UNITED STATES
INTERNATIONAL TRADE COMMISSION

Determinants of Diffusion and Downstreaming of Technology-Intensive Products In International Trade

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Prepared for the Joint Symposium

on U.S.-China Advanced Technology Trade and Industrial Development

October 23-24, 2009

Tsinghua University, Beijing, China

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Summary

- Using export data for 15 economies from 1997-2006, we study two phenomena associated with product cycles: *diffusion* (the tendency of exports of a product to come from a wider range of economies) and *downstreaming* (the tendency of exports to move from higher-income to lower-income countries of origin).
- High rates of downstreaming and diffusion are associated with product maturity, at least of certain stages of the production process, while low rates are associated with technological complexity.
- As revealed by the trade data,
  - Chemicals are more complex than electronics.
  - Electronic components are more complex than consumer electronics
  - Chemical precursors are simpler than more complex products, such as photographic film and cosmetics.
- Rates of diffusion and downstreaming may be influenced by technological change, FDI, fragmentation, and policies.

The product-cycle (or "technology-gap") theory of dynamic comparative advantage is appealing, but only demonstrated for specific cases

- Posner (1961) and Vernon (1966) suggested that new goods would be developed in, and exported from, rich countries
  - Because they had more innovative capacity
  - Because of "demand-push" innovation to satisfy rich consumers
  - And then eventually be produced in, and exported from, other countries than the original innovators,
  - When the technologies became mature, the goods would be produced in low-wage countries.
- Tests of the product cycle hypothesis show long-run persistence in national comparative advantage, with occasional "downstreaming" (Gagnon and Rose (1995), Proudman and Redding (2000))

What does trade theory predict about dynamic comparative advantage?

- *Heckscher-Ohlin*: if factor proportions evolve over time, CA can shift accordingly
- *Chamberlin-HO* with increasing returns/product differentiation (Helpman (1981), Helpman-Krugman (1985): same prediction as long as scale economies are firm-specific:
- *Implication*: If some countries have faster-growing K/L and Human K / L (e.g. Asia), they will pick up CA and K and Human K -intensive goods

"New trade" theories with technology often predict that initial conditions drive the trade pattern

- *National, sector-specific economies of scale:* If sectoral differences in scale economies outweigh sectoral differences in factor proportions, then CA is determined by initial conditions (Kemp (1969), Markusen and Melvin (1981)).
- *Nation-specific learning-by-doing:* initial conditions also determine the pattern of trade (Lucas (1988), Grossman and Helpman (1991, ch. 8).
- These can come from regional agglomerations or "Silicon Valleys" (Marshall (1890)), Krugman (1991).

Factors tending to preserve historical advantage	Factors tending to obscure historical comparative advantage, causing diffusion and downstreaming
•Nation-specific economies of scale •Nation-specific learning-by-doing •Relative factor abundance that changes only slowly over time	•General diffusion (global spillovers) •Differential relative factor accumulation •FDI (Vernon (1977)) •Fragmentation and vertical disintegration (Dean, Fung, and Wang (2007), Koopman, Wang, and Wei (2008))

Properties of our sample

Time period – 1997-2006

Aggregation – HS6

Economies – China, Germany, France, United Kingdom, Hong Kong, Indonesia, Italy, Japan, Korea, Malaysia, Philippines, Singapore, Thailand, Chinese Taipei, United States

Products – HS 29-40 (chemicals), 84-91 (machines, transport equipment and instruments), 93 (arms and ammunition), at HS6 (1992), for 1997-2006.

2035 HS-6 products total. Of these, 173 have been identified by U.S. Census as Advanced Technology Products (ATP) based on technological characteristics.

Diffusion is measured by the Herfindahl-Hirschman index (HHI)

For each product, *i*, and year, *t*

$$HHI_{it} = \sum_{j} s_{ijt}^{2}$$

Where *x* is exports, *j* is the index over economies and

$$s_{ijt} = \frac{x_{ijt}}{\sum_{j} x_{ijt}}$$

Downstreaming is measured by EXPRELY

For each economy *j* in year *t*, the total exports of economy *j* in that year are given by:

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

GDPs are are normalized by dividing by US GDP in a given year:

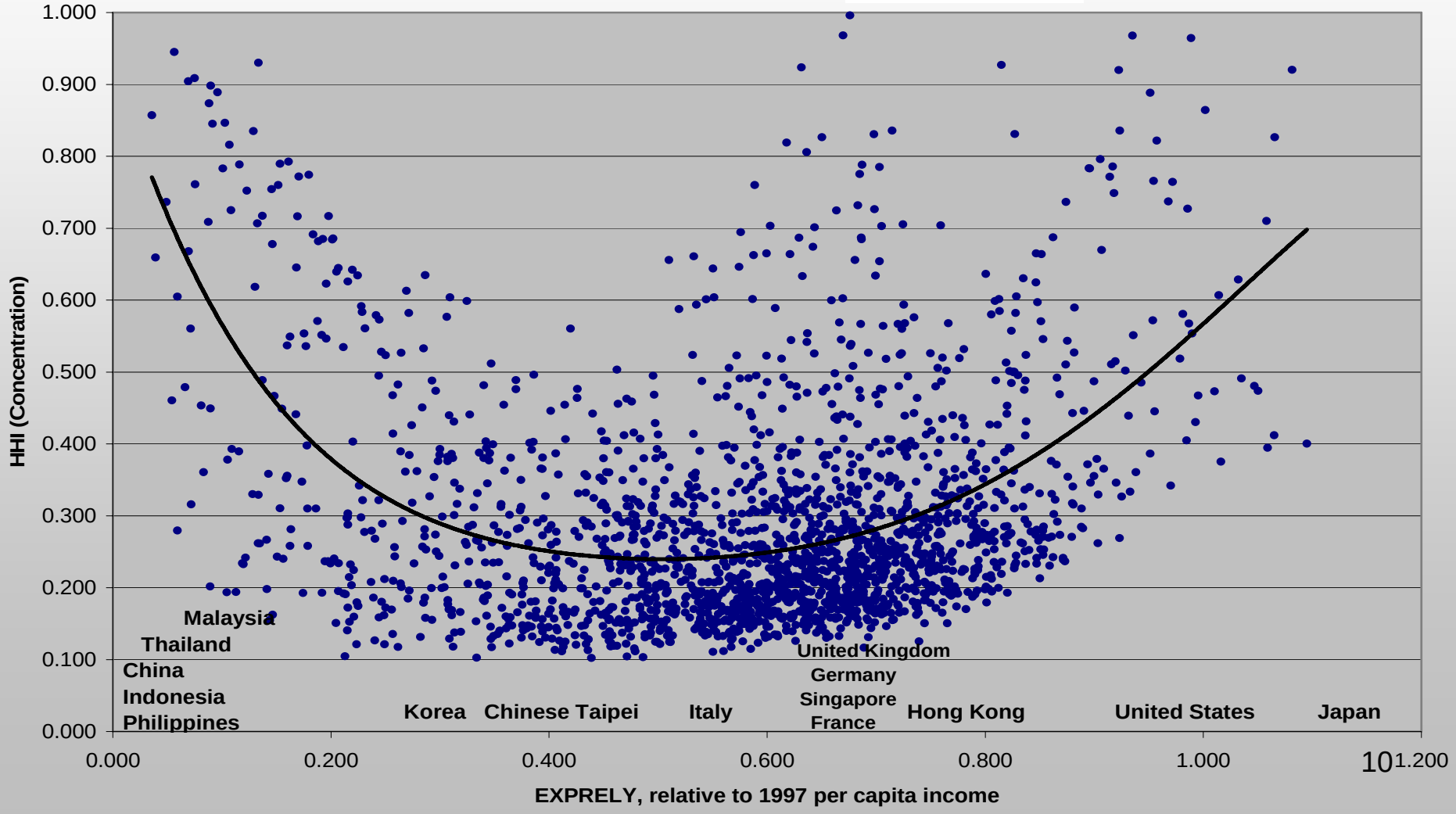
$$Y_{jt} = \frac{GDP_{jt}}{GDP_{US,t}}$$

Then, for each product i,

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

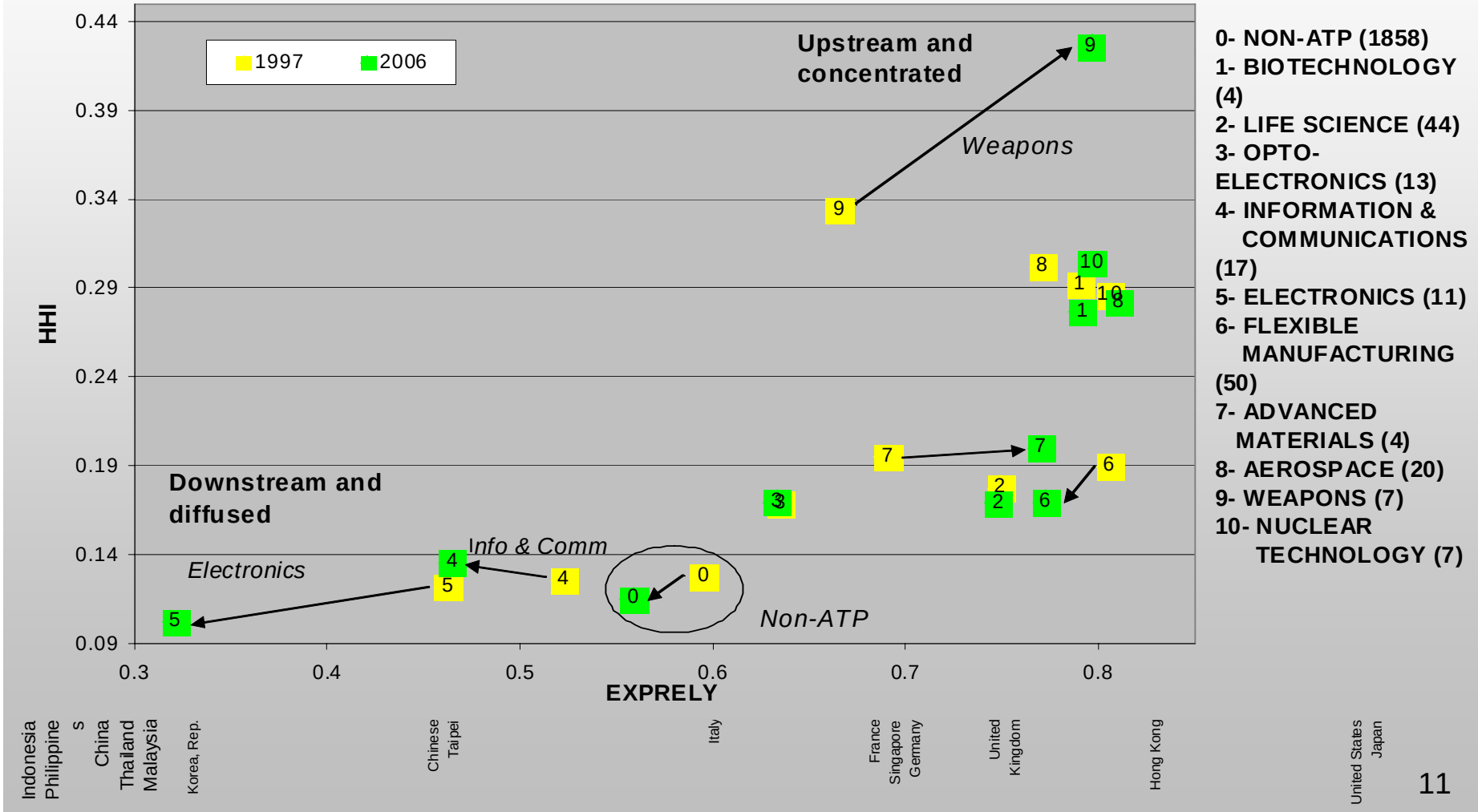
EXPRELY is a normalized version of the PRODY index in Hausman, Hwang, and Rodrik (2007)

The exports of both "high-income" and "low-income" products tend to concentrate in one or a few economies



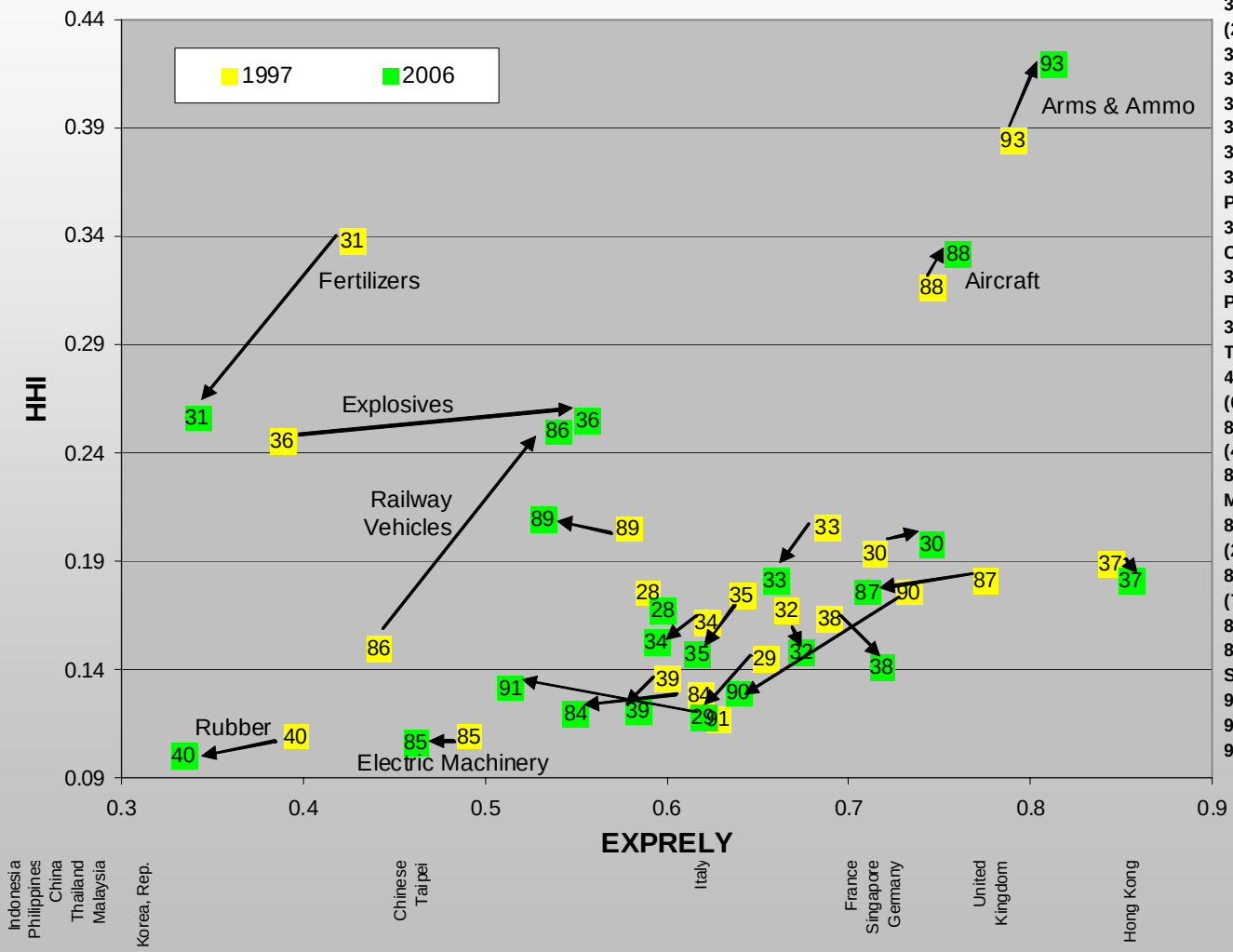
Census' ATP products vary greatly in terms of diffusion and downstreaming

(number of products in parentheses)



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)

All of the products by HS2 (number of products in each category in parentheses)



28- INORGANIC CHEMICALS (181)
29- ORGANIC CHEMICALS (290)
30- PHARMACEUTICAL PRODUCTS (29)
31- FERTILIZERS (26)
32- DYES, PAINTS, TANNINS, ETC. (45)
33- COSMETICS AND PERFUMES (34)
34- SOAPS, WAXES, ETC. (23)
35- STARCHES, GLUES, ENZYMES (13)
36- EXPLOSIVES; PYROTECHNIC PRODUCTS (8)
37- PHOTOGRAPHIC OR CINEMATOGRAPHIC GOODS (36)
38- MISCELLANEOUS CHEMICAL PRODUCTS (55)
39- PLASTICS AND ARTICLES THEREOF (122)
40- RUBBER AND ARTICLES THEREOF (66)
84- MACHINERY AND COMPUTERS (494)
85- ELECTRICAL AND ELECTRONIC MACHINERY (261)
86- RAILWAY VEHICLES AND PARTS (24)
87- MOTOR VEHICLES AND PARTS (76)
88- AIRCRAFT, SPACECRAFT (15)
89- SHIPS, BOATS AND FLOATING STRUCTURES (17)
90- INSTRUMENTS (150)
91- CLOCKS AND WATCHES (53)
93- ARMS AND AMMUNITION (17)

Electronics vs. Chemicals:

Technological Complexity In The Production Chain

ELECTRONICS

Semiconductor-making equipment → **Semiconductors and Integrated Circuits** → **Bigger Components** → **Final Goods (PCs, iPods, Cell Phones)**

Complex, research intensive → Final assembly, labor intensive

CHEMICALS

Fossil Fuels → **Basic Organic Chemical Precursors** → **More complex organic chemicals** → **Final Goods (pharmaceuticals, cosmetics)**

Simple, raw materials → Complex, research intensive

We expect exports of basic chemical products to be downstream (produced by lower-income countries) relative to exports of secondary products, and secondary products to be downstream relative to exports fom chemical-consuming industries

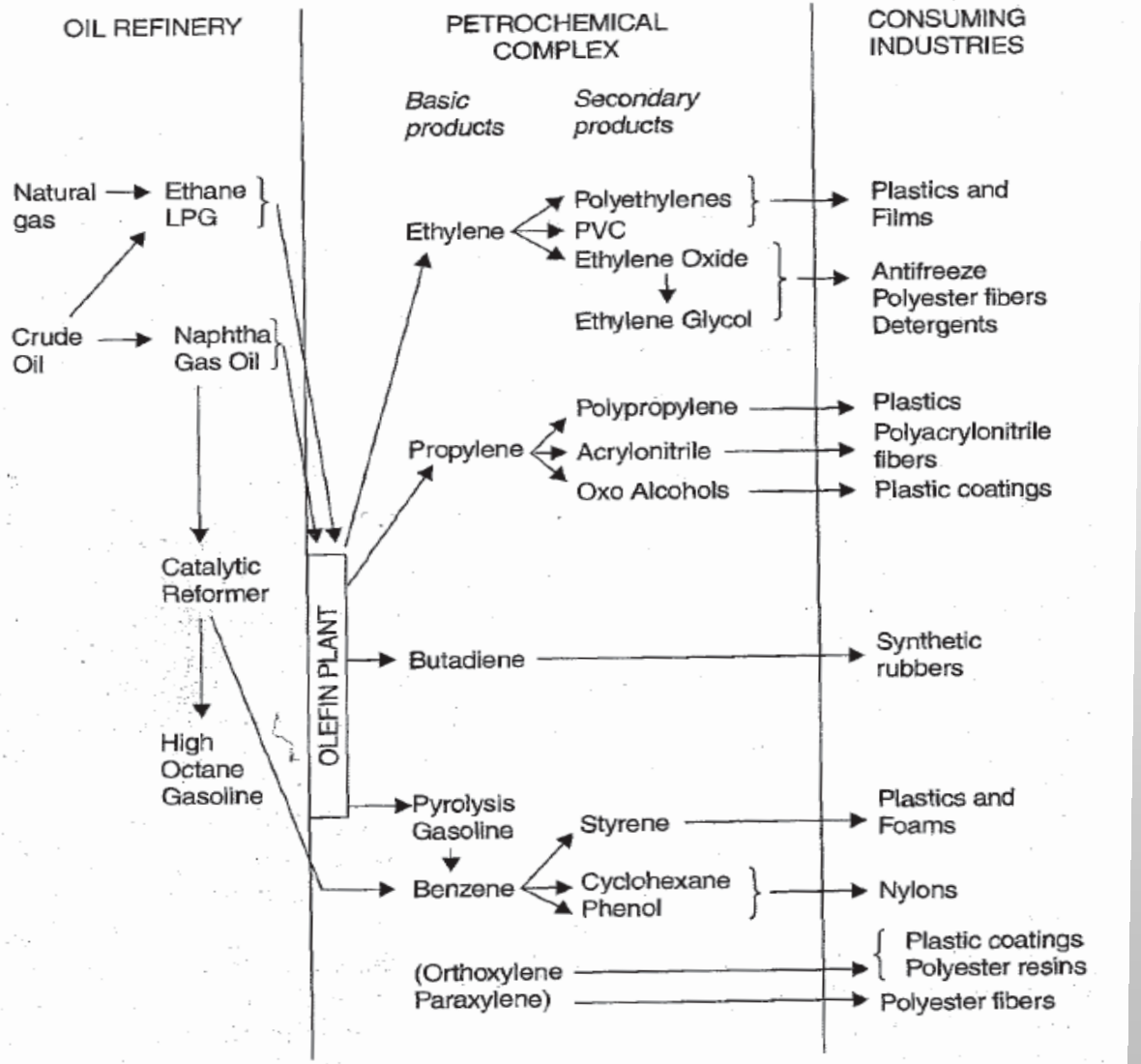
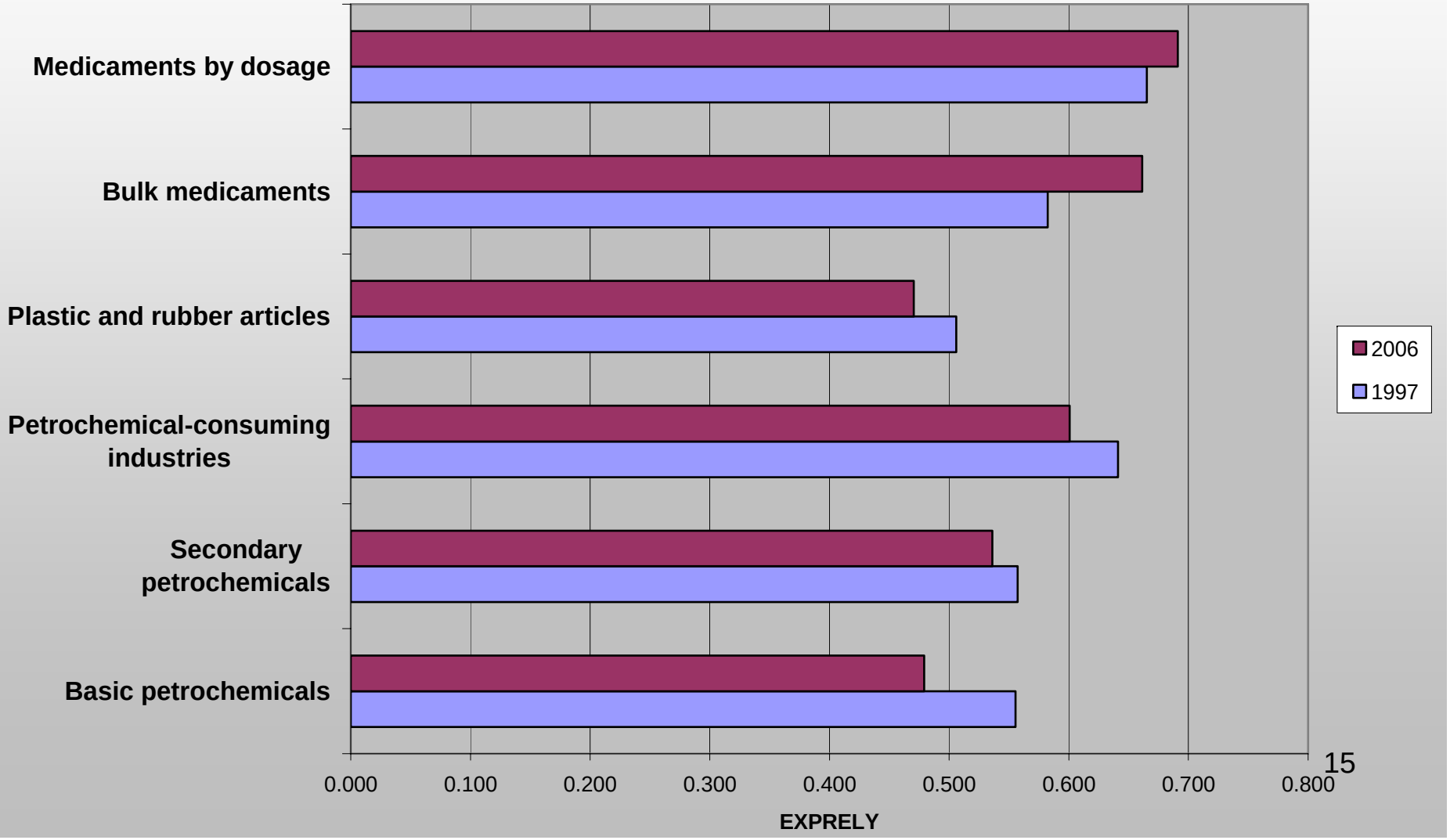
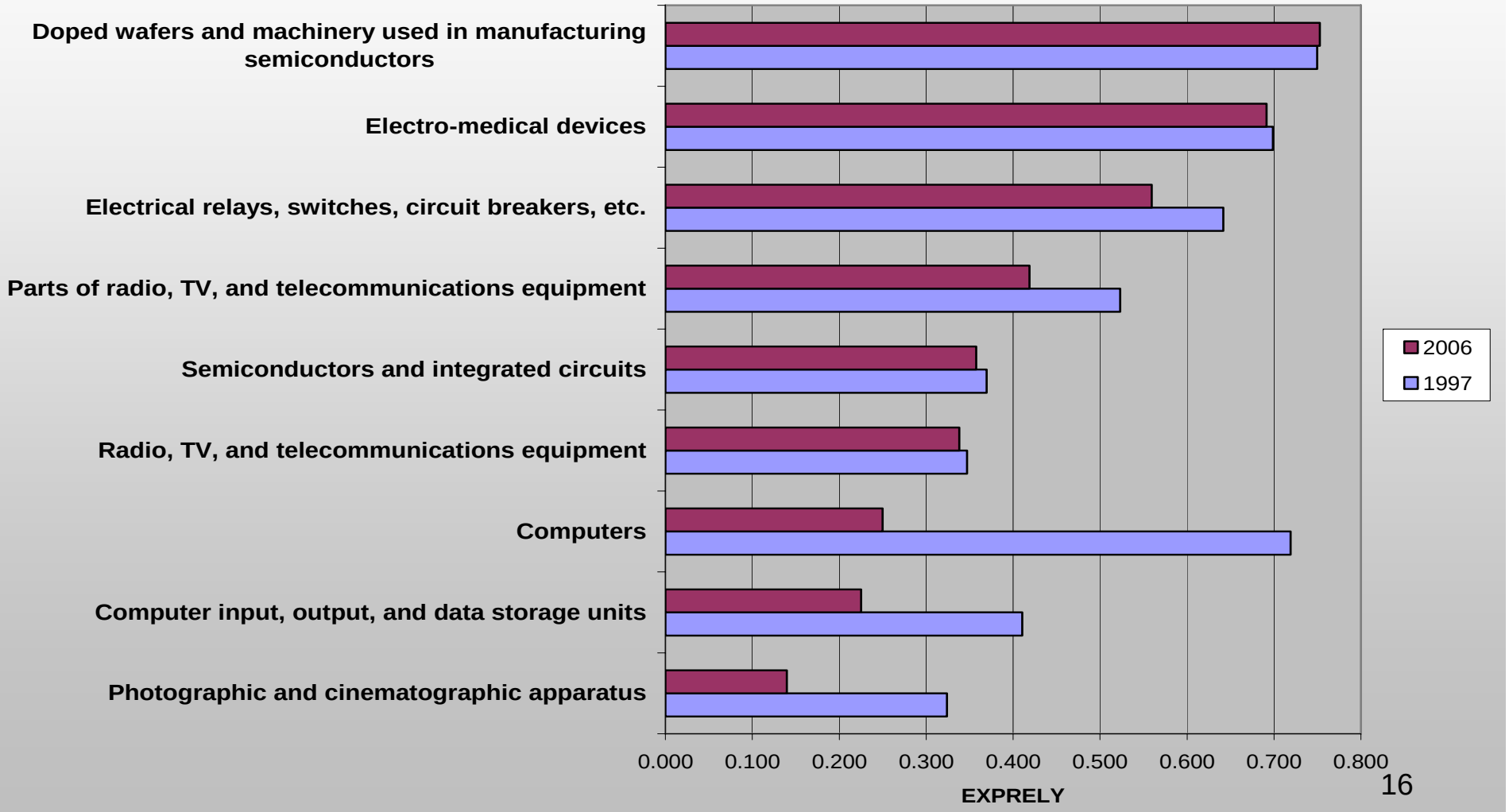


Figure 8.2 Petrochemicals: the production pathway from basic feedstock. (*Source:* Margaret Sharp. "Innovations in the Chemicals Industry." In *The Handbook of Industrial Innovation*, Mark Dodgson and Roy Rothwell, eds. Aldershot, England: Edward Elgar, 1994:171.)

Exports involving later stages of chemical processing are associated with higher income levels



Some electronics and related products have "downstreamed" rapidly, others have not



Our indices for machinery, computers, and instruments (HS 84, 85, 90) are correlated with Census' technological definition of ATP

Cluster	No. of Products	HHI	EXPRELY	Description	# of Products designated ATP	% of Products designated ATP
1	560	0.233	0.669	Low HHI; High EXPRELY – diffuse	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%

But there are a lot of "revealed ATP" products not on Census' list

Some products that are both upstream and concentrated, but not on the census ATP list

- Outboard motors
- Cylinders for rolling machines
- Commercial dish washing machines
- Ski lifts and chair lifts
- Bulldozer blades
- Milking machines
- 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
- Cameras for narrow-gauge film

Only a few ATP electronics products have "downstreamed" very much

Product	Product_Name	HHI	EXPRELY	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 ***(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

Many chemical products are strongly concentrated in Germany, the United States, or China

Cluster	1	2	3	4	5	6
Number of Products	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%

Thank you for coming!

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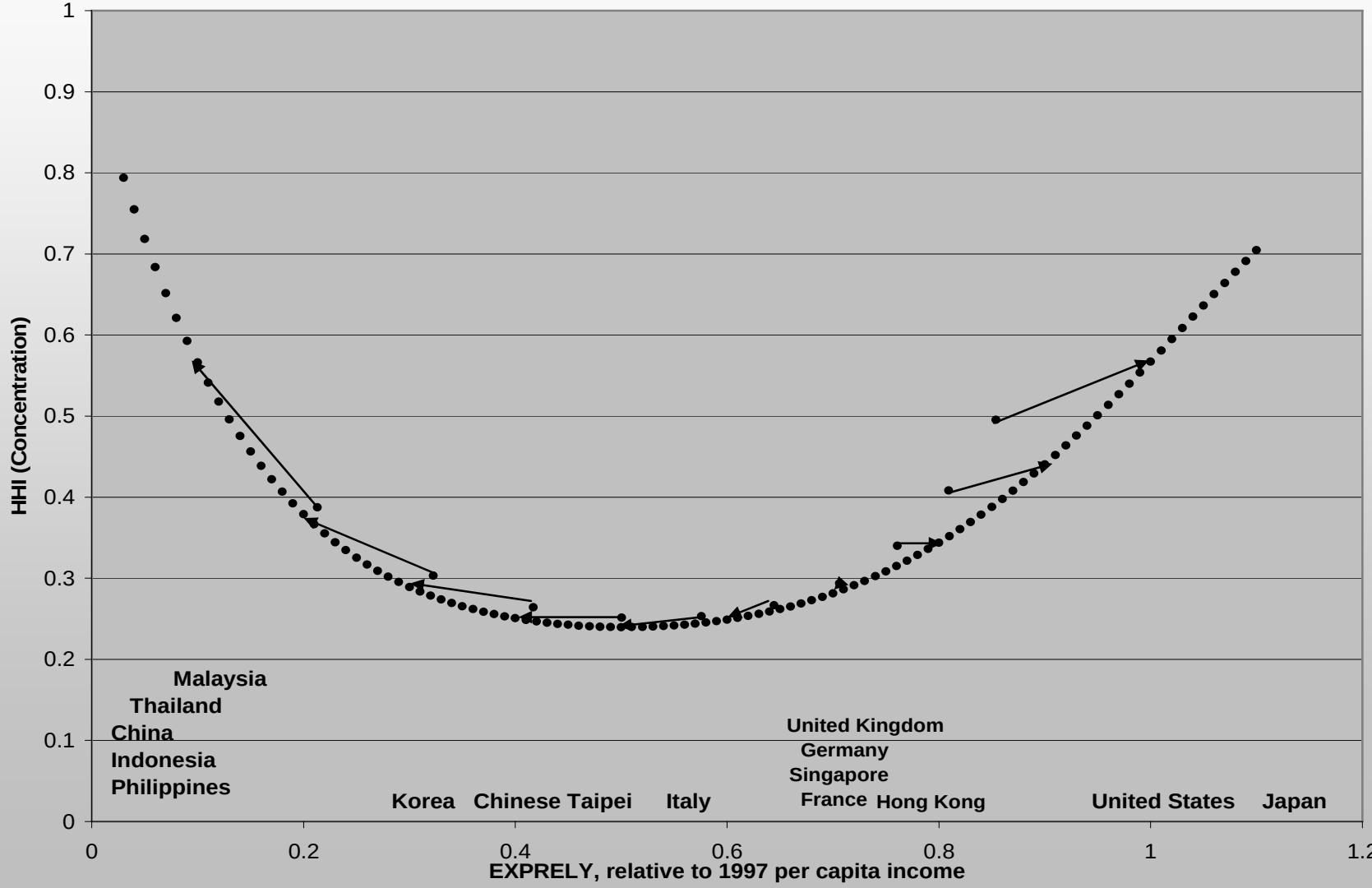
Tests of the product cycle hypothesis show long-run persistence in national comparative advantage, with occasional "downstreaming"

- Gagnon and Rose (1995) – Six countries at SITC4 from 1965-1989
  - **Only about 1 percent of products switch between surplus and deficit over the period (4 percent for UK, 6 percent for Japan) (±1 sd of mean is defined as "balanced" trade)**
- Proudman and Redding (2000) – Five countries for 22 ISIC-defined manufacturing sectors sectors from 1970-74 to 1990-93
  - **For France, Germany, the UK, and the United States, only a couple of categories switch from RCA > 1 to RCA < 1 over the period**
  - **Japan is the most dynamic, losing CA in "rubber and plastic," "textiles and clothing" and "other manufacturing" and gaining CA in "non-electrical machinery," "electrical machinery," "motor vehicles" and "computers." The other 15 industries don't change CA.**

- The extent to which the technological factors favor persistence of CA vs. product cycles is an empirical question…
  - –Trade-related knowledge spillovers are partly localized and fall with distance (Keller, 2004)
  - –Learning curves are sometimes nation-specific, e.g. Navy ships (Searle (1945) and sometimes more global, e.g. light-water nuclear reactors (Cowan (1990))
- The answer may be important…
  - –Some endogenous growth literature suggests that the "right" specialization permanently affects long-run growth (Lucas (1988), Young (1991), Grossman and Helpman (1991), Hausman, Hwang, and Rodrik (2007)

Both "low-income" and "high-income" products became more geographically concentrated from 1997-2006



Persistent CA consists in large part of the history of technological difficulty

- The stubbornness of science means some innovations are much easier to make than others (Rosenberg (2004)
- The results of innovations may take decades to play out (Schumpeter, Kondratieff)
- The history of innovation tells us a lot about relative difficulty

Easier	**Harder**
Electricity (19th century)	Electronics (post-WWII)
Simple systems (flashlights)	Complex systems (planes, warships)
Inorganic chemistry (industrialized in 18th c).	Organic chemicals (c. 1840s)
Small organic molecules	Giant organic molecules
Giant non-living organic molecules (plastics)?	Giant organic molecules for biological use (pharmaceuticals)?

Many electronics products are German exports, and some are Italian, but Japan/HK/Korea exports contain a higher share of ATP products

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%

For organic chemicals, our indices are more weakly associated with Census' ATP list

Cluster	No. of Products	HHI	EXPRELY	Description	# of Products designated ATP	% of Products designated ATP
1	304	0.283	0.717	Low HHI, High EXPRELY -- diffuse, exported from High income Countries	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 countries	7	2.9%
4	109	0.370	0.254	Low/Moderate HHI; Low EXPRELY - "downstreamed"	0	0.0%