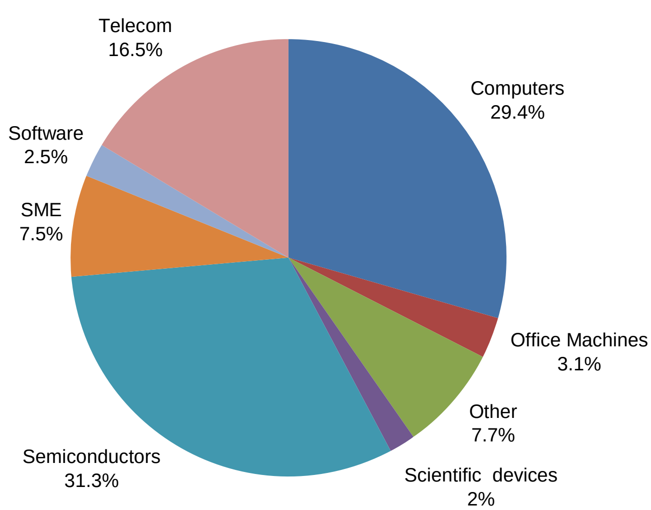
Examining imports separately, similar patterns emerge. The decline in the share of computer imports from 37 percent to 27 percent was captured by imports of semiconductors. The share of import shipments of SME also declined displaced by rising shares of telecommunications and other ITA products and parts imports. In contrast, export share for computers increased modestly, from 33 to 36 percent, along with semiconductors. Shares of telecom, SME, and to a lesser extent, scientific devices slipped 4 percentage points collectively.

**FIGURE 6** ITA total trade by product segment, 1996




*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 7** ITA total trade by product segment, 2008




*Source*: Compiled by USITC staff from UN Comtrade database.

## Product Composition by Country

Since the Agreement went into force, developing countries account for increasing export and import shares of leading ITA products segments. Further, ITA members continue to dominate world ITA trade relative to their non-ITA counterparts. Examining the three largest ITA product segments[29]—computers, semiconductors, and telecommunications a clear pattern emerges of robust growth in exports and imports by ITA developing countries. This growth was most pronounced for exports and imports in Asia, notably China, as several post-1996 ITA members captured increasing market share from developed countries in these products. This momentous shift in global production is most evident in computers and telecommunications exports, where China and South Korea alone have displaced the U.S., Japan, and several European countries as the leading producers and exports of these products. The elimination of tariffs under the ITA facilitated opportunities for many developing countries to enter global production networks,[30] driving shifting trade patterns for these products.

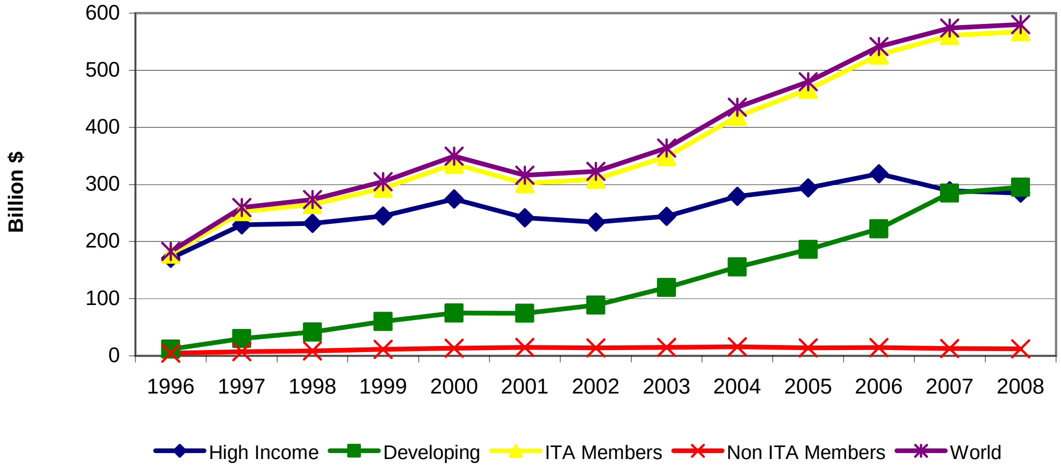
### *Computers*

ITA members continue to dominate global computer trade, representing 98 percent of exports, unchanged from 1996. However, the shift to developing ITA members as leading exporters of computers is significant. Led by several Asian countries, particularly China, developing countries' share of global computer exports surged from 6.5 percent in 1996 to nearly 51 percent in 2008 (figure 8). The rapid expansion of computer exports by developing countries was further characterized by a 30.6 percent annual growth rate compared with 10.1 percent for developed countries between 1996 and 2008. The composition of the top ten computer exporters similarly shifted to China, and other Asian countries. In 1996, four countries, the U.S., Japan, United Kingdom, and the Netherlands accounted for over 50 percent of exports. By 2008, China and South Korea alone accounted for nearly half (46.6 percent) of exports, illustrating a significant shift and increasing concentration of global computer production and export patterns (figures 9-10). Other developing ITA members, including Malaysia and Thailand also experienced a rapid increase in computer exports since joining the ITA, accounting for 4.4 percent and 3.2 percent, respectively, of 2008 exports.

[29] Based on 2008 total trade (table 5).

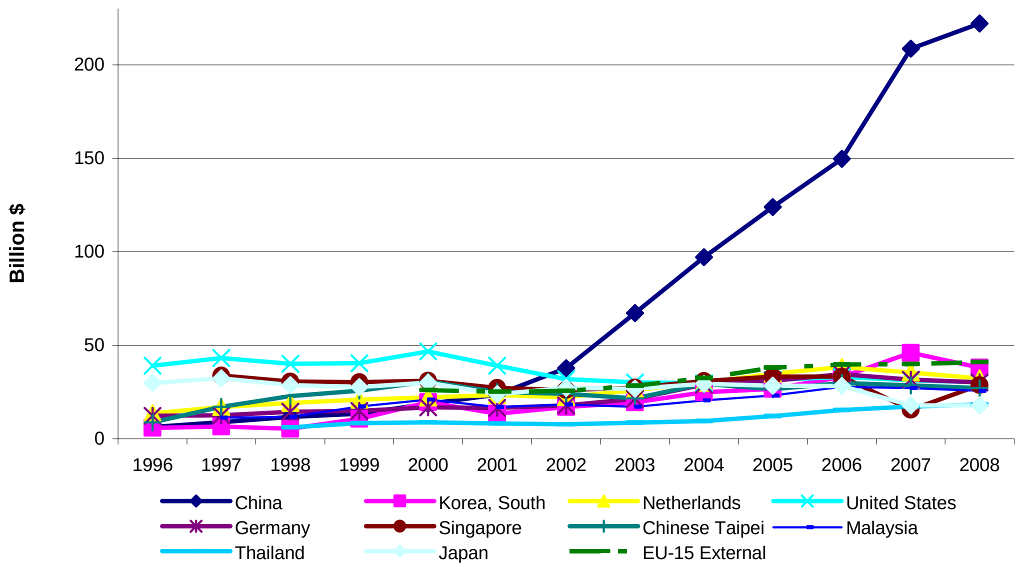
[30] According to Slaughter, developing countries may enter global production networks by leveraging comparative advantages in importing intermediate goods, adding value through these advantages, and subsequently exporting outputs to other countries (Slaughter 2003, 27).

**FIGURE 8** ITA computer exports, by income and ITA status, 1996–2008



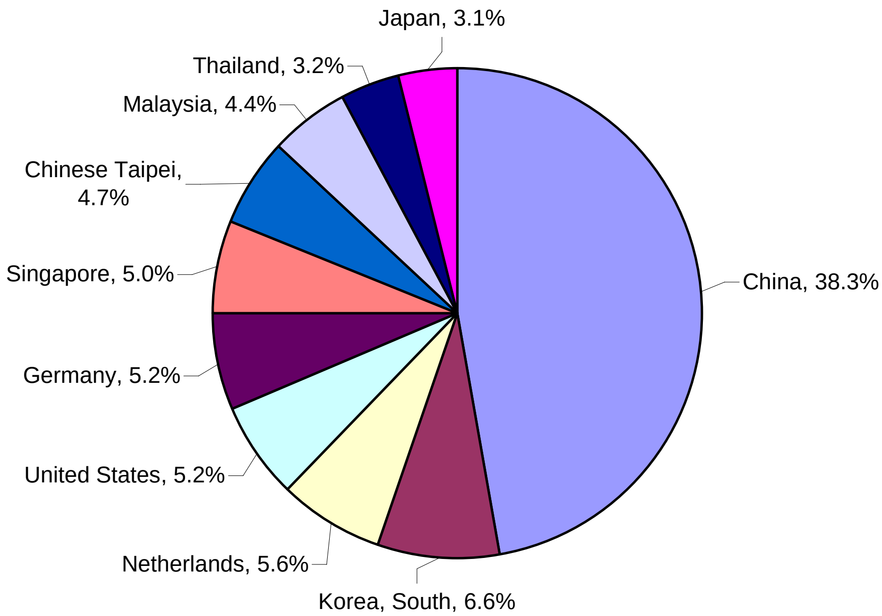

*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 9** ITA computers: Top 10 exporters and EU, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

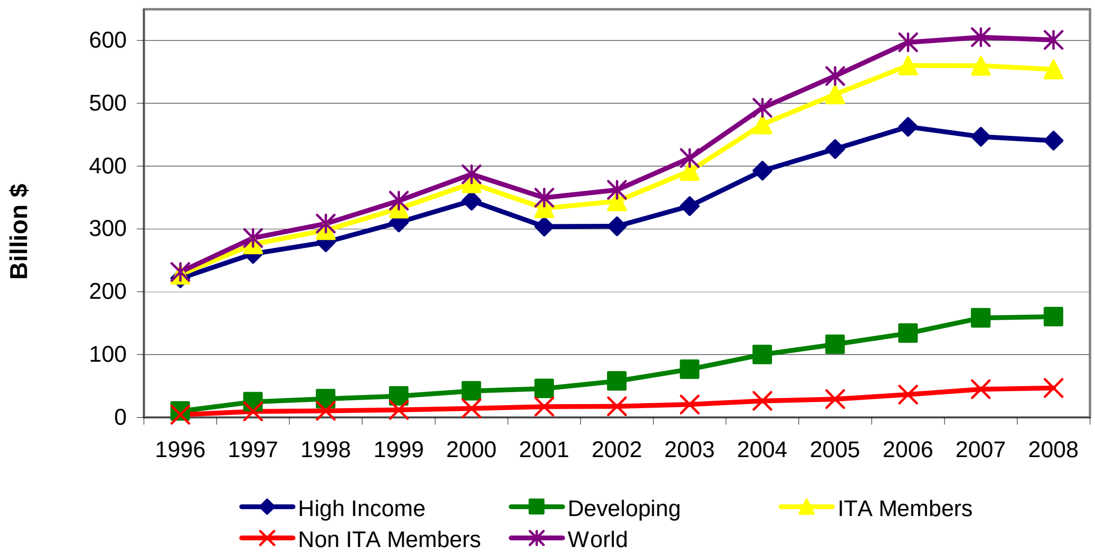
**FIGURE 10** Computers: Top 10 exporters, 2008




*Source* : Compiled by USITC staff from UN Comtrade database.

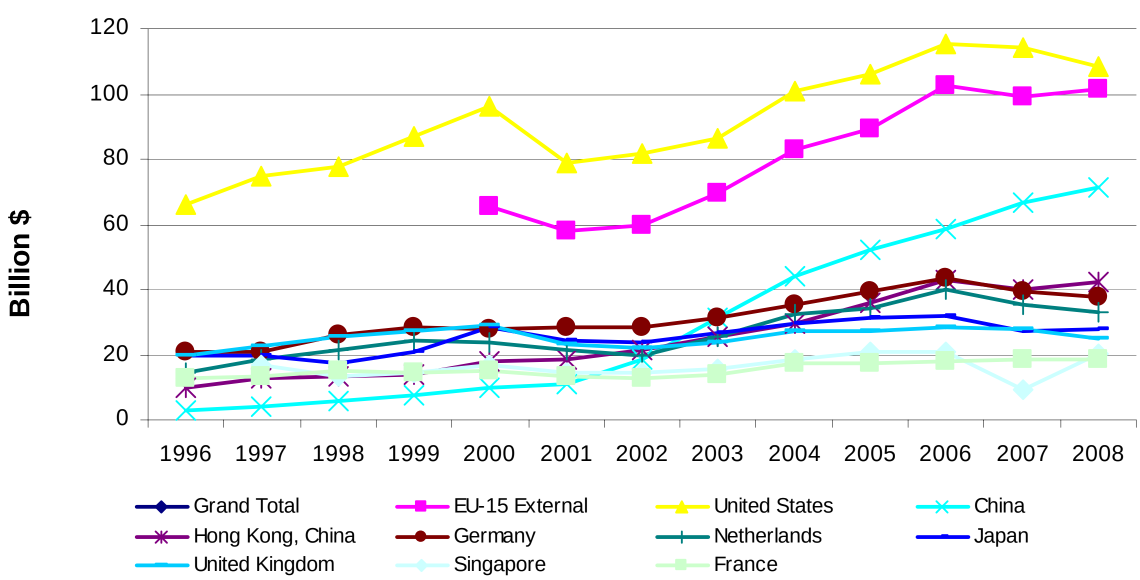
ITA members account for the vast majority of gains in computer imports since 1996 (92 percent of imports in 2008), despite increasing non-ITA member import trade (figure 11). Non-ITA members' share of computer imports increased 6 percentage points, principally driven by increasing imports from Mexico, Brazil, and Russia. These rising imports reflect duty free access to computer products under the MFN principle of the ITA and general economic expansion since 1996. The share of developing country imports expanded to 26 percent from 4 percent. Based on annual growth rates, China (29.7 percent), Hong Kong, China (12.8 percent), Mexico (18.4 percent) and Russia (30.7 percent) were principal contributors to developing country import growth since 1996. Among the top ten importers in 2008, U.S. imports increased to over $100 million, albeit unevenly. China became the second largest importer with the sharpest growth after the 2001-2002 period (figure 12). Overall, shifts in computer imports were less pronounced than exports. The U.S. Japan, Germany and other original ITA signatories were leading importers of computers in 1996. With the exception of China (12 percent), developed ITA members countries remain the leading importers of computer products in 2008 (figure 13).

**FIGURE 11** ITA computer imports, by income and ITA status, 1996–2008



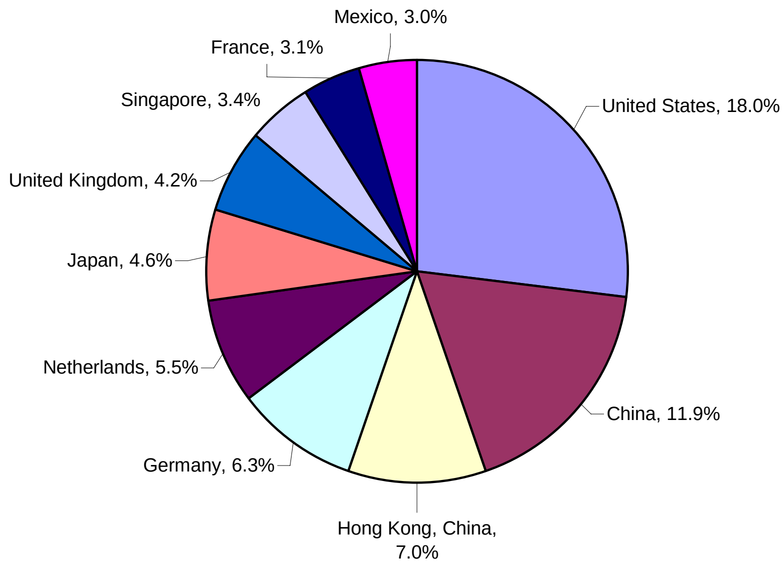

*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 12** ITA Computers: Top 10 importers and EU, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 13** Computers: Top 10 importers, 2008




*Source* : Compiled by USITC staff from UN Comtrade database.

### *Semiconductors*

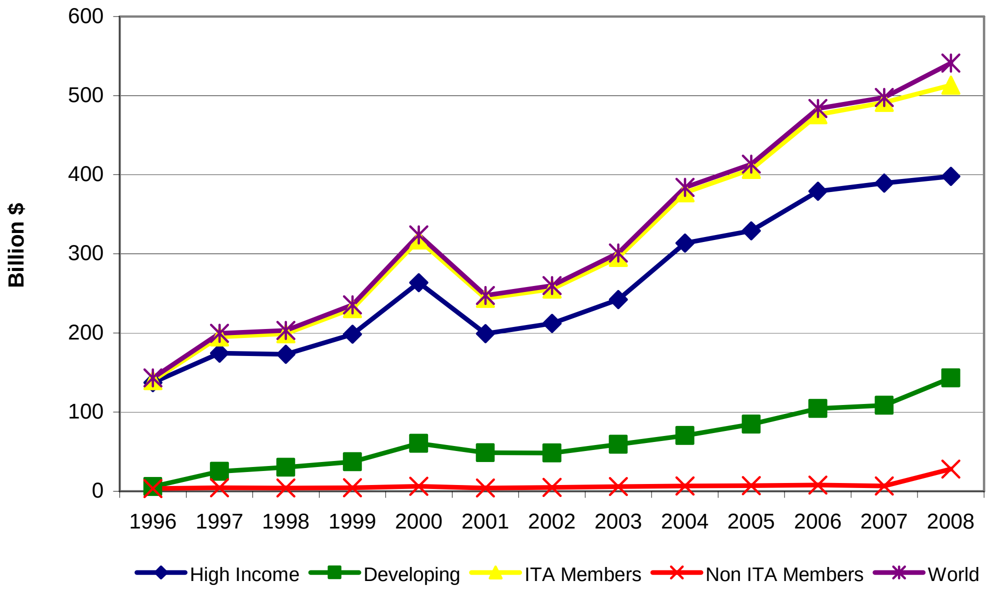
The preponderance of global semiconductor trade is conducted by ITA members, who accounted for 94.8 percent and 95.3 percent of exports and imports, respectively, in 2008. These shares have remained fairly constant, indicating ITA members captured the vast majority of growth in semiconductor trade since 1996 (figure 14). ITA developing members, and to a lesser extent Mexico, led the increase in developing countries' share of semiconductors exports, from 4.2 percent to 26.5 percent, during 1996–2008. With the exception of China, developed ITA members remained leading exporters with Singapore (15.5 percent),[31] Japan (12.9 percent), and the United States (9.0 percent) the largest exporters based on 2008 export share (figure 15). Between 1996 and 2008, Singapore and China emerged as the largest semiconductor exporters, surpassing Japan and the United States (figure 16).[32] The robust expansion of China's semiconductor exports in part reflects the global fragmentation of back end production (i.e. packaging and testing) to lower cost countries, China's policy shifts and incentives to encourage FDI in semiconductor manufacturing, and semiconductor manufacturers' desire for proximity to the world's largest market (Yinug).[33]

[31] Singapore has a long history as a leading location for semiconductor device assembly and more recently computer peripherals, including hard disk drives (Athulkorala, 4).

[32] Annual export growth rates during 1996-2008 were 13.2 percent and 33.9 percent for Singapore and China, respectively, compared with 5.5 percent and 4.1 percent for Japan and the U.S., respectively.

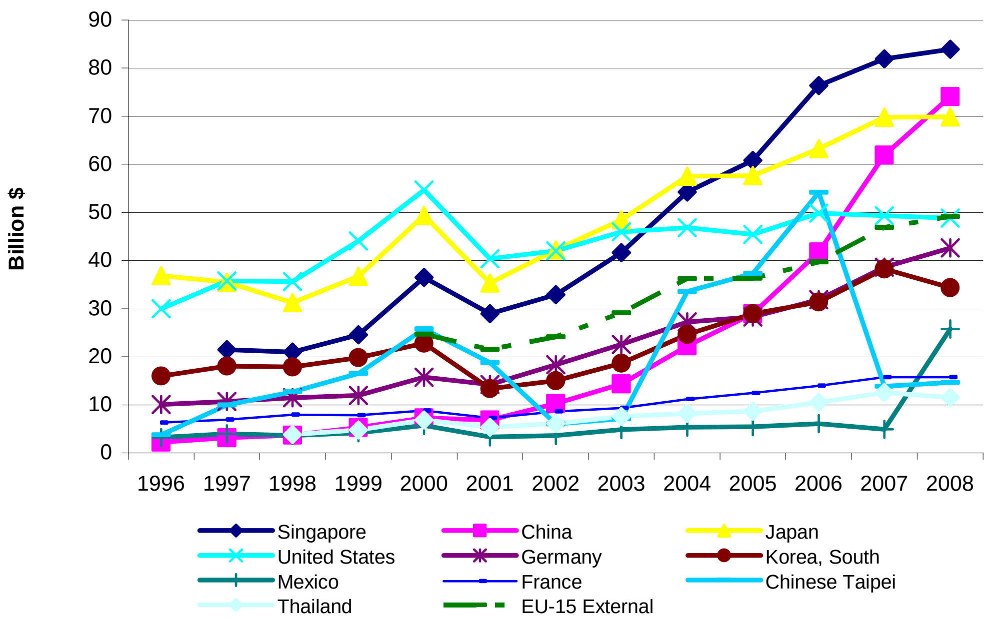
[33] Yinug notes that while front-end production (capital intensive design and fabrication) is emerging in China, foreign semiconductor firms' investments in China remain limited and often entails older generation production technology.

**FIGURE 14** ITA semiconductor exports, by income and ITA status,



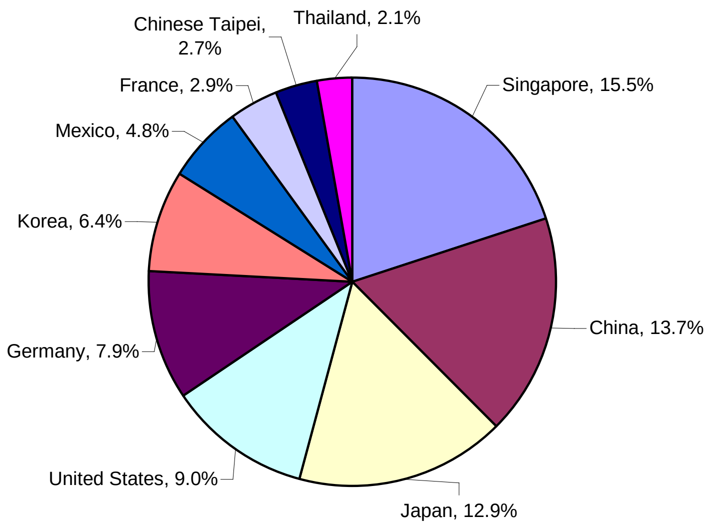

*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 15** ITA semiconductor: Top 10 exporters and EU, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 16** Semiconductor: Top 10 exporters, 2008



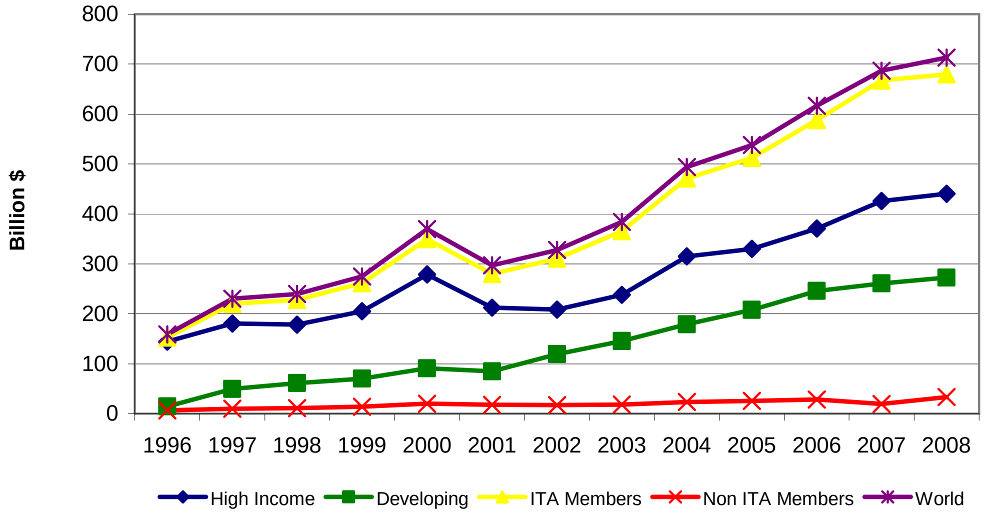

*Source*: Compiled by USITC staff from UN Comtrade database.

Similar to exports, ITA members accounted for the vast majority of the increase in semiconductor imports since 1996, accounting for over 95 percent of imports in 2008 (figure 17). The share of developing country imports expanded to 38.2 percent from 9.1 percent, led principally by China, with an annual import growth rate of nearly 33 percent. Other ITA developing countries experiencing strong import growth since joining the ITA include, Malaysia (6.4 percent), Philippines (4.2 percent), and Thailand (8.9 percent). The present composition of leading semiconductors importers was heavily influenced by China's exponential import growth. China's market share among the top 10 imports increased to 21.5 percent, from 3.2 percent, surpassing the U.S. and Singapore (figures 18–19) to become the largest importer.[34] Along with tariff liberalization under the ITA, the increasing concentration of electronics assembly and production in China (McClean, 2-50 to 2-54), along with the shifting global semiconductor production patterns contributed importantly to China becoming the largest semiconductor market (Yinug, 10–13).[35]

[34] China accounted for nearly one-third (32.4 percent) of semiconductor imports in 2008 when including Hong Kong, China.

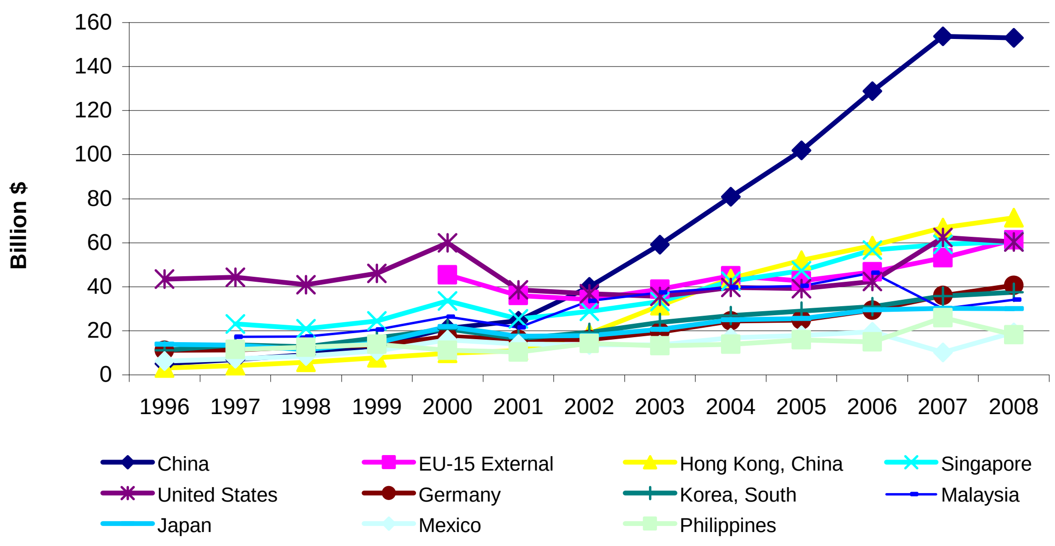
[35] See Yinug, "Challenges to Foreign Direct Investment for Hi-Tech Semiconductor Production in China" for more details on semiconductor manufacturing stages and increasing global fragmentation of production.

**FIGURE 17** ITA semiconductor imports, by income and ITA status,



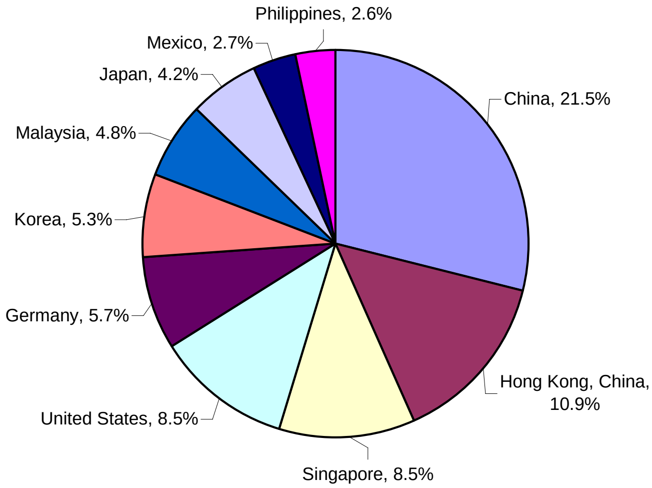

*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 18** ITA semiconductors: top 10 importers and EU, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 19** Semiconductor: Top 10 importers, 2008



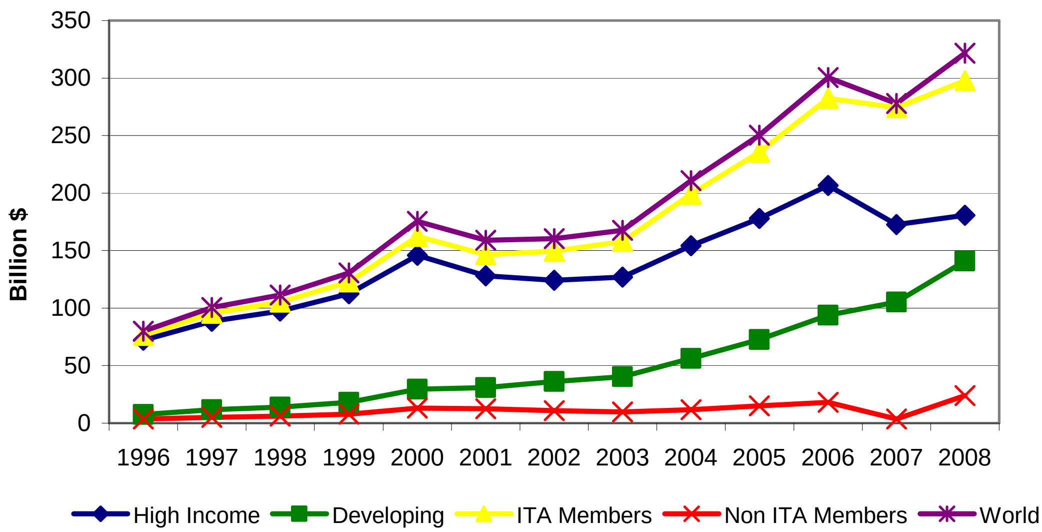

*Source* : Compiled by USITC staff from UN Comtrade database.

## *Telecommunications*

ITA members accounted for over 90 percent of global telecommunications equipment trade in 1998, down slightly from 1996. Non ITA countries' share of telecommunications exports and imports were 7.4 percent and 12.5 percent, respectively in 2008. Developed countries including South Korea, the U. S., Germany, and Finland traditionally dominated telecommunications trade, but a sizeable shift towards developing country exporters, namely China, occurred subsequent to China joining the WTO and ITA. Developing countries' export share climbed from 9.5 percent in 1996 to 43.8 percent in 2008 (figure 20). Propelled by robust export growth, China and South Korea moved past the United States as the leading telecommunications exporter (figure 21).[36] While leading European exporters collectively accounted for nearly 20 percent of exports, China was the source of one-third (33.4 percent) of world telecommunications exports in 2008, followed by South Korea with 11.4 percent (figure 22), illustrating a significant shift in global telecommunications production and export patterns. The elimination of tariffs on several intermediary products, coupled with the strengthening of global electronics production networks in Asia were catalysts behind China's exponential export growth.[37]

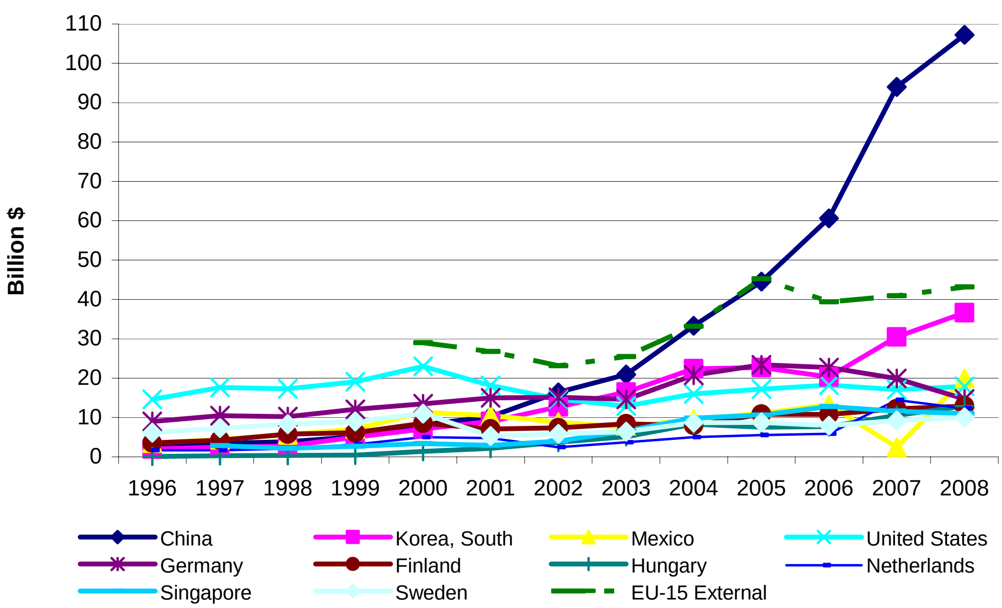
[36] China and South Korea's exports grew an annualized 35.0 percent 27.2 percent, respectively during 1996-2008.
[37] See Luthje (4) for a illustration of China's role in the global production network of cell phones for a major manufacturer.

**FIGURE 20** ITA Telecom exports, by income and ITA status, 1996–2008



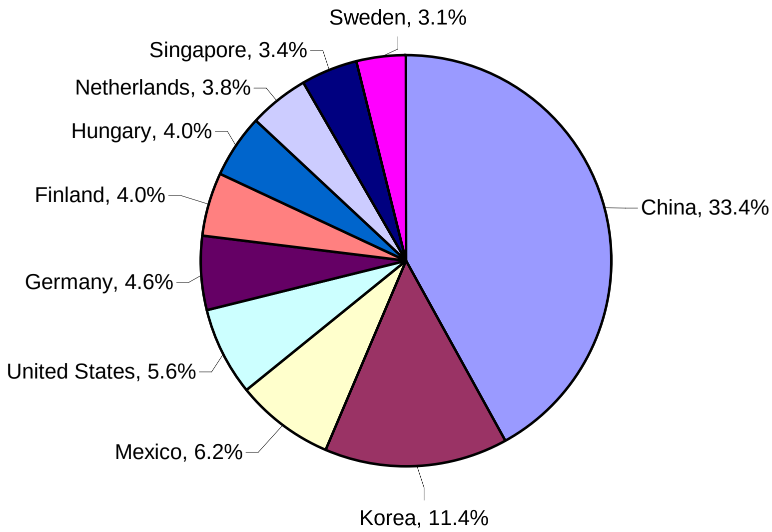

*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 21** ITA Telecom: Top 10 exporters and EU, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 22** Telecom: Top 10 exporters, 2008

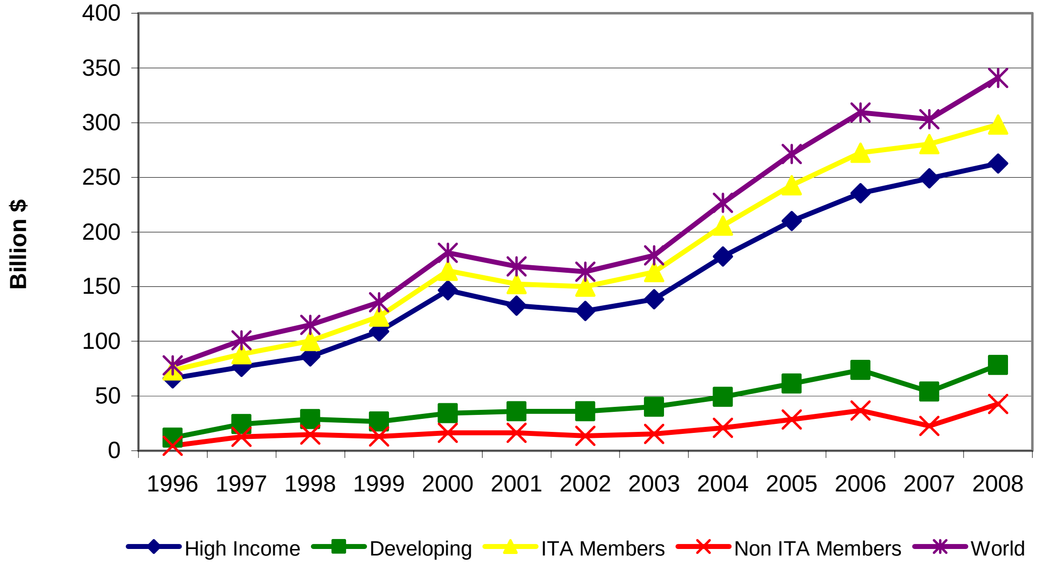



*Source* : Compiled by USITC staff from UN Comrade database.

Led by developed countries, ITA member's share of telecommunications imports was 87.5 percent in 2008, down slightly from 94.1 in 1996, as non ITA members, namely Mexico, expanded imports to meet growing demand for telecommunications technology (figure 26). Increasing imports from China, and to a lesser extent, Malaysia, Mexico, and the Philippines, account for the jump in developing countries' share of import trade, from 15 percent to 23 percent between 1996 and 2008. The United States and several EU members (i.e. Germany, United Kingdom, the Netherlands, and France) remain leading telecommunications importers during the period examined, accounting for 20.4 percent and 16.8 percent of 2008 imports, respectively, followed by China (including Hong Kong) at 14.1 percent (figures 24-25). The consistently high import level of developed ITA members seems consistent with the rapid growth in broadband internet and broadband wireless subscribers over the period.[38]

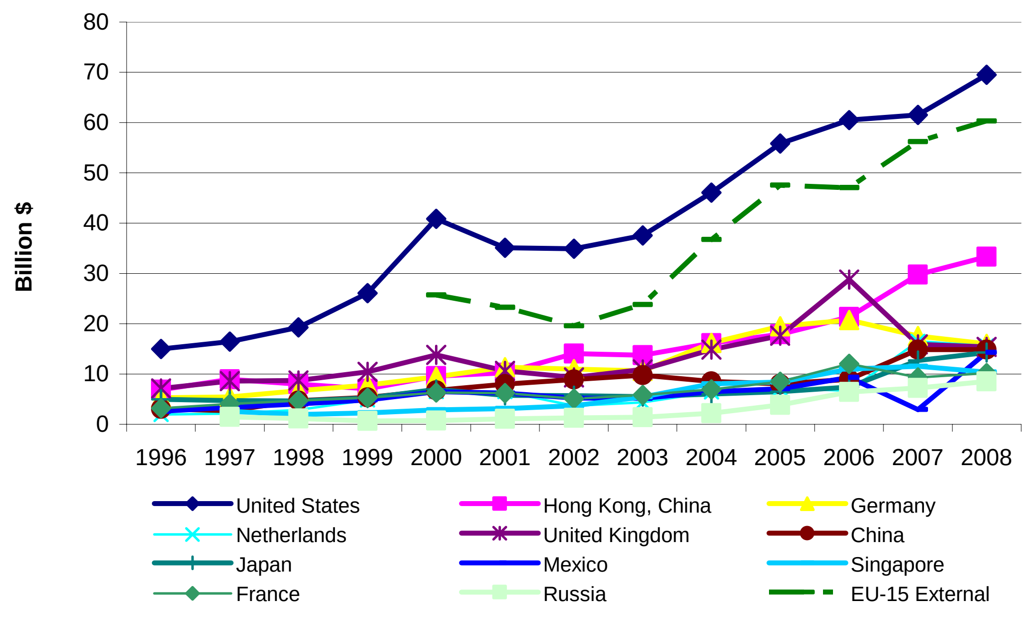
[38] Worldwide broadband wireless subscriptions surged from 20.5 million to 32.5 million between 2001 and 2008 and wireless subscriptions increased to 3.1 billion from 0.8 billion during the same period. (TIA 2008 Telecommunications Market Review and Forecast, 231–232).

**FIGURE 23** ITA telecom imports, by income and ITA status, 1996–2008



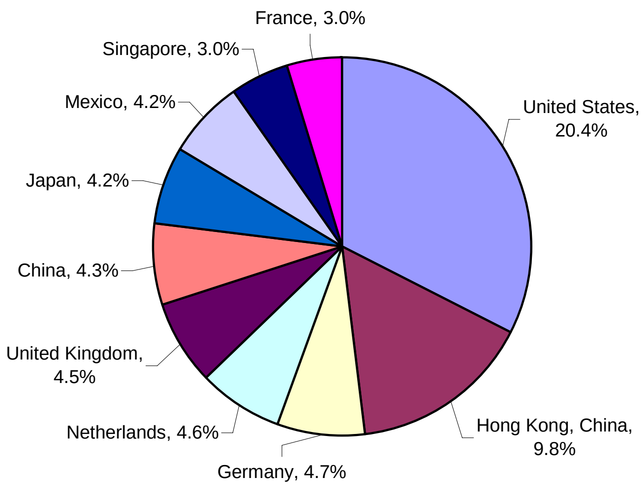

*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 24** ITA telecom: Top 10 importers and EU, 1996–2008




*Source*: Compiled by USITC staff from UN Comtrade database.

**FIGURE 25** Telecom: Top 10 importers, 2008




*Source*: Compiled by USITC staff from UN Comtrade database.

# Achieving objectives of the ITA

To what extent have the ITA's objectives in increasing world IT production and trade, and promoting diffusion of technology, particularly among developing countries been achieved? The social and economic benefits of trade liberalization are well documented, suggesting a positive outcome from the ITA. However, in the case of tariff liberalization framed under the ITA, systematically capturing the effects of increased market access and technology diffusion through tariff elimination remains complex and imperfect (box 2). Most non-empirical work suggests that the ITA has contributed positively to enhance IT trade and technology diffusion, including among developing countries (Dryer and Hindley, 11-12). Reduced prices for IT products and heightened competition stemming from lower tariffs are commonly linked to the ITA (Suh and Poon, 388).[39] Further, the ITA is often attributed as a catalyst for the rapid growth in technological advancements and technology diffusion beyond that which would have otherwise occurred (AEA, 2; Slaughter 2003, 26). While considerable discussion and analysis remains to determine the magnitude of the ITA's impact on IT trade and technology diffusion, changes in trade patterns and ITA membership over the past twelve years demonstrates elimination of tariffs on ITA products contributed importantly to these developments in global IT trade.

[39] The results of a 2003 survey of Korean computer firms showed that firms attributed a large portion of the WTO's impact directly to the tariff reductions that occurred under the ITA. Firms surveyed viewed the WTO as a major factor contributing to improved Korean export performance from 1995 to 2002, compared to 1990-1994. Suh, Jeongwook; Poon, Jessie. "The Impact of The WTO on South Korea's Computer Industry." *The International Trade Journal*, Winter 2006.

**BOX 2** Empirically estimating the ITA's impact on global trade

While empirically estimating the overall impact of the ITA remains outside the scope of this paper, several analytical challenges are noted here, which likely contribute to the limited empirical research measuring the impact of the ITA on world trade and competition in IT products. A brief review of the challenges and associated literature is provided.

Analytical Challenges.

The beneficial effects of the ITA are difficult to quantify owing to the complexity of data and several external factors. Because duty elimination on ITA products was staged over multiple years, with differing stages for each country, capturing a single point of full implementation is elusive. Changes in product classifications since 1996 for several ITA products under the WCO pose transposition challenges as well, particularly in 2007.[a] Further, data that isolate other duty free mechanisms outside the ITA encompassing IT products is generally not available. Because the preponderance of trade data available at the 6-digit HS level is recorded in U.S. dollars, adequately addressing fluctuations in exchange rates for numerous trading partners poses additional analytical burdens. Finally, estimating the overall impact on the ITA on global trade is further complicated by several exogenous factors during the period under examination. Since 1996, the Asian financial crisis, the internet bubble, the September 11, 2001 terrorist attacks, and recent global economic slowdown significantly affected values of world trade, and by extension, ITA products.

Limited Empirical Analysis.

A review of prior work on empirically assessing the impact of the ITA is limited. Two initial assessments at the outset of the ITA focused on the benefits to consumers and downward pressure on prices expected from tariff liberalization on ITA products. These estimates ranged between $50 billion and $100 billion in savings from duty free access to ITA goods (Unctad 1999, 4). In perhaps the most rigorous assessment of the ITA, Bora and Liu (2006) find significant trade creation under the ITA for developing countries. Comparing trade levels among WTO members participating and not participating in the ITA, they conclude that the value of bilateral trade has increased through ITA participation, and that developing countries account for most of the progress in ITA trade liberalization. They find that a non-ITA WTO member would increase imports by 14 percent from other WTO members under ITA membership. (Bora and Liu, 1, 14).[b, c] Conversely, an assessment covering ITA trade during 1997–2002 concluded that "joining the ITA had no statistically significant impact on the rise in IT imports" (Ares). This analysis examined the economics behind a country's decision to the join the ITA and postulated that recent growth of IT trade was not closely correlated to ITA tariff reductions. Another study examined the extent to which lower prices stemming from ITA tariff liberalization was a catalyst for increasing demand and diffusion of ITA products in developing countries (Joseph and Parayil, 7–8). In comparing ITA trade among developed versus developing countries during 1999-2003, the authors found that the ITA had "only a negligible or negative impact in promoting world demand for ICT goods," based on declining world exports during 2001–03. They further noted that examining ICT diffusion in developing countries, certain non-ITA countries have achieved greater success than many ITA member countries.[d]

The paucity of conclusive research on the impact of the ITA on global trade attests to the difficulties in empirically measuring the effects of the ITA and signals that further work remains.

[a] According the WTO, transposition of HS 1996 to HS 2002 for listed ITA product codes had limited impact, as only 14 subheadings were affected, most of which were simple mergers or splits. However, the HS 2007 amendments significantly altered the structure of the HS codes for a significant number of ITA products; 158 f the 241 (over 50 percent) of the HS 2002 subheadings were amended. Owing to the breadth and complexity of the HS 2007 amendments ITA members continue to review and address these changes.

[b] Bora and Liu conclude that a country's ITA imports would be 7 percent higher if it is an ITA member and the exporter is a WTO (non-ITA member) than if neither trade partner were a WTO member (base line). Conversely, if the importer is not an ITA member, its ITA imports would be 6 percent less compared to the base line.

[c] Mann and Liu conclude, based on a review of the empirical literature that ITA participation results in increased bilateral trade (Mann and Liu, 20).

[d] Joseph and Parayil utilized a Network Readiness Index, household IT spending, and telephone intensity, among others, to assess ICT diffusion (15–16).

# Conclusions

Twelve years since creating the objectives of increased trade and technology diffusion through tariff elimination for many information technology goods, remarkable growth in ITA trade has occurred. Aggressive tariff liberalization facilitated growth in ITA trade from $1.2 trillion to $4.0 trillion. Notably the growth in ITA trade was nearly 11 percent annually, despite the bursting of internet bubble bursting and advent of the current global economic downturn. Primarily a domain of developed countries at its inception, the ITA has expanded participation by developing countries and, in turn, enhanced IT trade for these countries. WTO member participation in the Agreement more than doubled in the past twelve years, with developing countries representing over one-third of the 72 members by 2008. The diversification of ITA membership, previously dominated by developed countries with high trade levels in technology products, reflects significant assimilation of developing countries into the largest WTO sectoral trade agreement, and continued liberalization of tariffs in the global IT sector. Further, the increasing diversification of the economic income and trade levels of new ITA entrants after 1996, both for developing and developed countries, suggests an expanding role for ITA products in global IT trade and production.

Commensurate with expanding membership, developing members' ITA trade has increased substantially, both in terms of volume and share. Developing countries now represent more than one-third of ITA trade, with growth rates frequently outpacing their developed country counterparts. The robust expansion of ITA trade by developing countries is most evident in Asia, with China a consistently a dominate force. Already a strong trader in ITA products, China's rapid ascension to become a leading exporter and importer accelerated in conjunction with implementation of its WTO and ITA obligations. Despite the prominent role of China, other developing countries, including other Asian countries realized expanded trade opportunities following ITA membership. Further, growth in developing countries' ITA trade exceeded that of the largest non-ITA countries, demonstrating a positive proposition from ITA membership.

Highlighting the changes in composition of ITA products' trade, were computers and telecommunications which accounted for an increasing share of total ITA trade. However, strong growth in imports and exports for all ITA products occurred, with the most significant growth in telecommunications, office equipment, and semiconductors paralleling the increasing fragmentation of global production networks for all IT products. Finally, a striking shift in global production and trade patterns is most evident in computers and telecommunications where China and South Korea alone have displaced the U.S., Japan, and several European countries as the leading producers and exporters.

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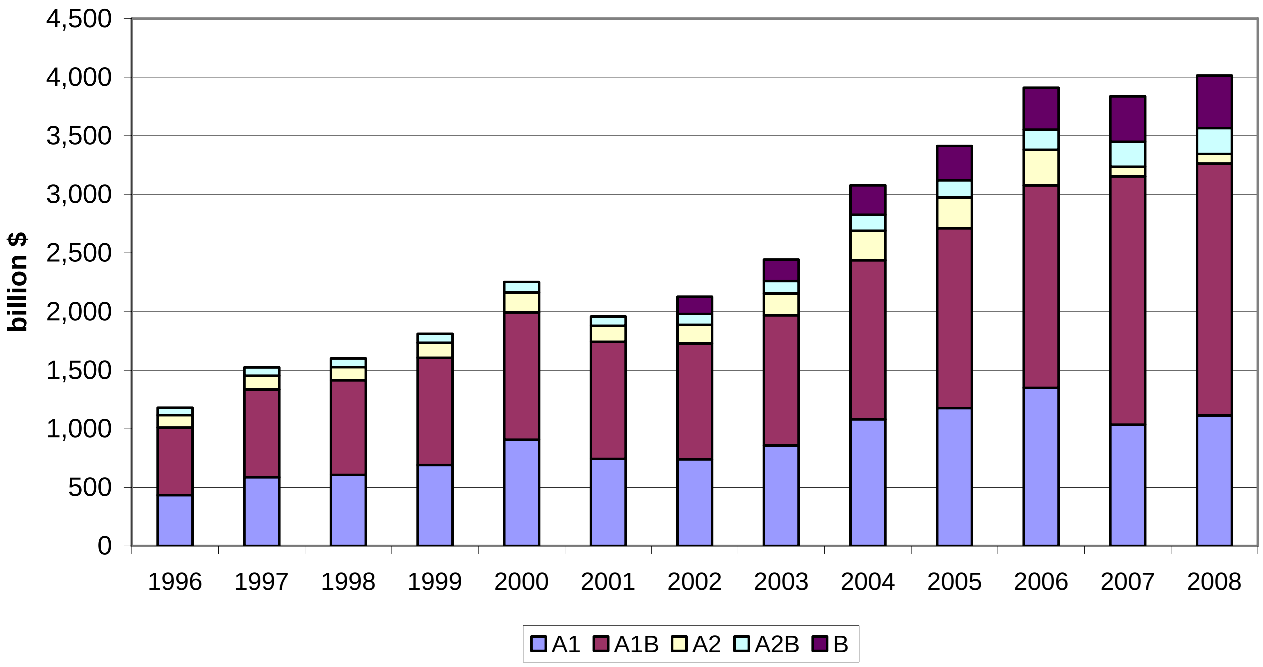
# Appendix A

**Figure A1** ITA total trade by attachment, 1996-2008




*Source: Compiled by USITC staff from UN Comtrade database.*

# The Efficiency of China’s Fiscal Policies on the Promotion of High-tech Industry

## 1 Background

### 1.1 Review of China’s Fiscal Policies on the Promotion of High-tech Industry

China’s High-tech industry is advancing rapidly in recent years. Many indexes of China’s High-tech industry are growing fast and China’s High-tech industry has been in the first three of the world based on the industry scale. As a developing country, the progression of China’s High-tech industry is connected tightly to the background of the blooming of economy and science and technology (S&T) after China’s Reforming and Opening, and also due to the implementation of supporting policies on High-tech industry to a certain extent. Besides industry policy, investment policy and the establishment of the High-tech zone, fiscal policies are critical to the development of China’s High-tech industry. Specifically, the framework of fiscal policies on supporting China’s High-tech industry includes enterprise income tax, value-added tax, business tax and personal income tax, among which the most efficient ways are the deduction of enterprise income tax and the enlargement of the scope and proportion of tax credit.

For the deduction of enterprise income tax, the Ministry of Finance (MOF) and the State Administration of Taxation (SAT) jointly issued the ‘Notice of Preferential Policies of Enterprise Income Tax’ in 1994, which stipulated definitely that the tax rate for High-tech companies in High-tech zones authorized by the State Council is 15 percent and a two-year tax exemption of enterprise income tax is offered to new established High-tech companies from the commissioning date. In the mean time, according to the ‘Notice of the State Council on the approval of High-tech Zones and Related Policies’ in 1991, if the proportion of export relative to total production is greater than 70 percent , the tax rate of enterprise income tax in the High-tech zones is 10 percent under the approval of tax authorities. In addition, this notice also authorized preferential policies to encourage technology transfer. Among High-tech industries, the main objective of the preferential police was Electronic Information Industry. Based on the ‘Tax policies on encouraging the development of Software Industry and Integrated Circuit Industry’, the tax rate of enterprise income tax is 15 percent for new established companies in these two industries from 2000; and moreover for companies which obtain profits for the first time, a two-year full exemption of enterprise income tax will be offered, continued by a three-year half exemption. In 2008, the ‘Enterprise Income Tax Law of the People's Republic of China’ was implemented formally, which authorized the unification of two taxation systems on domestic and foreign companies and the 20 percent unified tax rate. This law also approved a 15 percent tax rate for High-tech companies which need the support by the state. According to the new law, identified High-tech enterprises would not be in the High-tech zone definitely, which was an improvement relative to the ‘Administration Work on identification of High-tech Enterprises’ issued several years ago.

For the enlargement of the scope and proportion of tax credit, according to the ‘Regulation of Tax Policies on Encourage the Technical Progress of Enterprises’ in 1996, the R&D fees can be deducted by the proportion of 150 percent before the income tax. This regulation also authorized strict conditions of tax deduction that the deduction should be only permitted for profitable companies whose R&D fees in this year is greater than last year by at least 10 percent, the 50 percent above quota should be lower than total income tax in the current period, and forward or backward transfers of the tax deduction is strictly prohibited. In the ‘Enterprise Income Tax Law of the People's Republic of China’ implemented in 2008, the 50 percent additional deduction of R&D fees was retained and above restrictions was cancelled. Additionally, machines of electronic enterprises can be depreciated at an increasing rate, which was regulated in the ‘Regulation of Tax Policies on Encourage the Technical Progress of Enterprises’ in 1996 was implemented continually after the implementation of the income tax law. With the reform of enterprise value-added tax in 2009, the depreciation of fixed assets entered the scope of tax credit; therefore the implementation of the increasing-rate depreciation of High-tech companies was not only good for reducing income tax but also for value-added tax.

**1.2 The Trend of the Tax Burden of China’s High-tech Industry**

On the grounds of the above analysis, 1996 and 2000 were crucial points of promoting the development of China’s High-tech industry with on doubt. However, from the perspective of the tax burden of China’s High-tech industry, the burden in 1996 was not decreased obviously relative to 1995, the same for 2001 relative to 2000. This had two main reasons: the first one is that besides mentioned preferential tax policies above, China’s local governments also issued other ones to motivate the High-tech industry including consumption tax, sale tax and so on; the second one is that before the unification of two tax systems of domestic and foreign enterprises, foreign High-tech companies, which accounted an large part of the total High-tech industry, had been already offered a 15 percent preferential tax rate, therefore a 15 percent preferential tax rate of income tax of High-tech companies not causing distinct reduction of tax burden of the total industry.

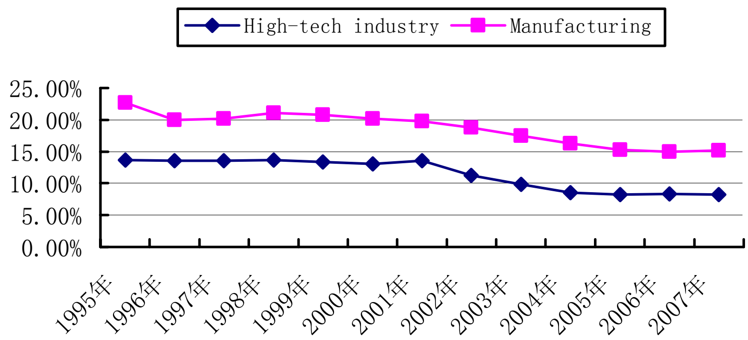



Figure 1 The Tax Burden of High-tech Industry and Manufacturing

**Source:** China’s Statistics Yearbook ON High-tech Industry

But it should be also realized that fiscal policies of advancing the High-tech industry lowered the tax burden of High-tech enterprises. From the time, after 1996 there was a decreasing trend in the macro tax burden of China’s High-tech industry. Specifically, the macro tax burden of China’s High-tech industry was 13.7 percent in 1995, and decreased to 13.1 percent in 2000 and to 8.2 percent in 2007. From the perspective of the comparison between different industries, the tax burden of the High-tech industry was obvious lower than that of Manufacturing as a whole. As early as 1995, the average tax burden of China’s High-tech industry was lower than that of Manufacturing by 9 percent before the implementation of the tax deduction. After that, the tax burden of Manufacturing also descended to some extent, but still greater than that of High-tech industry by 6 percent on the average.

For different sectors in the High-tech industry, Manufacture of Medicines and Manufacture of Medical Equipments and Measuring Instrument had the highest tax burdens which were 15.1 percent and 10.8 percent in 2007 respectively, greater than the average level. Manufacture of Computers and Office Equipments had the lowest one which was only 3.4% in 2007. For the structure of different High-tech sectors, if the foreign enterprises accounted a large proportion, the tax burden would be lower and not so volatile relatively over time. For example, for Manufacture of Computers and Office Equipments, the lowest tax burden sector, there were 121 projects in 2007 in total and foreign companies accounted 58 with the proportion of 47.9 percent, much greater the average level of 17.4 percent. Due to more tax deduction of foreign companies and relative stability of related policies before the unification, the tax burden was much lower in high foreign proportion sector and also the extent of the tax burden fluctuation.

**Table 1 The Tax Burden of Sub Sectors of High-tech Industry**

| | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|
| Average Level | 9.8% | 8.5% | 8.2% | 8.3% | 8.2% |
| Manufacture of Medicines | 18.3% | 17.5% | 16.1% | 15.0% | 15.1% |
| Manufacture of Aircrafts and Spacecrafts | 9.2% | 4.9% | 5.8% | 6.1% | 4.1% |
| Manufacture of Electronic Equipment and Communication Equipment | 8.3% | 6.4% | 6.9% | 7.5% | 7.2% |
| Manufacture of Computers and Office Equipments | 3.8% | 4.6% | 3.7% | 3.9% | 3.4% |
| Manufacture of Medical Equipments and Measuring Instrument | 14.4% | 12.7% | 11.5% | 10.7% | 10.8% |

**Source:** China's Statistics Yearbook ON High-tech Industry

## 2 Theoretical Analysis

### 2.1 Literature Review

Today, there are a large number of literatures concentrating on the effect of fiscal policies on the promotion of High-tech Industry, which make use of two main methods.

The first one is investment effect by fiscal policies, which can influence the industry size. Gordon&Jorgenson (1974) calculate to what extent the tax credit of investment tax can influence investment base on the data from 1964 to 1974 and argue that if the rate of the investment tax credit grows from 7 percent to 15 percent, investment rate will increase by 12.5 percent approximately. Eckstein（1976）analyzes the influence of enterprise income tax to investment by building 800 models using the data from 1970 to 1980 of U.S., and concludes that if the enterprise income tax rate falls from 33 percent to 15 percent, the capital stock and the investment of companies will increase by 9.9 percent and 15.5 percent respectively. Feldstein&Fane(1973) compute the influence of tax to private investment by using the data of U.K., and conclude that for every one percent decrease of investment yield tax rate, total private investment will raise by 0.6 percent approximately.

The second one is technology effect by fiscal policies, which can influence the industry efficiency. Gorgenson(1981) analyzes the relation between the fiscal encouraging and the technology level, and confirms that the tax rate of capital has an obvious negative relation with technology progress, high capital tax rate could cause low technology progress , vice verse.

In sum, most literatures reach one point that reducing tax rates could cause the enlargement of industry size the progress of industry technology level. However, the main objective of the empirical research of these studies is developed countries. For China, a big developing country with ‘dual-gap’, owing to different develop stages, the conclusion may be not the same as developed countries. Besides other conditions, China’s High-tech industry development is connected closely with Foreign Direct Investment (FDI) inflow under the background of globalization especially. As a result, the influence of fiscal polices to China’s High-tech industry development requires further quantitative analysis.

**2.2 Index Determination**

2.1.1 The Measurement of the encouraging extent of fiscal policies

According to the former analysis, only implemented polices are not enough to reflect the encouraging extent to China’s High-tech industry. This paper will analyze the real encouraging extent to China’s High-tech industry by fiscal policies through the fluctuation of the macro real tax burden, which leads to the requirement of a relative index. In order to do this, the gap between the tax burden of Manufacturing as a whole and that of High-tech industry can be employed to reflect the encouraging extent of fiscal policies. The formulation is as follows,

$$TAXF=TAXM-TAXH$$

where TAXM is the macro tax burden of Manufacturing as a whole and TAXH is that of High-tech industry or one sub sector.

2.2.2 The Measurement of the Innovation Capacity of China’s High-tech Industry

Compared with traditional industries, besides gross product, value-added, tax and so on, the innovation capacity and the technology level are more suitable to reflect the development of China’s High-tech industry. Generally speaking, Total Factor Productivity (TFP) is often used to measure the development level of one industry. However, it is difficult to obtain TFP directly and econometric models have to be used. But different econometric models tend to reach different outcomes, which illustrates that the calculation of TFP index is subjective to some extent. In this paper, the value-added rate is employed to measure the innovation capacity and the technology level of China’s High-tech industry, where the value-added rate is the proportion of value-added product relative to gross product. Under unchanged input, higher value-added rate means more output, which can exemplify the effect of technology progress in producing and reflects more innovation capacity. The formulation is as follows,

$$VAD\_RATE=VAD/OUTPUT$$

where VAD_RATE is the value-added rate to measure the innovation capacity and the technology level, VAD is value-added product in the industry level and OUTPUT is gross product。

**2.3 Theoretical Model**

There are two ways to measure the effect of fiscal policies on the advancement of China’s High-tech industry: first, the influence of policies on the industry size will be depicted and the main variable being explained is the gross product of the industry; second, whether the innovation capacity has been triggered by policies will be analyzed based on characters of China’s High-tech industry and the main variable being explained is the value-added rate created above.

2.3.1 Industry Size Analysis

In traditional production functions, output can be mainly explained by capital and labor. In this paper, the focus is the effect of fiscal policies, therefore the variable of the encouraging extent of fiscal policies entering the function. The new model is as follows:

$$HIOUTPUT = f(K, L, TAXF) \qquad (1)$$

where K is capital stock and in this paper the data source of K is the 'Original Value of Productive Equipment' from China's Statistics Yearbook ON High-tech Industry; L is the volume of labor force and TAXF is the encouraging extent variable.

2. Innovation Capacity and Technology Level

The variable of the innovation capacity of China's High-tech industry created above will be employed to measure the industry competitiveness. According to other literatures, the Research and Development (R&D) input and the quality of labor force are generally main elements influencing the innovation capacity and the technology level of industry. Specifically, more R&D input can trigger the increase of the innovation capacity, therefore causing the increase of the value-added rate; in the total labor force, if research and development personnel account for a higher proportion, the innovation capacity of one industry will be higher relatively. By introducing the variable of the encouraging extent of fiscal policies, a new model can be reached,

$$VAD\_RATE = f(R\&D, HR, TAXF) \qquad (2)$$

where VAD_RATE is the value-added rate to measure the innovation capacity of China's High-tech industry, R&D is the Research and Development input, HR is the proportion of research and development personnel relative to total labor force and TAXF is the encouraging extent variable.

## 3 Empirical Analysis

In China, different sub sectors of High-tech industry have different backgrounds. Electronic and Information Industry has a close connection with the inflow of FDI and the market demand is the main promoting factor of the industry development. Manufacture of Aircrafts and Spacecrafts has a tight relation with the state strategy and large scale companies account for a great proportion in this industry. Thus, different backgrounds lead to different tax burdens. Moreover, due to the industry character, the R&D input and the quality of labor force are not the same across sub sectors. As a consequence, panel data will be employed in the empirical work to the influence of fiscal policies on different sectors. The data is all from the 'China's Statistics Yearbook ON High-tech Industry' and in the form of natural logarithm.

### 3.1 Output Analysis

High-tech industries are mostly technology intensive and capital intensive and therefore labor yield a limited influence. In the calculation, labor has only a little effect on industry output and therefore is deleted from the model. In regression, the data from 1996 to 2007 are used based on formula (1). After Hausman Test, outcomes in table 2 can be reached by adopting fixed-effect model of panel data.

In table 2, C is the constant term, TAXF_M, TAXF_AS, TAXF_EE, TAXF_CO, TAXF_MM represent the encouraging extent of fiscal policies on Manufacture of Medicines, Manufacture of Aircrafts and Spacecrafts, Manufacture of Electronic Equipment and Communication Equipment, Manufacture of Computers and Office Equipments and Manufacture of Medical Equipments and

Measuring Instrument respectively. Based on the test of equations, adjusted R-square can reach 0.92, which illustrates that variables selected can represent explaining factors of the output of China's High-tech industries.

For explaining variables, capital stock is deterministic on output and if it rises by 1 percent, output will increase by 0.8 percent. For the variable of the encouraging extent of fiscal policies, the influence is not the same across sectors. Based on regress outcomes, the t-value of Manufacture of Medicines and Manufacture of Aircrafts and Spacecrafts is higher than that of other sectors relatively, which indicates that fiscal policies have more obvious effects on these two sectors. The elasticity coefficients of the encouraging extent for these two sectors are 0.19 and 0.37 respectively, which states that if the encouraging variable grows by 1 percent, the output of Manufacture of Medicines and Manufacture of Aircrafts and Spacecrafts will increase by 0.19 percent and 0.37 percent respectively. Among the other three sectors, the encouraging variable is not significant, which states that fiscal policies have limited effects on these sectors.

**Table 2 Regress Outcomes of the Output Equation**

Dependent Variable: Ln(OUTPUT)

Method: Pooled Least Squares

Sample (adjusted): 1996 2007

Included observations: 12 after adjustments

Cross-sections included: 5

Total pool (balanced) observations: 60

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -6.38 | 1.25 | -5.11 | 0.00 |
| Ln(K) | 0.81 | 0.08 | 10.51 | 0.00 |
| Ln(TAXF_M) | 0.19 | 0.08 | 2.55 | 0.01 |
| Ln(TAXF_AS) | 0.37 | 0.25 | 1.45 | 0.15 |
| Ln(TAXF_EE) | 0.20 | 1.04 | 0.19 | 0.85 |
| Ln(TAXF_CO) | 0.06 | 0.10 | 0.61 | 0.55 |
| Ln(TAXF_MM) | -0.39 | 0.54 | -0.73 | 0.47 |
| Effects Specification | | | | |
| Cross-section fixed (dummy variables) | | | | |
| R-squared | 0.93 | Mean dependent var | | 7.34 |
| Adjusted R-squared | 0.92 | S.D. dependent var | | 1.27 |
| Log likelihood | -17.87 | Hannan-Quinn criter. | | 1.11 |
| F-statistic | 68.37 | Durbin-Watson stat | | 1.54 |
| Prob(F-statistic) | 0.00 | | | |

**Source:** The Author's Caculation

### 3.2 Innovation Capacity Analysis

The equation of panel data has been created to analyze the innovation capacity of High-tech industry based on formula (2) and the sample is from 1995 to 2007. The variable being explained is the value-added rate and explaining variables are the R&D input, the proportion of research and development personnel relative to total labor force and the encouraging extent variable. By Hausman test, outcomes in table 3 can be reached by adopting fixed-effect model of panel data.

**Table 3 Regress Outcomes of the Innovation Capacity Equation**

Dependent Variable: Ln(VAD_RATE)

Sample (adjusted): 1995 2007

Included observations: 13 after adjustments

Cross-sections included: 5

Total pool (balanced) observations: 65

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.50 | 0.21 | -2.36 | 0.02 |
| Ln(HR) | 0.17 | 0.06 | 2.74 | 0.01 |
| Ln(R&D) | 0.05 | 0.02 | 2.42 | 0.03 |
| Ln(TAXF_M) | 0.01 | 0.06 | 0.13 | 0.90 |
| Ln(TAXF_AS) | -0.01 | 0.05 | -0.16 | 0.87 |
| Ln(TAXF_EE) | 0.20 | 0.15 | 1.36 | 0.18 |
| Ln(TAXF_CO) | 0.86 | 0.16 | 5.53 | 0.00 |
| Ln(TAXF_MM) | -0.09 | 0.09 | -0.94 | 0.35 |
| Effects Specification | | | | |
| Cross-section fixed (dummy variables) | | | | |
| R-squared | 0.93 | Mean dependent var | | -1.33 |
| Adjusted R-squared | 0.92 | S.D. dependent var | | 0.22 |
| Log likelihood | 94.08 | Hannan-Quinn criter. | | -2.37 |
| F-statistic | 65.35 | Durbin-Watson stat | | 1.68 |
| Prob(F-statistic) | 0.00 | | | |

**Source:** The Author's Caculation

According to regress outcomes, the adjusted R-square reaches 0.92, which states that selected variables can reflect main elements on influencing the innovation capacity of China's High-tech industry. Specifically, the significances of the proportion of research and development personnel and R&D both exceed 5 percent and the coefficients are positive, which indicates that these two variables are imperative to determine the innovation capacity of China's High-tech industry. The coefficient of the proportion of research and development personnel is 0.17 and that of R&D is 0.05, which illustrates that the influence of the former variable is greater relatively.

Not the same as output equations, the encouraging extent variable of fiscal policies has some positive effects on the innovation capacity of Manufacture of Electronic Equipment and

Communication Equipment and Manufacture of Computers and Office Equipments to some extent, but not significant on other sectors. Specifically, the t-values of these two sectors are 2.74 and 2.42 respectively, both passing the significance test at 1 percent and 3 percent. Moreover, the elasticities of the encouraging variable of these two sectors are 0.2 and 0.86 respectively, which means that fiscal policies have more influence on the latter sector relatively. For the other three sectors, it can be concluded that fiscal policies have little influence on their innovation capacities because the statistical test is not significant.

## 4 Conclusion

With China's Reforming and Opening, especially after 1990s, a number of fiscal polices have been implemented to promote the development of High-tech industry. As a result, the tax burden of China's High-tech industry was much lower than that of Manufacturing as a whole in the same period and had a decreasing trend over time. However, for sub sectors of China's High-tech industry, the tax burden was not the same across sectors. Because of more preferential policies on foreign companies, the tax burdens of Manufacture of Electronic Equipment and Communication Equipment and Manufacture of Computers and Office Equipments, with high proportion of foreign companies, were lower than the average level of High-tech industry as a whole. According to outcomes derived from the panel data model with the sample since 1995, fiscal policies have supported the advancement of China's High-tech industry indeed, but the influence on different sub sectors is not the same. Specifically, fiscal policies have more effects on the output of Manufacture of Medicines and Manufacture of Aircrafts and Spacecrafts, and on the innovation capacity of Manufacture of Electronic Equipment and Communication Equipment and Manufacture of Computers and Office Equipments.

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# *Does a Leapfrogging Growth Strategy Raise Growth Rate?*

## *--Evidence across Countries and within China**

Zhi Wang (U.S. International Trade Commission)

Shang-Jin Wei (Columbia University, NBER and CEPR)

Anna Wong (University of Chicago)

**Abstract**

Openness to trade is a hallmark of the Asian Growth Model, with empirical evidence supporting its importance for the high growth rates in the region. Another aspect of the Asian Growth Model is a leapfrogging strategy – the use of policies to guide the industrial structural transformation ahead of a country's factor endowment. Does it work? Opinions vary but the evidence is scarce in part because it is more difficult to measure the degree of leapfrogging than the extent of trade openness. We undertake a systematic look at the evidence both across countries and across regions within a large Asian economy to assess the efficacy of such a strategy. There is no strong and robust evidence that this strategy works reliably.

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Shang-Jin Wei (Corresponding Author), Graduate School of Business, Columbia University, Uris Hall #619, 3022 Broadway, New York, NY 10027. Email: shangjin.wei@columbia.edu , http://www.nber.org/~wei. Zhi Wang, Research Division, Office of Economics, United States International Trade Commission, Room 603F, 500 E Street SW, Washington, DC 20436. E-mail: zhi.wang50@usitc.gov. Anna Wong, Department of Economics, University of Chicago. E-mail: annawyw@uchicago.edu

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## 1. Introduction

All countries want to grow fast on a sustained basis. Many Asian economies excel in this area. Following Japan after World War II, the "four little dragons" – Korea, Singapore, Taiwan and Hong Kong are by now familiar success stories. Many more economies in the region, including Malaysia, Thailand, and Indonesia quickly followed, achieving higher growth rates than most other developing countries that had a comparable level of development in the 1960s. Since 2000, China, India and Vietnam are the new "growth miracles" – achieving the same high growth rates as their neighbors for 2-3 decades in a row[1]. Naturally, this record invites admiration and scrutiny. What is the Asian growth model? Is it something that can be transplanted to Latin America, Africa, or elsewhere, and have the same magic effect?

While the growth records of the Asian economies are (almost) uncontroversial, what is responsible for the growth results is subject to debate. At the risk of over-simplification, we suggest that two aspects of the Asian growth model merit particular attention. First, almost all high-growing Asian economies embrace trade openness. Trade barriers are taken down or progressively reduced either at the start of the growth process or not long after the start of the process. Trade liberalization doesn't take the narrow form of reducing tariff rates on imports, although that is often part of the process. It can take the form of de-monopolizing and de-licensing. That is the right to import and export before the liberalization was concentrated in a small number of firms by government regulations. Trade liberalization broadens the set of firms that could directly participate in international trade. Even holding tariff rates constant, such "democratization" of trading rights could dramatically increase a country's trade openness. This was a significant part of the Chinese trade liberalization in the 1980s. Trade liberalization can also come in conjunction with reducing entry barriers or offering incentives for foreign firms to jump start the domestic export industry. This may be particularly important for those countries that have been isolated from the world market for a while. Sometimes, the Asian model is called an "outward-oriented strategy." This is not very accurate since many Asian economies do not

[1] Myanmar (Burma) also consistently reports double-digit real GDP growth rates every year since 2001, but international financial institutions and other observers appear to be somewhat skeptical about the reliability of the statistics. Chinese official growth rates are sometimes challenged for its veracity, although most scholars, economists of major international investment banks, and international financial institutions take the view that the officially released figures are reliable. (Or, if there is a bias, the bias could be either positive or negative.)

simultaneously embrace capital account openness, at least not by the same degree in the areas of cross-border portfolio equity and portfolio debt.

The second aspect of the Asian growth model is the use of government policies to promote high-tech and high domestic value-added industries, presumably beyond what the economies would naturally develop if left on their own device. This aspect may be labeled as a leapfrogging strategy. China, Singapore, and Malaysia all have various aggressive policies to promote certain high value added sectors. Other countries in the region do not wish to fall behind. For example, Philippines' National Information Technology Council announced in 1997: "Within the first decade of the 21st Century, the Philippines will be a knowledge center in the Asia Pacific: the leader in IT education, in IT-assisted training, and in the application of information and knowledge to business, professional services, and the arts."

Are these two aspects responsible for the growth success? The first aspect – the role of trade openness in economic growth – has been subject to extensive (and intensive) scholarly scrutiny. While there is notable skepticism (Rodriguez and Rodrik, 2000), most economists read the evidence as suggesting that trade openness does help to promote economic growth. Following and extending the work by Frankel and Romer (1999), Feyrer (2009), in a recent paper that pays attention to sort out causality from correlation, again shows that greater trade openness causally leads to a rise in income. Using changes in infant mortality and life expectancy as an alternative measure of wellbeing, one of us (Wei and Wu, 2004) present evidence that trade openness helps to improve social welfare by reducing infant mortality and raising life expectancy to a degree beyond raising per capita income. Based on the overwhelming amount of evidence, we lean strongly toward believing that trade openness has played a key role in the success stories in Asia, and indeed in most high growth episodes in the world.

How about the second aspect of the Asian model? Has a leapfrogging strategy played a key role as well? In comparison to the trade openness issue, there is far less scholarly work on the effectiveness of a leapfrogging strategy. In theory, if the production of sophisticated goods generates positive externalities via learning-by-doing, then there generally would be an under-investment among private economic agents relative to the socially optimal level. A leapfrogging strategy - a government-led industrial policy that tilts resource allocation to technologically sophisticated industries - could correct this market failure. The natural inference from this argument suggests that a country may benefit more from exporting sophisticated products than from exporting unsophisticated and low domestic value-added products, even if its comparative advantage in the current time is to produce the latter type of goods. Recent academic studies have reported evidence supporting such comparative advantage-defying development strategy. In Hausman, Hwang, and Rodrik (2007) (henceforth, abbreviated as HHR), the authors suggest that some export goods have higher spillover effects than others. They develop a measure of export sophistication and find that a positive relationship exists between their measure and the country's subsequent economic growth rate. However, there is no shortage of skepticism toward the leapfrogging growth strategy. On one hand, one might question the size of any such market failure in the real world if there is one. On the other hand, one might wonder whether the existence of a "government failure" if it were to pursue a leapfrogging strategy, could overwhelm whatever benefits a country may derive from correcting the market failure. In a series of papers, including Lin (2007), the World Bank chief economist Justin Lin, advocate strongly for development strategies that follow a country's comparative advantage, and against what he calls "comparative advantage defying strategies" which include a leapfrogging industrial policy.

In this paper, we aim to test the validity of the leapfrogging hypothesis with fresh evidence both from a cross-country data set and exploring variations across regions within China. One bottleneck in testing this hypothesis is to identify which countries (regions) engage in such a growth strategy[2]. We employ four different measures including a new indicator proposed in this paper based on the proportion of identifiable high-tech products in a country's exports. Cross country growth regressions are criticized for ignoring the role of culture, legal systems, and other institutions in general, and their interactions with other regressors. Since we are mindful of this potential pitfall, we complement the cross-country regressions with evidence from comparing different regions within a single country (China). Relative to across country comparisons, legal systems, political and other institutions are more similar within a country. Therefore, this within-China investigation would give us additional, complementary evidence on the efficacy of a leapfrogging strategy.

Our main results can be summarized as follows. First, across countries, there is no strong and robust evidence that a leapfrogging strategy contributes to a higher growth rate. Second, across different regions within China, there is no such evidence either. Overall, the empirical investigation does not support the contention that a government intervention that is aimed at

[2] Literature review of previous tests of the hypothesis will be added in the next revision.

raising a country's technological sophistication beyond what is expected of its level of development could produce a better growth result on a sustained basis.

The paper is organized as follows. Section 2 discusses our measures of leapfrogging. Section 3 examines the empirical connections between technological leapfrogging and economic growth rate. Section 4 concludes.

## 2. Measuring leapfrogging

A key to this exercise is to assess whether a country pursues a leapfrogging strategy, and, if it does, what the degree of leapfrogging is. Ideally, we would want to compare a country's actual production structure with what would have been predicted based on its factor endowment. There are two challenges. First, data on production structure by an internationally comparable classification are not available for most countries, especially developing countries for which evaluating the efficacy of a leapfrogging strategy is most pertinent. Second, even when internationally comparable production data are available, one gets only a relatively coarse classification, with less than 100 sectors. Many differences in the economic structure do not reveal themselves at such an aggregate level. For example, many countries have electronics industries, but different types of electronic products may have very different levels of skill content. We address these challenges by looking at trade data instead. Generally speaking, a country's export structure closely resembles its production structure. Trade data are available for a much large set of economies (over 250 in the WITS database). At the most detailed and still internationally comparable level (Harmonized System 6-digit, there are over 5000 products a country can export (or import). To control for the "normal" amount of sophistication based on a country's factor endowment, we include a country's income and education levels as controls in a growth regression framework.

In the rest of the section, we first review two existing measures of export sophistication in the literature, and propose two additional measures that may address some shortcomings of the existing measures. We then describe the data that we use to implement the measures. Finally, we conduct some simple "smell checks" to see how well these measures capture those countries that are commonly reported as having a leapfrogging industrial policy.

### 2.1 Measures of a country's industrial sophistication based on export data

While it is difficult to directly measure a country's industrial sophistication, in part because the standard industrial classification is too coarse for this purpose, the existing literature has considered proxies based on the data on a country's export bundles. The idea is that, leaving aside non-tradable goods, the structure of the export bundle should mimic that of production. One measure is the level of income implied in the export bundle, introduced in Hausmann, Hwang, and Rodrik (2007). This measure builds on the concept that the degree of sophistication in a country's exports can be inferred by the income level of each good's exporter. The second measure is the Export Dissimilarity Index (EDI), introduced by Schott (2007) and adopted by Wang and Wei (2008), which gauges the distance between a country's export structure and that of high-income economies such as Japan, the U.S. and the European Union (EU15). Both measures assume that higher income countries, on average, produce more sophisticated products. One can avoid making this arbitrary assumption, and focus on the degree of technological sophistication of the product itself, based on a classification of high-tech "advanced technology products" (ATP) that comes from the OECD and the United States.

*Income implied in a country's export bundle* (EXPY)

This indicator of export sophistication is a measure of the typical income associated with a given country's export basket. For every good, one can compute the "typical income" (PRODY) of the countries that export the good, or the weighted average of the income levels across the exporters of this good, with weights proportional to the value of the exports by countries. For any given exporter, one can look at its export basket and compute the weighted average of the typical income levels across all products in the basket, with the weights proportional to the value of each good in the basket. The key underlying assumption here is that advanced countries produce more sophisticated goods and poorer countries produce less sophisticated goods.

$$PRODY_i = \sum_k^n \frac{s_{ik}}{\sum_j s_{ij}} \bullet Y_k \quad (1)$$

$$EXPY_k = \sum_i s_{ik} \bullet PRODY_i \quad (2)$$

Where $s_{ik}$ is the share of country $k$'s exports in product $i$,$Y_k$ is country $k$'s per capta GDP. Table 1 displays the summary statistics for the EXPY over the time period 1992-2006.

There are two major merits of this index. First, it does not require one to tediously sift through and classify goods as "sophisticated goods" or "high tech products". Second, it can be computed easily with data in trade flows and GDP per capita. But it also has several weaknesses. First, the key assumption underlying PRODY, that more advanced countries produce sophisticated goods, may not be true. Advanced countries often produce a larger set of goods than poor countries. Furthermore, larger countries also often produce a larger set of goods than smaller countries. These features suggest that the PRODY index may over-weight advanced and large countries. Second, the index may conceal diversity in the quality and type of goods in finest details within a product category. Third, the index fails to capture processing trade, where a country imports sophisticated product parts to produce the final sophisticated product. This is the case in China, where a significant share of sophisticated exports is based on processing trade. Given the weaknesses of the EXPY index, we construct the following index in hopes of avoiding some of its pitfalls.

*Unit value adjusted implied income in the export bundle - Modified EXPY*

In this modified version of the EXPY index, we discount the PRODY of each good by the ratio of the unit value of the exporter to the mean unit value of the same goods in G3 (The United States, Great Britain, and Germany) countries.

$$PRODY_i = \sum_k^n \frac{s_{ik}}{\sum_j s_{ij}} \bullet Y_k \bullet \frac{v_{ik}}{v_{iG3}} \qquad (3)$$

The modified EXPY is computed similarly as in the original EXPY index in equation (2).

The motivation of this modification is our belief that the unit value data adds an additional layer of differentiation among goods of different quality or varieties. This can take account of the diversity within the 6-digit HS category. The assumption behind this modification is that unit value proxy quality, and the G3 countries export higher quality goods.

Since we only have unit value of products at 6-digit HS level across the world for 2005, we apply the same unit value discount factor to the PRODY during our whole sample period. Table 2 shows the summary statistics of this modified EXPY.

*Distance to the export bundle by high-income countries*

We define an index for a lack of sophistication by the dissimilarity between the structure of a country (city)'s exports and that of the G3 economies or the export dissimilarity index (EDI), as:

$$EDI_{rft} = 100(\sum_i abs(s_{irt} - s_{i,t}^{ref})) \quad (4)$$

where $$s_{irt} = \frac{E_{irt}}{\sum_i E_{irt}} \quad (5)$$

where $s_{irft}$ is the share of HS product $i$ at 6-digit level in a country (city) $r$'s exports at year $t$, and $s_{i,t}^{ref}$ is the share of HS product $i$ in the 6-digit level exports of G3 developed countries. The greater the value of the index, the more dissimilar the compared export structures are. If the two export structures were identical, then the value of the index would be zero; if the two export structures were to have no overlap, then the index would take the value of 200. We regard an export structure as more sophisticated if the index takes a smaller value. Alternatively, one could use the similarity index proposed by Finger and Kreinin (1979) and used by Schott (2006) (except for the scale):

$$ESI_{rft} = 100\sum_i min(s_{irft},\ s_{i,t}^{ref}) \quad (6)$$

This index is bounded by zero and 100. If a country (city) $r$'s export structure had no overlap with that of the G3 developed countries, then ESI would be zero; if the two export structures had a perfect overlap, then the index would take the value of 100. It can be verified that there is a one-to-one, linear mapping between ESI and EDI:

$$ESI_{rft} = \frac{200 - EDI_{rft}}{2} \quad (7)$$

*Share of Advanced Technology Products in total exports – ATP share*

Besides the measures already in the literature, we also propose a new measure on the share of high-tech products in a country's exports bundle that does not require assuming that richer countries automatically export more sophisticated products.

$$ATPSH_{it} = 100\frac{EXP_{it}^{ATP}}{EXP_{it}^{TOT}} \quad (8)$$

where $EXP_{it}^{ATP}$ is exports of ATP of country i at time t, $EXP_{it}^{TOT}$ is total exports of country i at time t. This measure of export sophistication requires us to specifically define what is meant by "high-tech exports", thus it sacrifices EXPY's simplicity.

To compute this measure, one needs an expert definition of which product is high-tech. Two lists of expert definitions are well respected. One is developed by the U.S. Census Bureau, which identified about 700 product categories as "Advanced Technology Products" (ATP) from about 20,000 10-digit HS codes used by the United States. The other is developed by the Organization for Economic Co-operation and Development (OECD), which identified 195 product categories from 5-digit SITC codes as "high tech" products. Because the Harmonized System classification (HS) is more detailed and is cross-country comparable at the 6-digit level, we concord both lists into 6-digit HS product categories. We convert the OECD "high tech" product list to 328 6-digit HS codes based on concordance between SITC (rev3) and HS (2002) published by the United Nation Statistical Division.

To condense the U.S. Census ATP list from 10-digit HS to 6-digit HS, we first calculate the ATP value share in both U.S. imports from the world at the HS-6 level based on U.S. trade statistics in 2006, bearing in mind that within each HS-6 heading, some of the U.S. HTS-10 lines are considered to be ATP and others are not. We choose two separate cut off points. For a narrow ATP definition, we select the 6-digit HS categories which the ATP share is 100 percent in total U.S. import from the world according to Census ATP list, which resulted in 92 HS-6 lines. For a wider ATP definition, we select the 6-digit HS categories which the ATP share is at least 25 percent in total U.S. import from the world, which resulted 157 HS-6 lines. We use the 6-digit HS code in which all products are in the Census ATP list and also in the OECD "high tech" product list as our narrow definition of ATP. For a wider ATP definition, we deem a HS-6 line as ATP when either it is in the OECD high-tech product list or at least 25 percent of its value is ATP products in U.S. imports from the world according to the Census ATP list.

The recent literature also documents significant variations within a same product. Although both developed and developing countries may export products under the same 6-digit HS code, their unit value usually varies significantly, largely reflecting the difference in quality between their exports. To allow for the possibility that a very large difference in the unit values may signal different products (that are misclassified as in the same 6-digit category), we take unit value for all products from Japan, EU15 and the United States (G3) in our narrow ATP definition as reference, and any products with unit value below the G3 unit value minus 5 times standard deviation will not be counted as ATP. This gives our third definition of ATP.

2.2 Data and Basic Facts

The EXPY measure requires data on trade flow and GDP per capita. We computed EXPY for both a short and a long sample. For the short sample, dating from 1992 to 2006, the data on country exports come from the United Nations' COMTRADE database, downloaded from the World Integrated Trade Solution (WITS). The data from 1992 to 2006 is at 6 digit HS (1988/1992 version) covering 5016 product categories and 167 countries. For the long sample, dating from 1962-2000, the trade flow data is taken from the NBER-UN data compiled by Feenstra *et al.,* which could be downloaded from the NBER website. The data is at 4 digit SITC, revision 2, covering 700 to more than 1000 product categories and 72 countries. The GDP per capita data on PPP basis is taken from the Penn World Table.

The modified EXPY measure in addition requires data on unit value. The data are obtained from Ferrantino, Feinberg, and Deason (2008), which in turn are obtained from the United Nations' COMTRADE database. The data is only for the year 2005, and is cleaned of products that do not have well defined quantity units, have inconsistent reporting, have small value, or have unit value belonging to 2.5 percent tail of the distribution of the product's unit values. In total, the resulting unit value dataset covers 3628 6-digit HS subheadings.

The other two export sophistication indices -- EDI and ATP share (narrow, broad) – are computed excluding HS Chapters 1-27 (agricultural and mineral products) as well as raw materials and their simple transformations (mostly at HS 4-digit level) in other HS chapters. A list of excluded products is reported in Appendix Table 1. Each country's ATP exports share is computed by the country's ATP exports divided by its total manufacturing exports. Our sample of countries is listed in Appendix Table 2.

The other explanatory variables included in the growth regressions are human capital, GDP per capita, and institutional quality. The human capital variable in the cross country regressions uses the average school year in the Barro-Lee education database. GDP per capita is on PPP basis and taken from the Penn World Table. The institutional quality variable is proxies by the government effectiveness index downloaded from the World Bank and Transparency International websites.[3]

Data on China's exports were obtained from the China Customs General Administration at the 8-digit HS level. The data report the geographic origin of exports (from more than 400 cities in China), firm ownership, and transaction type (whether an export is related to processing trade, as determined by customs declarations) for the period from 1996 through 2006. Each Chinese city's EDI is computed between a Chinese city's manufacturing export structure and the combined manufacturing export structure of G3 countries. Each Chinese city's ATP exports share is computed by the city's ATP exports divided by its total manufacturing exports. Similar to the cross country exports, we only consider manufactures. We link this database with a separate database on Chinese cities, including gross metropolitan product (GMP) per capita, population, percent of non-agricultural population in the total population, and college enrolment, downloaded from China Data Online (a site managed by the University of Michigan China Data Center). Unfortunately, the coverage of this second database is more limited (270 cities from 1996 through 2006), which effectively constrains the sample size used in our regression analyses. In these cities, only about 210 cities have 10 years or more complete data. About 11 cities only have records for 3 years or less. Therefore we deleted them from the sample. There also are 8 major cities that had redrawn their administration area during the sample period. They are Nanning, LiuZhou, Fuyang, Haikou, Chongqing, Kunming, Xinning, and Yinchuan. Total cities in our data set contain number 259. They are listed in Appendix Table 3. Since we do not have data on city level consumer price index (CPI), we using provincial CPI to deflate cities in that province to obtain real GMP; the base year we chose is 2002.

## 3. Do Leapfroggers Grow Faster? An Examination of the Evidence

### 3.1 The Elusive Growth Effect of a Leapfrogging Strategy

Since Hausman et al (2007) is the most recent and the best known paper that is supposed to have provided an empirical foundation for the proposition that a leapfrogging strategy as measured by a country's export sophistication delivers a faster economic growth rate, we start our statistical analysis by taking a careful look at their specification, with a view to check the

[3] http://www.worldbank.org/wbi/governance/govdata/ and http://ww1.transparency.org/surveys/index.html#cpi .

robustness of their conclusion. In particular, we follow their econometric strategy, regressing economic growth rate across countries on a leapfrogging measure and other control variables that typically included in empirical growth papers. After replicating their regressions with EXPY as the leapfrogging proxy, we use the alternative measures discussed above - modified EXP, the EDI indicator, and the ATP shares.

Table 1 shows our replication of the HHR's cross-section regressions for the short sample of 1992-2003 (corresponding to their Table 8). The controls include human capital and a measure of institutional quality. Since the source of their "rule of law" index is not clearly stated, we use four other well-known institution variables: corruption, government effectiveness, regulation quality, and the CPI score. In the OLS regressions, the coefficients on the first three institution measures are significant; in particular, the coefficient on regulation quality (0.013) is close to HHR's coefficient on their rule of law index (0.011). Column 1, 2, 7, and 8 in Table 1 can be compared to the corresponding regression in HHR's Table 8; the coefficients on the initial GDP per capita and human capital variables are basically the same as HHR's. While the coefficients on log initial EXPY have different magnitudes than HHR's results for the same sample period of 1992-2003, they are all statistically significant (though not as strong, depending on the institution variable) and are positive as HHR's. A possible explanation for this difference in the size of the coefficients is that trade data for the countries in the 1992-2003 sample has been revised since their usage. The bottom line from this replication exercise is that their results can be replicated.

In the next step, we replace the EXPY variable with alternative measures of export sophistications—modified EXPY, EDI, and the ATP shares—and re-estimated the regressions. The results for each of these respective variables are displayed in Tables 2-5. In Table 2, the coefficient on the modified EXPY is statistically insignificant in all but the first specification with only human capital as control, even as the direction of the coefficients and significance on initial GDP per capita, human capital, and institution variables remains the same as in Table 1. This observation extends to the case where either EDI or the broad definition of ATP is used as the export sophistication measure, as shown in Tables 3 and 4. However, the coefficient on the ATP share using a more stringent definition is positively significant across all specification. We will show in the next section that even this result is not robust.

To summarize, the positive association between a country's export sophistication and economic growth rate is not a strong and robust pattern of the data. In particular, alternative measures of export sophistication often produce statistically insignificant coefficients. For example, a reasonable adjustment to the HHR measure of sophistication by taking into possible differences in unit values when computing the implied income in an export bundle would render the positive association to disappear. We therefore infer that that it may be too early to conclude that pursuing a leapfrogging strategy would raise a country's growth rate.

## 4. Further Investigations

Does growth in sophistication lead to growth in income?

It is possible that the level of a country's export sophistication may not capture well policy incentives or other government actions. In particular, if a country happens to have an unusually large pool of scientists and engineers, its level of export sophistication may surpass what can be predicted based on its income or endowment. A useful empirical strategy is to look at the growth of a country's export sophistication. Holding constant the initial levels of export sophistication, would those that have an unusually fast increase in sophistication also have an unusually high rate of economic growth?

In Table 6**,** we rank the 49 countries in our sample, by descending order in the pace of the growth of its export sophistication. As a smell test, we pay particular attention to where Ireland and China fit by this metric as both countries are often said to be examples of extensive government programs to promote industrial transformation toward high-tech industries. All five measures are able to capture China as having experienced a high level of changes in its export sophistication. But only the modified EXPY variable is able to capture both China and Ireland as having undergone a significant change in export sophistication during the period. This again strengthens our confidence in the relative adequacy of the modified EXPY against the original EXPY in capturing leapfrogging in industrial structure.

Table 7 displays the regression results with this specification for all five export sophistication measures and their changes over the period 1992-2003. The initial GDP level, human capital, and institution variable all have the correct signs. None of the export sophistication growth variables enters significantly into the regression. But the most conspicuous observation is the initial export sophistication measures: all but the EXPY variable is insignificant with this specification. In contrast to the previous specification, the ATP share is no longer significant either. This once again shows that when export sophistication is constructed in alternative ways, it no longer indicates significant impact on growth.

To summarize, these results raise skepticism of the view that leapfrogging leads to higher growth.

<u>Non-normality and non-linearity</u>

If the effect of leapfrog policies is not linear on log productivity, a potential omission bias will occur. Rodriguez (2007) shows that a linear regression of a nonlinear data generation process will only produce an average policy effect if the data generating process of the policy variable —in other words, the leapfrogging measure —are distributed according to a normal distribution. We therefore test the normality of leapfrogs. Observe that export sophistication can be decomposed into a function of factor endowments, leapfrog policies, and other factors:

Export sophistication = *f*(factor endowments, leapfrog policies, other factors).

The growth regression specification is:

$$\begin{aligned} LnGDPc_{it} - LnGDPc_{it-1} = \alpha_0 + \alpha_1 LnGDPc_{it-1} + \alpha_2 ExpSophis_{it-1} \\ + \alpha_3 HumanCap_{it-1} + \alpha_4 Institution_{it-1} + \omega_{it} \end{aligned} \tag{9}$$

The interpretation on $\alpha_2$ can be taken as the average impact of leapfrogging policies, since it represents the variation on export sophistication that is unexplained by human capital, institution variable, and the initial level of development—these three variables are already included as covariates in the regression. These covariates well capture the factor endowment and the other factor aspects of export sophistication. We reformulate the procedure to isolate the part of export sophistication that is not attributable to factor endowment and other factors as leapfrog policies.[4]

Stage 1: Isolate the variation due to leapfrogging. We interpret $\varepsilon_i$ as the portion of export sophistication attributable to government leapfrog policy:

$$ExpSophis_{it} = \beta_0 + \beta_1 LnGDPc_{it} + \beta_2 HumanCap_{it} + \beta_3 Institution_{it} + \xi_{it} \tag{10}$$

Stage 2: Growth regression

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[4] The results from the normality test would be the same regardless of whether one uses the isolated leapfrog variables or the export sophistication variables. We reformulate the variable here for clarity.

$$LnGDPc_{it} - LnGDPc_{it-1} = \gamma\xi_{it-1} + \nu_{it} \quad (11)$$

$\gamma$ is interpreted as the impact of leapfrogging on growth. It is the equivalent of $\alpha_2$ estimated from equation (1). We then set out to test the normality of the leapfrog variable. Table 8 displays the results from the Shapiro-Wilk and skewness/kurtosis tests of normality of variables. Normality in the distribution of EXPY and the ATP share variables would be comfortably rejected in both tests. On the other hand, the modified EXPY and EDI passed the normality test. We take away two messages from this exercise: First, a linear regression may not give a meaningful interpretation on the coefficient of EXPY, even if it otherwise correctly captures the degree of leapfrogging. Second, the modified EXPY appears to be a better regressor to use in the linear model from a pure statistical sense.

Panel regressions with instrumental variables

The cross section regressions assume that the productivity growth is the same for all countries except for the differences in the leapfrog policies. As an extension that relaxes this assumption, we turn to an panel analysis with separate country fixed effects. New challenges emerge with the panel analysis: one has to deal with shorter time intervals and has to have instrumental variables that have meaningful time series variations.

We propose to use the professional background and educational preparedness of the political leader as variables that may affect their choice of the economic strategy. Dreher, Lamla, Lein, and Somogyi (2008) constructed a database of the profession and education for more than 500 political leaders from 73 countries for the period 1970-2002. One set of dummies codify the educational background for the chief executives: law, economics, politics, natural science, and other. Another set of dummies codify the professions of the chief executives before they take office: entrepreneur, white collar, blue collar, union executive, and science, economics, law, military, politician, and others. We use this set of variables as instruments for export sophistication.

Table 9 shows the growth regression results for the long sample of 1970-2000, for using EXPY and EDI as measures of export sophistication. Unfortunately, we cannot use the ATP shares as they are not available for early years. Panel A shows the results for using EXPY as export sophistication. To compare with the analysis in Hausman et al, our sample starts a few years later (as opposed to their 1962-2000). Our OLS estimation closely replicates their estimates: the coefficient on initial GDP per capita is negative and significant at –0.001, and the coefficient on initial EXPY is positive and significant at 0.02, and the coefficient on human capital is positive and significant at 0.01. In the fixed effects and IV specifications, neither of the coefficients on initial EXPY is significant, despite the improved Hansen-J statistics given our set of instruments. The R-squared of our regression for the OLS case is more than twice as large as theirs, despite the similarities in the estimates. Panel B shows the results for the same regression except replacing EXPY with EDI. None of the export sophistication variables are significant, while the initial GDP per capita and human capital variables are both significant. We conclude that in the panel regressions, there is no strong and robust support for the notion that a leapfrogging strategy promotes growth.

## 5. What If Comparing Regions within a Single Country

Cross country analyses could suffer from a serious omitted variable bias: Countries differ in history, culture, legal system and other institutions and a myriad of other ways. There are always some such variables that are not properly controlled in the cross country regressions. If none of them is time-varying, then fixed effects in a panel regression would take care of them. If some of the are time-varying (and correlated with the export sophistication measures), then we cannot obtain a consistent estimate of the true effect of a leapfrogging strategy. Assuming these omitted country-level variables can be plausibly held constant within a country, one solution to this problem is to explore cross-regional variations within a single country. In our context, regions have to differ in their pursuit of a leapfrogging policy, and the country has to be relatively large so that enough statistical power is available from a cross-regional analysis.

In this section, we conduct such an analysis across cities in China. Specifically, at the city level, we compute the same set of export sophistication measures as before. In addition, we can pay attention to the role of processing trade, and imported ATP inputs that we could not do in a cross country analysis. Recent international trade literature (Koopman, Wang and Wei, 2008; Dean, Fung and Wang, 2009; De La Cruz et al., 2009) provide evidence that "export sophistication" in developing countries such as China and Mexico can be explained in large part by vertical specialization and global production fragmentation. The two ratios of ATP processing and total imports over ATP total exports in a city provide a very rough lower and higher bound for a proxy measure of the foreign content embodied in a Chinese city's total ATP exports, which may contribute directly to the sophistication of a city's exports.

By comparing the values of export sophistication measures against per capita Gross Metropolitan Product (GMP), we can infer which cities may be more aggressive in upgrading their economic structure (beyond their income level). In 1996, Wuxi, Zhuhai, and Tianjian can be identified as ahead of other cities in terms of advanced technological goods exports. By 2006, however, Shenzhen, Xiamen, Dongguan, Shanghai, and Guangzhou are among the cities that had risen according to the leapfrog measure. How sensible is this leapfrog measure in identifying the cities where the government had installed favorable industrial policy? All the aforementioned cities and other cities that had experienced a rise in their leapfrog measure, with the exception of Dongguan, were established as export processing zones between 2001 and 2002 and Hi-Technology Industry Development Areas between 1996 to 1997.[5] Overall, the leapfrog measures seem to be able to consistent with regional variations in local government policies in favor of high tech industries in the local economies.

We now turn to a formal regression analysis.[6] The results are reported in Table 10. Most coefficients of export sophistication measures are not statistically significant; the exceptions are the ATP (narrow) share and the modified EXPY. However, the coefficient on the modified EXPY is negative. In other words, if a leapfrogging strategy has an effect on local growth, the effect is negative. In any case, the significance of the modified EXPY variable disappears after adding the leapfrog growth as a covariate.

For both sets of regressions, there is no clear evidence of a conditional convergence, unlike the cross-country analyses reported in the earlier sections. The variation in growth across cities explained is low; The R-squared ranges from 0.04 to 0.06 in Table 10. The Shapiro-Wilk tests of normality for the export sophistication measures reject normality for all of them, suggesting that some non-linearity is likely present in the data generating process. We also supplemented the cross section results with panel analysis for the period 1996-2005, sampling 3 years for each city, and report the results in Table 11. The coefficients for the six leapfrog policy variables

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[5] Wang and Wei (2008) report the years of establishment of economic zones (SEZ, economic & tech development area, Hi-Tech industry development area, Export processing zone) in China in their Appendix Table 2.

[6] Eight major cities had redrawn their administration area during the sample period. They are Nanning, LiuZhou, Fuyang, Haikou, Chongqing, Kunming, Xinning, and Yinchuan. Thus we also reestimated the regressions to include the interaction of these eight cities with the export sophistication variable on the right hand side. But the general results don't change.

across three regression specifications are insignificant except for one specification for EXPY and the IV specification for EDI. To summarize, across cities in China, there is no strong case supporting a robust and positive causal effect of leapfrogging on economic growth.

## 6. Conclusion

To be able to transform an economy's economic structure ahead of its income level toward higher domestic value added and more sophisticated sectors is desirable in abstract. Many governments have pursued policies to bring out such transformations. To be sure, there are examples of individual success cases – promotion of a certain industry by government policies that result in an expansion of that industry. However, any such policy promotion takes away resources from other industries, especially those that are consistent with the country's factor endowment and level of development. On balance, the effect is conceptually less clear. Given the popularity of such leapfrogging strategies, it is important to evaluate empirically if they work. Unfortunately, such an evaluation is difficult because it is not straightforward to quantify the degree of leapfrogging an economy may exhibit. Typical data on production structures are not refined enough. Most relevant policies are not easily quantifiable or comparable across countries.

One way to gauge the degree of leapfrogging is by inferring from a country's detailed export data. This paper pursues this strategy. It develops a number of different ways to measure leapfrogging from revealed sophistication in a country's exports, recognizing that any particular measure may have both advantages and shortcomings.

After a whole battery of analyses, a succinct summary of the findings is a lack of strong and robust support for the notion that a leapfrogging industrial policy can reliably raise economic growth. Again, there may be individual success stories. But there are failures. If leapfrogging is a policy gamble, there is no systematic evidence that suggests that the odd is favorable.

We conclude by noting again two distinct aspects of a growth model that embraces the world market. The first aspect is export orientation – an investment environment with few policy impediments to firms participating in international trade. While this paper does not reproduce the vast quantity of analysis on this, we do not doubt its validity. The second aspect of is leapfrogging – the use of policy instruments to engineer a faster industrial transformation than what may emerge naturally based on an economy's stage of development and factor endowment. We cast some doubt on how effective such strategy is empirically.

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Table 1: Replicating Hausman et al Cross National Growth Regressions with EXPY, 1992-2003

**Dependent variable: growth rate of GDP per capita over 1992-2003**

| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** | **(11)** | **(12)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | OLS | OLS | OLS | OLS | OLS | IV | IV | IV | IV | IV | IV |
| log initial GDP/cap | -0.011 | -0.02 | -0.025 | -0.026 | -0.03 | -0.023 | -0.009 | -0.017 | -0.025 | -0.025 | -0.024 | -0.02 |
| | [0.005]* | [0.007]** | [0.007]** | [0.006]** | [0.007]** | [0.007]** | [0.006] | [0.011] | [0.012]* | [0.010]* | [0.011]* | [0.012] |
| log initial EXPY | 0.036 | 0.029 | 0.025 | 0.019 | 0.03 | 0.027 | 0.031 | 0.023 | 0.023 | 0.016 | 0.025 | 0.023 |
| | [0.011]** | [0.011]* | [0.010]* | [0.010] | [0.010]** | [0.011]* | [0.014]* | [0.015] | [0.012] | [0.011] | [0.013] | [0.014] |
| log human capital | | 0.033 | 0.028 | 0.026 | 0.021 | 0.029 | | 0.03 | 0.029 | 0.024 | 0.016 | 0.029 |
| | | [0.012]* | [0.012]* | [0.010]* | [0.010]* | [0.013]* | | [0.017] | [0.015]* | [0.012]* | [0.012] | [0.016] |
| corruption | | | 0.008 | | | | | | 0.008 | | | |
| | | | [0.003]* | | | | | | [0.004] | | | |
| government effectiveness | | | | 0.013 | | | | | | 0.013 | | |
| | | | | [0.003]** | | | | | | [0.004]** | | |
| regulation quality | | | | | 0.021 | | | | | | 0.018 | |
| | | | | | [0.005]** | | | | | | [0.006]** | |
| cpi score | | | | | | 0.002 | | | | | | 0.001 |
| | | | | | | [0.001] | | | | | | [0.002] |
| Constant | -0.193 | -0.114 | -0.023 | 0.041 | -0.029 | -0.066 | -0.168 | -0.079 | -0.014 | 0.054 | -0.019 | -0.057 |
| | [0.066]** | [0.072] | [0.065] | [0.074] | [0.061] | [0.070] | [0.078]* | [0.080] | [0.064] | [0.069] | [0.062] | [0.072] |
| Observations | 52 | 42 | 42 | 42 | 42 | 42 | 52 | 42 | 42 | 42 | 42 | 42 |
| R-squared | 0.24 | 0.35 | 0.41 | 0.5 | 0.53 | 0.38 | | | | | | |
| Hansen J | | | | | | | 0.93 | 1.69 | 1.61 | 0.82 | 0.35 | 1.95 |
| Chi-sq p-value | | | | | | | 0.33 | 0.19 | 0.2 | 0.36 | 0.56 | 0.16 |

Table 2: Alternative Measure of Export Sophistication – Unit Value Adjusted Implied Income in the Export Bundle: Modified EXPY, 1992-2003

| **Dependent variable: growth rate of GDP per capita over 1992-2003** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| | OLS | OLS | OLS | OLS | OLS | OLS | IV | IV | IV | IV | IV | IV |
| log initial GDP/cap | -0.004 | -0.016 | -0.02 | -0.023 | -0.022 | -0.018 | -0.005 | -0.017 | -0.032 | -0.034 | -0.031 | -0.022 |
| | [0.004] | [0.006]* | [0.006]** | [0.006]** | [0.007]** | [0.006]** | [0.005] | [0.011] | [0.017] | [0.012]** | [0.013]* | [0.016] |
| log initial modified EXPY | 0.011 | 0.009 | 0.004 | -0.001 | 0.004 | 0.006 | 0.012 | 0.01 | 0.006 | -0.001 | 0.005 | 0.008 |
| | [0.004]** | [0.006] | [0.006] | [0.006] | [0.007] | [0.006] | [0.004]** | [0.006] | [0.006] | [0.006] | [0.006] | [0.006] |
| log human capital | | 0.033 | 0.03 | 0.027 | 0.025 | 0.031 | | 0.035 | 0.041 | 0.038 | 0.033 | 0.035 |
| | | [0.014]* | [0.013]* | [0.011]* | [0.012] | [0.014]* | | [0.023] | [0.024] | [0.016]* | [0.018] | [0.024] |
| corruption | | | 0.009 | | | | | | 0.013 | | | |
| | | | [0.003]* | | | | | | [0.009] | | | |
| government effectiveness | | | | 0.016 | | | | | | 0.021 | | |
| | | | | [0.004]** | | | | | | [0.007]** | | |
| regulation quality | | | | | 0.019 | | | | | | 0.024 | |
| | | | | | [0.007]* | | | | | | [0.010]* | |
| cpi score | | | | | | 0.002 | | | | | | 0.002 |
| | | | | | | [0.002] | | | | | | [0.003] |
| Constant | -0.024 | 0.037 | 0.123 | 0.195 | 0.144 | 0.077 | -0.023 | 0.038 | 0.188 | 0.264 | 0.193 | 0.085 |
| | [0.029] | [0.043] | [0.052]* | [0.061]** | [0.052]** | [0.050] | [0.029] | [0.048] | [0.125] | [0.103]* | [0.086]* | [0.089] |
| Observations | 52 | 42 | 42 | 42 | 42 | 42 | 52 | 42 | 42 | 42 | 42 | 42 |
| R-squared | 0.17 | 0.28 | 0.34 | 0.45 | 0.4 | 0.3 | | | | | | |
| Hansen J | | | | | | | 0.11 | 1.05 | 1.22 | 0.66 | 0.13 | 1.49 |
| Chi-sq p-value | | | | | | | 0.74 | 0.31 | 0.27 | 0.42 | 0.72 | 0.22 |

Robust standard errors in brackets; Instruments for IV regressions are log(population) and log(land) ; * significant at 5%; ** significant at 1%

Table 3: Cross National Growth Regressions with ATP Share (narrow), 1992-2003

| **Dependent variable: growth rate of GDP per capita over 1992-2003** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| | OLS | OLS | OLS | OLS | OLS | OLS | IV | IV | IV | IV | IV | IV |
| log initial GDP/cap | -0.002 | -0.015 | -0.021 | -0.023 | -0.022 | -0.019 | -0.008 | -0.017 | -0.033 | -0.026 | -0.03 | -0.026 |
| | [0.003] | [0.006]* | [0.007]** | [0.007]** | [0.007]** | [0.007]* | [0.006] | [0.015] | [0.019] | [0.014] | [0.020] | [0.020] |
| initial ATP share (narrow) | 0.087 | 0.076 | 0.069 | 0.049 | 0.056 | 0.07 | 0.112 | 0.083 | 0.077 | 0.05 | 0.055 | 0.081 |
| | [0.026]** | [0.027]** | [0.024]** | [0.027] | [0.023]* | [0.025]** | [0.034]** | [0.030]** | [0.022]** | [0.025]* | [0.022]* | [0.024]** |
| log human capital | | 0.036 | 0.03 | 0.027 | 0.026 | 0.031 | | 0.041 | 0.042 | 0.03 | 0.035 | 0.039 |
| | | [0.014]* | [0.013]* | [0.011]* | [0.013] | [0.014]* | | [0.032] | [0.023] | [0.018] | [0.023] | [0.026] |
| corruption | | | 0.009 | | | | | | 0.015 | | | |
| | | | [0.003]** | | | | | | [0.009] | | | |
| government effectiveness | | | | 0.014 | | | | | | 0.015 | | |
| | | | | [0.004]** | | | | | | [0.008]* | | |
| regulation quality | | | | | 0.018 | | | | | | 0.024 | |
| | | | | | [0.006]** | | | | | | [0.015] | |
| cpi score | | | | | | 0.003 | | | | | | 0.004 |
| | | | | | | [0.002] | | | | | | [0.004] |
| Constant | 0.054 | 0.098 | 0.164 | 0.181 | 0.172 | 0.129 | 0.105 | 0.112 | 0.241 | 0.198 | 0.225 | 0.173 |
| | [0.030] | [0.036]** | [0.045]** | [0.043]** | [0.042]** | [0.044]** | [0.056] | [0.071] | [0.119]* | [0.088]* | [0.124] | [0.111] |
| Observations | 52 | 42 | 42 | 42 | 42 | 42 | 52 | 42 | 42 | 42 | 42 | 42 |
| R-squared | 0.13 | 0.32 | 0.41 | 0.49 | 0.44 | 0.36 | | | | | | |
| Hansen J | | | | | | | 0 | 0.59 | 0.16 | 0.02 | 0.07 | 0.72 |
| Chi-sq p-value | | | | | | | 0.97 | 0.44 | 0.69 | 0.88 | 0.78 | 0.4 |

Robust standard errors in brackets; Instruments for IV regressions are log(population) and log(land) ; * significant at 5%; ** significant at 1%

Table 4: Cross National Growth Regressions with ATP Share (broad), 1992-2003

| **Dependent variable: growth rate of GDP per capita over 1992-2003** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| | OLS | OLS | OLS | OLS | OLS | OLS | IV | IV | IV | IV | IV | IV |
| log initial GDP/cap | -0.002 | -0.014 | -0.021 | -0.023 | -0.023 | -0.019 | -0.007 | -0.018 | -0.033 | -0.028 | -0.03 | -0.027 |
| | [0.004] | [0.006]* | [0.007]** | [0.006]** | [0.007]** | [0.007]* | [0.006] | [0.014] | [0.017] | [0.013]* | [0.017] | [0.018] |
| initial ATP share (broad) | 0.056 | 0.041 | 0.035 | 0.019 | 0.031 | 0.036 | 0.074 | 0.049 | 0.046 | 0.022 | 0.034 | 0.048 |
| | [0.022]* | [0.026] | [0.023] | [0.023] | [0.020] | [0.024] | [0.028]** | [0.028] | [0.020]* | [0.020] | [0.020] | [0.022]* |
| log human capital | | 0.036 | 0.029 | 0.027 | 0.025 | 0.031 | | 0.044 | 0.041 | 0.031 | 0.032 | 0.039 |
| | | [0.014]* | [0.013]* | [0.011]* | [0.013] | [0.014]* | | [0.030] | [0.023] | [0.018] | [0.021] | [0.026] |
| corruption | | | 0.01 | | | | | | 0.015 | | | |
| | | | [0.003]** | | | | | | [0.008] | | | |
| government effectiveness | | | | 0.015 | | | | | | 0.017 | | |
| | | | | [0.004]** | | | | | | [0.007]* | | |
| regulation quality | | | | | 0.019 | | | | | | 0.024 | |
| | | | | | [0.006]** | | | | | | [0.012] | |
| cpi score | | | | | | 0.003 | | | | | | 0.004 |
| | | | | | | [0.002] | | | | | | [0.003] |
| Constant | 0.055 | 0.097 | 0.164 | 0.183 | 0.178 | 0.129 | 0.094 | 0.118 | 0.244 | 0.212 | 0.222 | 0.18 |
| | [0.032] | [0.036]* | [0.045]** | [0.041]** | [0.043]** | [0.044]** | [0.049] | [0.067] | [0.108]* | [0.082]** | [0.104]* | [0.101] |
| Observations | 52 | 42 | 42 | 42 | 42 | 42 | 52 | 42 | 42 | 42 | 42 | 42 |
| R-squared | 0.09 | 0.26 | 0.36 | 0.46 | 0.41 | 0.31 | | | | | | |
| Robust standard errors in brackets | | | | | | | | | | | | |
| * significant at 5%; ** significant at 1% | | | | | | | | | | | | |
| Hansen J | | | | | | | 0.03 | 1.2 | 0.48 | 0.23 | 0.01 | 1.34 |
| Chi-sq p-value | | | | | | | 0.85 | 0.27 | 0.49 | 0.63 | 0.91 | 0.25 |

Robust standard errors in brackets; Instruments for IV regressions are log(population) and log(land) ; * significant at 5%; ** significant at 1%

Table 5: Cross National Growth Regressions with EDI, 1992-2003

| Dependent variable: growth rate of GDP per capita over 1992-2003 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| | OLS | OLS | OLS | OLS | OLS | OLS | IV | IV | IV | IV | IV | IV |
| log initial GDP/cap | -0.005 | -0.017 | -0.024 | -0.026 | -0.025 | -0.021 | -0.007 | -0.02 | -0.035 | -0.034 | -0.03 | -0.031 |
| | [0.004] | [0.007]* | [0.007]** | [0.006]** | [0.007]** | [0.007]** | [0.004] | [0.008]* | [0.010]** | [0.008]** | [0.011]** | [0.009]** |
| log initial EDI | -0.025 | -0.011 | -0.001 | 0.008 | -0.007 | -0.002 | -0.029 | -0.012 | -0.011 | 0.002 | -0.01 | -0.011 |
| | [0.012]* | [0.014] | [0.012] | [0.010] | [0.014] | [0.013] | [0.015]* | [0.017] | [0.014] | [0.011] | [0.015] | [0.015] |
| log human capital | | 0.038 | 0.029 | 0.027 | 0.026 | 0.03 | | 0.044 | 0.043 | 0.036 | 0.031 | 0.044 |
| | | [0.014]** | [0.013]* | [0.011]* | [0.013]* | [0.014]* | | [0.019]* | [0.017]* | [0.014]* | [0.016] | [0.018]* |
| corruption | | | 0.012 | | | | | | 0.016 | | | |
| | | | [0.004]** | | | | | | [0.005]** | | | |
| government effectiveness | | | | 0.018 | | | | | | 0.021 | | |
| | | | | [0.004]** | | | | | | [0.005]** | | |
| regulation quality | | | | | 0.019 | | | | | | 0.023 | |
| | | | | | [0.007]** | | | | | | [0.010]* | |
| cpi score | | | | | | 0.004 | | | | | | 0.005 |
| | | | | | | [0.002]* | | | | | | [0.002]* |
| Constant | 0.213 | 0.174 | 0.195 | 0.165 | 0.233 | 0.162 | 0.248 | 0.197 | 0.318 | 0.246 | 0.286 | 0.264 |
| | [0.081]* | [0.104] | [0.095]* | [0.083] | [0.108]* | [0.097] | [0.103]* | [0.122] | [0.114]** | [0.085]** | [0.130]* | [0.111]* |
| Observations | 52 | 41 | 41 | 41 | 41 | 41 | 52 | 41 | 41 | 41 | 41 | 41 |
| R-squared | 0.09 | 0.23 | 0.37 | 0.48 | 0.36 | 0.31 | | | | | | |
| Hansen J | | | | | | | 0.97 | 1.36 | 1.26 | 0.39 | 0.15 | 2.08 |
| Chi-sq p-value | | | | | | | 0.33 | 0.24 | 0.26 | 0.53 | 0.7 | 0.15 |

Robust standard errors in brackets; Instruments for IV regressions are log(population) and log(land) ; * significant at 5%; ** significant at 1%

Table 6: Ranking Growth in Export Sophistication, 1992-2003

| Ranking | Country | EXPY | Country | Modified EXPY | Country | ATP (narrow) | Country | ATP (broad) | Country | EDI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hungary | 3.14 | Ireland | 5.54 | Malaysia | 1.50 | Malaysia | 2.01 | Australia | -2.32 |
| 2 | Bangladesh | 3.12 | Hungary | 4.44 | Iceland | 1.41 | Hungary | 1.93 | Korea, Rep. | -1.70 |
| 3 | Kenya | 3.05 | Madagascar | 4.38 | China | 1.20 | China | 1.88 | Oman | -1.56 |
| 4 | Madagascar | 2.78 | Kenya | 3.55 | Singapore | 1.09 | Finland | 1.31 | Hungary | -1.50 |
| 5 | Korea, Rep. | 2.10 | Ecuador | 3.41 | Netherlands | 0.88 | Singapore | 1.10 | Mexico | -1.46 |
| 6 | Thailand | 2.07 | Indonesia | 3.22 | Hungary | 0.56 | Korea, Rep. | 1.09 | Kenya | -1.45 |
| 7 | China | 2.03 | South Africa | 3.12 | Indonesia | 0.50 | Iceland | 1.08 | Greece | -1.42 |
| 8 | Trinidad and Tobago | 1.96 | Bangladesh | 3.04 | Thailand | 0.49 | Netherlands | 1.04 | Thailand | -1.40 |
| 9 | Paraguay | 1.89 | Singapore | 3.01 | Korea, Rep. | 0.40 | Indonesia | 0.95 | Indonesia | -1.38 |
| 10 | Singapore | 1.83 | China | 2.98 | Mexico | 0.33 | Mexico | 0.93 | Turkey | -1.35 |
| 11 | Turkey | 1.82 | Brunei | 2.98 | Portugal | 0.33 | Thailand | 0.70 | Portugal | -1.28 |
| 12 | Colombia | 1.50 | Turkey | 2.91 | St. Lucia | 0.20 | Greece | 0.64 | Ecuador | -1.09 |
| 13 | Iceland | 1.40 | Malaysia | 2.87 | Tunisia | 0.16 | Croatia | 0.61 | China | -1.02 |
| 14 | Malaysia | 1.37 | Thailand | 2.61 | Switzerland | 0.15 | Switzerland | 0.59 | India | -1.00 |
| 15 | Cyprus | 1.30 | Korea, Rep. | 2.29 | Australia | 0.15 | Brazil | 0.54 | Spain | -0.98 |
| 16 | Bolivia | 1.24 | Greece | 2.05 | Finland | 0.15 | Denmark | 0.49 | Saudi Arabia | -0.96 |
| 17 | Portugal | 1.24 | Portugal | 1.96 | Bolivia | 0.13 | Portugal | 0.45 | Malaysia | -0.79 |
| 18 | Croatia | 1.16 | Cyprus | 1.94 | Sweden | 0.13 | St. Lucia | 0.42 | Colombia | -0.73 |
| 19 | Greece | 1.15 | Colombia | 1.78 | Greece | 0.11 | Australia | 0.39 | Sweden | -0.63 |
| 20 | Finland | 1.12 | Tunisia | 1.75 | Kenya | 0.09 | New Zealand | 0.39 | Denmark | -0.59 |
| 21 | India | 1.08 | Croatia | 1.70 | Croatia | 0.09 | Paraguay | 0.30 | Paraguay | -0.55 |
| 22 | Ecuador | 1.01 | Mexico | 1.67 | India | 0.08 | Tunisia | 0.26 | New Zealand | -0.54 |
| 23 | Mexico | 0.99 | Iceland | 1.41 | New Zealand | 0.08 | Sweden | 0.24 | Romania | -0.51 |
| 24 | Indonesia | 0.90 | Sri Lanka | 1.35 | Denmark | 0.07 | Romania | 0.21 | Iceland | -0.50 |
| 25 | Sri Lanka | 0.86 | New Zealand | 1.24 | Cyprus | 0.05 | Kenya | 0.20 | St. Lucia | -0.48 |
| 26 | South Africa | 0.86 | St. Lucia | 1.15 | Romania | 0.05 | India | 0.15 | Brazil | -0.46 |
| 27 | Switzerland | 0.65 | Australia | 1.06 | Algeria | 0.04 | Bolivia | 0.14 | Cyprus | -0.46 |
| 28 | Australia | 0.63 | India | 1.06 | Saudi Arabia | 0.03 | Algeria | 0.14 | Japan | -0.43 |
| 29 | New Zealand | 0.54 | Netherlands | 1.04 | Paraguay | 0.03 | Saudi Arabia | 0.10 | Tunisia | -0.42 |
| 30 | Oman | 0.52 | Switzerland | 0.98 | Ecuador | 0.03 | Turkey | 0.08 | South Africa | -0.40 |
| 31 | Ireland | 0.31 | Finland | 0.93 | Peru | 0.01 | Chile | 0.05 | Croatia | -0.39 |
| 32 | Brazil | 0.27 | Denmark | 0.91 | Chile | 0.01 | Spain | 0.03 | Sri Lanka | -0.37 |
| 33 | Tunisia | 0.27 | Bolivia | 0.88 | Turkey | 0.01 | Peru | 0.02 | Canada | -0.36 |
| 34 | Denmark | 0.27 | Paraguay | 0.80 | Bangladesh | 0.00 | Japan | 0.02 | Peru | -0.31 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 35 | Japan | 0.25 | Spain | 0.67 | South Africa | 0.00 | Bangladesh | 0.01 | Singapore | -0.25 |
| 36 | Sweden | 0.25 | Peru | 0.66 | Belize | 0.00 | Belize | 0.01 | Bolivia | -0.22 |
| 37 | Netherlands | 0.20 | Brazil | 0.24 | Trinidad and Tobago | 0.00 | Trinidad and Tobago | 0.00 | Algeria | -0.07 |
| 38 | St. Lucia | 0.20 | Japan | 0.24 | Brunei | 0.00 | Canada | 0.00 | Brunei | -0.01 |
| 39 | Spain | 0.20 | Sweden | 0.17 | Jamaica | 0.00 | Brunei | 0.00 | Bangladesh | -0.01 |
| 40 | Canada | 0.17 | Algeria | 0.11 | Spain | -0.01 | Jamaica | -0.01 | Netherlands | 0.00 |
| 41 | Chile | 0.07 | Chile | 0.09 | Japan | -0.01 | Ecuador | -0.02 | Chile | 0.00 |
| 42 | Algeria | 0.01 | Macao | -0.22 | Colombia | -0.02 | Madagascar | -0.02 | Switzerland | 0.01 |
| 43 | Brunei | -0.03 | Canada | -0.37 | Madagascar | -0.02 | Sri Lanka | -0.03 | Belize | 0.02 |
| 44 | Saudi Arabia | -0.07 | Belize | -0.42 | Brazil | -0.03 | Cyprus | -0.05 | Trinidad and Tobago | 0.04 |
| 45 | Jamaica | -0.25 | Saudi Arabia | -0.50 | Sri Lanka | -0.04 | Colombia | -0.05 | Finland | 0.11 |
| 46 | Macao | -0.40 | Oman | -0.51 | Macao | -0.06 | Ireland | -0.08 | Madagascar | 0.14 |
| 47 | Romania | -0.68 | Romania | -0.91 | Ireland | -0.15 | South Africa | -0.10 | Jamaica | 0.16 |
| 48 | Peru | -0.84 | Trinidad and Tobago | -2.74 | Canada | -0.24 | Macao | -0.13 | Ireland | 0.34 |
| 49 | Belize | -1.09 | Jamaica | -3.17 | Oman | -0.25 | Oman | -0.23 | Macao | 0.48 |

Table 7: Cross National Growth Regression, with Growth in Export Sophistication

| **Dependent variable: growth in real GDP per capita, 1992-2003** | | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Log initial GDP per capita | -0.028 | -0.02 | -0.02 | -0.02 | -0.02 |
| | [0.005]** | [0.005]** | [0.005]** | [0.005]** | [0.005]** |
| Human Capital | 0.016 | 0.021 | 0.022 | 0.019 | 0.023 |
| | [0.010] | [0.011] | [0.010]* | [0.010] | [0.011] |
| Regulation quality | 0.018 | 0.015 | 0.015 | 0.016 | 0.018 |
| | [0.006]** | [0.007]* | [0.006]* | [0.006]* | [0.007]* |
| Log initial EXPY | 0.032 | | | | |
| | [0.009]** | | | | |
| Growth in log EXPY | 0.252 | | | | |
| | [0.240] | | | | |
| Log initial modified EXPY | | 0.005 | | | |
| | | [0.005] | | | |
| Growth in log modified EXPY | | 0.081 | | | |
| | | [0.153] | | | |
| initial ATP share (narrow) | | | 0.04 | | |
| | | | [0.031] | | |
| Growth in ATP share (narrow) | | | 0.891 | | |
| | | | [0.567] | | |
| initial ATP share (broad) | | | | 0.026 | |
| | | | | [0.023] | |
| Growth in ATP share (broad) | | | | 0.731 | |
| | | | | [0.388] | |
| initial log EDI | | | | | -0.001 |
| | | | | | [0.015] |
| Growth in log EDI | | | | | -0.003 |
| | | | | | [0.407] |
| Constant | -0.06 | 0.12 | 0.16 | 0.162 | 0.17 |
| | [0.070] | [0.052]* | [0.033]** | [0.033]** | [0.095] |
| Observations | 41 | 41 | 41 | 41 | 39 |
| R-squared | 0.51 | 0.36 | 0.44 | 0.43 | 0.33 |

Robust standard errors in brackets; * significant at 5%; ** significant at 1%

Table 8: Test for Normality

**Shapiro-Wilk W Test for Normal Data**

| Variable | Obs | W | V | z | Prob>z |
|---|---|---|---|---|---|
| log EXPY | 42.00 | 0.94 | 2.41 | 1.86 | 0.03 |
| log Modified EXPY | 42.00 | 0.96 | 1.47 | 0.81 | 0.21 |
| ATP (narrow) | 42.00 | 0.76 | 9.86 | 4.83 | 0.00 |
| ATP (broad) | 42.00 | 0.87 | 5.34 | 3.53 | 0.00 |
| log ATP | 41.00 | 0.99 | 0.59 | -1.13 | 0.87 |

**Skewness/Kurtosis Tests for Normality**

| Variable | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | Prob>chi2 |
|---|---|---|---|---|
| log EXPY | 0.028 | 0.192 | 6.09 | 0.0475 |
| log Modified EXPY | 0.131 | 0.894 | 2.44 | 0.2946 |
| ATP (narrow) | 0 | 0.004 | 19.43 | 0.0001 |
| ATP (broad) | 0.001 | 0.074 | 11.16 | 0.0038 |
| log ATP | 0.491 | 0.926 | 0.5 | 0.78 |

Table 9: Long sample, Panel Regressions with Fixed Effects

A. EXPY

| 5-year panels | | | |
|---|---|---|---|
| | **(1)** | **(2)** | **(3)** |
| | OLS | FE | IV |
| log initial GDP/cap | -0.0103 | -0.0479 | -0.0113 |
| | [0.0027]** | [0.0060]** | [0.0104] |
| log initial EXPY | 0.0208 | 0.0027 | 0.0223 |
| | [0.0055]** | [0.0091] | [0.0423] |
| log human capital | 0.0116 | -0.0102 | 0.0088 |
| | [0.0027]** | [0.0065] | [0.0078] |
| Constant | -0.059 | 0.3688 | -0.0573 |
| | [0.0379] | [0.0788]** | [0.3033] |
| Observations | 640 | 640 | 369 |
| R-squared | 0.39 | 0.47 | |
| First stage F stat | | | 1.35 |
| Hansen J-statistics (p-value) | | | 0.186 |

B. EDI

| **5-year panels** | | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | OLS | FE | IV |
| log initial GDP/cap | -0.0065 | -0.0517 | -0.0097 |
| | [0.0026]* | [0.0062]** | [0.0054] |
| Initial log EDI | -0.0117 | 0.004 | -0.0271 |
| | [0.0071] | [0.0191] | [0.0180] |
| log human capital | 0.0128 | -0.0256 | 0.0081 |
| | [0.0030]** | [0.0079]** | [0.0041]* |
| Constant | 0.1555 | 0.4266 | 0.2709 |
| | [0.0473]** | [0.1136]** | [0.1222]* |
| Observations | 475 | 475 | 314 |
| R-squared | 0.43 | 0.59 | |
| First stage F stat | | | 3.08 |
| Hansen J-statistics (p-value) | | | 0.089 |

* significant at 5%; ** significant at 1%; Robust standard errors in brackets; The instruments are professions and educational background of political leaders from Dreher, Lamla, Lein, and Somogyi (2008).

Table 10: Cross section Growth Regressions, Chinese Cities (1997-2006)

| **Dependent variable: growth rate over 1997-2006** | | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (4) | (6) | (8) | (10) |
| | OLS | OLS | OLS | OLS | OLS | OLS |
| log initial GDP/cap | 0.0089 | 0.0095 | 0.0103 | 0.0096 | 0.0094 | 0.0065 |
| | [0.0050] | [0.0051] | [0.0049]* | [0.0051] | [0.0050] | [0.0057] |
| initial Human Capital | 0.1505 | 0.1372 | 0.153 | 0.135 | 0.1624 | 0.1045 |
| | [0.1501] | [0.1484] | [0.1489] | [0.1488] | [0.1468] | [0.1528] |
| SEZdummy | -0.0053 | -0.0046 | -0.0028 | -0.0039 | -0.0036 | -0.0068 |
| | [0.0080] | [0.0079] | [0.0079] | [0.0081] | [0.0078] | [0.0089] |
| log initial ATP share (narrow) | 0.0549 | | | | | |
| | [0.0215]* | | | | | |
| log initial ATP share (broad) | | 0.0103 | | | | |
| | | [0.0158] | | | | |
| log initial ATP share (G3) | | | -0.0354 | | | |
| | | | [0.0248] | | | |
| log initial EXPY | | | | -0.0073 | | |
| | | | | [0.0077] | | |
| log initial modified EXPY | | | | | -0.0084 | |
| | | | | | [0.0030]** | |
| log initial EDI | | | | | | -0.0556 |
| | | | | | | [0.0623] |
| Constant | 0.0257 | 0.0197 | 0.0145 | 0.0867 | 0.0972 | 0.339 |
| | [0.0426] | [0.0434] | [0.0418] | [0.0845] | [0.0536] | [0.3527] |
| Observations | 209 | 209 | 208 | 208 | 208 | 208 |
| R-squared | 0.04 | 0.04 | 0.06 | 0.04 | 0.06 | 0.04 |

Robust standard errors in brackets; * significant at 5%; ** significant at 1%

Table 11: Panel Growth Regressions, Chinese Cities (1996-2005)

**3-year panels**

| | (1) OLS | (2) FE | (3) IV | (4) OLS | (5) FE | (6) IV | (7) OLS | (8) FE | (9) IV |
|---|---|---|---|---|---|---|---|---|---|
| log initial GDP/cap | 0.0042 | -0.2007 | 0.0337 | 0.0044 | -0.2013 | -0.0004 | 0.0038 | -0.2038 | 0.0107 |
| | [0.0049] | [0.0228]** | [0.0205] | [0.0048] | [0.0227]** | [0.0064] | [0.0049] | [0.0227]** | [0.0187] |
| human capital | 0.0373 | 0.0316 | -0.5121 | 0.0415 | 0.0363 | 0.0952 | 0.0477 | 0.0374 | -0.951 |
| | [0.1240] | [0.1947] | [0.3847] | [0.1228] | [0.1946] | [0.1271] | [0.1231] | [0.1946] | [1.4628] |
| initial ATP (narrow) | -0.0158 | -0.0426 | -1.5058 | | | | | | |
| | [0.0325] | [0.0733] | [0.9376] | | | | | | |
| initial ATP (broad) | | | | -0.0188 | -0.0096 | 0.113 | | | |
| | | | | [0.0160] | [0.0225] | [0.1406] | | | |
| initial ATP (G3) | | | | | | | -0.0036 | 0.0041 | 0.777 |
| | | | | | | | [0.0022] | [0.0037] | [1.1354] |
| Constant | 0.0653 | 1.972 | -0.1181 | 0.0644 | 1.9778 | 0.1432 | 0.0681 | 1.9997 | 0.0224 |
| | [0.0424] | [0.2051]** | [0.1616] | [0.0419] | [0.2047]** | [0.0532]** | [0.0428] | [0.2043]** | [0.1673] |
| Observations | 662 | 662 | 662 | 662 | 662 | 662 | 661 | 661 | 661 |
| R-squared | 0.32 | 0.55 | | 0.32 | 0.55 | | 0.32 | 0.55 | |
| Number of id | | 256 | | | 256 | | | 256 | |
| Hansen J (p-value) | | | 0.307 | | | 0.05 | | | 0.855 |

**3-year panels**

| | (10) OLS | (11) FE | (12) IV | (13) OLS | (14) FE | (15) IV | (16) OLS | (17) FE | (18) IV |
|---|---|---|---|---|---|---|---|---|---|
| log initial GDP/cap | 0.004 | -0.2072 | 0.0075 | 0.0044 | -0.2056 | 0.0068 | 0.0022 | -0.2019 | 0.044 |
| | [0.0049] | [0.0226]** | [0.0089] | [0.0049] | [0.0227]** | [0.0055] | [0.0058] | [0.0231]** | [0.0213]* |
| human capital | 0.0431 | 0.0418 | 0.0865 | 0.066 | 0.051 | 0.1945 | 0.0292 | 0.0368 | 0.3632 |
| | [0.1231] | [0.1937] | [0.1218] | [0.1211] | [0.1946] | [0.1468] | [0.1282] | [0.1960] | [0.2083] |
| initial log EXPY | -0.0028 | 0.0343 | -0.1094 | | | | | | |
| | [0.0117] | [0.0151]* | [0.1574] | | | | | | |
| initial log Modified EXPY | | | | -0.008 | 0.0086 | -0.0482 | | | |
| | | | | [0.0041] | [0.0055] | [0.0260] | | | |
| initial log EDI | | | | | | | -0.0307 | 0.0116 | 0.7304 |
| | | | | | | | [0.0531] | [0.1680] | [0.3678]* |
| Constant | 0.0928 | 1.71 | 1.0948 | 0.1353 | 1.9377 | 0.5175 | 0.2439 | 1.9219 | -4.0894 |
| | [0.1205] | [0.2362]** | [1.3989] | [0.0615]* | [0.2059]** | [0.2194]* | [0.3080] | [0.9396]* | [2.1198] |
| Observations | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 |
| R-squared | 0.32 | 0.56 | | 0.33 | 0.55 | | 0.32 | 0.55 | |
| Number of id | | 256 | | | 256 | | | 256 | |
| Hansen J (p-value) | | | 0.048 | | | 0.289 | | | 0.516 |

All regressions include time dummies and SEZ dummies. Standard errors in brackets. The instruments are log(land) and log(population) ; * significant at 5%; ** significant at 1%

**Appendix Table 1: HS products excluded from export data**

| HS Code | Description | HS Code | Description |
|---|---|---|---|
| 01-24 | Agricultural products | 25-27 | Mineral products |
| 4103 | Other raw hides and skins (fresh, o | 8002 | Tin waste and scrap. |
| 4104 | Tanned or crust hides and skins of | 8101 | Tungsten (wolfram) and articles the |
| 4105 | Tanned or crust skins of sheep or l | 8102 | Molybdenum and articles thereof, in |
| 4106 | Tanned or crust hides and skins of | 8103 | Tantalum and articles thereof, incl |
| 4402 | Wood charcoal (including shell or n | 8104 | Magnesium and articles thereof, inc |
| 4403 | Wood in the rough, whether or not s | 8105 | Cobalt mattes and other intermediate |
| 7201 | Pig iron and spiegeleisen in pigs, | 8106 | Bismuth and articles thereof, inclu |
| 7202 | Ferro-alloys. | 8107 | Cadmium and articles thereof, inclu |
| 7204 | Ferrous waste and scrap; remelting | 8108 | Titanium and articles thereof, incl |
| 7404 | Copper waste and scrap. | 8109 | Zirconium and articles thereof, inc |
| 7501 | Nickel mattes, nickel oxide sinters | 8110 | Antimony and articles thereof, incl |
| 7502 | Unwrought nickel. | 8111 | Manganese and articles thereof, inc |
| 7503 | Nickel waste and scrap. | 8112 | Beryllium, chromium, germanium, van |
| 7601 | Unwrought aluminium. | 8113 | Cermets and articles thereof, inclu |
| 7602 | Aluminium waste and scrap. | 9701 | Paintings, drawings and pastels, ex |
| 7801 | Unwrought lead. | 9702 | Original engravings, prints and lit |
| 7802 | Lead waste and scrap. | 9703 | Original sculptures and statuary, i |
| 7901 | Unwrought zinc. | 9704 | Postage or revenue stamps, stamp-po |
| 7902 | Zinc waste and scrap. | 9705 | Collections and collectors' pieces |
| 8001 | Unwrought tin. | 9706 | Antiques of an age exceeding one hundred years |
| 530521 | Coconut, abaca (Manila hemp or Musa | 811252 | Beryllium, chromium, germanium, van |

*Appendix Table 2: Countries (165) included in the sample used in cross country regression*

| Code | Reporting Country | No. Year reported | Code | Reporting Country | No. Year reported | Code | Reporting Country | No. Year reported |
|---|---|---|---|---|---|---|---|---|
| ABW | Aruba | 5 | GBR | United Kingdom | 14 | NCL | New Caledonia | 8 |
| AIA | Anguila | 6 | GEO | Georgia | 11 | NER | Niger | 11 |
| ALB | Albania | 11 | GHA | Ghana | 10 | NGA | Nigeria | 8 |
| AND | Andorra | 12 | GIN | Guinea | 8 | NIC | Nicaragua | 14 |
| ARG | Argentina | 14 | GMB | Gambia, The | 12 | NLD | Netherlands | 15 |
| ARM | Armenia | 9 | GRC | Greece | 15 | NOR | Norway | 14 |
| AUS | Australia | 15 | GRD | Grenada | 14 | NPL | Nepal | 5 |
| AUT | Austria | 13 | GRL | Greenland | 13 | NZL | New Zealand | 15 |
| AZE | Azerbaijan | 11 | GTM | Guatemala | 14 | OMN | Oman | 15 |
| BDI | Burundi | 14 | GUY | Guyana | 10 | PAK | Pakistan | 4 |
| BEL | Belgium | 8 | HKG | Hong Kong, China | 14 | PAN | Panama | 12 |
| BEN | Benin | 8 | HND | Honduras | 13 | PER | Peru | 14 |
| BFA | Burkina Faso | 10 | HRV | Croatia | 15 | PHL | Philippines | 11 |
| BGD | Bangladesh | 12 | HTI | Haiti | 6 | PNG | Papua New Guinea | 6 |
| BGR | Bulgaria | 11 | HUN | Hungary | 15 | POL | Poland | 13 |
| BHR | Bahrain | 7 | IDN | Indonesia | 15 | PRT | Portugal | 15 |
| BHS | Bahamas, The | 6 | IND | India | 15 | PRY | Paraguay | 15 |
| BIH | Bosnia and Herzegovina | 4 | IRL | Ireland | 15 | PYF | French Polynesia | 11 |
| BLR | Belarus | 9 | IRN | Iran, Islamic Rep. | 10 | QAT | Qatar | 7 |
| BLZ | Belize | 15 | ISL | Iceland | 15 | ROM | Romania | 15 |
| BOL | Bolivia | 15 | ISR | Israel | 12 | RUS | Russian Federation | 11 |
| BRA | Brazil | 15 | ITA | Italy | 13 | RWA | Rwanda | 10 |
| BRB | Barbados | 10 | JAM | Jamaica | 13 | SAU | Saudi Arabia | 14 |
| BRN | Brunei | 9 | JOR | Jordan | 12 | SDN | Sudan | 12 |
| BTN | Bhutan | 4 | JPN | Japan | 15 | SEN | Senegal | 11 |
| BWA | Botswana | 7 | KAZ | Kazakhstan | 7 | SER | Yugoslavia | 11 |
| CAF | Central African Republic | 13 | KEN | Kenya | 11 | SGP | Singapore | 15 |
| CAN | Canada | 15 | KGZ | Kyrgyz Republic | 9 | SLV | El Salvador | 13 |
| CHE | Switzerland | 15 | KHM | Cambodia | 5 | STP | Sao Tome and Principe | 8 |
| CHL | Chile | 15 | KIR | Kiribati | 6 | SUR | Suriname | 6 |
| CHN | China | 15 | KNA | St. Kitts and Nevis | 13 | SVK | Slovak Republic | 13 |
| CIV | Cote d'Ivoire | 12 | KOR | Korea, Rep. | 15 | SVN | Slovenia | 13 |
| CMR | Cameroon | 10 | LBN | Lebanon | 8 | SWE | Sweden | 15 |
| COK | Cook Islands | 4 | LCA | St. Lucia | 15 | SWZ | Swaziland | 6 |
| COL | Colombia | 15 | LKA | Sri Lanka | 9 | SYC | Seychelles | 11 |
| COM | Comoros | 10 | LSO | Lesotho | 5 | SYR | Syrian Arab Republic | 6 |
| CPV | Cape Verde | 10 | LTU | Lithuania | 13 | TCA | Turks and Caicos Isl. | 6 |
| CRI | Costa Rica | 13 | LUX | Luxembourg | 8 | TGO | Togo | 12 |
| CUB | Cuba | 8 | LVA | Latvia | 13 | THA | Thailand | 15 |
| CYP | Cyprus | 15 | MAC | Macao | 14 | TTO | Trinidad and Tobago | 15 |
| CZE | Czech Republic | 14 | MAR | Morocco | 14 | TUN | Tunisia | 15 |
| DEU | Germany | 15 | MDA | Moldova | 11 | TUR | Turkey | 15 |
| DMA | Dominica | 13 | MDG | Madagascar | 15 | TWN | Taiwan, China | 10 |
| DNK | Denmark | 15 | MDV | Maldives | 12 | TZA | Tanzania | 10 |
| DZA | Algeria | 15 | MEX | Mexico | 15 | UGA | Uganda | 13 |
| ECU | Ecuador | 15 | MKD | Macedonia, FYR | 13 | UKR | Ukraine | 11 |
| EGY | Egypt, Arab Rep. | 13 | MLI | Mali | 11 | URY | Uruguay | 13 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ESP | Spain | 15 | MLT | Malta | 13 | USA | United States | 15 |
| EST | Estonia | 12 | MNG | Mongolia | 11 | VCT | St. Vincent and the Grena | 14 |
| ETH | Ethiopia(excludes Eritrea | 11 | MOZ | Mozambique | 7 | VEN | Venezuela | 13 |
| FIN | Finland | 15 | MSR | Montserrat | 8 | VNM | Vietnam | 6 |
| FJI | Fiji | 6 | MUS | Mauritius | 14 | WSM | Samoa | 5 |
| FRA | France | 13 | MWI | Malawi | 13 | ZAF | South Africa | 15 |
| FRO | Faeroe Islands | 11 | MYS | Malaysia | 15 | ZMB | Zambia | 12 |
| GAB | Gabon | 13 | NAM | Namibia | 7 | ZWE | Zimbabwe | 6 |

**Appendix Table 3: Chinese cities included in the sample used in cross city regressions (259 in total)**

| Code | City | Province | Noyear | Code | City | Province | Noyear | Code | City | Province | Noyear |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1100 | BeijingCY | Beijing CY | 11 | 3404 | Huainan | Anhui | 11 | 4311 | Chenzhou | Hunan | 11 |
| 1200 | TianjinCY | Tianjin CY | 11 | 3405 | Maanshang | Anhui | 11 | 4313 | Huaihua | Hunan | 10 |
| 1301 | Shijiazhuang | Hebei | 11 | 3406 | Huaibei | Anhui | 11 | 4401 | Guangzhou | Guangdong | 11 |
| 1302 | Tangshan | Hebei | 11 | 3407 | Tongling | Anhui | 11 | 4402 | Shaoguan | Guangdong | 11 |
| 1303 | Qinhuangdao | Hebei | 11 | 3408 | Anqing | Anhui | 11 | 4403 | Shenzhen | Guangdong | 11 |
| 1304 | Handan | Hebei | 11 | 3409 | Huangshan | Anhui | 11 | 4404 | Zhuhai | Guangdong | 11 |
| 1305 | Xingtai | Hebei | 11 | 3410 | Fuyang | Anhui | 11 | 4405 | Shantou | Guangdong | 11 |
| 1306 | Baoding | Hebei | 11 | 3411 | Suxian | Anhui | 9 | 4406 | Foshan | Guangdong | 11 |
| 1307 | Zhangjiakou | Hebei | 11 | 3412 | Chuxian | Anhui | 11 | 4407 | Jiangmen | Guangdong | 11 |
| 1308 | Chongde | Hebei | 11 | 3413 | Liuan | Anhui | 8 | 4408 | Zhanjiang | Guangdong | 11 |
| 1309 | Changzhou | Hebei | 11 | 3414 | Xuancheng | Anhui | 7 | 4409 | Maoming | Guangdong | 11 |
| 1310 | Langfang | Hebei | 11 | 3415 | Chaohu | Anhui | 8 | 4412 | Zhaoqing | Guangdong | 11 |
| 1311 | Hengshui | Hebei | 11 | 3416 | Chizhou | Anhui | 7 | 4413 | Huizhou | Guangdong | 11 |
| 1401 | Taiyuan | Shanxi | 11 | 3501 | Fuzhou | Fujian | 11 | 4414 | Meizhou | Guangdong | 11 |
| 1402 | Datong | Shanxi | 11 | 3502 | Xiamen | Fujian | 11 | 4415 | Shanwei | Guangdong | 11 |
| 1403 | Yangquan | Shanxi | 11 | 3503 | Putian | Fujian | 11 | 4416 | Heyuan | Guangdong | 11 |
| 1404 | Changzhi | Shanxi | 11 | 3504 | Sanming | Fujian | 11 | 4417 | Yangjiang | Guangdong | 11 |
| 1405 | Jincheng | Shanxi | 11 | 3505 | Quanzhou | Fujian | 11 | 4418 | Qingyuan | Guangdong | 11 |
| 1406 | Suozhou | Shanxi | 11 | 3506 | Zhangzhou | Fujian | 11 | 4419 | Dongguan | Guangdong | 11 |
| 1408 | Xinzhou | Shanxi | 7 | 3507 | Nanpin | Fujian | 11 | 4420 | Zhongshan | Guangdong | 11 |
| 1410 | Jinzhong | Shanxi | 7 | 3508 | Ningde | Fujian | 7 | 4421 | Chaozhou | Guangdong | 11 |
| 1411 | Linfen | Shanxi | 7 | 3509 | Longyian | Fujian | 11 | 4424 | Jieyang | Guangdong | 11 |
| 1412 | Yuncheng | Shanxi | 7 | 3601 | Nanchang | Jiangxi | 11 | 4501 | Nanning | Guangxi Zhuan AR | 11 |
| 1501 | Hohhot | Inner Mongolia AR | 11 | 3602 | Jingdezhen | Jiangxi | 11 | 4502 | Liuzhou | Guangxi Zhuan AR | 11 |
| 1502 | Baotou | Inner Mongolia AR | 11 | 3603 | Pingxiang | Jiangxi | 11 | 4503 | Guilin | Guangxi Zhuan AR | 9 |
| 1503 | Wuhai | Inner Mongolia AR | 11 | 3604 | Jiujiang | Jiangxi | 11 | 4504 | Wuzhou | Guangxi Zhuan AR | 10 |
| 1504 | Chifeng | Inner Mongolia AR | 11 | 3605 | Xingyu | Jiangxi | 11 | 4505 | Beihai | Guangxi Zhuan AR | 11 |
| 1507 | Holunbeir | Inner Mongolia AR | 6 | 3606 | Yingtan | Jiangxi | 11 | 4506 | Yulin | Guangxi Zhuan AR | 10 |
| 2101 | Shenyang | Liaoning | 11 | 3607 | Ganzhou | Jiangxi | 8 | 4507 | Baise | Guangxi Zhuan AR | 5 |
| 2102 | Dalian | Liaoning | 11 | 3608 | Yichun | Jiangxi | 7 | 4508 | Hechi | Guangxi Zhuan AR | 5 |
| 2103 | Anshan | Liaoning | 11 | 3609 | Shangrao | Jiangxi | 7 | 4509 | Qinzhou | Guangxi Zhuan AR | 11 |
| 2104 | Fushen | Liaoning | 11 | 3610 | Ji'an | Jiangxi | 7 | 4512 | Fangchenggang | Guangxi Zhuan AR | 4 |
| 2105 | Benxi | Liaoning | 11 | 3611 | Fuzhou | Jiangxi | 7 | 4516 | Hezhou Area | Guangxi Zhuan AR | 5 |
| 2106 | Dandong | Liaoning | 11 | 3701 | Jinan | Shandong | 11 | 4601 | Haikou | Hainan | 11 |
| 2107 | Jinzhou | Liaoning | 11 | 3702 | Qingdao | Shandong | 11 | 4602 | Sanya | Hainan | 11 |
| 2108 | Yingkou | Liaoning | 11 | 3703 | Zibo | Shandong | 11 | 5000 | Chongqing | Chongqing | 10 |
| 2109 | Fuxin | Liaoning | 11 | 3704 | Zaozhuang | Shandong | 11 | 5101 | Chengdu | Sichuan | 11 |
| 2110 | Liaoyang | Liaoning | 11 | 3705 | Dongying | Shandong | 11 | 5103 | Zigong | Sichuan | 11 |
| 2111 | Panjin | Liaoning | 11 | 3706 | Yantai | Shandong | 11 | 5104 | Panzhihua | Sichuan | 11 |
| 2112 | Tieling | Liaoning | 11 | 3707 | Weifang | Shandong | 11 | 5105 | Luzhou | Sichuan | 11 |
| 2113 | Chaoyang | Liaoning | 11 | 3708 | Jining | Shandong | 11 | 5106 | Deyang | Sichuan | 11 |
| 2201 | Changchun | JiIin | 11 | 3709 | Taian | Shandong | 11 | 5107 | Mianyan | Sichuan | 11 |
| 2202 | Jilin | JiIin | 11 | 3710 | Weihai | Shandong | 11 | 5108 | Guangyuan | Sichuan | 11 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 2203 | Sipin | JiIin | 11 | 3711 | Rizhao | Shandong | 11 | 5109 | Suining | Sichuan | 11 |
| 2204 | Liaoyuan | JiIin | 11 | 3713 | Dezhou | Shandong | 11 | 5110 | Neijiang | Sichuan | 9 |
| 2205 | Tonghua | JiIin | 11 | 3714 | Liaochen | Shandong | 9 | 5111 | Leshan | Sichuan | 10 |
| 2209 | Baicheng | JiIin | 11 | 3715 | Linyi | Shandong | 11 | 5114 | Yibin | Sichuan | 10 |
| 2301 | Harbin | Heilongjing | 11 | 3716 | Heze | Shandong | 7 | 5115 | Nanchong | Sichuan | 11 |
| 2302 | Qiqihar | Heilongjing | 11 | 3720 | Laiwu | Shandong | 11 | 5116 | Daxian | Sichuan | 8 |
| 2303 | Jixi | Heilongjing | 11 | 4101 | Zhengzhou | Henan | 11 | 5117 | Yaan | Sichuan | 7 |
| 2304 | Hegang | Heilongjing | 11 | 4102 | Kaifeng | Henan | 11 | 5201 | Guiyang | Guizhou | 11 |
| 2305 | Shuangyashan | Heilongjing | 11 | 4103 | Luoyang | Henan | 11 | 5202 | Liupanshan | Guizhou | 10 |
| 2306 | Daqing | Heilongjing | 11 | 4104 | Pindinshan | Henan | 11 | 5203 | Zunyi | Guizhou | 10 |
| 2307 | Yichun | Heilongjing | 11 | 4105 | Anyang | Henan | 11 | 5207 | Anshun | Guizhou | 7 |
| 2308 | Jiamusi | Heilongjing | 11 | 4106 | Hebi | Henan | 11 | 5301 | Kunming | Yunnan | 11 |
| 2309 | Qitaiher | Heilongjing | 11 | 4107 | Xinxiang | Henan | 11 | 5303 | Zhaotong | Yunnan | 6 |
| 2310 | Mudanjiang | Heilongjing | 11 | 4108 | Jiaozhuo | Henan | 11 | 5304 | Qujing | Yunnan | 10 |
| 2311 | Heihe | Heilongjing | 11 | 4109 | Puyang | Henan | 11 | 5306 | Yuxi | Yunnan | 9 |
| 2314 | Suihua | Heilongjing | 7 | 4110 | Xuchang | Henan | 11 | 5312 | Baoshan | Yunnan | 7 |
| 3100 | ShanghaiCY | Shanghai CY | 11 | 4111 | Luohe | Henan | 11 | 5314 | Lijiang | Yunnan | 5 |
| 3201 | Nanjing | Jiangsu | 11 | 4112 | Sanmenxia | Henan | 11 | 6101 | Xi'an | Shanxi | 11 |
| 3202 | Wuxi | Jiangsu | 11 | 4113 | Shangqiu | Henan | 10 | 6102 | Tongzhou | Shanxi | 11 |
| 3203 | Xuzhou | Jiangsu | 11 | 4114 | Zhoukou | Henan | 7 | 6103 | Baoji | Shanxi | 11 |
| 3204 | Changzhou | Jiangsu | 11 | 4115 | Zhumadian | Henan | 7 | 6104 | Xianyang | Shanxi | 11 |
| 3205 | Suzhou | Jiangsu | 11 | 4116 | Nanyang | Henan | 11 | 6105 | Weinan | Shanxi | 11 |
| 3206 | Nantong | Jiangsu | 11 | 4117 | Xinyang | Henan | 9 | 6106 | Hanzhong | Shanxi | 11 |
| 3207 | Lianyungang | Jiangsu | 11 | 4201 | Wuhan | Hubei | 11 | 6107 | Ankang | Shanxi | 7 |
| 3208 | Huaiyin | Jiangsu | 7 | 4202 | Huangshi | Hubei | 11 | 6108 | Shangluo | Shanxi | 6 |
| 3209 | Yancheng | Jiangsu | 11 | 4203 | Shiyan | Hubei | 11 | 6109 | Yanan | Shanxi | 9 |
| 3210 | Yangzhou | Jiangsu | 11 | 4205 | Yichang | Hubei | 11 | 6110 | Yulin | Shanxi | 8 |
| 3211 | Zhenjiang | Jiangsu | 11 | 4206 | Xiangfan | Hubei | 11 | 6201 | Lanzhou | Gansu | 11 |
| 3212 | Taizhou | Jiangsu | 11 | 4207 | Ezhou | Hubei | 11 | 6202 | Jiayuguan | Gansu | 11 |
| 3217 | Suqian | Jiangsu | 11 | 4208 | Jingmen | Hubei | 11 | 6203 | Jinchang | Gansu | 11 |
| 3301 | Hangzhou | Zhejiang | 11 | 4209 | Huanggang | Hubei | 11 | 6204 | Baiyin | Gansu | 11 |
| 3302 | Ningbo | Zhejiang | 11 | 4210 | Xiaogan | Hubei | 11 | 6205 | Tianshiu | Gansu | 11 |
| 3303 | Wenzhou | Zhejiang | 11 | 4211 | Xianning | Hubei | 8 | 6206 | Jiuquan | Gansu | 5 |
| 3304 | Jiaxing | Zhejiang | 11 | 4212 | Jingzhou | Hubei | 9 | 6207 | Zhangye | Gansu | 5 |
| 3305 | Huzhou | Zhejiang | 11 | 4215 | Suizhou | Hubei | 7 | 6208 | Wuwei | Gansu | 6 |
| 3306 | Shaoxing | Zhejiang | 11 | 4301 | Changsha | Hunan | 11 | 6211 | Pinliang | Gansu | 5 |
| 3307 | Jinhua | Zhejiang | 11 | 4302 | Zhuzhou | Hunan | 11 | 6212 | Qingyang | Gansu | 5 |
| 3308 | Quzhou | Zhejiang | 11 | 4303 | Xiangtan | Hunan | 11 | 6301 | Xining | Qinghai | 11 |
| 3309 | Zhoushan | Zhejiang | 11 | 4304 | Hengyang | Hunan | 11 | 6401 | Yinchuan | Ningxia Hui AR | 11 |
| 3310 | Lishui | Zhejiang | 7 | 4305 | Shaoyang | Hunan | 11 | 6402 | Shizuishan | Ningxia Hui AR | 11 |
| 3311 | Taizhou | Zhejiang | 11 | 4306 | Yueyang | Hunan | 11 | 6501 | Urumqi | Xinjiang AR | 11 |
| 3401 | Hefei | Anhui | 11 | 4307 | Changde | Hunan | 11 | 6502 | Kelamayi | Xinjiang AR | 10 |
| 3402 | Wuhu | Anhui | 11 | 4309 | Yiyang | Hunan | 11 | | | | |
| 3403 | Bangbu | Anhui | 11 | 4310 | Loudi | Hunan | 8 | | | | |