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THE TRANSMISSION OF PRODUCTIVYTY AND INVESTMENT SHOCKS IN THE ASIA PACIFIC REGION

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ABSTRACT

An important aspect of macroeconomic interdependence in the Asia Pacific region is the adjustment of trade and current account balances in response to changes in saving and investment rates in individual economies. Greater trade flows, reliance on imported intermediate goods as well as more integrated capital markets imply that shifts in private or public saving and investment rates in an economy in the region can potentially have large impacts on other economies. This paper explores the quantitative nature of these linkages by focusing on a number of shocks within the context of a new dynamic multi-sector global model called the Asia-Pacific G-Cubed Model (AP-GCUBED). This model integrates sectoral adjustment with macroeconomic interdependence including explicit treatment of capital flows to explore the implications of a variety of productivity and investment shocks in the Asia Pacific Region. The first shock considered is a permanent decline in private investment in Japan. The second shock is a temporary rise in total factor productivity growth in China. The fall in Japanese investment is found to have a significant effect on trade flows and financial flows in the region whereas the rise in Chinese productivity has a quite different effect on the region .

A key aspect of the study is the role of international capital flows, imported intermediate goods and expectations in determining the short run and longer term adjustment within the region to these types of shocks.

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1. Introduction

In recent decades, economies in the Asia Pacific region have become increasingly linked through both goods, factor and financial markets. The growth of trade and capital flows in this region is well documented as is the changing composition of trade flows between economies in the Asia Pacific region. Rather than describe the process by which economies have become increasingly interdependent, this paper is concerned with analyzing the impact of these macroeconomic as well as sectoral linkages between countries for the transmission of shocks within the region.

There are a number of important economic linkages between economies in the Asia Pacific regions. Clearly trade in goods and services is an important mechanism through which shocks in one economy are transmitted to other economies. Changes in final demand in one country affect the demand for goods from other economies. This is a standard channel that all multi country economic models have incorporated since the very beginning of the Project Link models (e.g. See Ichimura and Ezaki (1985)). In addition to this standard macroeconomic linkage for trade in final goods, trade between economies in this region is importantly in intermediate goods that are used as inputs to production in these economies. A change in the relative price of an imported good has a differential effect on an economy depending on whether the imported good is an intermediate input in the production function of the importing country or a final demand good. For example an appreciation of the real exchange rate of a country will make imported intermediate inputs cheaper thereby shifting out the aggregate supply schedule of that country. This is importantly different to a change in the relative price of final goods imports. The more imports are used as intermediate inputs in production the more the supply side of the

economy will be responsive to changes in real exchange rates.

Another source of interdependence is the flows of factors of production between economies. Although the data on the flows of direct foreign investment between economies is poor, it is clear that flows of capital are become increasingly important. Directly related to the flows of physical capital are the flows of financial capital between economies. The increasing openness of financial markets (see De Brouwer (1996) for empirical evidence) provides an important channel through which shocks in one economy are transmitted to other economies. Financial capital flows very quickly between economies in response to changes in expected rates of return and the simulation results presented below illustrate that this channel is very important in the short run adjustment to shocks. Capital flowing in response to changes in expected rates of return can lead to significant changes in real exchange rate rates which affect the flows of goods and services (both final and intermediate) between economies.

The focus of this paper is to use a simulation model that captures these crucial channels of transmission of shocks between economies to illustrate the nature of transmission of shocks that would be expected in a region in which goods markets and financial markets are increasingly integrated. In particular this paper focuses on the impacts of changes in productivity growth and investment demand on economies in the region. Elsewhere I have explored changes in macroeconomic policies and how these are transmitted between economies (see McKibbin and Sundberg (1995) and McKibbin and Bok (1995)). What are the impacts on the region of a general decline in Japanese investment expenditure for a number of years (similar for example to the early 1990s)? What is the impact on the region of a temporary rise in Chinese total factor productivity growth?

This paper demonstrates that an important aspect of how these shocks are transmitted is the nature of expectations about the shocks, the adjustment of international capital markets and the structure of trade flows between economies.

In order to quantify the channels through which these shocks are transmitted this paper uses a new multisectoral dynamic intertemporal general equilibrium model following the approach in the GCUBED model developed by McKibbin and Wilcoxen (1992, 1995, 1996). Because of this link, this new model is named the GCUBED Asia Pacific model (AP-GCUBED). As with the GCUBED model, this new model captures simultaneously the macroeconomic and sectoral linkages in a global model with partially forward looking asset market and spending decisions. The extension in the AP-GCUBED model is the extensive country disaggregation in the Asia-Pacific region. The AP-GCUBED model has country/regional disaggregation of: Korea, Japan, Thailand, Indonesia, China, Malaysia, Singapore, Taiwan, Hong Kong, Philippines, Australia, United States, Rest of the OECD, Oil exporting developing countries, Eastern Europe and Former Soviet Union and all other developing countries. The version of the model used in this paper also includes a new module for South Asia (incorporating India, Pakistan and Bangladesh). Each country/region has an explicit internal macroeconomic and sectoral structure with sectoral disaggregation in production and trade into 6 sectors based on data from standardized input/output tables. McKibbin and Sundberg (1995) showed elsewhere using an extension of the MSG2 model that the sectoral composition of trade and production can be important for the nature of the transmission of shocks within the Asia-Pacific region. This paper supports and significantly extends that earlier analysis.

In this paper the modelling approach is developed in some detail. Because the innovative

approach of this new modelling strategy may be unfamiliar to readers from particular schools of economic modeling, section 2 gives an overview of where the new approach fits into the various traditional streams of modelling. The theoretical basis of the AP-GCUBED model is then summarized (further details and some evaluation of model properties including macroeconomic and sectoral policy changes can be found in McKibbin and Wong (1996)).

The alternative scenarios for investment and productivity shocks are analyzed in section 3. Finally a conclusion is presented in section 4.

2. Integrating Macroeconometric and CGE models for Studying Economic Interdependence [1]

I. Alternative Approaches to Economic Modeling

Until recently, computable general equilibrium (CGE) models[2] and macro-econometric (ME) models[3] co-existed with very little interaction between the modelers in the two modeling streams or very little cross fertilization of the two approaches[4]. Both modeling techniques have made significant contributions to understanding various empirical aspects of economies yet

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[1]This section draws on McKibbin (1996).

[2] These are also referred to as Applied General Equilibrium (AGE) models. Hereafter I will only use the term CGE models. See de Melo (1988), Robinson (1989) and Shoven and Whalley (1984) for an overview of CGE models. Examples of this approach include models by Dixon et al (1982), Whalley (1985), Deardorff and Stern (1985), Hertel et al (1995).

[3] See Bryant et al (1988) for a summary of the major multi-country macro-econometric models and a list of references relating to each model.

[4] Attempts have been made to reconcile the two approaches. See for example Powell (1981) and more recently Parsell, Powell and Wilcoxen (1989).

attempts to combine existing models from the different approaches have been unsuccessful.[5]

The distinction between the two approaches is much the same as that between microeconomic and macroeconomic theory. However, as the distinction between microeconomic and macroeconomic theory has blurred, so has the distinction between CGE models, which have begun to incorporate dynamics[6], and a new generation of macro-econometric models which are more firmly based on optimization theory[7]. In addition to the theoretical basis of the models there is also a significant range of techniques for parameterizing both schools of models. Parameters are either based on econometric estimates by the modelers or are "calibrated" by creating parameters that are based on "empirical evidence".

CGE models are derived from microeconomic optimization theory, with considerable attention to individual behavior whereas macro-econometric models are based on aggregate behavior with reliance placed heavily on correlations found in time series of aggregate data. There is by now a vast literature containing applications of computable general equilibrium models. The reader is referred to papers by Dervis et. al. (1982), de Melo (1988), Robinson (1989) and Shoven and Whalley (1984) for a detailed overview of CGE models.

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[5] A number of attempts to link macro-econometric models and CGE models do exist. See Cooper and McLaren (1983) for one such attempt using Australian models.

[6] The treatment of dynamics varies considerably across CGE models. Some are very simple while others are integrated more completely into behavior. Examples of dynamic CGE models include Burniaux et al (1991), Goulder and Eichengreen (1989) and Jorgenson and Wilcoxen (1990).

[7] The Multimod econometric model at the International Monetary fund outlined in Masson et al (1988) and the MSG2 multi-country model in McKibbin and Sachs (1991) are examples. It should be noted that the MSG2 model is very different to the MSG model that appears in Bryant et al (1988). That earlier model was a typical macroeconomic model whereas MSG2 is more like a dynamic CGE model.

The CGE modeling work descends directly from the work of Arrow and Debreu (1954). These models use the Walrasian general equilibrium framework together with real world data to attempt to explain economic behavior. They contributed quantitative results to the theoretical literature on microeconomic general equilibrium analysis. Given the focus on individual optimization, the key parameters in these type of models are parameters such as expenditure shares and the elasticities of substitution of households and firms. These parameters are sometimes "calibrated" to a data set given an assumption about functional form of utility and production functions. Or they are estimated from extensive cross sectional data on households and firms. In addition to parameter calibration, it is often the case that the data behind the model is adjusted to be consistent with the equilibrium of the model.

The applied aspects of CGE modeling descend from the fixed coefficient work of Wassily Leontief. By using input-output tables constructed for fixed coefficient models, introducing relative prices and empirical evidence on substitution in production and consumption, the CGE approach added a new dimension to this earlier modeling strategy. An early example of this type of work is Johansen (1960).

With the focus on micro-economic theory, CGE models are particularly well suited to analyzing questions in tax policy and international trade (see Shoven and Whalley (1984)). In addition they have played an important role in the literature on economic development (see the survey by de Melo et. al. (1982)).

The advantage of this approach is the transparency of the key mechanisms in many of the models. Also considerable sectoral detail can be handled and even the results from the larger models can be understood from theoretical intuition. One problem with this approach is

interpreting the time horizon over which the results are relevant. This partly relates to how long it takes for markets to clear. The early static CGE models were used for comparative static analysis of the change between equilibria given a change in some policy. They were particularly useful for analyzing the long run effects of policies. Recent work has attempted to incorporate dynamics to allow for simple adjustment between equilibria (e.g. Bourgignon et al (1989), Burniaux et.al. (1991), and Feltenstein (1986)). However these extensions have usually had macroeconomic closures which are considered unsatisfactory by macro-economists. The absence of an aggregate price level or any role for money (or nominal exchange rate fluctuations) in particular is an important omission from most CGE models.

Other attempts to introduce dynamics through explicit intertemporal optimization of agents, such as papers by McKibbin (1986), Goulder and co-authors (1989,1990), Jorgenson and Wilcoxen (1990), McKibbin and Sachs (1991), McKibbin and Wilcoxen (1992), Laxton and Tetlow (1992), and Servin and Schmidt-Hebbel (1992) are more promising. The approaches by McKibbin and Sachs (1991) and McKibbin and Wilcoxen (1992) form the basis for the remainder of this paper.

In contrast to the approach taken in CGE models, the standard approach in macro-econometric models developed during the 1960s and 1970s was for macroeconomic theory to be used as a guide as to the appropriate variables to use in regression equations. These variables were then tested and either included or excluded based on various tests of statistical significance. Because of the focus on aggregate relationships, it was rare that these models imposed the types of constraints across equations to satisfy conditions from microeconomic optimization theory. In some cases, the conditions of homogeneity were not even imposed.

With fewer theoretical constraints or seldom any imposition of steady state conditions to impose stability, the larger econometric models tended to be explosive over long periods and were only really useful for simulations over short time horizons. This was less of a problem when the models were used for short term forecasting but was a fundamental problem for medium term policy analysis.

These macro-econometric models broke down empirically in the 1970s, in part because they relied on data periods in which events such as supply shocks were relatively unimportant. While these models were criticized for their poor tracking performance in the face of shocks that were not in their estimation sample, the Lucas Critique dealt a theoretical blow by pointing out the role of expectations and the need to worry about theoretical structure and policy regimes[8]. The modeling profession responded to this challenge by introducing rational expectations into a number of models. The multi-country models that incorporated the assumption of rational expectations such as the Liverpool, Taylor, MSG and Minimod (parent of Multimod) tended to be small models with relatively simple dynamics. This was partly due to the size constraints placed by the numerical techniques used to solve RE models. It was also because the long distributed lag structures in the traditional macro econometric models made it virtually impossible to numerically solve these models including rational expectations. The main problem was that in many, if not all cases, these models were basically unstable. The instability which gradually appeared over a simulation horizon of a decade or less, manifested itself into the first year when attempting to introduce rational expectations. To give the saddle path stability that is required in rational expectations models required a tighter structure and more careful

[8] See Lucas (1973).

constraining of parameter estimates. Even today it is not a matter of size of models that prevents the use of rational expectations. The key problem is related to model stability. It is not that rational expectations was necessarily a desirable assumption to incorporate into these models. However, attempts to implement this assumption showed that the conventional style of macro econometric model building produced models with medium term properties that were less transparent and less stable than more theoretically constrained models.

Global macro-econometric models that have been developed in the 1980s spanned the spectrum of macroeconomic and microeconomic theory with a variety of reliance on estimation versus calibration techniques. Models such as Multimod[9], Liverpool model[10], the Taylor Model[11] and perhaps GEM are closer to the microeconomic theory part of this spectrum than the derivative models of the large scale models of the 1970s such as the DRI, EPA, INTERLINK, LINK, MCM or WHARTON models[12]. The MSG model is close to the macroeconomic theory part because it is based on macroeconomic theory and is calibrated to a data set. The MSG2 model in contrast, lies closer to the microeconomic theory end of the spectrum because it has explicit structural parameters and it is calibrated to a data set rather than estimated over a time series of data.

In building a new model for analyzing economic interdependence in the Asia Pacific region, it is natural to ask which approach should be followed? Total or excessive reliance on

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[9] See Masson et al (1988).

[10] See Minford et al (1986).

[11] See Taylor (1988).

[12] For an overview of these models see Bryant et al (1988).

aggregate data with very little regard to theoretical structure is the wrong modeling strategy to follow for a number of reasons. Firstly, the data at the aggregate level are so poor that theoretical restrictions are required for any useful analysis of the information contained in the data. Secondly many shocks we care about (e.g. German unification, the breakup of the Soviet Union, regime changes such as shifts from fixed to floating exchange rates, moving into or out of the EMS or the shift from exchange controls to free capital mobility etc.) are not in our data samples or at least not with sufficient numbers of observations. Thirdly there is considerable structural change occurring in the Asian regional economies which I believe can be handled by using a model with explicit structural detail and allowing for differential sectoral productivity growth and changing consumption preferences. Fourth, for a model to be useful in a practical sense, it must be able to adequately replicate the recent experience to a significant extent but it also must be understandable so the user gets quantitative information and a better intuition of the main issues in any analysis. This suggests a tradeoff between constraining a model to a tight theoretical structure based on stable deep structural parameters and following data-intensive reduced form approaches to modeling. There is also an apparent tradeoff between capturing macroeconomic phenomena and sectoral detail although we will show below that recent developments in dynamic intertemporal general equilibrium (DIGE) modeling have apparently resolved this tradeoff. Estimated models that are to be used for policy work should, in full model simulation, be able to explain recent major events rather than just give a good single equation fit on average over a thirty year sample. We also need to understand the intuition as to why the results come out as they do. Theoretical models should be subject to these same evaluations. If they do not explain statistical relationships in the data or the consequences of large observed

shocks then they are not so useful for applied policy.

ii. The Theoretical Structure of the AP- GCUBED model

The AP-GCUBED multi-country model is based on the GCUBED model developed in McKibbin and Wilcoxen (1992, 1995, 1996). It combines the approach taken in the MSG2 model of McKibbin and Sachs (1991) with the disaggregated, econometrically-estimated, intertemporal general equilibrium model of the U.S. economy by Jorgenson and Wilcoxen (1989). The MSG2 model had one sector per country. The Jorgenson-Wilcoxen model breaks the economy down into 35 separate industries, each of which is represented by an econometrically estimated cost function. The GCUBED model was constructed to contribute to the current policy debate on global warming, trade policy and international capital flows, but it has many features that make it useful for answering a range of issues in environmental regulation, microeconomic and macroeconomic policy questions. It is a world model with substantial regional disaggregation and sectoral detail. In addition, countries and regions are linked both temporally and intertemporally through trade and financial markets. Like MSG2, GCUBED contains a strong foundation for analysis of both short run macroeconomic policy analysis as well as long run growth consideration of alternative macroeconomic policies. Intertemporal budget constraints on households, governments and nations (the latter through accumulations of foreign debt) are imposed. To accommodate these constraints, forward looking behavior is incorporated in consumption and investment decisions. Unlike MSG2, the GCUBED model also contains substantial sectoral detail. This permits analysis of environmental policies which tend to have their largest effects on small segments of the economy. By integrating

sectoral detail with the macroeconomic features of MSG2, GCUBED can be used to consider the long run costs of alternative environmental regulations yet at the same time consider the macroeconomic implications of these policies over time. The response of monetary and fiscal authorities in different countries can have important effects in the short to medium run which, given the long lags in physical capital and other asset accumulation, can be a substantial period of time. Overall, the model is designed to provide a bridge between computable general equilibrium models and macroeconomic models by integrating the more desirable features of both approaches. The AP-GCUBED model differs from the GCUBED model because of the focus on the Asia-Pacific region as well as having 6 sectors compared to 12 for GCUBED.

The AP-GCUBED model is still in the very early stages of development but it is already a large model. In the form used in this paper, it contains around 7,800 equations and 140 intertemporal costate variables. Nonetheless, it can be solved using software developed for a personal computer[13]. In addition, an extensive set of software exists that will permit the AP-GCUBED model to be used for game theoretic analysis of how one or more countries might respond strategically to unilateral policies adopted by other nations.

The key features of AP-GCUBED are summarized in Table 1. The country and sectoral breakdown of the model are summarized in Table 2. It consists of seventeen economic regions with six sectors in each region. The seventeen regions in AP-GCUBED can be divided into two groups: 14 core countries/regions and three others. For the core regions, the internal macroeconomic structure as well as the external trade and financial linkages are completely specified in the model. We begin by presenting the structure of a particular one of these

[13] See the Computer manual by McKibbin (1995).

economies: the United States. The other countries have similar structure and differ only in the values of behavioral parameters, so our description of the United States applies to the other industrial regions as well. This is more problematic for the countries in the Asia-Pacific Region. Our approach for these countries is to first model them assuming the theoretical structure we use for the "generic" country but calibrating each country to actual country data. We then propose to proceed country by country to impose institutional features, market structures, market failures or government regulations that cause certain aspects of these economies to differ from our generic country model. In this paper we have only just begun this process, therefore the countries we represent in the region are endowed with resources, trading patterns, saving and investment patterns etc that are based on actual data for these countries but in many important ways may not be truly representative of these countries because of institutional factors that we are still implementing into the model.

Each core economy or region in the model consists of several economic agents: households, the government, the financial sector and the 6 production sectors listed in table 2. We now present an overview of the theoretical structure of the model by describing the decisions facing these agents. The reader is referred to McKibbin and Wilcoxen (1995,1996) for more details on the GCUBED model and McKibbin and Wong (1996) for the AP-GCUBED Model.

A key aspect of the model is the integration of data from input-output tables with

Table 1: Summary of Main Features of AP-GCUBED

☻ Specification of the demand and supply sides of economies;

☻ Integration of real and financial markets of these economies;

☻ Intertemporal accounting of stocks and flows of real resources and financial assets;

☻ Imposition of intertemporal budget constraints so that agents and countries cannot forever borrow or lend without undertaking the required resource transfers necessary to service outstanding liabilities;

☻ Short run behavior is a weighted average of neoclassical optimizing behavior and ad-hoc "liquidity constrained" behavior;

☻ The real side of the model is disaggregated to allow for production and trade of multiple goods and services within and across economies;

☻ Full short run and long run macroeconomic closure with macro dynamics at an annual frequency around a long run Solow/Swan/Ramsey neoclassical growth model.

☻ The model is solved for a full rational expectations equilibrium at an annual frequency from 1995 to 2100.

Table 2: Overview of the AP-GCUBED Model

Regions

United States
Japan
Australia
Rest of the OECD
Korea
Thailand
Indonesia
China
Malaysia
Singapore
Taiwan
Hong Kong
Philippines
South Asia
Oil Exporting Developing Countries
Eastern Europe and the former Soviet Union
Other Developing Countries

Sectors

Energy
Mining
Agriculture
Durable Manufacturing
Non-Durable Manufacturing
Services

conventional macroeconomic data. An example of an interindustry accounting matrix and the relationship between sectoral and aggregate data is shown in figure 1. This data mapping lies behind the behavioral assumptions which follow. In the top left hand quadrant is a 6 X 6 matrix which tracks the flows of goods between the 6 sectors in country k. The first column contains the number of each industry. Each row corresponds to the use of an industry's output. The first six elements of the row is the use of an industry's output in each of the twelve industries. To the right of this is the use of each industry's good for Consumption (C), Investment (I), Government purchases (G), exports (X) and imports (IM) from foreign countries of the same good to satisfy domestic demand. For example the first row is the production of sector 1 good. This output is used by the industry columns 1 through 6 representing use by each other sector and also for final demand. For each industry there is a row which gives similar information. Below the six sectors in the lower left hand corner, are the uses of the primary factors of production: sector specific resources (R), Capital (K) and labor (L). Note that some capital and labor are used in final consumption, investment and government spending. Gross output of sector 1 is the sum of each element along a row. The sum across the columns of final demand for each row gives the value added of that sector. Gross output for sector 1 is also the sum of each element of a column, since the value of inputs equals the value of outputs.

a. Firms

Each of the six sectors is represented by a single firm in each sector which chooses its inputs and its level of investment in order to maximize its stock market value subject to a multiple-input production function and a vector of prices it takes to be exogenous. The nesting for the production decision is set out in Figure 2. For each sector h, output (Q_h) is produced with

inputs of capital (K_h), labor (L_h), energy (E_h), materials (M_h) and a sector-specific resource (R_h). Energy and materials are an aggregate of inputs of intermediate goods. These intermediate goods are, in turn, aggregates of imported and domestic commodities which are taken to be imperfect substitutes. Due to data limitations we assume that all agents in the economy have identical preferences over foreign and domestic varieties of each particular commodity. We represent these preferences by defining twelve composite commodities that are produced from imported and domestic goods. For commodity h the production function for composite good Y_h in terms of domestic output Q_h and imported good IM_h. For example, agricultural products purchased by agents in the model are a composite of imported and domestic agricultural products. By constraining all agents in the model to have the same preferences over the origin of goods, we require that (for example) the agricultural and service sectors have the identical preferences over domestic energy and energy imported from the middle east.[14] This accords with the input-output data we use and allows a very convenient nesting of production, investment and consumption decisions.

Following the approach in the MSG2 model, we assume that the capital stock in each sector changes according to the rate of fixed capital formation and the rate of geometric depreciation. The investment process is assumed to be subject to rising marginal costs of installation, with total real investment expenditures in sector h equal to the value of direct purchases of investment plus the per unit costs of installation. These per unit costs, in turn, are assumed to be a linear function of the rate of investment. One advantage of using an adjustment

[14] This does not require that both sectors purchase the same amount of oil, or even that they purchase oil at all; only that they both feel the same way about the origins of oil they buy.

cost approach is that the adjustment cost parameter can be varied for different sectors to capture the degree to which capital is sector specific.

The goal of each firm is to choose inputs of labor, energy, materials and sector specific resources to maximize intertemporal net-of-tax profits. For analytical tractability, this problem is assumed to be deterministic (in other words, the firm is assumed to believe its estimates of future variables with subjective certainty) subject to constraints on capital accumulation and cost function. Solving the optimization problem facing this representative firm, gives the set of derived demands for factors of production. These factors (L, E, and M are hired to the point where the marginal productivity of these factors equals their prices relative to the output price of the sector. We can also use these factor demand equations together with the production function to rewrite the model in terms of cost functions. In this case the price of the output at each level of the tier structure will be a function of the price of variable inputs and the quantities of available fixed factors (such as capital).

The price of labor is determined by assuming that labor is mobile between sectors in each region, but is immobile between regions. Thus, wages will be equal across sectors[15]. The wage is assumed to adjust according to an overlapping contracts model where nominal wages are set based on current and expected inflation and on labor demand relative to labor supply. In the long run, labor supply is given by the exogenous rate of population growth, but in the short run, the hours worked can fluctuate depending on the demand for labor. For a given nominal wage, the demand for labor will determine short run unemployment in each industry. This will vary across

[15] In future developments of the model we propose to introduce an adjustment cost model of labor mobility.

industries depending on the composition of demand for each sectors good.

The solution of the optimization problem also gives that the rate of gross investment in sector h is a function of "Tobin's q" for that sector. Following the MSG2 model, it is assumed that investment in each sector is a weighted average of forward looking investment and investment out of current profits.

So far, we have described the demand for investment by each sector. Investment goods are assumed to be supplied by a firm facing an optimization problem similar to those of the twelve industries described above (and not repeated here). Like other industries, the investment sector demands labor and capital services as well as intermediate inputs. The investment column in the input-output table is used to parameterize the investment sector's production function. As with the discussion above, there is a shadow "q" associated with investment in the investment goods sector.

b. Households

Households consume a basket of composite goods and services in every period and also demand labor and capital services. Household capital services consist of the service flows of consumer durables plus residential housing. Households receive income by providing labor services to firms and the government, and from holding financial assets. In addition, they also receive transfers from the government.

The behavior of a representative household can be thought of as a sequence of decisions. Households first decide on aggregate consumption for each period. Once this is determined expenditure is allocated across goods and services based on preferences and relative prices. We

use a nested constant elasticity of substitution utility function, so income elasticities will be unity and price elasticities can differ from unity.[16] Total private consumption is allocated between capital, labor, a basket of energy goods and a basket of non-energy goods. Materials are a sub-aggregate of intermediate goods.

Aggregate consumption is chosen to maximize an intertemporal utility function subject to the constraint that the present value of consumption be equal to human wealth plus initial financial assets. Human wealth in real terms is defined as the expected present value of future stream of after tax labor income of households. Financial wealth is the sum of real money balance, real government bonds in the hand of the public, net holding of claims against foreign residents and the value of capital in each sector. The solution to this maximization problem is the familiar result that aggregate consumption is equal to a constant proportion of private wealth, where private wealth is defined as financial wealth plus human wealth. However, based on the evidence cited by Campbell and Mankiw (1987) and Hayashi (1982)) we follow the approach in the MSG2 model and assume that only a portion of consumption is determined by these intertemporally-optimizing consumers and that the remainder is determined by after tax current income. This can be interpreted as liquidity constrained behavior or a permanent income model in which household expectations regarding income are backward-looking. Either way we assume that total consumption is a weighted average of the forward looking consumption and backward-looking consumption.

Once the level of overall consumption has been determined, spending is allocated among

[16] In the preliminary version of the model presented here, the elasticities of substitution are assumed to be unity. We are in the process of estimating the elasticities econometrically using a long time series of input-output data.

goods and services. Households demand each of the model's 6 commodities and also demand labor and capital services. Household capital services consist of the service flows of consumer durables plus residential housing. The result is a system of household demand equations which depend on the level of aggregate consumption and the price of the individual goods relative to the price of the consumption basket.

The solution for the consumption of capital services is a little more complex. Here we assume that consumers invest in household capital in order to generate a desired flow of capital services subject to the accumulation equation for capital and a cost of adjustment model. Solving this problem yields results similar to those discussed for firms above. However, since no variable factors are used in producing capital services, the first order conditions for the problem give investment as a function of the shadow price of capital. The demand for capital services arising in the household consumption problem determines the price of capital services given the supply of services. The stock of household capital at each point in time is determined by the initial stock of capital, the rate of depreciation and the rate of gross investment in the stock of capital. In the same way that investment by firms is determined, the investment by households depends on the Tobin's q associated with the stock of household capital.

c. Government

We take each region's real government spending on goods and services to be exogenous and assume that it is allocated among final goods, services and labor in fixed proportions, which we set to 1987 values. Total government outlays include purchases of goods and services plus interest payments on government debt, investment tax credits and transfers to households.

Government revenue comes from sales, corporate and personal income taxes, and by issuing government debt. We assume that agents will not hold government bonds unless they expect the bonds to be paid off eventually. This transversality condition implies that the current level of debt will be equal to the present value of future budget surpluses.[17]

The implication of these constraints is that a government running a budget deficit today must run an appropriate budget surplus as some point in the future. Otherwise, the government would be unable to pay interest on the debt and agents will not be willing to hold it. To ensure that the constraint holds at all points in time we assume that the government levies a lump sum tax in each period equal to the value of interest payments on the outstanding debt.[18] In effect, therefore, any increase in government debt is financed by consols, and future taxes are raised enough to accommodate the increased interest costs. Thus, any increase in the debt will be matched by an equal present value increase in future budget surpluses. Other fiscal closure rules are possible, such as requiring the ratio of government debt to GDP to be unchanged in the long run. These closures have interesting implications but are beyond the scope of this paper[19].

d. Financial Markets and the Balance of Payments

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[17] Strictly speaking, public debt must be less than or equal to the present value of future budget surpluses. For tractability we assume that the government is initially fully leveraged so that this constraint holds with equality.

[18] In the model the tax is actually levied on the difference between interest payments on the debt and what interest payments would have been if the debt had remained at its base case level. The remainder, interest payments on the base case debt, is financed by ordinary taxes.

[19] See Bryant and Zhang (1996) for an overview.

The seventeen regions in the model are linked by flows of goods and assets. Flows of goods are determined by the import demands described above. These demands can be summarized in a set of bilateral trade matrices which give the flows of each good between exporting and importing countries. There is one 17 by 17 trade matrix for each of the six goods.

Trade imbalances are financed by flows of assets between countries (except where capital controls are in place). In the simulations presented below we assume asset markets are perfectly integrated across the region. With free mobility of capital, expected returns on loans denominated in the currencies of the various regions must be equalized period to period according to an uncovered interest parity condition. While we allow for exogenous risk premium in the calibration of the model, there is no allowance for endogenous risk premia on the assets of alternative currencies.

Determining initial net asset positions and hence base-case international capital flows is non-trivial. We assume that capital flows are composed of portfolio investment, direct investment and other capital flows. These alternative forms of capital flows are perfectly substitutable ex ante, adjusting to the expected rates of return across economies and across sectors. Within an economy, the expected return to each type of asset (i.e. bonds of all maturities, equity for each sector etc) are arbitraged, taking into account the costs of adjusting physical capital stock and allowing for exogenous risk premia. Because physical capital is costly to adjust, any inflow of financial capital that is invested in physical capital (i.e. direct investment) will also be costly to shift once it is in place. The decision to invest in physical assets is based on expected rates of return. However, if there is an unanticipated shock then ex-post returns could vary significantly. Total net capital flows for each economy in which there are open capital

markets are equal to the current account position of that country. The global net flows of private capital are constrained to zero.

We treat the OPEC region differently to the regions which have full internal structures. We assume that OPEC chooses its foreign lending in order to maintain a desired ratio of income to wealth.

e Data, Parameterization and Model Solution

The data used in the AP-GCUBED model comes from a number of sources. Unlike the GCUBED model we have not yet estimated the CES production elasticities of substitution. We currently assume the production function are Cobb-Douglas.

The input-output tables for the Asia-Pacific economies are from the Institute of Developing Economies updated to 1992. The Australian table is from the Australian Bureau of Statistics. In lieu of obtaining input-output tables for the aggregate ROECD region, we currently create the tables for this region based on the U.S. table and adjusted for actual final demand components from aggregate ROECD macroeconomic data. In effect, we are assuming that all countries modeled share the same production technology but differ in their endowments of primary factors and patterns of final demands. This assumption is a temporary necessity while we complete construction of the AP-GCUBED database.

Trade shares are based on the United Nations SITC (Standard Industry Trade Classification) data for 1992 with sectors aggregated from 4 digit levels to map as closely as

possible to the SIC (Standard Industry Classification) used in the U.S. input/output data[20]. This data is from the International Economic Databank at the ANU.

The parameters on shares of optimizing versus backward looking behavior are taken from the MSG2 model. These are based on a range of empirical estimates as well as a tracking exercise used to calibrate the MSG2 model to the experience of the 1980s.

AP-GCUBED is solved using the same software as the MSG2 model The model has approximately 7,400 equations in its current form with 140 jumping or forward looking variables, and 263 state variables.

3. Results for Investment and Productivity Shocks

This section considers results for a permanent reduction in Japanese investment and a temporary rise in total factor productivity growth in China.

A) Permanent fall in Japanese Autonomous Investment

The Japanese economy experienced a long recession beginning in the latter part of 1991 from which it is now (mid 1996) only beginning to emerge. An important aspect of this recession was the large decline in private investment expenditure (see Suzuki (1996), Kawasaki and Tsutsumi (1996) and McKibbin (1996)). This simulation is intended to explore what a substantial decline in investment in a large economy such as Japan's would have on the region. Traditional Keynesian models with only goods linkages between economies would predict a negative stimulus to neighboring economies depending on the extent of trade between the

[20] A full mapping of SITC and SIC codes is contained in a technical appendix available from the authors by request.

economies. With open capital markets and financial as well as goods market linkages the results below suggest quite a different outcome. Before proceeding with analyzing these results it is worth clarifying how to think about the results in relation to the decline in Japanese investment through the recent recession.

One of the problems with any simulation study is what variables are to be taken as exogenous. For example in modeling the Japanese experience since 1990 private investment would be an endogenous variable responding to changes in underlying determinants such as expected future demand, interest rates etc. In another paper (McKibbin (1996)) the Japanese experience is found to be due importantly to announcements of fiscal expansion that were not carried through. The result was not only that a demand stimulus was not injected into the economy in the 1992 through 1993 period, but there was crowding out of private demand through the reaction of financial markets generating high real interest rates and a strong exchange rate. This caused private investment to fall and net exports to contract. In the experiment presented in the current paper we are not modeling the fiscal aspects of the recent Japanese experience. Indeed in the simulation presented, some of the asset prices will move in the opposite direction to that actually experienced during the early 1990s in Japan precisely because we are not modeling all aspects of that period. This simulation is meant to be indicative of the macroeconomic linkages between economies and how an autonomous decline in investment would be transmitted throughout the region.

The simulation is a permanent decline in autonomous investment spending in each sector in Japan by 0.4% of GDP forever. The total effect is therefore a permanent decline of 2.4% of GDP in autonomous private investment expenditure. In smaller sectors this is a large investment

decline because it is scaled to GDP rather than sectoral output.

The results are presented in figure 3. The results in each figure are the percentage deviation of a range of variables from what otherwise would have occurred relative to the baseline projection of the model without the shocks imposed. The variables presented are: real gross domestic product (GDP); real consumption; real investment; and trade and current account balances, all expressed as percent of baseline GDP deviation from baseline. Real and nominal effective exchange rates are expressed as percentage deviation from what otherwise would have been experienced (with a rise being an appreciation). The interest rates presented are the 1 year (short term) and 10 year (long term) nominal interest rates expressed as percentage point deviation from what otherwise would have been. A decline of 0.18 is a decline of 18 basis points or 0.18 percentage points. For example if the interest rate on ten year bonds would have been 7 percent , the result of -0.18 change would be an interest rate of 6.82 percent.

Figure 3 contains results for the effect on Japan of the decline in investment. The immediate impact is on financial markets. The decline in investment tends to lower real long term interest rates which leads to a net outflow of financial capital in search of higher returns abroad. This outflow of capital depreciates the real and nominal effective exchange rates. The effect on aggregate demand in Japan is mixed. In the short term the decline in private investment imparts a negative demand shock to the economy, however the depreciation of the real exchange rate stimulate net exports. The fall in investment dominates and therefore GDP declines on balance by 0.6 percent in 1996. Over time the decline in investment relative to baseline implies a capital stock that is growing less than baseline. The demand effects are then supplemented by declining aggregate supply over time (relative to baseline). By 2018, real GDP is 2.8% below

baseline (in levels). Note that the Japanese growth rate is not affected in the medium to longer term but only the level of income or output at each point in time.

The results for consumption are also contained in panel 1 of figure 3. Consumption initially declines because of the decline in future wealth as well as the short term decline in economic activity. After initially declining (relative to baseline) consumption begins to rise, in contrast to GDP which flattens out at a lower level. The difference between consumption and GDP reflects the difference between GDP (value added of production in Japan) and GNP or income (return to all Japanese factors of production) because a crucial part of the adjustment process is that the Japanese saving that was being used for domestic investment is now channeled into foreign investment. Indeed the improvement in the trade and current account balances reflect this capital outflow into foreign economies. This capital that accumulates abroad yields a flow of future returns which are reflected in the increasing gap between the trade balance and current account balance shown in panel 2 of figure 3. Consumption is lower that baseline by 2018 but not by as much as GDP because the saving that would have gone into Japanese investment is still going into investment but in overseas capital stock rather than capital stock located in Japan.

It is important to stress that macroeconomic policy is assumed not to respond to undesirable fluctuations in short run economic activity. Monetary policy is assumed to be targeting a stock of nominal money balances in each economy. Fiscal policy is defined as a set of fixed tax rates and government spending constant in real terms with a lump sum tax varying to satisfy the intertemporal budget constraint facing the government. In terms of the short run nominal interest rate in Japan you see from panel 4 a slight spike in nominal rates even though real short rates fall. This is due to the rise in prices from a depreciated exchange rate which

temporarily reduced real money balances and therefore raises short term nominal interest rates.

The implications for other countries in the region of the decline in Japanese investment spending vary according to the extent of trade linkages and openness of financial markets in these economies. To give a representative overview of how the adjustment process occurs in these economies results are presented for Korea in Figure 4. The units for each panel are the same as for the Japanese results.

The outflow of capital from Japan implies an inflow into other economies. In the case of Korea this occurs through the appreciation of the exchange rate which worsens the current account and trade balances. Investment in physical capital jumps in Korea in 1996 by 0.6 percent of Korean GDP which is around 2 percent of investment. The effects on GDP are similar to those for Japan in the sense that there is a short term demand effect on production as well as a gradual supply side effect as physical capital is put in place. The rise in investment is offset by a deterioration in the trade balance but GDP still rises in the short run. The Keynesian stimulus raises consumption for a number of years although the higher production does not sustain higher consumption forever because an increasing part of the higher production is repatriated to Japan as returns to capital invested in Korea. Thus the initial worsening on the trade balance as financial capital flows into Korea is gradually reversed as returns to that capital are repatriated to Japan in the form of a gradually rising Korean trade surplus.

Apart from an appreciation of the Korean exchange rate in real and nominal effective terms, the inflow of capital tends to lower interest rates in Korea and indeed throughout the world as the capital flowing out of Japan enters world capital markets.

The results from this simulation illustrate that macroeconomic interdependence is

affected in important ways by the adjustment of international capital flows and movements in financial prices. These adjustments in financial prices and flows of financial capital have important effects on demand and supply in the markets for goods and services. Foreign economies are impacted by a negative shock to aggregate demand because of a decline in their exports of goods and services to Japan. These countries also experience a positive shock to aggregate supply because the slowdown in Japanese investment makes funds available to the rest of the world at a lower interest rate than otherwise. In addition, the inflow of foreign capital tends to appreciate the real exchange rate in the receiving economy which makes imported intermediate goods cheaper in those economies and therefore allow for more physical production at the same cost. In the case of Korea, the positive supply shock dominates the negative demand shock. In the case of Singapore (not shown) the demand effect dominates the supply side shock that occurs because of the changes in capital.

In an important sense the results presented above are only a partial indication of the experience of the early 1990s. For example, if the decline in Japanese private investment occurs at the same time as a substantial Japanese fiscal expansion financed by issuing bonds, the capital outflow would not occur and indeed the positive effects on the rest of the world would be reversed. In addition the real exchange rate would appreciate as capital flows into Japan to the extent that the increase in demand for saving by the government outweighed the decline in private investment.

b) A rise in Total factor productivity in China.[21]

The second simulation considered in this section is a temporary rise in total factor productivity (TFP) growth in all sectors in China. This is modeled as a rise in the level of TFP of 1 percent in 1996. The level of TFP is then 1 percent higher forever. The growth rate of TFP is therefore higher by 1 percent in 1996 and then returns to the baseline growth rate thereafter.

Results for this simulation are contained in Figure 5 for China and figures 6 and 7 for Japan and Hong Kong respectively. All variables are relative to the baseline simulation. Consider now the adjustment process that unfolds as TFP rises in China. The growth rate of output in each sector will respond differently to the rise in TFP because the rise in productivity growth raises the return to all factor inputs and therefore will change the amount of inputs used. Because labor is assumed mobile across sectors but fixed inside China but capital is mobile internationally there will be different responses at the sectoral level with labor intensive sectors experiencing real wage increases. The return to capital will also rise in China but this will induce a capital inflow from overseas to take advantage of the higher rate of return. This inflow of capital tends to appreciate the real and nominal effective exchange rate. In addition greater use of intermediate goods are also partly satisfied by imports. This effect, together with the stronger exchange rate tends to worsen the current account reflecting the capital inflow. Production rises in China due both to higher productivity but also due to the increased use of primary factors of production as well as intermediate inputs. GDP which is the measure of value added rises by over 3.4 percent in 1996 before gradually settling down to being close to 3 percent higher. This level

[21] Other simulations relating to growth in China can be found in McKibbin and Huang (1996) using the GCUBED model.

is significantly higher than the rise in TFP because labor share in value added in the database in close to 30 percent and therefore the change in output will be the change in productivity multiplied by the inverse of labor's share.

Panel 1 in Figure 5 shows that GNP moved quite differently to GDP in China. As production across the economy rises in China, this is increasingly used to fund the repatriation of the returns to foreign capital that is being used to produce the higher output. The increasing gap between GDP and GNP is also reflected in the increasing difference between the trade and current account balances shown in panel 3 of figure 5.

The effects of the shock in China on other countries depends importantly on the size of those economies relative to China as well as the nature of trade in both final and intermediate goods as well as investment flows between those economies. To illustrate this difference, figure 6 contains the results for Japan for the simulation and Figure 7 shows the results for Hong Kong for a rise in Chinese growth.

The results for Japan illustrate that the effect on Japan is small. Capital flows out of Japan into China which tends to reduce Japanese GDP but eventually raises Japanese GNP as the returns to capital are repatriated to Japan. The Japanese exchange rate depreciates reflecting the capital outflow and this improves the overall Japanese trade position.

The effects on Hong Kong are much larger as shown in Figure 7. GDP falls in Hong Kong for the same reasons as for Japan as capital is relocated to China. This effect is much larger for Hong Kong because China is much larger relative to Hong Kong than it is relative to Japan. If both Japan and Hong Kong provided a dollar of addition investment to China this would be a much larger share of Hong Kong GDP than Japanese GDP. Secondly, Hong Kong provides a

greater amount of intermediate inputs to China and therefore the increase in Chinese growth increase the exports of Hong Kong to China far more than exports from Japan to China. The Hong Kong trade balance improves by over 0.8 percent of Hong Kong GDP in 1996. Thirdly note that investment in Hong Kong initially falls but then rises above baseline forever because of the larger positive spillovers of the Chinese productivity growth to the Hong Kong economy which produces more goods for intermediate inputs into Chinese production. The exchange rate effects are much larger than for Japan with a depreciation of over 2.2 percent in effective terms in 1996.

These two simulation illustrate that the standard Keynesian results of positive short run spillovers between economies need not hold when allowance is made for financial capital flows between economies that affect the stock of physical capital and when allowance is made for imported intermediate goods whose demand depends on the real exchange rate. Incorporating the important role of imported intermediate inputs implies that the real exchange rate directly affects aggregate supply and therefore a capital inflow both directly raises the physical capital stock as well as appreciating the real exchange rate thus making imported inputs cheaper.

5. Conclusion

This paper presents a framework for analyzing macroeconomic and sectoral linkages within the Asia-Pacific region and the global economy. Using this new dynamic framework several insights emerge. The first is that macroeconomic interdependence depends importantly on the sectoral linkages between economies as well as the standard links through final goods trade. Secondly the financial linkages between economies through changes in interest rates and

exchange rates are potentially very important in transmitting macroeconomic shocks between economies. Thirdly the supply side adjustment through changes in real exchange rates on intermediate input prices are as important as the traditional demand side channels of transmission.

This paper is meant to be illustrative of the nature of the transmission mechanism of shocks between economies in the Asia Pacific region. As these results illustrate, allowing for sectoral linkages across economies and increasingly integrated financial markets can be very important for the magnitude and sign of the transmission of macroeconomic shocks.

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Figure 1: Stylized Interindustry Accounting Matrix for country k.

	1	2	3	6	C	I	G	X	M	tot
1	N_{k1}^{1k}			N_{k6}^{1k}	C_k^1	I_k^1	G_k^1	X_k^1	IM_k^1	Y_{k1}
2										
3										
6	N_{k1}^{6k}			N_{k6}^{6k}	C_k^6	I_k^6	G_k^6	X_k^6	IM_k^6	Y_k^6
R	R_{k1}				---	---	---	---	---	
K	K_{k1}			K_{k6}	K^C	K^I	---	---	---	
L	L_{k1}			L_{k6}	L^C	L^I	L^G	---	---	
Y										

Figure 2: Production Nesting

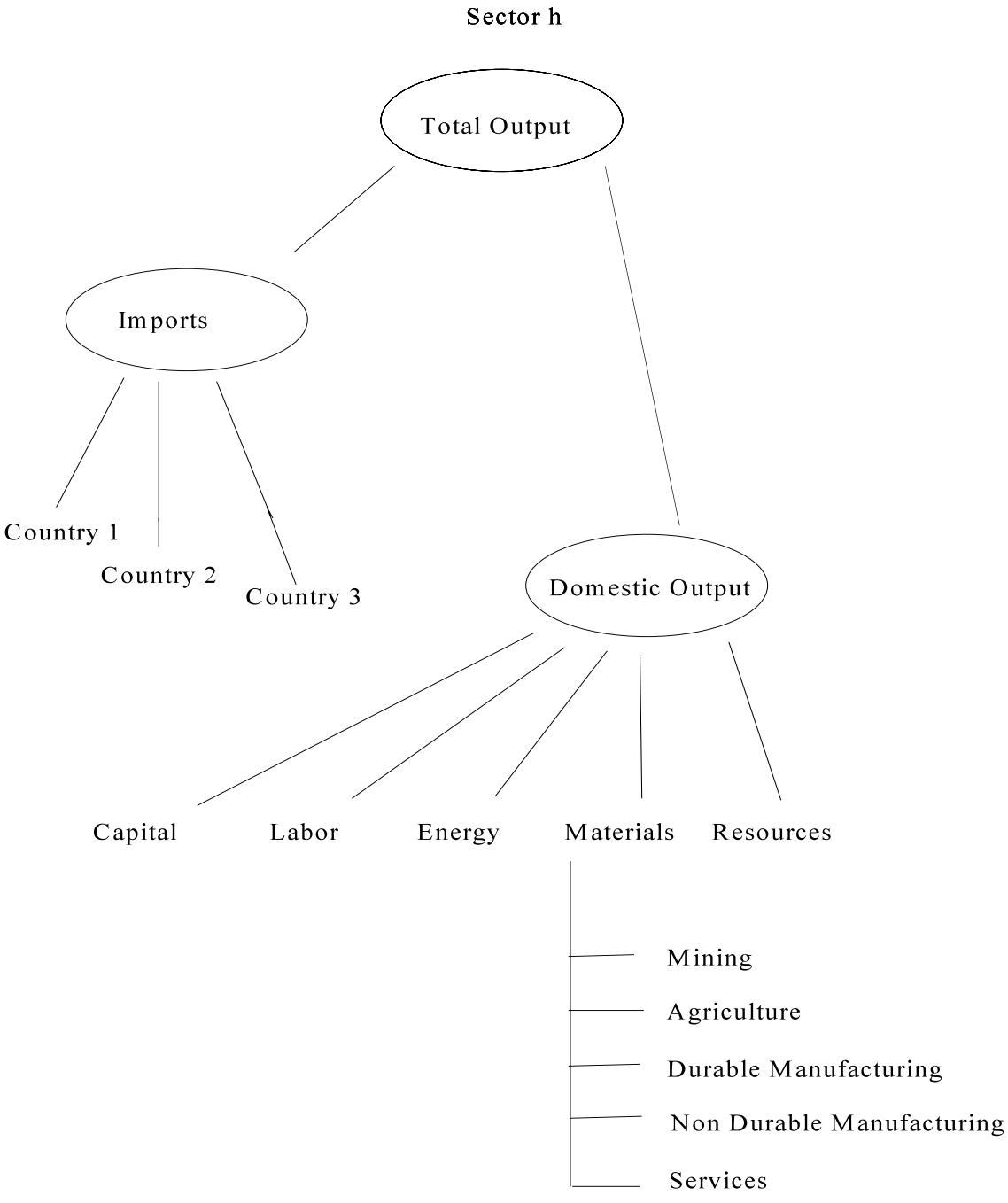

Figure 3: Effects on Japan of a Permanent Reduction in Japanese Private Investment of 2.4% of GDP

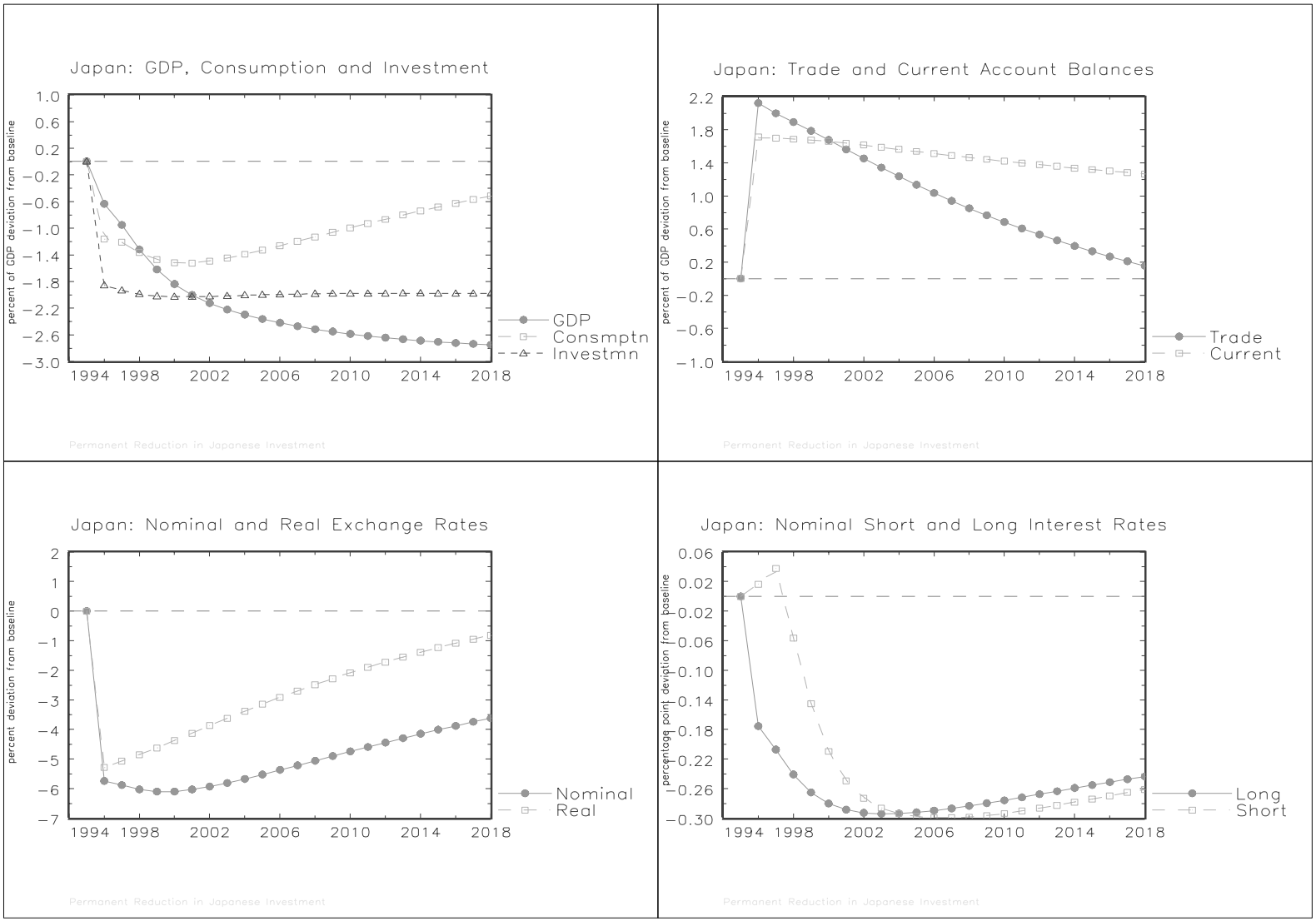

Figure 4: Effects on Korea of a Permanent Reduction in Japanese Private Investment of 2.4% of GDP

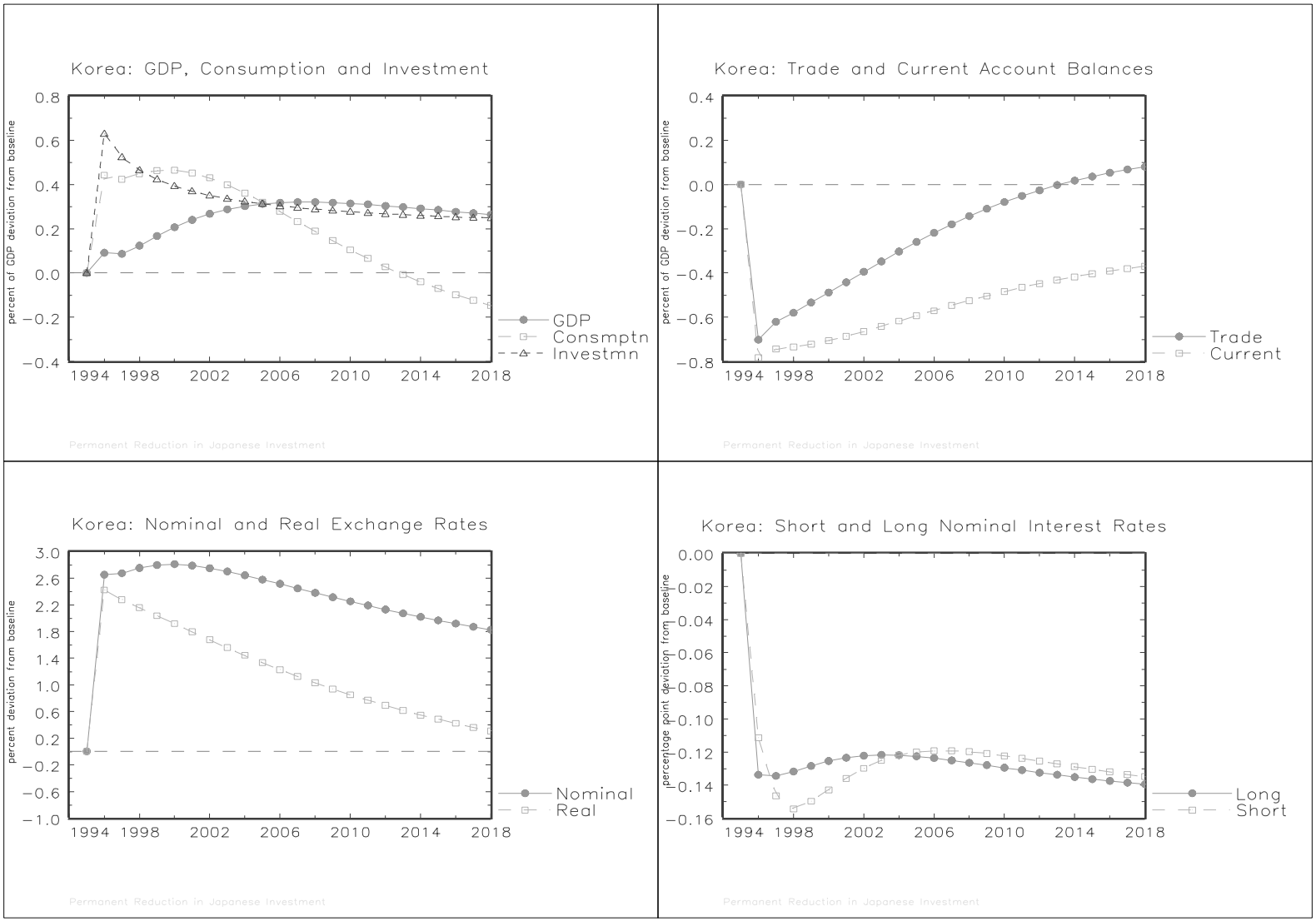

Figure 5: Effects on China of a Temporary Increase in the Growth Rate of Chinese Total Factor Productivity in All Sectors

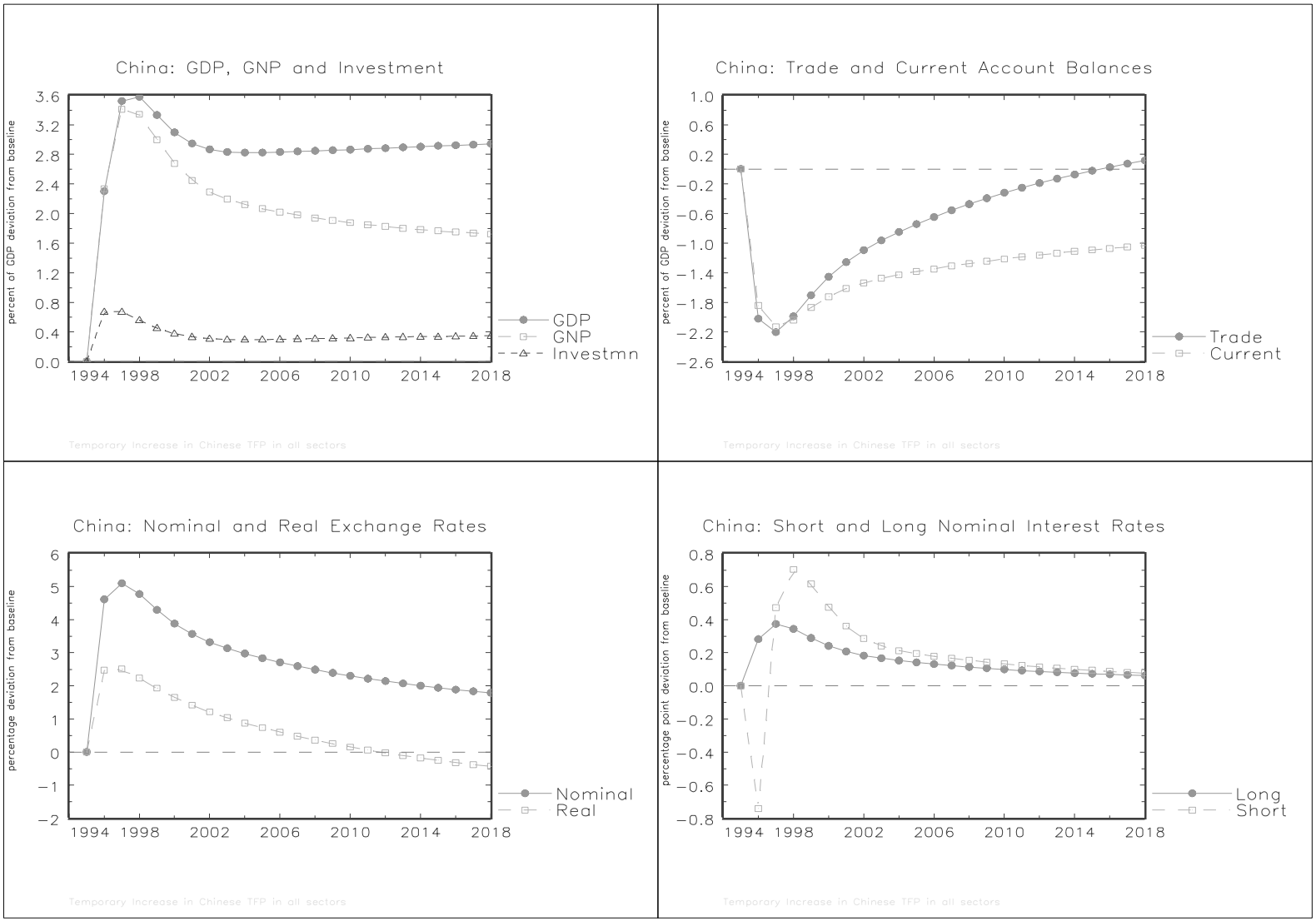

Figure 6: Effects on Japan of a Temporary Increase in the Growth Rate of Chinese Total Factor Productivity in All Sectors

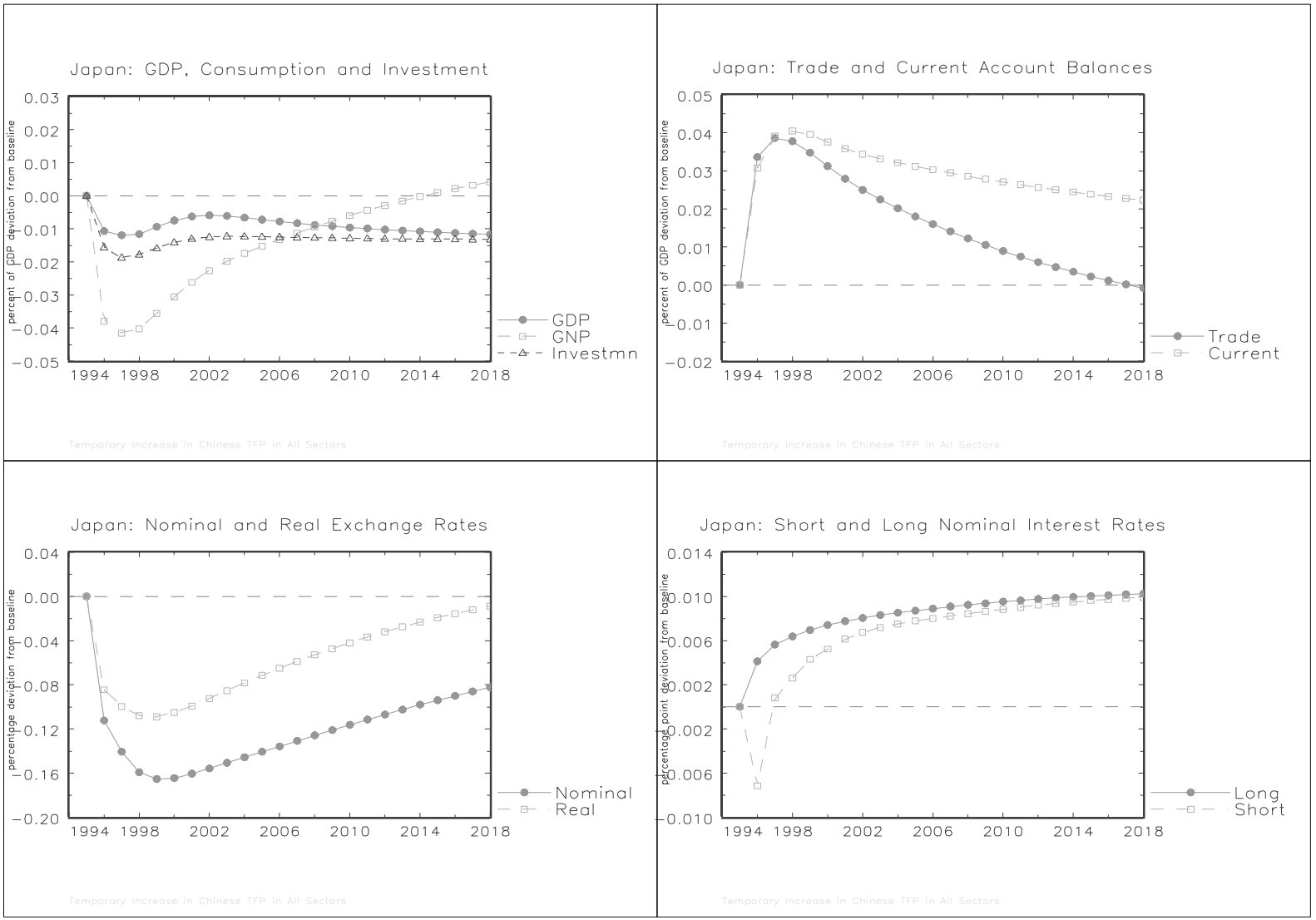

Figure 7: Effects on Hong Kong of a Temporary Increase in the Growth Rate of Chinese Total Factor Productivity in All Sectors