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School of Economics Discussion Papers

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November 2011

KDPE 1120

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November 15, 2011

Abstract

In this paper, we construct a two-country business cycle accounting model in order to investigate quantitatively the relationship between Japan and the Asian Tigers. Our model is based on Backus, Kehoe and Kydland (1994) in which each economy produces tradable intermediate goods that are aggregated to form final goods within each economy. We apply the business cycle accounting method of Chari, Kehoe and McGrattan (2007) and find that the main source of high frequency fluctuation in output in each economy is the fluctuation of production efficiency within its own economy. Furthermore, the growth in the Asian Tigers' production efficiency had a significant positive effect on Japanese economic growth over the 1980-2009 period through the endogenous terms of trade effect.

JEL Classification: E13, E32, F41

Keywords: International Business Cycles, Business Cycle Accounting, Terms of trade, Productivity

*The authors thank Jagjit Chadha, Kazumasa Iwata, M. Ayhan Kose, Tsutomu Miyagawa, Kenji Miyazaki, Andrea Raffo, Koichi Yano and participants of the ESRI International Conference 2010, 37th Eastern Economic Association Annual Conference, and the 2011 Asian Meeting of the Econometric Society for helpful comments. This research was conducted as an international collaboration project at the Economic and Social Research Institute, Cabinet Office, Government of Japan.

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1 Introduction

In this paper, we construct a two-country business cycle accounting model in order to investigate quantitatively the relationship between Japan and the Asian Tigers. Our model is based on Backus, Kehoe and Kydland (1994) in which each economy produces tradable intermediate goods that are aggregated to form final goods within each economy. We apply the business cycle accounting method of Chari, Kehoe and McGrattan (2007) and find that the main source of high frequency fluctuation in output in each economy is the fluctuation of production efficiency within its own economy. Furthermore, the growth in the Asian Tigers' production efficiency had a significant positive effect on Japanese economic growth over the 1980-2009 period through the endogenous terms of trade effect.

Business cycle relationship between Japan and the Asian Tigers are examined by various methods with mixed results. There are many studies using time series econometric methods. Chen and Shen (2007) use a Markov Switching VAR model and the Non-linear Granger causality test to find the output's lead-lag relationship of Japan and Taiwan. They find the weak evidence of Japan leading Taiwan from 1962:Q1 to 2004:Q4. Girardin (2005a, 2005b) also conducts a similar estimation of a Markov Switching models. Abeysinghe and Forbes (2005) use a structural VAR model to estimate the influence of a shock to one country affects output in other countries. They not only measure direct effects through bilateral trade but also measure indirect effects through output multipliers. They find that these effects from Japan to the East Asian countries are negative. Sato and Zhang (2006) conduct the bivariate cointegration test for Japan, NIEs including Korea and Taiwan, some other Asian countries, and the United States. They find cointegration of output both between Japan and Korea and between Japan and Taiwan for the period from 1978:Q1 to 2004:Q4. Selover (2004) examines the Japan-Korea synchronization of industrial production from 1960:Q1 to 2002:Q1 by using the Structural VAR, showing strong impact from Japan to Korea and limited impact from Korea to Japan. Weber (2010) extracts common stochastic growth trend and common business cycle components using a VECM estimation, and shows that the convergence of the Asian Tigers towards Japan in the long-run has started since the early 1990s.

Business cycle relationships between Japan and the Asian Tigers are also discussed from the viewpoint of the regional integration possibility. Several studies focus on the role of international trade on business cycles following

Frankel and Rose (1998) who show that greater trade integration increases output comovement by generating the spillover effects of aggregate demand. As stressed in Kimura (2006), Kim, Lee, and Park (2009) and many others, Japan and the Asian Tigers have created transnational production networks and trade networks, which can be the channel of business cycle transmission. Shin and Wang (2004) use the data for annual 1976-1997 for ten Asian countries including Japan, Korea, and Taiwan. Their results indicate that higher intra-trade intensity leads to higher business cycle comovement. Their experiment also implies that intra-trade intensity has stronger effects on comovement, if Japan is dropped from the sample. Rana (2007), extending Shin and Wang (2004) by adding the explanatory variables such as intra-industry trade and fiscal policy measures, also finds the importance of the role of trade channel. Choe (2001) conducts a regression of cyclical components of GDP on trade intensity for ten Asian countries for 1981-1995 and finds that Japan has a large impact on business cycle synchronization in this region. Weber (2009), employing the VECMs, studies output coherence of Japan, Korea, Taiwan, and other Asian countries through exports and investment. He finds that negative long-run effects of exports on output and positive long-run effects of investment on output between Japan and Korea and between Japan and Taiwan. Moneta and Ruffer (2009) conduct the dynamic common factor model estimation for ten Asian economies including Japan, Korea, and Taiwan, and find that most Asian countries including Taiwan and Korea share some common growth components, but Japan does not. Our dynamic general equilibrium approach shows that Japan and the Asian Tigers are affecting each other mainly through the endogenous terms of trade effect in response to production efficiency growth.

The role of financial integration in the Asian region is also highly paid attention, but the impact on welfare gains seems relatively small. Kim, Kim and Wang (2006) apply the model of Sorensen and Yosha (1998) to Japan, Korea, Taiwan and the other seven Asian countries for 1970-2000 and find the low degree of international risk sharing in the Asian region and the high degree of country specific unsmoothed component. This is consistent with van Wincoop (1999) and Prasad, Rogoff, Wei, and Kose (2003). Kim, Kim and Wang (2007) examine the Saving-Investment correlation of 10 Asian countries in 1980-2002. Even after controlling for cyclical effects, they show that each country's investment are largely financed by savings within the country due to the limited capital mobility in this region. Jeon, Oh, and Yang (2006) and Fujiki and Hagiwara (2007) find similar results that risk sharing within Asian region including Japan, Korea, and Taiwan is quite limited, although the regional financial integration has proceeded. Our results show that consumption fluctuations in each region are predominantly accounted for by domestic factors, which is consistent with these findings.

Our quantitative approach is related to two bodies of literature. The first is the international real business cycle literature which focuses on the propagation mechanism of productivity shocks in a two-country framework. Backus, Kehoe and Kydland (1992) and Baxter and Crucini (1995) find that a two-country real business cycle model faces a so called quantity anomaly in which the cross-country correlation of output is higher than that of consumption in the data while the model will indicate the opposite. In attempt to solve this puzzle, Stockman and Tesar (1995) consider a two-country economy in which each country produces tradable and non-tradable goods. Takeuchi (2008) applies this model to analyze the effect of production technology and investment specific technology shocks on the business cycle correlation between Asia and the U.S.-Japan coalition. He finds that the increase in the cross-region business cycle correlation is a result of the increase in the correlation of these technology shocks. Since we believe that Japan and the Asian Tigers are trading compliments rather than perfect substitutes, we apply the Backus, Kehoe and Kydland (1994) framework which considers two-countries that trade specialized intermediate goods with each other. Our results also show that production efficiency is the key to understand the business cycle correlation between Japan and the Asian Tigers.

The second is the business cycle accounting literature introduced by Chari, Kehoe and McGrattan (2007). They define distortions in relevant markets as wedges in equilibrium conditions derived from a general equilibrium model, compute the wedges using time series data of the economy of interest, and simulate the model using the computed wedges to investigate their impacts on the economy. Kobayashi and Inaba (2006) applies the method to Japan and finds that disturbances in production efficiency and the labor market are important in accounting for the lost decade. Otsu (2010a) applies the method to a small open economy model and shows that production efficiency and labor market disturbances are important in accounting for the Asian crisis in 1998. Otsu (2010b) applies the method to a two-country one-good model to account for the business cycle correlation between Japan and the U.S. We further extend the model to a two-country two-good setting to incorporate the cross-country business cycle relationship between Japan and the Asian Tigers through the trading of intermediate goods. Instead of focusing on the average moments of endogenous variables generated from random shocks such as Takeuchi (2006), we follow the time series paths of the computed wedges in Japan and the Asian Tigers and investigate their accountability for the growth and business cycle fluctuation patterns in each region as well as the correlation among them. This enables us to link the model prediction to actual historical events that occurred in the two regions. We find that domestic efficiency wedges are the main driving forces of output fluctuation in both economies. Furthermore, efficiency wedges in each economy affect the foreign economy through the endogenous fluctuation of the terms of trade.

The remainder of the paper is as follows. In section 2, we go over the data facts in Japan and the Asian Tigers, Korea and Taiwan. In section 3, we describe the two-region two-good business cycle accounting model. In section 4 we describe the quantitative method and present the results. In Section 5 we provide sensitivity analysis on our results. Section 6 concludes the paper.

2 Facts

Table 1 displays the basic statistics of Japan, Korea, and Taiwan during 1980-2007. The population ratios of Korea and Taiwan to Japan are roughly 36% and 17% respectively. The output ratio of the Asian Tigers to Japan is smaller than the population ratio at 22% and 11% respectively. However, the growth rate of Korean and Taiwanese per capita output is 2.9 times higher than that of Japan.

The linkages of Japan, Korea, and Taiwan through international trade are quite important. For the last twenty years, Japan, Korea, and Taiwan have increased trade integration, according to Table 2. For Japan, Korea, and Taiwan are the second and third largest trade (as exports plus imports) partners in Asia. In particular, Korea and Taiwan's share in Japanese total exports exceed 12% and the share of imports from Japan for both Korea and Taiwan is 19% and 25% respectively. Although Korean and Taiwanese exports to Japan is lower than those to the United States and China, Japan is still the one of their biggest trade partners. These facts suggest that Japan and Asian Tigers are important trade partners for each other.

Figure 1a presents the log of per capita output in each country detrended by a 0.5% quarterly linear trend, which is the average growth rate of the

US per capita output. We consider this as the universal growth rate along the balanced growth path. For convenience, we normalize both countries by setting the terminal period at zero. Japan grew faster than the trend during the late 1980s corresponding to the bubble economy period while its growth slowed down during the 1990s, which is also known as the lost decade. The Asian Tigers' output series is the population weighted sum of Korean and Taiwanese time series. Clearly, both Korea and Taiwan are growing faster than the trend. The Asian Tigers' output dropped sharply in late 1990s corresponding to the Asian crisis. In 2008, both Japan and the Asian Tigers suffered during the recent global crisis.

Figure 1b presents the HP filtered fluctuation of output in each country. The business cycle correlations between Japan and the Asian Tigers over the 1980s, 1990s and 2000s are -0.3, 0.5 and 0.84 respectively. During the Asian crisis in the late 1990s, Japan also experienced a mild recession which resulted in a high business cycle correlation. The correlation is rising recently not only because of the subprime crisis, but also because of the IT bubble in 2001 and the expansion during the early to mid-2000s.

3 Model

The model is based on the Backus, Kehoe and Kydland (1995) two-country two-good model. Each economy, Japan and the Asian Tigers, produces specialized intermediate goods. They combine both intermediate goods using aggregation technology and produce a common final good. The households in each region can trade international real state contingent claims among each other. The government imposes distortionary taxes on labor and capital income and intermediate -goods trade.

3.1 Intermediate-goods firm

Intermediate goods firms combine labor l_t and capital k_t and produce intermediate goods[1]. We assume that Japan produces good a and the Asian

[1] Labor is total hours worked defined as employment times average weekly hours worked per worker normalized by adult population and maximum hours available per week. We set the maximum hours available per week at 14×7.

Tigers produces good b so that

$$\begin{aligned}\varpi f_t^{JP}(s^t) &= \varpi a_t^{JP}(s^t) + (1-\varpi) a_t^{AS}(s^t) \\ \varpi f_t^{AS}(s^t) &= \varpi b_t^{JP}(s^t) + (1-\varpi) b_t^{AS}(s^t)\end{aligned} \quad (1)$$

where ϖ is the population weight of Japan, f_t^i is the per capita production in region i and s^t represents the state of the economy.

The detrended profit maximization problem in each region $i = JP, AS$ is

$$\max \pi_t^i(s^t) = p_{j,t}^i(s^t) f_t^i(s^t) - w_t^i(s^t) l_t^i(s^t) - r_t^i(s^t) k_t^i(s^t) \quad (2)$$

subject to

$$f_t^i(s^t) = \exp(z_t^i(s^t))(k_t^i(s^t))^{\theta^i}(l_t^i(s^t))^{1-\theta^i}. \quad (3)$$

$p_{j,t}^i$ is the price of the intermediate good j relative to the price of final goods in the region it is produced, where $j = a$ if $i = JP$ and $j = b$ if $i = AS$. w_t^i and r_t^i are the real wage and return on capital relative to final goods prices in each region. z_t^i represents the productivity of the intermediate-goods firm, which we call efficiency wedges following Chari, Kehoe and McGrattan (2007).

3.2 Final-goods firm

Final goods firms in each region combine intermediate goods both from the domestic and foreign markets and produce final goods using an aggregation technology $h(a, b)$. We assume that each country imposes distortionary tariffs τ_{pt}^i on intermediate goods imports. The detrended profit maximization problems of the final goods firm in each economy are

$$\begin{aligned}\max \widehat{\pi}_t^{JP}(s^t) &= h_t^{JP}(s^t) - p_{a,t}^{JP}(s^t) a_t^{JP}(s^t) - \exp(\tau_{pt}^{JP}(s^t)) p_{b,t}^{JP}(s^t) b_t^{JP}(s^t) \\ \max \widehat{\pi}_t^{AS}(s^t) &= h_t^{AS}(s^t) - \exp(\tau_{pt}^{AS}(s^t)) p_{a,t}^{AS}(s^t) a_t^{AS}(s^t) - p_{b,t}^{AS}(s^t) b_t^{AS}(s^t)\end{aligned} \quad (4)$$

subject to

$$\begin{aligned}h_t^{JP}(a_t^{JP}(s^t), b_t^{JP}(s^t)) &= \left(\eta (a_t^{JP}(s^t))^{\frac{\varepsilon-1}{\varepsilon}} + (1-\eta)(b_t^{JP}(s^t))^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}} \\ h_t^{AS}(a_t^{AS}(s^t), b_t^{AS}(s^t)) &= \left((1-\eta)(a_t^{AS}(s^t))^{\frac{\varepsilon-1}{\varepsilon}} + \eta (b_t^{AS}(s^t))^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}\end{aligned}$$

where the parameter η^i represents the home bias and ε is the elasticity of substitution between the intermediate-goods.

Since the tariffs τ_{pt}^i primarily affect the imports of foreign intermediate goods, we call these import wedges. For simplicity, we assume that $\tau_{pt}^{JP} = \tau_{pt}^{AS} = \tau_{pt}$.

3.3 Household

Households in each economy maximizes the life time expected utility obtained from consumption c_t and leisure $1 - l_t$ based on the preference function,

$$\max U = \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \varphi(s^t) \left[\Psi^i \ln c_t^i(s^t) + (1 - \Psi^i) \ln(1 - l_t^i(s^t)) \right],$$

where $\varphi(s^t)$ is the probability of that the state s^t occurs, β is the subjective discount factor, and Ψ is the time-variable preference weight on consumption.

The household receive labor and capital income, return on the state contingent international claim d_t^i and the lump-sum transfer from the government tr_t^i and spend on consumption, investment, and purchases of the state contingent international claim for next period. Therefore, the budget constraint that each household faces each period is

$$\begin{aligned} & \exp(-\tau_{lt}^i(s^t)) w_t^i(s^t) l_t^i(s^t) + \exp(-\tau_{kt}^i(s^t)) r_t^i(s^t) k_t^i(s^{t-1}) \\ & + \pi_t^i(s^t) + \widehat{\pi}_t^i(s^t) + rer_t^i(s^t) d_t^i(s^t) + tr_t^i(s^t) \\ = \; & c_t^i(s^t) + x_t^i(s^t) + rer_t^i(s^t) \sum_{s_t^{t+1}|s^t} q_t(s^{t+1}|s^t) d_{t+1}^i(s^{t+1}|s^t), \end{aligned} \tag{5}$$

where τ_{lt}^i and τ_{kt}^i are distortionary gross labor and capital income taxes. Following Chari, Kehoe and McGrattan (2007), we call these labor and investment wedges. We assume that the international claims d_t^i are denominated in Japanese final goods so that the real exchange rates rer_t^i are $rer_t^{JP} = 1$ and $rer_t^{AS} = \frac{P_t^{JP}}{P_t^{AS}} = rer_t$, where P_t^i.are the final goods prices in each region. The price of the state contingent claim for each possible state relative to a Japanese final good q_t is common across regions.

Capital stock is accumulated following the capital law of motion:

$$\Gamma^i k_{t+1}^i(s^t) = x_t^i(s^t) + (1 - \delta^i) k_t^i(s^{t-1}) + \Phi\left(\frac{x_t^i(s^t)}{k_t^i(s^{t-1})}\right) k_t^i(s^{t-1}), \tag{6}$$

where Γ^i is the growth trend of technology and population. We assume a standard quadratic capital adjustment cost function

$$\Phi\left(\frac{x_t^i(s^t)}{k_t^i(s^{t-1})}\right) = \frac{\phi^i}{2}\left(\frac{x_t^i(s^t)}{k_t^i(s^{t-1})} - \Omega^i\right)^2,$$

where $\Omega^i = \Gamma^i - (1 - \delta^i)$ so that the adjustment cost is zero in the steady state.

3.4 International Transactions

The accumulation of international claims must be balanced with the trade of intermediate goods. Therefore, the capital accounts in each region is defined as:

$$\begin{aligned}
& \omega \sum_{s_t^{t+1}|s^t} \left[q_t(s^{t+1}|s^t) d_{t+1}^{JP}(s^{t+1}|s^t) - d_t^{JP}(s^t)\right] \\
= \; & (1-\omega)\, p_{at}^{JP} a_t^{AS}(s^t) - \omega p_{bt}^{JP} b_t^{JP}(s^t) \\
& (1-\omega)\, rer_t(s^t) \sum_{s_t^{t+1}|s^t} \left[q_t(s^{t+1}|s^t) d_{t+1}^{AS}(s^{t+1}|s^t) - d_t^{AS}(s^t)\right] \\
= \; & \omega p_{bt}^{AS} b_t^{JP}(s^t) - (1-\omega)\, p_{at}^{AS} a_t^{AS}(s).
\end{aligned}$$

These guarantee that the capital accounts across regions sum up to zero.

The trade balance in each region is defined as

$$\begin{aligned}
\omega tb_t^{JP}(s^t) &= (1-\omega)\, p_{at}^{JP} a_t^{AS}(s^t) - \omega p_{bt}^{JP} b_t^{JP}(s^t) + \omega \tau_t^{JP}(s^t) \\
(1-\omega)\, tb_t^{AS}(s^t) &= \omega p_{bt}^{AS} b_t^{JP}(s^t) - (1-\omega)\, p_{at}^{AS} a_t^{AS}(s^t) + (1-\omega)\, \tau_t^{AS}(s^t), \qquad (7)
\end{aligned}$$

where τ_t^i represents exogenous surpluses in the trade balance, which we call international trade wedges following Otsu (2010b). This term is important to match the trade balance to data in the business cycle accounting procedure. For simplicity, we assume $\tau_t^{JP}(s^t) = \tau_t^{AS}(s^t) = \tau_t(s^t)$.

The terms of trade tot_t is defined as the price of Japanese intermediate goods relative to that of the Asian Tigers' intermediate goods:

$$tot_t = \frac{p_{a,t}^{JP}}{p_{b,t}^{JP}} = \frac{p_{a,t}^{AS}}{p_{b,t}^{AS}}. \qquad (8)$$

The real exchange rate rer_t is defined as the price of Japanese final goods relative to that of the Asian Tigers' final goods:

$$rer_t = \frac{P_t^{JP}}{P_t^{AS}} = \frac{p_{a,t}^{AS}}{p_{a,t}^{JP}} = \frac{p_{b,t}^{AS}}{p_{b,t}^{JP}}. \qquad (9)$$

Finally, the following international resource constraint can be derived from (7) and (9):

$$\omega tb_t^{JP}(s^t) + (1-\omega)\, \frac{tb_t^{AS}(s^t)}{rer_t(s^t)} = \left(\omega + \frac{1-\omega}{rer_t(s^t)}\right) \tau_t(s^t). \qquad (10)$$

3.5 Domestic Absorption and National Accounts

The government collects labor and capital income taxes as well as tariffs in order to finance exogenous government expenditures g_t^i and rebates the remaining through a lump-sum transfer tr_t^i. Therefore the government budget constraint is

$$\begin{aligned}
& (1-\exp(-\tau_{lt}^{JP}(s^t)))w_t^{JP}(s^t)l_t^{JP}(s^t)+(1-\exp(-\tau_{kt}^{JP}(s^t)))r_t^{JP}(s^t)k_t^{JP}(s^{t-1}) \\
& +(\exp(\tau_{pt}^{JP}(s^t))-1)p_{b,t}^{JP}(s^t)b_t^{JP}(s^t) \\
= \; & tr_t^{JP}(s^t)+g_t^{JP}(s^t), \\
& (1-\exp(-\tau_{lt}^{AS}(s^t)))w_t^{AS}(s^t)l_t^{AS}(s^t)+(1-\exp(-\tau_{kt}^{AS}(s^t)))r_t^{AS}(s^t)k_t^{AS}(s^{t-1}) \\
& +(\exp(\tau_{pt}^{AS}(s^t))-1)p_{a,t}^{AS}(s^t)a_t^{AS} \\
= \; & tr_t^{AS}(s^t)+g_t^{AS}(s^t). \qquad (11)
\end{aligned}$$

Combining the household budget constraint (5), intermediate-goods firm profit (2), final-goods firm profit (4), the government budget constraint (11) and the intermediate good resource constraint (1), we can derive the domestic resource constraint:

$$h_t^i(a_t^i(s^t),b_t^i(s^t))=c_t^i(s^t)+x_t^i(s^t)+g_t^i(s^t). \qquad (12)$$

Furthermore, we define the income-expenditure identity in GDP y_t^i in this model as

$$y_t^i(s^t)=c_t^i(s^t)+x_t^i(s^t)+g_t^i(s^t)+tb_t^i(s^t), \qquad (13)$$

where income components are the before tax labor and capital income; tariffs on imported intermediate goods, which correspond to indirect business taxes; and trade wedges which represent the income from exogenous surpluses in the trade balance.

3.6 Wedges

In this model, we have 10 exogenous variables: the government wedges g^i, labor wedges τ_l^i, capital wedges τ_k^i, efficiency wedges z^i, import wedges τ_p, and trade wedges τ. For convenience, we define

$$s_t=\left\{g_t^{JP},\exp(\tau_{lt}^{JP}),\exp(\tau_{kt}^{JP}),\exp(z_t^{JP}),g_t^{AS},\exp(\tau_{lt}^{AS}),\exp(\tau_{kt}^{AS}),\exp(z_t^{AS}),\exp(\tau_{pt}),\tau_t\right\}$$

and $\widetilde{s_t}=\ln s_t-\ln\overline{s}$.

We assume that the wedges follow the stochastic process

$$\widetilde{s_t} = P\widetilde{s_{t-1}} + \varepsilon_t, \varepsilon \sim N(0, V). \tag{14}$$

where

$$\varepsilon_t = \{\varepsilon_{gt}^{JP}, \varepsilon_{lt}^{JP}, \varepsilon_{kt}^{JP}, \varepsilon_{zt}^{JP}, \varepsilon_{gt}^{AS}, \varepsilon_{lt}^{AS}, \varepsilon_{kt}^{AS}, \varepsilon_{zt}^{AS}, \varepsilon_{pt}, \varepsilon_{\tau t}\}.$$

The wedges are defined by the income-expenditure identity (13), the labor first order condition

$$\frac{\Psi}{1-\Psi}\frac{c_t^i(s^t)}{1-l_t^i(s^t)} = \exp(-\tau_{lt}^i(s^t))p_{b,t}^i(s^t)(1-\theta)\frac{f_t^i(s^t)}{l_t^i(s^t)},$$

the capital Euler equation

$$\begin{aligned} & (1+\Phi_t'^i(s^t))\frac{\Gamma}{c_t^i(s^t)} \\ = \quad & \beta E_t\left[\frac{1}{c_{t+1}^i(s^{t+1})}\left(\begin{array}{c} \exp(-\tau_{kt+1}^i(s^{t+1}))p_{j,t+1}^i(s^{t+1})\theta\frac{f_{t+1}^i(s^{t+1})}{k_{t+1}^i(s^{t+1})} \\ +(1+\Phi_{t+1}'^i(s^{t+1}))\times \\ \left(1-\delta+\Phi_{t+1}'^i(s^{t+1})\frac{x_{t+1}^i(s^{t+1})}{k_{t+1}^i(s^{t+1})}-\Phi_{t+1}^i(s^{t+1})\right) \end{array}\right)\right], \end{aligned}$$

the intermediate goods production function (3), the international first order condition

$$rer_t = \frac{\Psi^{JP}}{\Psi^{AS}}\frac{c_t^{AS}}{c_t^{JP}} = \frac{p_{a,t}^{AS}(s^t)}{p_{a,t}^{JP}(s^t)},$$

and international resource constraint (10).

3.7 Equilibrium

The competitive equilibrium is a set of quantities $\{k^i, y^i, c^i, x^i, l^i, tb^i, a^i, b^i, f^i, h^i, tr^i\}$, prices $\{w^i, r^i, q^i, p_a^i, p_b^i, tot, rer\}$ and wedges $\{g^i, \tau_l^i, \tau_k^i, z^i, p, \tau\}$ such that, (i) the households in each region optimize taking $\{w^i, r^i, q^i, rer, tr^i, \tau_l^i, \tau_k^i, p, \tau\}$ as given, (ii) the final good firms and intermediate good firms in each region optimize taking $\{w^i, r^i, p_a^i, p_b^i, z^i\}$ as given, (iii) the government budget constraints (11) holds, (iv) the income-expenditure identities (13) hold, (v) the intermediate goods resource constraints (1) hold, (vi) the international resource constraint (10) holds, and (vii) the wedges follow the stochastic process (14). A full set of the equilibrium conditions is available in the appendix.

4 Quantitative Analysis

4.1 Parameter Values

4.1.1 Calibration

Most of the structural parameters are obtained through calibration using data of consumption to output ratio, investment to output ratio, government expenditure to output ratio, capital to output ratio, the openness and labor input. We take the average of these data over the 1980-2009 period and across countries. Table 3 shows the list of key parameter values.

The income share of capital θ is defined as

$$\theta = \frac{\text{capital income} + \text{imputed service from durables}}{\text{GDP} + \text{imputed service from durables (=output)}}.$$

The definition of capital income and the imputed service from durables follow Cooley and Hansen (1995). The depreciation rate δ is calibrated using the steady state capital law of motion

$$\delta = 1 + \frac{x}{k} - \Gamma.$$

We set the growth trend Γ so that the balanced growth path grows at an annual rate of 2%, which is equal to the average annual per capita growth rate of the U.S. per capita output[2]. The subjective discount factor is calibrated using the steady state capital Euler equation

$$\beta = \frac{\Gamma}{\exp(-\tau_k)\theta\frac{y}{k} + 1 - \delta},$$

where we assume that the steady state capital wedge τ_k is equal to zero. The preference parameter Ψ is calibrated using the steady state labor first order condition

$$\frac{1-\Psi}{\Psi} = \exp(-\tau_l)(1-\theta)\frac{y}{c}\frac{1-l}{l},$$

[2]In a neoclassical exogenous growth model, all growing variables should be growing at the rate of the labor augmenting technical progress. we compute this from the average TFP series in each countries. It turns out that the average growth rate of Japanese output per capita is close to this number, while the Asian countries are growing at a much higher rate. We assume that these countries will eventually slow down as they approach the U.S. income level. Therefore. we use 1.005 for the growth trend.

where we assume that the steady state labor wedge τ_l is equal to zero. The weight of region size ω is calibrated to the data of population share of Japan. The elasticity of substitution ε is set at 1.5 following Backus, Kehoe and Kydland (1994)[3].

The adjustment cost parameter is chosen so that the marginal Tobin's q is equal to 1 in the steady state following Christiano and Davis (2006). In our model, the Tobin's q can be computed as the effective price of investment relative to consumption which is $1+\phi\left(\frac{x}{k}-\Omega\right)$. Setting the marginal Tobin's q to 1 gives us

$$\frac{\partial q}{\partial x}x = \phi\frac{x}{k} = 1.$$

Therefore, the investment adjustment cost parameter is equal to the capital to investment ratio.

The home bias parameter η is calibrated to match the export to output ratio assuming balanced trade in the steady state. The link between the export to output ratio and the home bias parameter is described in the appendix. One issue is that the two economies not only trade among themselves but also with the rest of the world as shown in Table 2. Given the steady state balanced trade assumption and the openness data in Table 1, the Japanese import to output ratio is 0.11 while that of Korea and Taiwan are 0.35 and 0.5 respectively. However, limiting the data to the trade across Japan and Asia using the data in Table 2, the import to output ratio for the three economies are 0.011, 0.046, and 0.082 respectively, which gives an average of 0.043. We use this average value for the calibration of η.

4.1.2 Estimation

Since investment wedges are defined in the expectational equation, we can not directly compute them from data. Therefore, we estimate the stochastic process of the wedges using the maximum likelihood estimation[4]. In specific, we estimate the lag matrix P and the error term variance and covariance matrix V. The data we use for the estimation is the linearly detrended output, consumption, investment, labor and government expenditure.

The initial guess we provide for P is a diagonal matrix with 0.9 as the diagonal terms and zero otherwise. The boundaries for the diagonal terms and non-diagonal terms are set at 0 to 20 and -20 to 20 respectively. The

[3] We chck for other values such as $\varepsilon = 0.5$ and find that the main results are not affected.

[4] We use the Dynare package for the maximum likelihood estimation.

initial guess for V is a standard deviation of 0.01 for each error term with boundaries from 0 to 0.1. For simplicity, we assume that V is diagonal and thus set the off-diagonal terms in V equal to zero. The estimated parameters are

$$P = \begin{bmatrix} 0.88 & -0.03 & -0.05 & 0.06 & 0.00 & -0.01 & 0.00 & 0.02 & 0.00 & -0.01 \\ 0.02 & 0.85 & 0.04 & 0.09 & -0.01 & 0.01 & -0.02 & -0.02 & 0.02 & -0.01 \\ -0.46 & 0.16 & 0.52 & 0.15 & 0.02 & 0.02 & -0.16 & -0.09 & 0.05 & 0.00 \\ -0.66 & 0.11 & 0.23 & 0.45 & 0.01 & -0.04 & -0.40 & -0.43 & 0.02 & 0.00 \\ -0.10 & -0.59 & 0.16 & 0.42 & 0.84 & 0.12 & 0.06 & -0.08 & 0.13 & -0.01 \\ 0.18 & -0.08 & 0.05 & -0.02 & -0.03 & 0.80 & 0.06 & -0.29 & -0.04 & -0.05 \\ -0.05 & 0.07 & -0.21 & 0.08 & 0.01 & -0.04 & 0.99 & -0.06 & 0.00 & -0.01 \\ -0.24 & 0.06 & 0.10 & -0.25 & 0.01 & -0.10 & -0.14 & 0.76 & -0.02 & -0.02 \\ 1.11 & 0.58 & -0.49 & 0.15 & 0.07 & -0.13 & 0.65 & 0.57 & 0.79 & 0.03 \\ -0.35 & 0.51 & -0.04 & -0.39 & 0.11 & 0.09 & -0.43 & 0.28 & -0.08 & 1.03 \end{bmatrix}$$

$$V = 1e-3 \begin{bmatrix} 0.2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 9.9 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 3.3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2.5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.1 \end{bmatrix}.$$

Unfortunately, there are several issues with the estimation. First, the data is detrended by the common trend growth rate. Since the Asian Tigers are growing significantly faster than this trend, detrended output, consumption ,investment, and government expenditures are growing over time. Second, total hours worked in Japan and the Asian Tigers both are declining over time. Although the stochastic process assumes stationarity in the wedges, we choose not to adjust for the trends in data. Finally, the model turns out to be close to singular and the estimates may not be accurate.

4.2 Computing the Wedges

The wedges in our model is computed in the following steps.

1. Solve the model for linear decision rules
$$\left\{\widetilde{y_t^i}, \widetilde{c_t^i}, \widetilde{l_t^i}, \widetilde{x_t^i}\right\} = DR\left(\widetilde{k_t^i}, \widetilde{g_t^i}, \tau_{lt}^i, \tau_{kt}^i, z_t^i, \tau_{pt}, \widetilde{\tau}_t\right). \tag{15}$$

2. Compute $\widetilde{k_{t+1}^i}$ from a linearized version of the capital law of motion (6):
$$\Gamma\overline{k^i}\widetilde{k_{t+1}^i} = \overline{x^i}\widetilde{x_t^i} + (1-\delta)\overline{k^i}\widetilde{k_t^i}$$
given the data of $\widetilde{x_t^i}$ and the initial capital $\widetilde{k_1^i}$.

3. Compute $\left\{\widetilde{g_t^i}, \tau_{lt}^i, \tau_{kt}^i, z_t^i, \tau_{pt}, \widetilde{\tau}_t\right\}$ from (15) given the computed $\widetilde{k_t^i}$ the data of $\left\{\widetilde{y_t^i}, \widetilde{c_t^i}, \widetilde{l_t^i}, \widetilde{x_t^i}, \widetilde{g_t^i}\right\}$.

Figures 2a shows the computed wedges in Japan. The government wedges in Japan are growing slightly faster than the 2% per year growth trend. While output is not keeping up with the 2% per year growth pace as shown in Figure 1, the government expenditure to output ratio is increasing over time. In Japan, labor wedges are rising constantly throughout the time. There are several possible explanations for this result. For instance, Ohanian, Raffo and Rogerson (2007) show that the rise in effective labor income taxes can account for the growth in labor wedges in OECD countries. Gunji and Miyazaki (2011) show that the marginal labor income tax has been rising recently in Japan mainly due to the increasing social security burden. In Braun, Ikeda and Joines (2006) the household utility weight on consumption relative to leisure depends on the family size as the head of the household bases his labor-leisure choice on the consumption of the whole family. Therefore, family size distorts the labor first order condition in the same fashion as labor wedges. They show that the shrinking population in Japan leads to a decrease in labor supply. Investment wedges in Japan fell dramatically during the 1980s. This implies that the capital markets were favorable to invest during the bubble economy. The Japanese investment wedges slightly increased during the lost decade in the 1990s. In the early 2000s, they initially fell and then jumped up corresponding to the so-called IT bubble and its burst. Then during the mid to late 2000s, they declined rapidly until it jumped up during the subprime crisis. Efficiency wedges in Japan are declining from 1990 corresponding to the lost decade.

Figure 2b plots the wedges in the Asian Tigers. The government wedges in the Asian Tigers are growing much faster than 2% per year. However, since output is growing even faster, the government expenditure to output ratio is falling. In the Asian Tigers, the labor wedges suddenly jump up during the Asian crisis in the late 1990s and continue to rise during the 2000s. Investment wedges fluctuates erratically until the 2000s. They decline during the late 1980s to the mid 1990s corresponding to the period of capital market deregulation in the Asian Tigers. Interestingly, they fall sharply on the set of the Asian crisis in the first quarter of 1998 and then rapidly increases over the following year. Then, as in Japan, they fall and rise corresponding to the IT bubble and burst, then declines until they jump up during the subprime crisis. The efficiency wedges rapidly grew until the Asian crisis and then flattened out after that.

One important note on the efficiency wedges in our model is that they are not equivalent to the Solow residuals, i.e., total factor productivity (TFP). The efficiency wedges represent the productivity in the intermediate-goods firm production f_t while TFP represent the productivity of the aggregate output y_t. Therefore, a fluctuation in the relative price of intermediate goods creates a discrepancy between efficiency wedges and TFP[5]. Backus, Kehoe and Kydland (1994) infer the stochastic process of z_t^i from the observed fluctuation of Solow residuals, whereas, our business cycle accounting method enables us to disentangle the endogenous relative price and exogenous efficiency effects.

Figure 2c presents the international wedges. The import wedges are constantly rising until the Asian crisis. This implies that there were increasing forces in the international market which discourage imports of foreign intermediate goods. After 2000, the import wedges gradually declined. The trade wedges are rising rapidly especially after the mid 1990s. This represents an increase in the trade surplus of Japan and the Asian Tigers to the rest of the world, which reflects the so-called global imbalance.

4.3 Business Cycle Accounting

In this section, we present the business cycle accounting results. Each computed wedges is fed into the model one by one. We report the reactions of output in each economy in comparison with the data. First we discuss the main results which correspond to the linearly detrended data shown in Figure 1a. Next, we analyze the high frequency features of our results using

[5] The relationship between TFP and effiecincy wedges is shown in the appendix.

HP-filtered results, which correspond to the data shown in Figure 1b.

4.3.1 Linearly Detrended Data

Figure 3a presents the endogenous fluctuation of output in Japan in response to each wedge. The late 1980s in Japan is known as the bubble economy when output suddenly started to grow faster than the trend. Our results show that the main contributors to this abnormal growth are the Japanese efficiency wedges. The rise in the intermediate-goods production efficiency reduces the production cost of the final-goods firm, which leads to a rise in total factor productivity. The 1990s in Japan is called the lost decade in which output growth fell approximately 15% relative to trend. The main contributors to the output decline during this period are the decline in the efficiency wedges and the rise in labor wedges. This result is consistent with the finding of Kobayashi and Inaba (2006). Output growth returned to its trend level in the 2000s until the crash in 2008. The sudden drop in output in 2008 can mainly be accounted for by the drop in efficiency and trade wedges and the sudden rise of labor wedges. Throughout the entire period, international trade wedges had a positive impact while import wedges had a negative impact on Japanese output. Investment and government wedges do not seem to have played important roles on Japanese output. An important result is that the rise in the Asian efficiency wedges significantly contributed to output growth in Japan.

Figure 3b presents the results for the Asian Tigers. Output growth was extremely rapid in the Asian Tigers since 1980 until the Asian crisis in 1998. Clearly, the efficiency wedges played the most important role in accounting for the growth during this period. The sudden output drop in 1998 can manly be accounted for by the drop in efficiency wedges and the rise in labor wedges. This result is consistent with Otsu (2010a). The main contributors to the output drop in 2008 are the drops in efficiency wedges and trade wedges and the rise in labor wedges. Government, investment and import wedges did not play important roles in the Asian Tigers. Finally, the decline in the Japanese efficiency wedges during the lost decade led to a slight decrease in the Asian Tigers' output.

The main reason why foreign efficiency wedges affect domestic production is due to the endogenous terms of trade effect. Figure 4 shows how efficiency wedges in each country affects the terms of trade. The rapid growth in the Asian Tigers' efficiency wedges caused the relative price of Asian Tigers' product to fall. Since this improves the Japanese terms of trade, this manifests itself as an increase in the Japanese total factor productivity and results in higher output. On the other hand, a gradual decline in Japanese efficiency wedges during the lost decade leads to a deterioration in the Asian Tigers' terms of trade. This reduces total factor productivity in the Asian Tigers which results in a gradual decline in output. Figure 5 plots the measured TFP computed from data and the efficiency wedges. The discrepancies between efficiency wedges and TFP in each countries correspond to the fluctuation in the terms of trade shown in Figure 4.

4.3.2 HP Filtered Data

We also investigate the short run features of the model by detrending the results with the HP filter. Figure 6a shows the results for Japan. Labor, investment and efficiency wedges all contribute to the short run fluctuation in output. Investment wedges are particularly important in accounting for the recent recession. The drop in the Asian Tigers' efficiency wedges play a significant role in accounting for the output drop in Japan during the Asian crisis.

Figure 6b shows the results for the Asian Tigers. In the Asian Tigers', most of the short run fluctuations in output are accounted for by fluctuations in efficiency wedges. Labor wedges also play an important role during the Asian crisis. All other wedges do not seem to play important roles on short run output fluctuation.

Following Otsu (2010b), we compute the average contribution of each wedge to the fluctuation of output and consumption in Table 4. The contribution index which is defined as

$$CI = corr(v_{data}, v_{wedge}) * \frac{std(v_{wedge})}{std(v_{data})},$$

where v_{wedge} stands for the fluctuation of variable v in response to a particular wedge. For output in Japan, domestic efficiency wedges contribute to half of the fluctuation while Japanese labor wedges, the Asian Tigers' investment wedges and trade wedges explain the remaining. In the Asian Tigers, domestic efficiency wedges account for two-thirds and domestic labor wedges account for the remaining one-third of the output fluctuation. On average, foreign efficiency wedges do not contribute much to high frequency output fluctuation.

In terms of consumption, in Japan the domestic efficiency wedges alone can account for 90 percent of the fluctuation. In the Asian Tigers, the combination of domestic efficiency and labor wedges accounts for 90 percent of the fluctuation. Furthermore, foreign wedges are not contributing much to the fluctuation in consumption in each economy. This implies that the risk sharing of consumption across the two economies has been weak.

4.3.3 Sensitivity Analysis

In this section, we check the robustness of our results to changes in parameter values for ε, η and P. First, the elasticity of substitution among intermediate goods in the benchmark case is borrowed from Backus, Kehoe and Kydland (1994). We consider a case with lower elasticity of substitution where $\varepsilon = 0.5$ rather than 1.5. Next, the home bias in intermediate goods were calibrated to match the average import to output ratio in Japan and the Asian Tigers in the benchmark case. We consider a case with a steady state import to output ratio of 0.1 which is roughly double of the benchmark case. This leads to a lower home bias parameter of $\eta = 0.81$ rather than 0.88. Finally, we consider a case in which wedges do not have any spill over effects on each other. Therefore, we set the persistence matrix P as a diagonal matrix with persistence parameters for each wedge equal to 0.8.

Figures 7a and 7b present the results of simulations with only domestic efficiency wedges in each Economy. The results show that all simulations are similar to the benchmark simulation. Other main results are also robust across these alternative settings.

5 Conclusion

In this paper, we constructed a two-region two-good model in order to investigate the relationship between Japan and the Asian Tigers. We find that shocks to domestic production efficiency are the main sources of the short run fluctuations and long run growth of output in each region. Furthermore, the growth in the Asian Tigers' efficiency significantly helped the Japanese economy while the slow down in the Japanese efficiency harmed the Asian Tigers' economy through their endogenous effects on the terms of trade. We also find that high-frequency consumption risk sharing has been weak among the two economies.

Future study should consider the effect of other countries on Japan and the Asian Tigers. For instance, US and China are undoubtedly important trade partners for both economies. Although we believe that our main results in a two-country model will hold in an expanded multi-country model, it is interesting to see the relative importance of efficiency wedges in each economy on the other economies. Especially China has grown rapidly ever since the opening-up and reform policy in 1978. Fujiwara, Otsu and Saito (2011) show that the rapid productivity growth in China benefitted the rest of the world. Understanding how important the effect of this shock is on the Japan-Asian Tigers relationship is left for future research.

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A Data

The data consist of seasonally-adjusted quarterly data over the period 1980:Q1-2009:Q2. Data sources of GDP are Economic and Social Research Institute (ESRI), National Accounts for Japan, Korea National Statistical Office Statistical Database for Korea, Directorate General of Budget, Accounting and Statistics, National Accounts for Taiwan. Private corporate capital stock data are taken from ESRI's Quarterly Estimates of Gross Capital Stock of Private Enterprises for Japan, Pyo (2003) for Korea, and TEDC Taiwan Economic Statistical Databank System and Directorate General of Budget, Accounting and Statistics, National Wealth Statistics for Taiwan. In addition, Nikkei NEEDS-Financial QUEST, TEDC, and CEIC database are used for completing the data series.

Standard data adjustment was done for conducting theory-based empirical analysis. Consumption is defined as the sum of consumption on non-durables, services, and imputed service flow from durable goods. Investment comprises of gross fixed capital formation, public investment, and expenditure on durables. Government expenditure is defined as government consumption. Exports and imports are defined as exports of goods and services and imports of goods and services, respectively. Capital stock is defined as private corporate capital stock plus consumer durables. Labor is the product of average hours worked per worker and the number of workers.

B Equilibrium Conditions

The equilibrium is characterized by the following 28 equations and 28 variables $\{k^i, y^i, f^i, h^i, c^i, l^i, x^i, tb^i, a^i, b^i, p_a^i, p_b^i, tfp^i, rer, tot\}$.

The capital Euler equations:

$$\begin{aligned}
&(1+\Phi_t'^{JP}(s^t))\frac{\Gamma}{c_t^{JP}(s^t)} \\
=\ &\beta E_t\left[\frac{1}{c_{t+1}^{JP}(s^{t+1})}\left(\begin{array}{c}\exp(-\tau_{kt+1}^{JP}(s^{t+1}))p_{a,t+1}^{JP}(s^{t+1})\theta\frac{f_{t+1}^{JP}(s^{t+1})}{k_{t+1}^{JP}(s^{t+1})}\\ +(1+\Phi_{t+1}'^{JP}(s^{t+1}))\times \\ \left(1-\delta+\Phi_{t+1}'^{JP}(s^{t+1})\frac{x_{t+1}^{JP}(s^{t+1})}{k_{t+1}^{JP}(s^{t+1})}-\Phi_{t+1}^{JP}(s^{t+1})\right)\end{array}\right)\right], \qquad \text{(E1)}
\end{aligned}$$

$$\begin{aligned}
&(1+\Phi_t'^{AS}(s^t))\frac{\Gamma}{c_t^{AS}(s^t)} \\
=\ &\beta E_t\left[\frac{1}{c_{t+1}^{AS}(s^{t+1})}\left(\begin{array}{c}\exp(-\tau_{kt+1}^{AS}(s^{t+1}))p_{b,t+1}^{AS}(s^{t+1})\theta\frac{f_{t+1}^{AS}(s^{t+1})}{k_{t+1}^{AS}(s^{t+1})}\\ +(1+\Phi_{t+1}'^{AS}(s^{t+1}))\times \\ \left(1-\delta+\Phi_{t+1}'^{AS}(s^{t+1})\frac{x_{t+1}^{AS}(s^{t+1})}{k_{t+1}^{AS}(s^{t+1})}-\Phi_{t+1}^{AS}(s^{t+1})\right)\end{array}\right)\right] \qquad \text{(E2)}
\end{aligned}$$

The labor first order condition:

$$\frac{\Psi}{1-\Psi}\frac{c_t^{JP}(s^t)}{1-l_t^{JP}(s^t)} = \exp(-\tau_{lt}^{JP}(s^t))p_{a,t}^{JP}(s^t)(1-\theta)\frac{f_t^{JP}(s^t)}{l_t^{JP}(s^t)}, \qquad \text{(E3)}$$

$$\frac{\Psi}{1-\Psi}\frac{c_t^{AS}(s^t)}{1-l_t^{AS}(s^t)} = \exp(-\tau_{lt}^{AS}(s^t))p_{b,t}^{AS}(s^t)(1-\theta)\frac{f_t^{AS}(s^t)}{l_t^{AS}(s^t)}. \qquad \text{(E4)}$$

The international first order conditions:

$$rer_t(s^t) = \frac{c_t^{AS}(s^t)}{c_t^{JP}(s^t)}, \qquad \text{(E5)}$$

$$\frac{p_{a,t}^{JP}(s^t)}{p_{b,t}^{JP}(s^t)} = \frac{p_{a,t}^{AS}(s^t)}{p_{b,t}^{AS}(s^t)}. \qquad \text{(E6)}$$

The intermediate goods resource constraint:

$$\omega f_t^{JP}(s^t) = \omega a_t^{JP}(s^t) + (1-\omega)\,a_t^{AS}(s^t), \qquad \text{(E7)}$$

$$(1-\omega)\,f_t^{AS}(s^t) = \omega b_t^{JP}(s^t) + (1-\omega)\,b_t^{AS}(s^t). \qquad \text{(E8)}$$

The final goods resource constraint:

$$h_t^{JP}(s^t) = c_t^{JP}(s^t) + x_t^{JP}(s^t) + g_t^{JP}(s^t), \quad \text{(E9)}$$

$$h_t^{AS}(s^t) = c_t^{AS}(s^t) + x_t^{AS}(s^t) + g_t^{AS}(s^t). \quad \text{(E10)}$$

The capital law of motion:

$$\Gamma k_{t+1}^{JP}(s^t) = x_t^{JP}(s^t) + (1-\delta)k_t^{JP}(s^{t-1}) - \Phi\left(\frac{x_t^{JP}(s^t)}{k_t^{JP}(s^{t-1})}\right)k_t^{JP}(s^{t-1}), \quad \text{(E11)}$$

$$\Gamma k_{t+1}^{AS}(s^t) = x_t^{AS}(s^t) + (1-\delta)k_t^{AS}(s^{t-1}) - \Phi\left(\frac{x_t^{AS}(s^t)}{k_t^{AS}(s^{t-1})}\right)k_t^{AS}(s^{t-1}) \quad \text{(E12)}$$

The income expenditure identity:

$$y_t^{JP}(s^t) = h_t^{JP}(s^t) + tb_t^{JP}(s^t), \quad \text{(E13)}$$

$$y_t^{AS}(s^t) = h_t^{AS}(s^t) + tb_t^{AS}(s^t). \quad \text{(E14)}$$

The intermediate goods production function:

$$f_t^{JP}(s^t) = \exp(z_t^{JP})(s^t)\left(k_t^{JP}(s^{t-1})\right)^{\theta}(l_t^{JP}(s^t))^{1-\theta}, \quad \text{(E15)}$$

$$f_t^{AS}(s^t) = \exp(z_t^{AS})(s^t)(k_t^{AS}(s^{t-1}))^{\theta}(l_t^{AS}(s^t))^{1-\theta}, \quad \text{(E16)}$$

The final goods production function:

$$h_t^{JP}(s^t) = \left(\eta(a_t^{JP}(s^t))^{\frac{\varepsilon-1}{\varepsilon}} + (1-\eta)(b_t^{JP}(s^t))^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad \text{(E17)}$$

$$h_t^{AS}(s^t) = \left((1-\eta)(a_t^{AS}(s^t))^{\frac{\varepsilon-1}{\varepsilon}} + \eta(b_t^{AS}(s^t))^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad \text{(E18)}$$

The definition of domestic relative prices:

$$p_{a,t}^{JP}(s^t) = \eta\left(\frac{h_t^{JP}(s^t)}{a_t^{JP}(s^t)}\right)^{\frac{1}{\varepsilon}}, \quad \text{(E19)}$$

$$p_{b,t}^{JP}(s^t) = \frac{1-\eta}{\exp(\tau_{pt}(s^t))}\left(\frac{h_t^{JP}(s^t)}{b_t^{JP}(s^t)}\right)^{\frac{1}{\varepsilon}}, \quad \text{(E20)}$$

$$p_{a,t}^{AS}(s^t) = \frac{1-\eta}{\exp(\tau_{pt}(s^t))}\left(\frac{h_t^{AS}(s^t)}{a_t^{AS}(s^t)}\right)^{\frac{1}{\varepsilon}}, \quad \text{(E21)}$$

$$p_{b,t}^{AS}(s^t) = \eta\left(\frac{h_t^{AS}(s^t)}{b_t^{AS}(s^t)}\right)^{\frac{1}{\varepsilon}}. \quad \text{(E22)}$$

The definition of international relative prices:

$$rer_t(s^t) = \frac{p_{a,t}^{AS}(s^t)}{p_{a,t}^{JP}(s^t)}, \tag{E23}$$

$$tot_t(s^t) = \frac{p_{a,t}^{JP}(s^t)}{p_{b,t}^{JP}(s^t)}, \tag{E24}$$

The definition of the trade balance:

$$\omega tb_t^{JP}(s^t) = (1-\omega)\, p_{at}^{JP} a_t^{AS}(s^t) - \omega p_{bt}^{JP} b_t^{JP}(s^t) + \omega \tau_t(s^t), \tag{E25}$$

$$(1-\omega) tb_t^{AS}(s^t) = \omega p_{bt}^{AS}(s^t) b_t^{JP}(s^t) \tag{E26}$$

$$- (1-\omega)\, p_{at}^{AS}(s^t) a_t^{AS}(s^t) + (1-\omega)\tau_t(s^t). \tag{16}$$

The definition of total factor productivity:

$$tfp_t^{JP} = \frac{y_t^{JP}}{\left(k_t^{JP}(s^{t-1})\right)^{\theta} \left(l_t^{JP}(s^t)\right)^{1-\theta}}, \tag{E27}$$

$$tfp_t^{AS} = \frac{y_t^{AS}}{\left(k_t^{AS}(s^{t-1})\right)^{\theta} \left(l_t^{AS}(s^t)\right)^{1-\theta}}. \tag{E28}$$

C Calibrating the Home Bias Parameter

Assuming balanced trade in the steady state leads to

$$(1-\omega)\, p_a^{JP} a^{AS} = \omega p_b^{JP} b^{JP},$$
$$tb^{JP} = tb^{AS} = \tau.$$

Define the common import share to domestic absorption in the symmetric steady state as φ. That is,

$$\varphi = \frac{im^{JP}}{h^{JP}} = \frac{(1-\omega) p_a^{JP} a^{AS}}{p_a^{JP}\left(\omega a^{JP} + (1-\omega)\, a^{AS}\right)},$$

$$\varphi = \frac{im^{AS}}{h^{AS}} = \frac{\omega p_b^{AS} b^{JP}}{p_b^{AS}\left(\omega b^{JP} + (1-\omega)\, b^{AS}\right)}.$$

Therefore,

$$\frac{a^{JP}}{a^{AS}} = \frac{1-\varphi}{\varphi}\frac{1-\omega}{\omega}, \frac{b^{JP}}{b^{AS}} = \frac{\varphi}{1-\varphi}\frac{1-\omega}{\omega}. \tag{17}$$

Assuming that the steady state international price wedge τ_p is equal to zero, we get

$$\begin{aligned} p_a^{JP} &= \eta \left(\frac{h^{JP}}{a^{JP}} \right)^{\frac{1}{\varepsilon}}, p_b^{JP} = (1-\eta) \left(\frac{h^{JP}}{b^{JP}} \right)^{\frac{1}{\varepsilon}}, \\ p_a^{AS} &= (1-\eta) \left(\frac{h^{AS}}{a^{AS}} \right)^{\frac{1}{\varepsilon}}, p_b^{AS} = \eta \left(\frac{h^{AS}}{b^{AS}} \right)^{\frac{1}{\varepsilon}}. \end{aligned} \tag{18}$$

Combining (17) and (18) we get,

$$tot = \frac{p_a^{JP}}{p_b^{JP}} = \frac{\eta}{1-\eta} \left(\frac{b^{JP}}{a^{JP}} \right)^{\frac{1}{\varepsilon}} = \frac{p_a^{AS}}{p_b^{AS}} = \frac{1-\eta}{\eta} \left(\frac{b^{AS}}{a^{AS}} \right)^{\frac{1}{\varepsilon}}.$$

Therefore, we can compute η from φ given ε:

$$\frac{\eta}{1-\eta} = \left(\frac{1-\varphi}{\varphi} \right)^{\frac{1}{\varepsilon}} \text{ or } \eta = \frac{1}{1 + \left(\frac{\varphi}{1-\varphi} \right)^{\frac{1}{\varepsilon}}}.$$

Finally, since $h^i = y^i - tb^i$, the home bias parameter can be calibrated to the import to output ratio and trade balance to output ratio:

$$\varphi = \frac{im^i}{h^i} = \frac{im^i/y^i}{\left(1 - \frac{tb^i}{y^i}\right)}.$$

D Efficiency Wedges and Total Factor Productivity

Define TFP as

$$A_t^i = \frac{y_t^i}{(k_t^i)^{\theta} (l_t^i)^{1-\theta}}.$$

Since output is the sum of domestic absorption and the trade balance $y_t^i = h_t^i + tb_t^i$, we can express it as

$$\begin{aligned} y_t^{JP} &= p_{at}^{JP} f_t^{JP} + (\exp(\tau_{pt}) - 1) p_{bt}^{JP} b_t^{JP} + \tau_t, \\ y_t^{AS} &= p_{bt}^{AS} f_t^{AS} + (\exp(\tau_{pt}) - 1) p_{at}^{AS} b_t^{AS} + \tau_t, \end{aligned}$$

using zero profit condition for the final goods firm (4), the intermediate goods resource constraint (1), and the definition of the trade balance (7). Therefore,

$$
\begin{aligned}
A_t^{JP} &= p_{at}^{JP} \exp(z_t^{JP}) + \zeta_t^{JP}, \\
A_t^{AS} &= p_{bt}^{AS} \exp(z_t^{AS}) + \zeta_t^{AS},
\end{aligned}
$$

where

$$
\begin{aligned}
\zeta_t^{JP} &= \frac{(\exp(\tau_{pt}) - 1) p_{bt}^{JP} b_t^{JP} + \tau_t}{\left(k_t^{JP}\right)^{\theta} \left(l_t^{JP}\right)^{1-\theta}}, \\
\zeta_t^{AS} &= \frac{(\exp(\tau_{pt}) - 1) p_{at}^{AS} a_t^{AS} + \tau_t}{\left(k_t^{AS}\right)^{\theta} \left(l_t^{AS}\right)^{1-\theta}}.
\end{aligned}
$$

Thus, total factor productivity will be affected by changes in the relative prices (and international wedges).

E Tables and Figures

Table 1. Basic Statistics of Japan and The Asian Tigers

	Population (in thousands)	GDP (billion of PPP)	GDP per capita (in PPP)	Real Growth (%)	Openness (%)
Japan	123,988	2,620	20,964	1.8	22
Korea	44,073	569	12,453	5.3	69
Taiwan	20,730	298	13,856	5.4	99

Note: All data are average over 1980-2007.

Source: Penn World Trable 6.3.

Table 2. Direction of Trade

Japan

	Exports to		Imports from	
1.	USA	27.2%	USA	17.6%
2.	China	8.2%	China	13.1%
3.	Korea	6.3%	Saudi Alabia	5.7%
4.	Taiwan	5.9%	Indonesia	5.1%
5.	Hong Kong	5.3%	Australia	5.0%
6.	Germany	4.2%	UAE	4.5%
7.	Singapore	3.5%	Korea	4.4%
8.	UK	3.0%	Taiwan	3.5%
9.	Thailand	3.0%	Germany	3.4%
10.	Malaysia	2.3%	Malaysia	3.0%

Korea

	Exports to		Imports from	
1.	China	17.1%	Japan	18.7%
2.	USA	16.2%	USA	14.7%
3.	Japan	9.5%	China	12.7%
4.	Hong Kong	6.3%	Saudi Arabia	5.6%
5.	Taiwan	3.4%	Australia	3.9%

Taiwan

	Exports to		Imports from	
1.	USA	19.8%	Japan	25.0%
2.	Hong Kong	18.6%	USA	15.6%
3.	China	12.3%	China	7.6%
4.	Japan	9.0%	Korea	5.7%
5.	Singapore	3.8%	Germany	4.0%

Note: Each data is the share of each trade partner in own country's total exports or imports. Data are average over 1990-2009.
Source: Japan: Trade Statistics of Japan Ministry of Finance.
Korea: Bank of Korea Economic Statistic System.
Taiwan: Ministry of Finance R.O.C. Trade Statistics.

Table 3. Parameters

θ	Capital Share	0.407
δ	Depreciation	0.014
Γ	Growth Trend	1.005
β	Discount Factor	0.995
Ψ	Preference Weight	0.260
ϕ	Adjustment Cost	53.04
ε	Goods Elasticity	1.5
η	Home Bias	0.882
ϖ	Population Weight	0.667

Table 4. Contribution Index

	Output		Consumption	
wedges	*Japan*	*Asia*	*Japan*	*Asia*
Government	0.00	−0.01	0.03	0.01
Labor	0.13	0.00	0.10	0.00
Investment	0.06	0.02	0.00	0.00
Efficiency	0.54	0.01	0.89	−0.01
Government	0.01	−0.01	−0.01	0.01
Labor	0.03	0.30	0.00	0.38
Investment	0.12	0.03	0.10	0.10
Efficiency	0.02	0.68	0.00	0.52
Import	−0.05	−0.07	−0.13	0.01
Trade	0.13	0.04	0.03	−0.02

Figure 1a. Output Detrended by 2% Annual Linear Trend

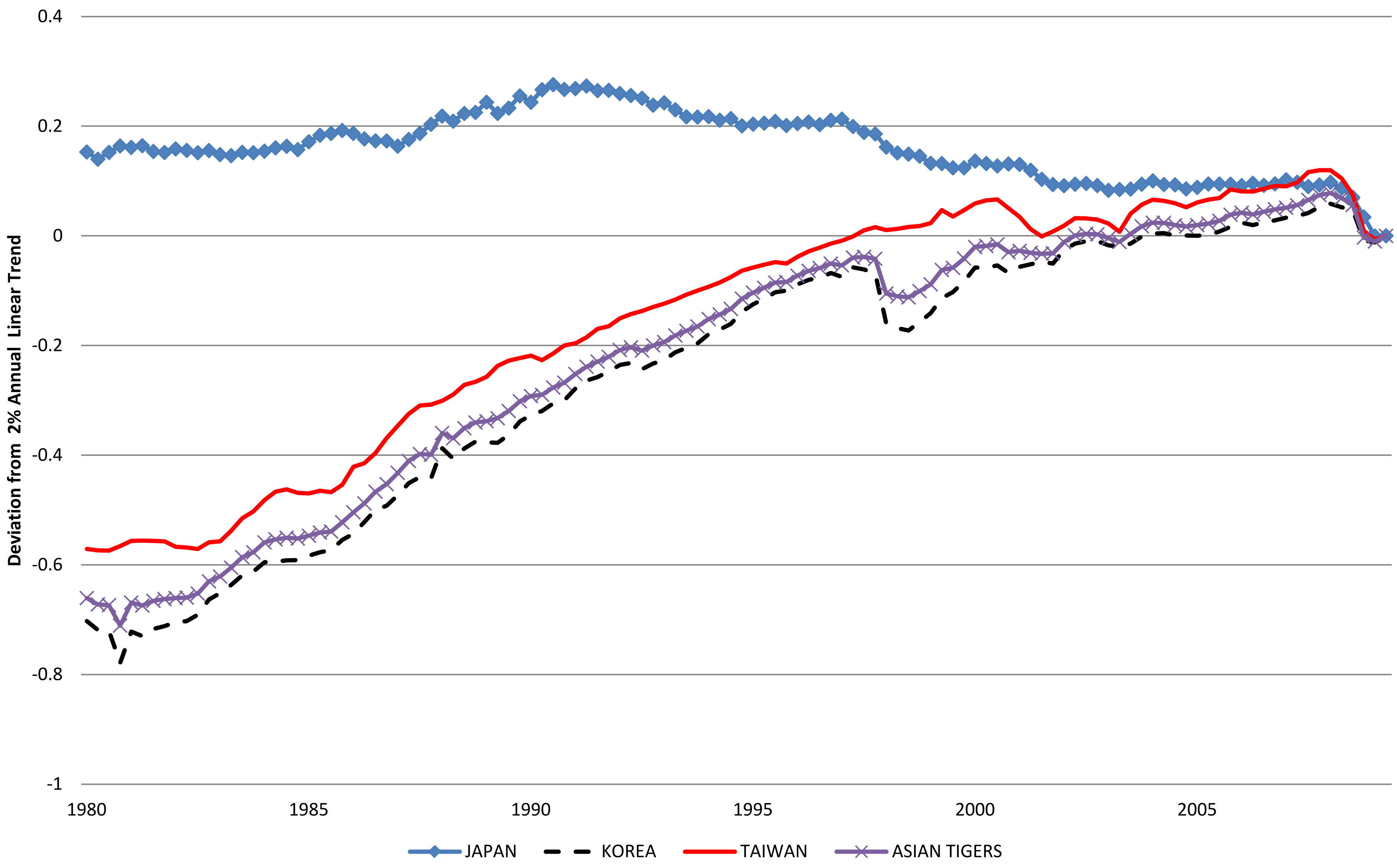
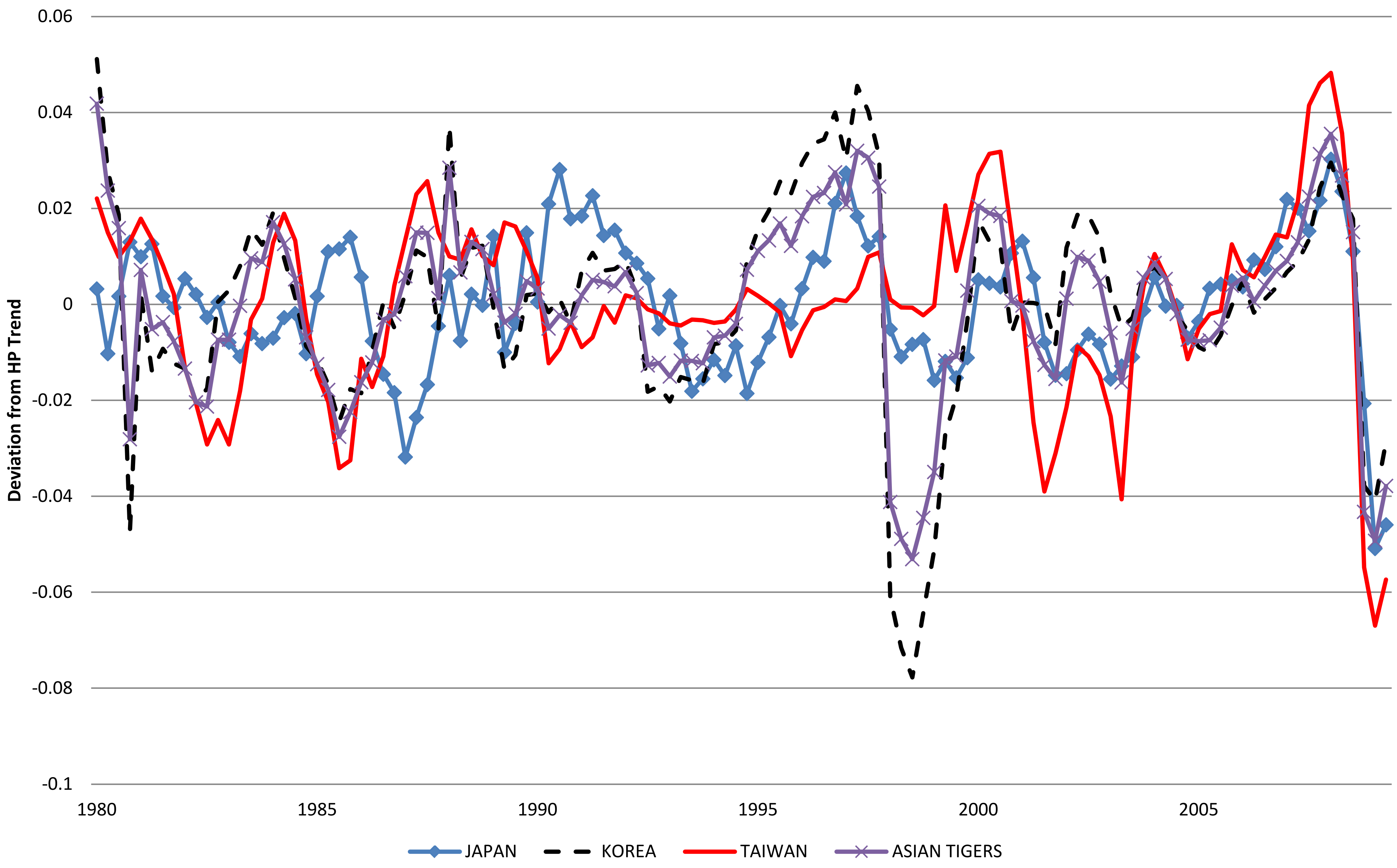


Figure 1b. Output Detrended by HP Filtered



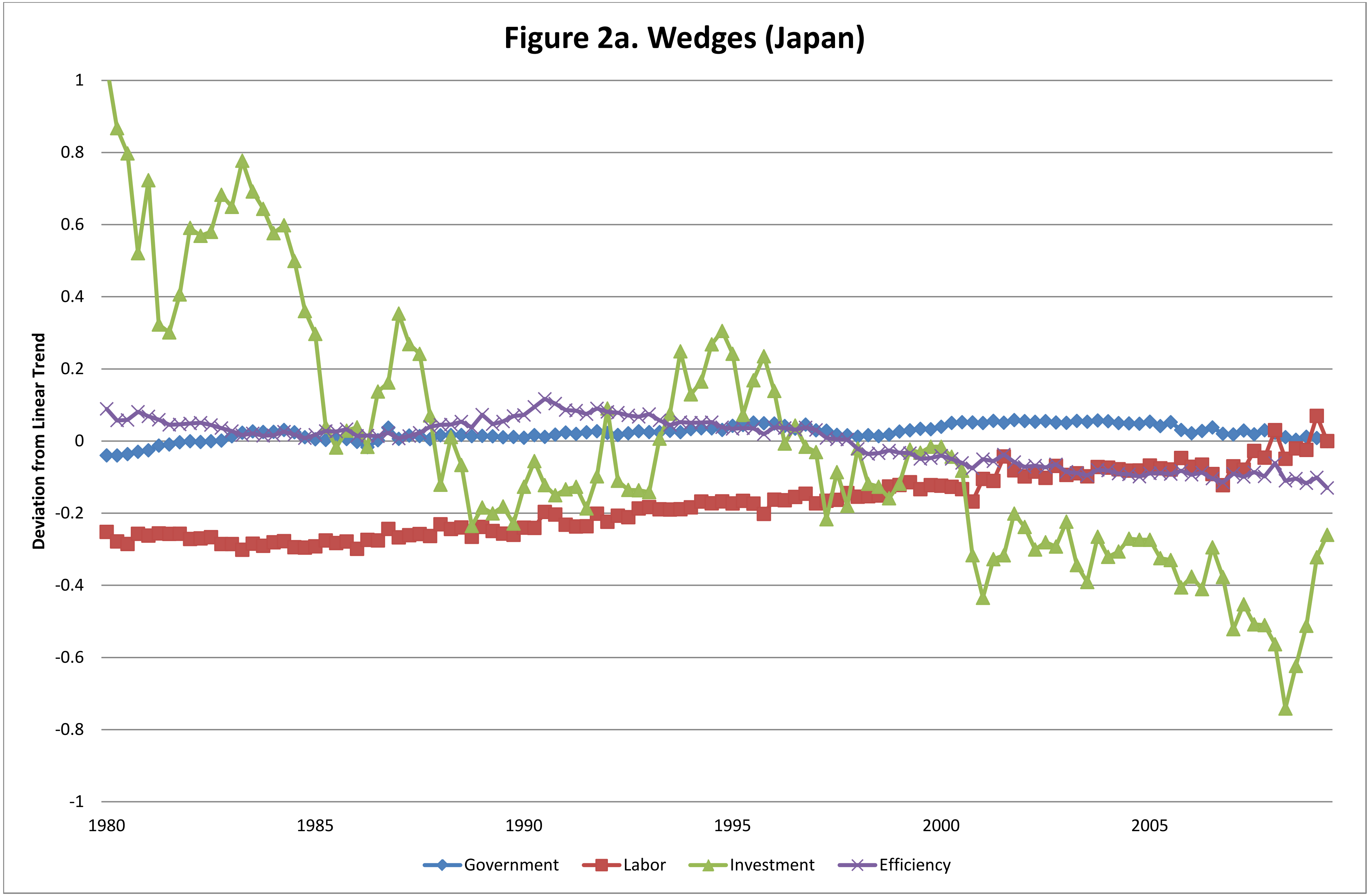


Figure 2a. Wedges (Japan)
Deviation from Linear Trend
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1980
1985
1990
1995
2000
2005
Government
Labor
Investment
Efficiency

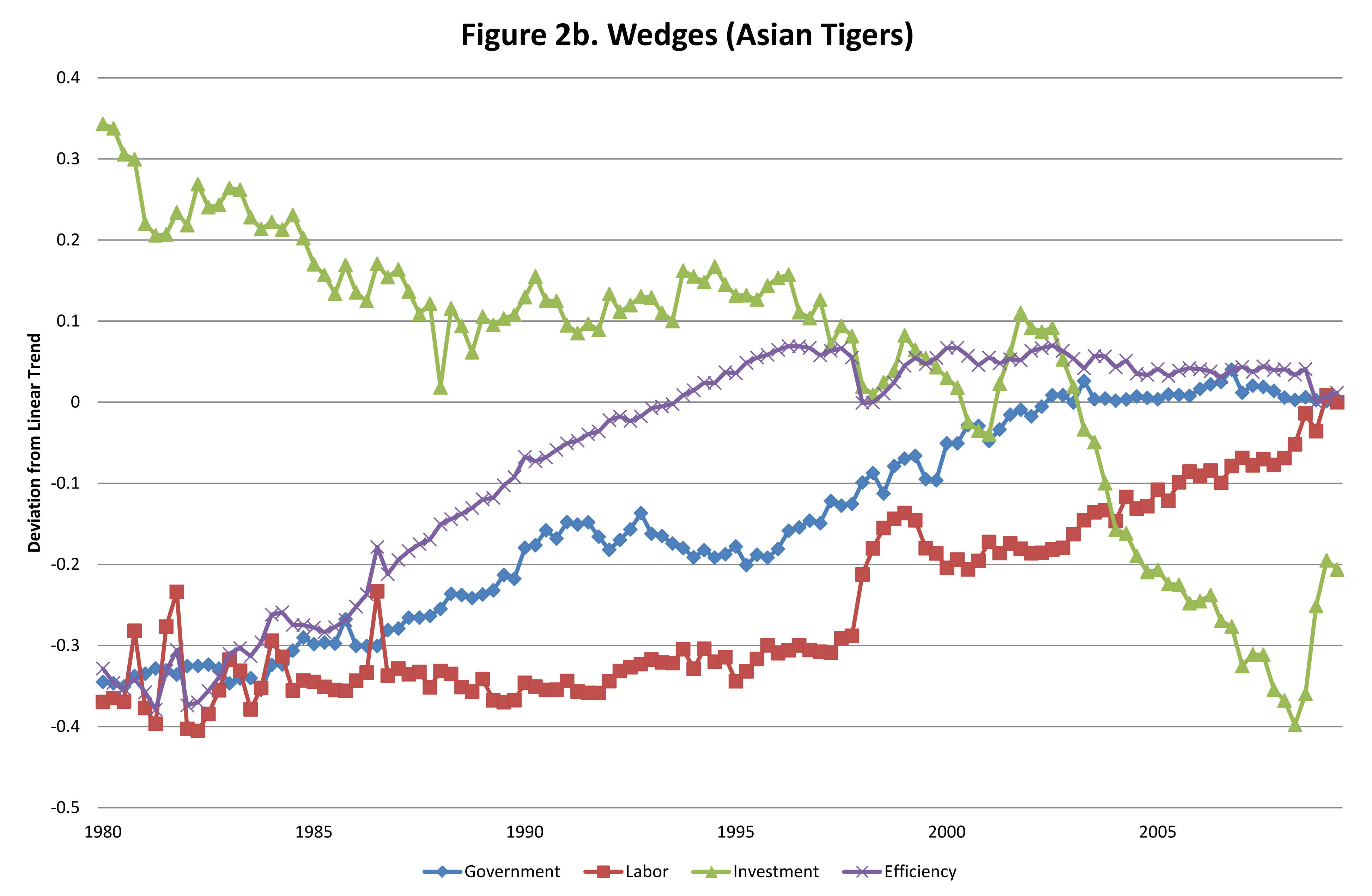


Figure 2b. Wedges (Asian Tigers)
Deviation from Linear Trend
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1980
1985
1990
1995
2000
2005
Government
Labor
Investment
Efficiency

Figure 2c. Wedges (International)

Figure 3a. Results-Japanese Output

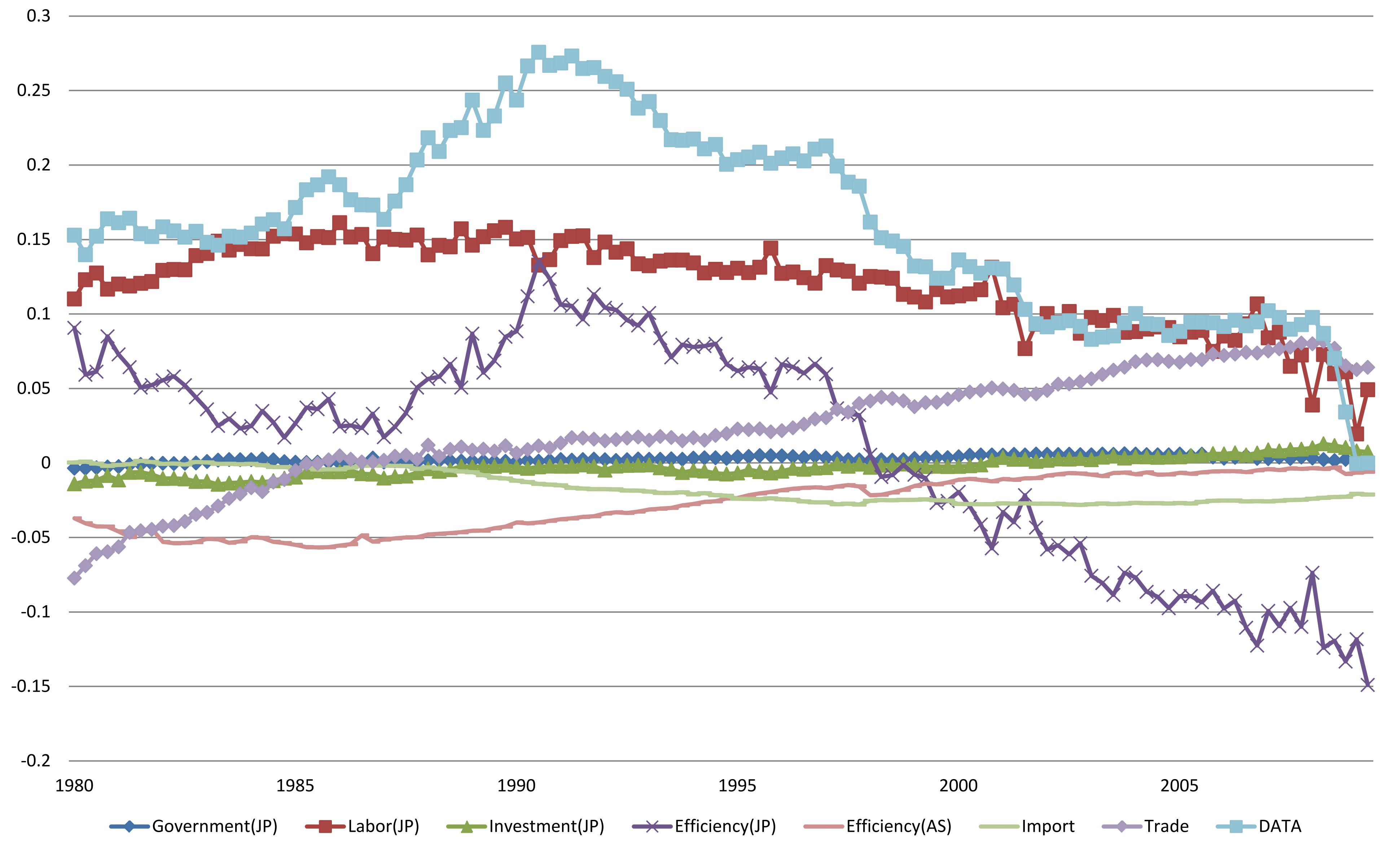
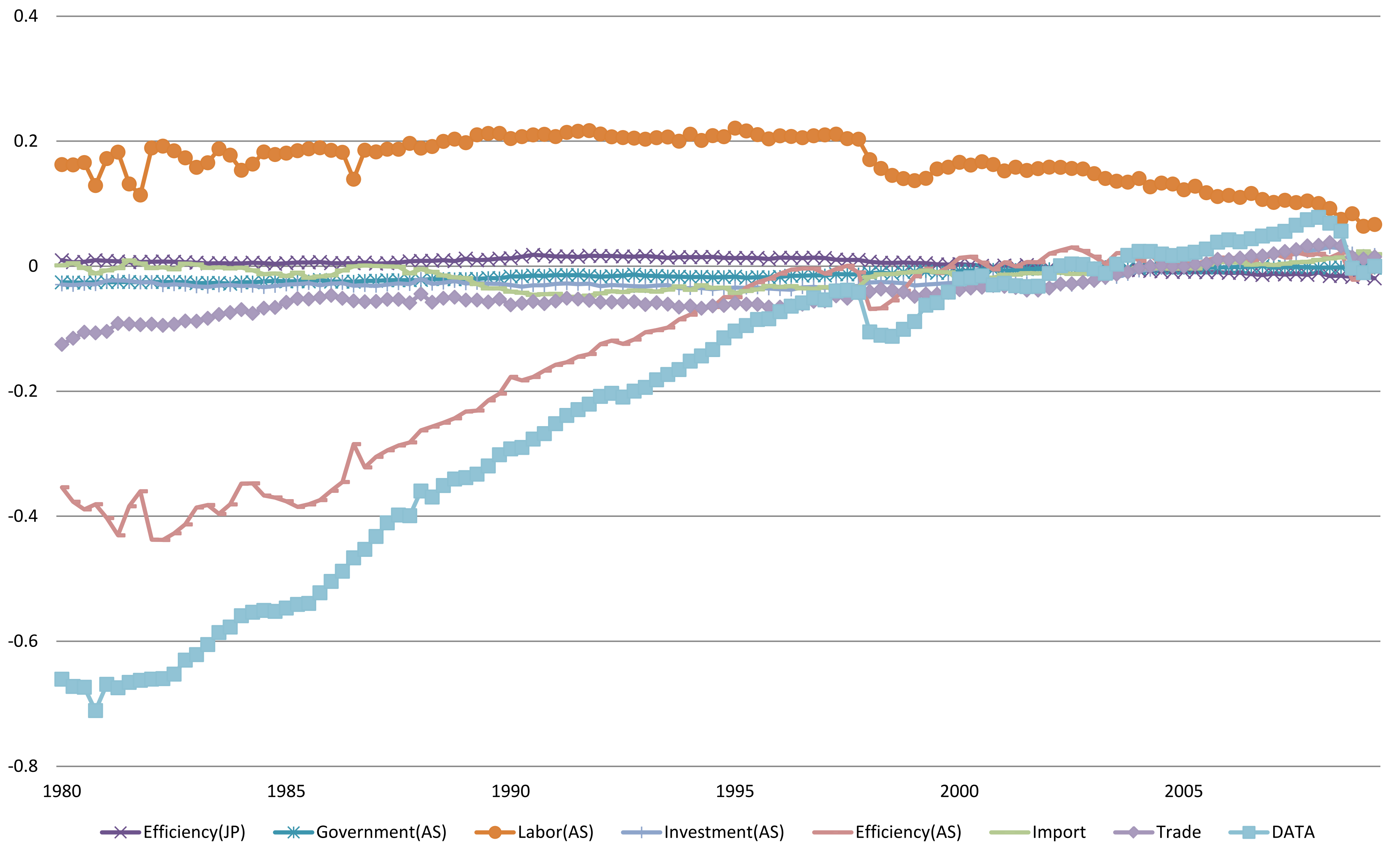


Figure 3b. Results-Asian Tigers' Output



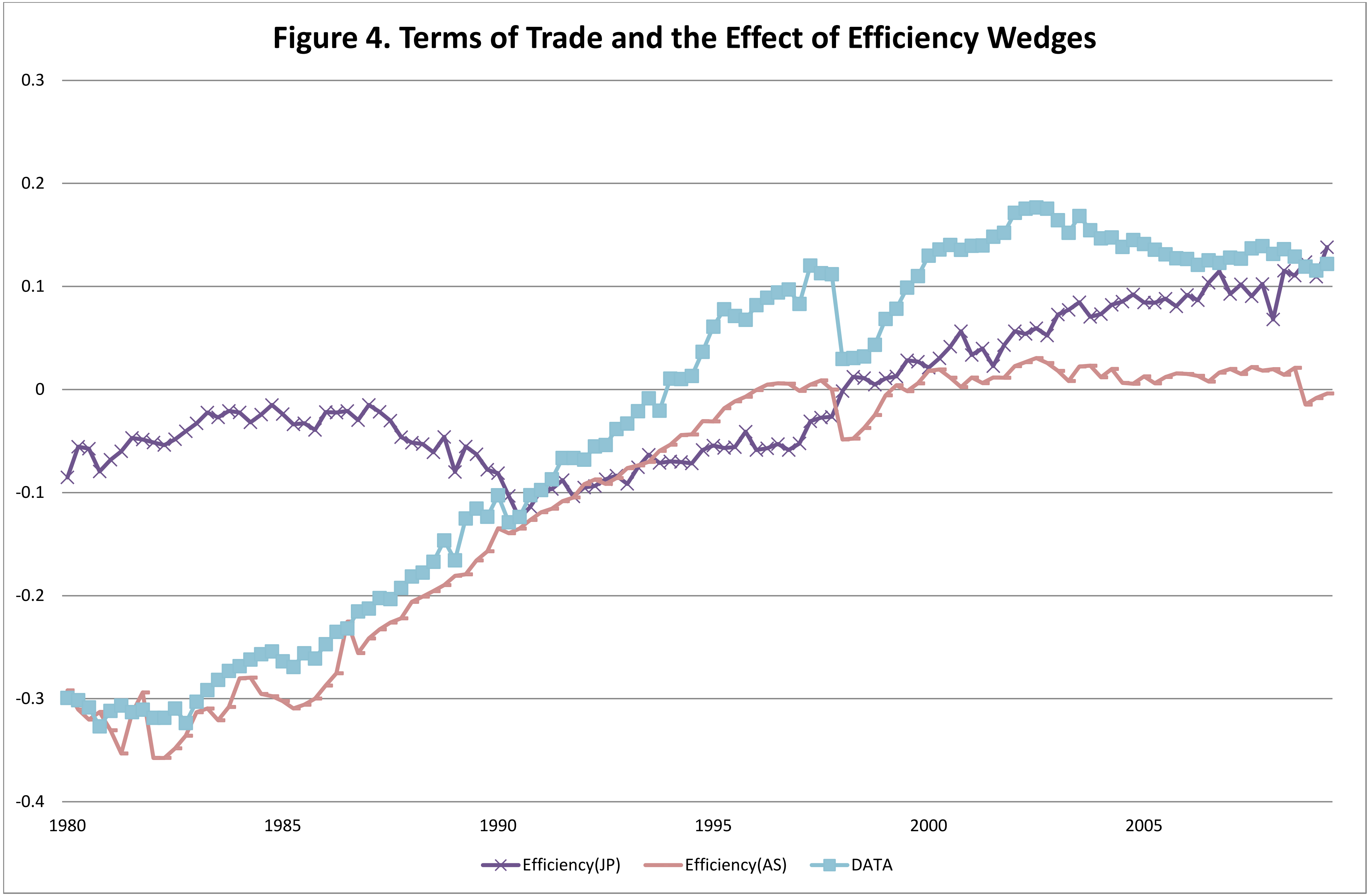


Figure 4. Terms of Trade and the Effect of Efficiency Wedges
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1980
1985
1990
1995
2000
2005
Efficiency(JP)
Efficiency(AS)
DATA

Figure 5. Total Factor Productivity and Efficiency Wedges

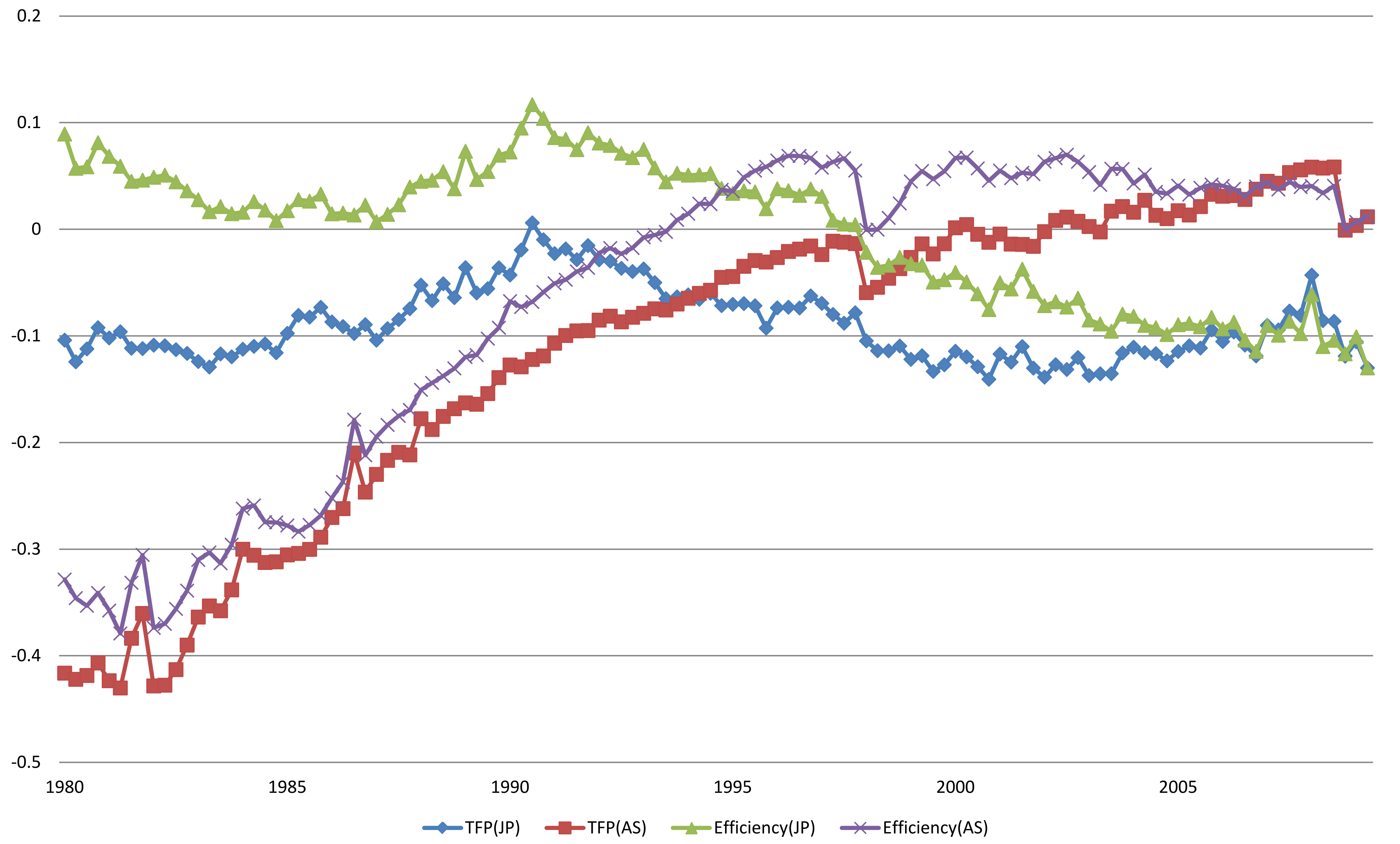
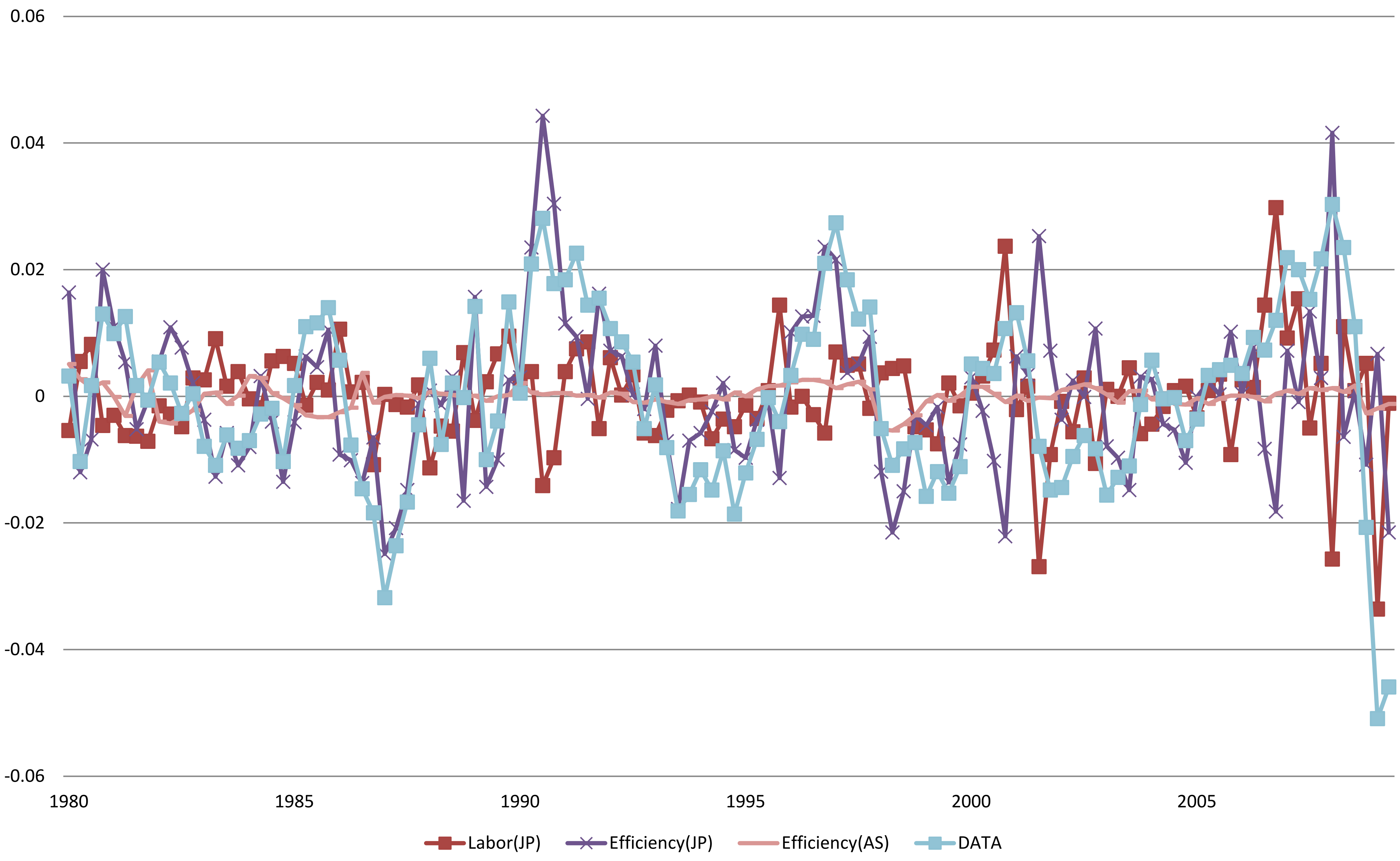


Figure 6a. Results-Japanese Output (HP Filtered)



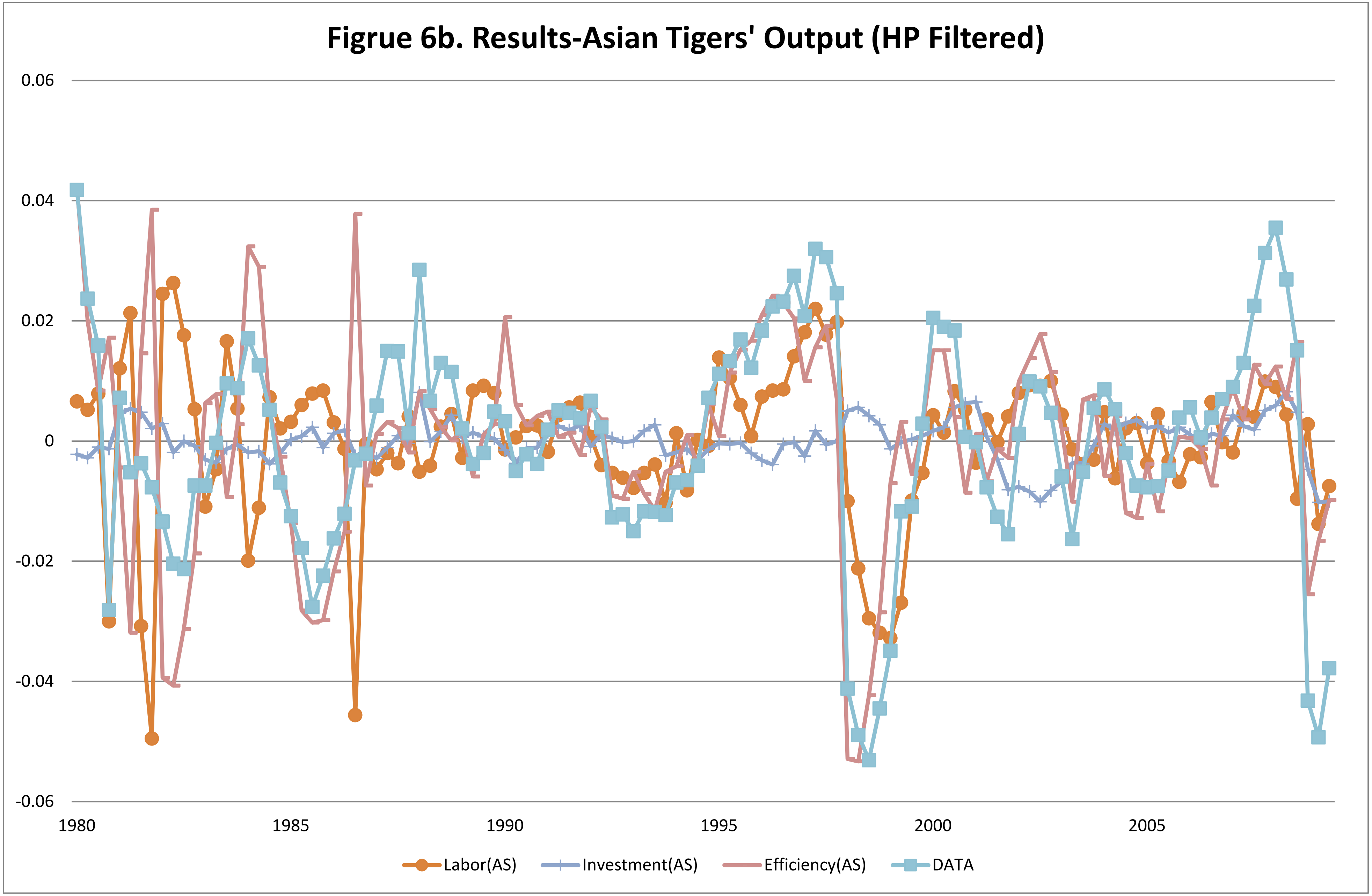
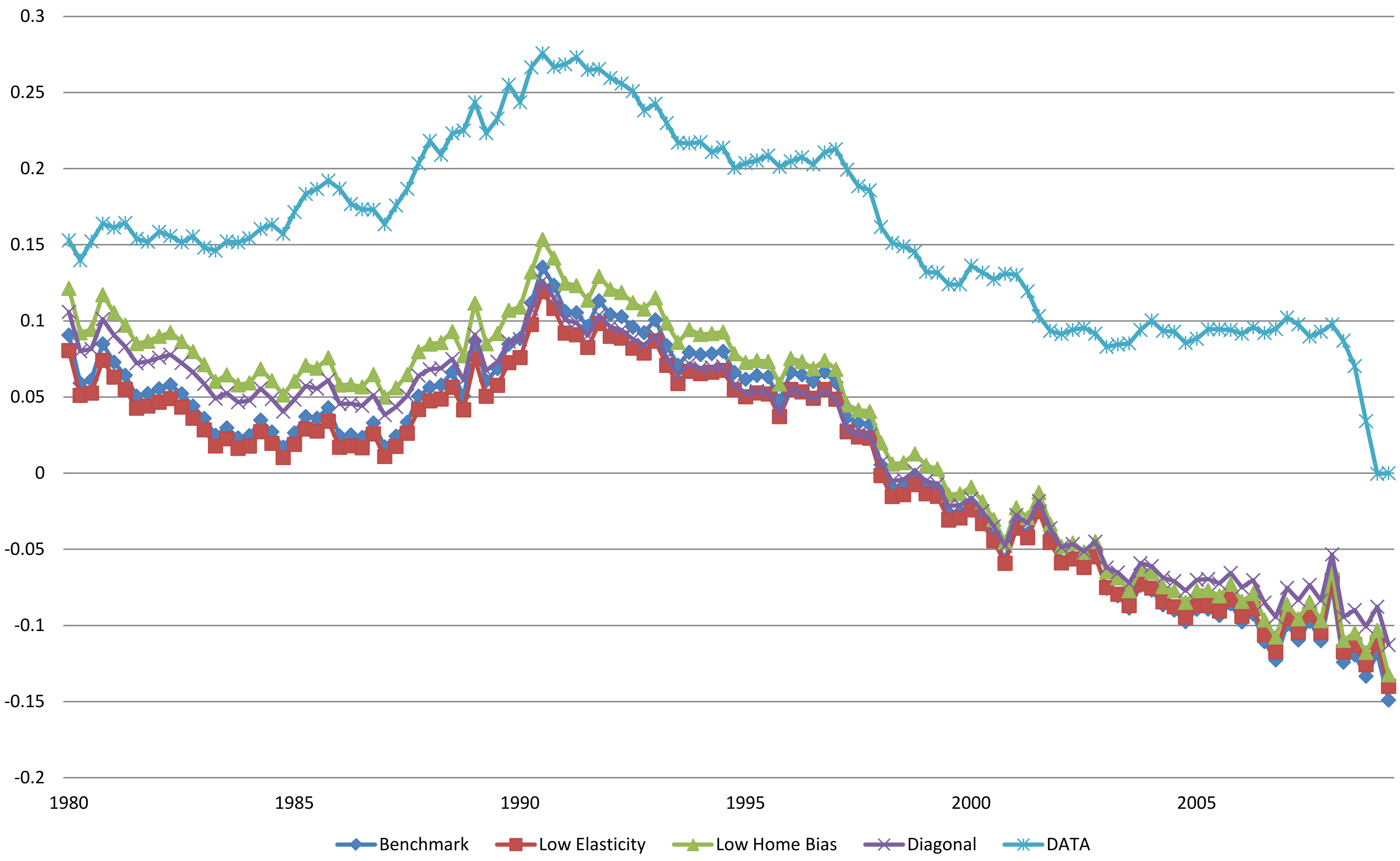

Figrue 6b. Results-Asian Tigers' Output (HP Filtered)
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
1980
1985
1990
1995
2000
2005
Labor(AS)
Investment(AS)
Efficiency(AS)
DATA

Figure 7a. Sensitivity Analysis-Japanese Output with Efficiency Wedges



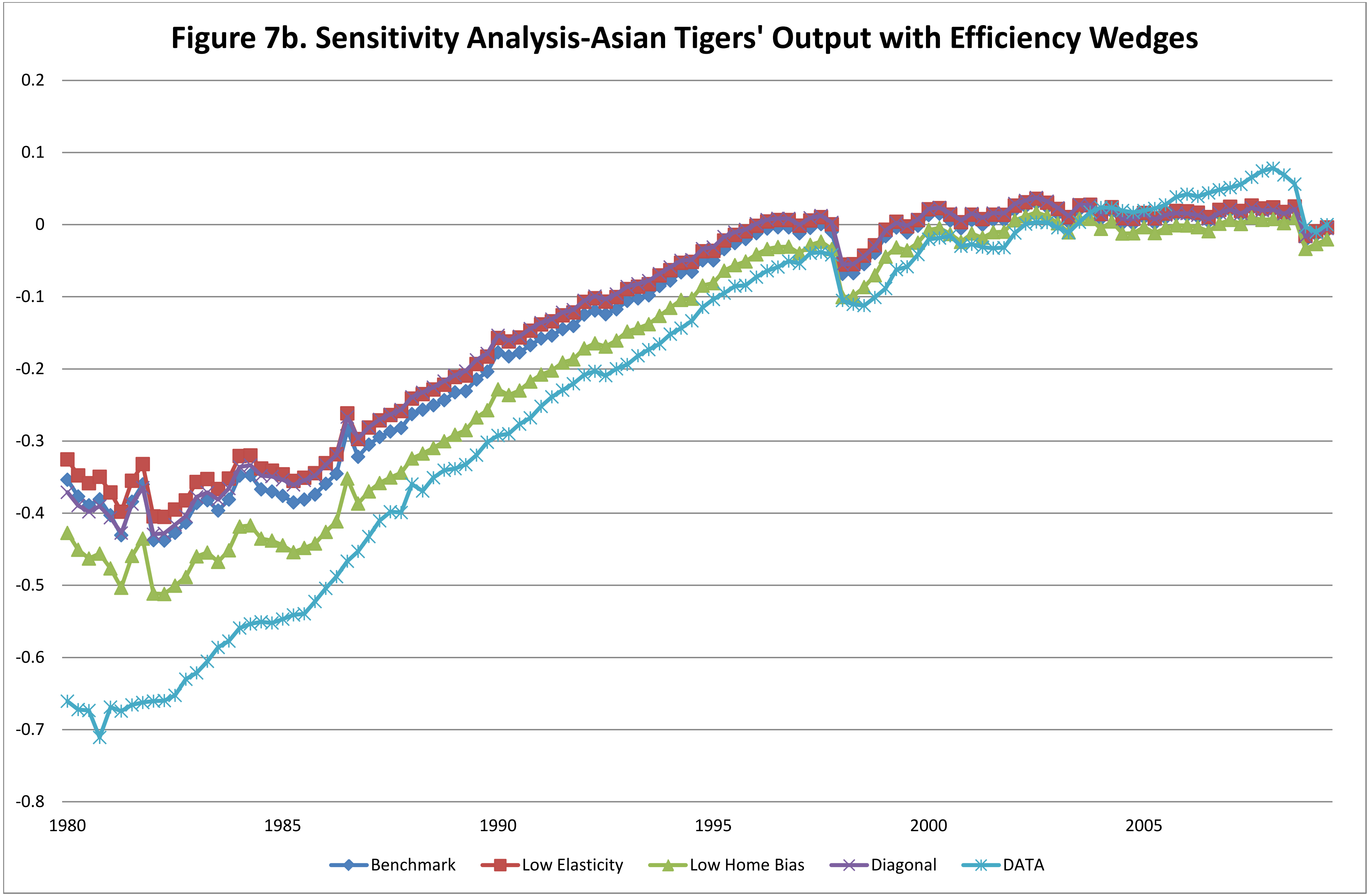


Figure 7b. Sensitivity Analysis-Asian Tigers' Output with Efficiency Wedges
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
1980
1985
1990
1995
2000
2005
Benchmark
Low Elasticity
Low Home Bias
Diagonal
DATA

	Common events	Japan	Korea	Taiwan
Pre-1980 And 1980	・**Second Oil shock (1979-80)**	・**New Foreign Exchange Law (Dec)** It allows any foreign exchange transaction unless specifically restricted.	・**Adoption of the VAT (July 1977)** The rate is 10% (until now) ・**Korean Trade Deficit and Foreign Debt Crisis (1979-80)** ・**Kwangju Uprising Incident (May)** ・**President Chun Doo-hwan (-1988)**	
1981				
1982			・**The Fifth Five-Year Economic and Social Development Plan (82-86)** Shifting to technology-intensive industries.	
1983			・**Import Liberalization (-88)** Import liberalization ratio goes up from 80% in 1983 to 95% in 1988.	
1984			・**The Revision of Foreign Capital Inducement Act** Relaxing FDI restriction.	・**Establishment of Offshore Market (Dec)**
1985	・**The Plaza Agreement (Sep)**			・**Economic Reform Commission** Promoting economic liberalization and internationalization. In the second half of the 80s, liberalization of imports and FDI, lowered tariff, and industrial liberalization take place.
1986	・**Sharp Decline of Oil Prices**	・**High-yen recession**	・**"Three Lows" Boom** the low won, the low international interest rate, and the low oil price.	・**Adoption of the VAT (Apr)** The rate is 5% (until now)
1987		・**The Bubble Economy Era (1987-1989)**	・**The sixth Five-Year Economic and Social Development Plan (87-91)** ・**The Nationwide Uprising (June)** Political struggle for democracy. ・**Lowering in the Ceiling on Foreign ・Security Investments (Sep)** More liberalization takes place in July 1988 and March 1990.	・**Deregulated the foreign exchange controls on capital movements (Jul)** Similar to the Japanese liberalization in 1980.
1988		・**Revision of the Labor Standards Law**	・**President Roh Tae-Woo (-1993)** ・**Seoul Olympics (Sep-Oct)**	・**President Lee Teng-hui (-2000)** ・**Revision of Securities Exchange Act**

		Legislated workweek is shortened to 40 hours from 44 hours by 1993.		**(Feb)** Foreign security companies can open their branches.
1989		・**Adoption of the Consumption Tax (Apr)** The rate is 3% (until Mar 1997) ・**The Peak of the Bubble Economy**	・**Revision of the Labor Standards Act** Legislated workweek is shortened to 44 hours from 48 hours.	・**Lending rates deregulation (Jul)** ・**Deposit rates deregulation (Jul)**
1990	・**The Gulf War (Aug-'91 Feb)**	・**The Collapse of the Bubble Economy and the Start of the Lost Decade**	・**Adopting a Variant of a Managed Floating Exchange Rate Regime,**	
1991			・**Revision of the Foreign Exchange Management Act** Encouraging capital inflows to finance the accumulated current account deficits. ・**Liberalization of Interest Rates (Nov)**	
1992			・**The Seven Five-Year Economic and Social Development Plan (92-96)** ・**Nonresidents can directly purchase Korean stocks (Jan)**	
1993			・**President Kim Young-Am (-1998)** ・**Liberalization of Interest Rates (Nov)**	
1994		・**Kobe Earthquake (Jan)**	・**Liberalization of Interest Rates (Jul and Dec)** ・**The Redefinition of Individual consumption (Formerly Special Excise)tax Law** Simplify from 10-60% to 10%, 15%, and 25%.	
1995		・**A Series of Bankruptcy of Banks** Two Shinkumi Banks, Hyogo Bank, Kidu Shinkin Bank, and	・**Liberalization of Interest Rates (Jul, Nov)** ・**Introduction of the Automatic Approval System of FDI** ・**The Foreign Exchange Management Act was amended (1995-1999)**	

1996			**·Joining OECD (Dec)** The government commits financial liberalization.	**·First Direct Elections for President**
1997	**Asian Currency Crisis**	**·Raising the Consumption Tax Rate (Apr)** The rate increases to 5% from 3% (until now) **·Financial System Crisis (Nov-)** Collapse of Hokutaku Bank, Yamaichi Securities, Sanyo Securities, Tokuyo-City Banks.	**·Bankruptcy of Hanbo, Jinro, Kia, and the other groups (Jan-Jul)** **·Sharp depreciation of won.** **·Liquidity Shortage Problem** **·The IMF Rescue Package (Dec)** **·Changes in the Ceiling on Foreign Equity Ownership** It increases to 23% from 20%. **·Interest rates liberalization (1991-97)** By 1997, lending and borrowing rates are fully liberalized.	
1998		**·Financial System Crisis (cont.)** Collapse of LTCB, NCB, and others. **·New Foreign Exchange Law (Apr)** Liberalize cross-border capital transactions..	**·President Kim Dae-Jung (-2003)** **·The 5 Principles of Corporate Re-structuring** **·Changes in the Ceiling on Foreign Equity Ownership** It increases to 26% from 23%.	
1999		**·Introducing the Zero-Interest Rate Policy (Feb)** **·Financial System Crisis (cont.)**	**·Changes in the Ceiling on Foreign Equity Ownership** It increases to 29% from 26%.	**·President Chen Shui-bian (-2008)** **·Earthquake (Sep)**
2000		**·Exit from the Zero-Interest Rate Policy (Aug)**		
2001	**·The IT recession**	**·Introducing the Quantitatively Easing Monetary Policy (Mar)**	**·Completion of Early Repayment of IMF Loan (Aug)**	**·Revision of the Labor Standards Law (Jan)** Legislated workweek is shortened to 44 hours from 48 hours. **·Easing the restrictions for investing in companies in China.**

2002				・**Joining WTO**
2003		・**Financial System Crisis** Nationalization of Resona Banks and Ashikaga Bank.	・**President Roh Moo-Hyun (-2008)** ・**Revision of the Labor Standards Act** Legislated workweek is shortened to 40 hours from 44 hours. More flexible work is allowed.	
2004				
2005				
2006				
2007	・**The Sub-Prime Problem**	・ **Baby Boomers retirements (2007-09)**		
2008-	・**The Lehman Shock (Sep)**		・**President Lee Myung-Bak (-2003)** ・ **Credit Card Recession (2008)**	・**President Ma Ying-jeou (-2008)**

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