Accounting for the business cycle relationship between Japan and Asia

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May 16, 2010

Abstract

In this paper, we construct a two country business cycle accounting model in order to quantitatively investigate the relationship between Japan and the Asian Tigers. The model is based on Backus, Kehoe and Kydland (1994) in which each country produces tradable intermediate goods that are aggregated to form final goods in each country. We apply the business cycle accounting method a la Chari, Kehoe and McGrattan (2007) and find that the main source of both the growth and high frequency fluctuation in output in each region is domestic production efficiency. Furthermore, the growth in Asian production efficiency had a significant positive effect on Japanese economic growth over the 1980-2009 period while it had a significant negative effect during the Asian crisis in 1998 propagated by the terms of trade.

JEL Classification: E13, E32, F41
Keywords: International Business Cycles, Business Cycle Accounting

1 Introduction

In this paper, we construct a two country business cycle accounting model in order to quantitatively investigate the relationship between Japan and the

*The authors thank Andrea Raffo and the participants of the ESRI meeting for helpful comments.
Asian Tigers. The model is based on Backus, Kehoe and Kydland (1994) in which each country produces tradable intermediate goods that are aggregated to form final goods in each country. We apply the business cycle accounting method a la Chari, Kehoe and McGrattan (2007) and find that the main source of both the growth and high frequency fluctuation in output in each region is domestic production efficiency. Furthermore, the growth in Asian production efficiency had a significant positive effect on Japanese economic growth over the 1980-2009 period while it had a significant negative effect during the Asian crisis in 1998 propagated by the terms of trade.

The business cycle relationship between Japan and Asian Tigers is examined by various methods where mixed results are found. 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 weak evidence of Japan leading Taiwan from 1962:Q1 to 2004:Q4. Girardin (2005a, 2005b) also conducts a similar estimation of a Markov switching model. Abeysinghe and Forbes (2005) use a structural VAR model to estimate the influence of shocks to one country on output in other countries. They not only measure the direct effects through bilateral trade but also measure the 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 using the structural VAR, showing a strong impact from Japan to Korea and a limited impact from Korea to Japan. Weber (2010) extracts a common stochastic growth trend and common business cycle components using a VECM estimation, and shows that the convergence of Asian Tigers towards Japan in the long-run has started in the early 1990s.

The business cycle relationship between Japan and Asian Tigers are also discussed from the viewpoint of the regional integration. In particular, some 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 Asian Tigers have created transnational production networks
and trade networks, which can be an important 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 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 the cyclical components of GDP on trade intensity for ten Asian countries for 1981-1995 and find 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 the negative long-run effects of exports on output and positive long-run effects of investment on output. Moneta and Ruffer (2009) conduct a dynamic common factor 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 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 its effect on welfare 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 a low degree of international risk sharing in the Asian region and a high degree of country specific unsmoothed component. This result 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 is largely financed by savings within the country due to the limited capital mobility in the 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, despite the regional financial integration. Our model also indicates that disturbances in the international financial market led to low cross-region consumption correlation especially during the Asian crisis.

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 tradeable and nontradeable goods. Takeuchi (2006) 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 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 Asia.

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. Otsu (2009) extends their closed economy model to a two-country one-good model to account for the business cycle correlation between Japan and the U.S. We further extend their 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 Asia 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.\footnote{The historical events affecting those regions are listed in Table 4.}

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 size of Korea and Taiwan is roughly 36% and 17% of Japan respectively. The size of the Asia-Japan output ratio is smaller than the population ratio at 22% and 11% respectively. However, the growth rate of Korean and Taiwanese 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 the largest. Those facts suggest that Korea and Taiwan are very important trade partners for Japanese exporting industries and their contribution to Japanese output is significant. Although Korean and Taiwanese exports to Japan is lower than those to the United States and China, Japan is still the one of the biggest trade partners.

Figure 1a presents the log of per capita output in each country detrended by a 0.5% quarterly growth rate normalized at 1980=0. This quarterly growth rate is the average growth rate of the US per capita output. We consider this as the universal growth rate along the balanced growth path. Japan grew faster than the trend during the late 1980s corresponding to the bubble economy period while its growth slowed down during the 1990s also known as the lost decade. The Asian output series is a population weighted sum of Korean and Taiwanese time series. Clearly, both Korea and Taiwan are growing faster than the trend. Asian output drops rapidly in late 1990s corresponding to the Asian crisis.

Figure 1b presents the HP filtered fluctuation of output with the smoothing parameter = 1600. The business cycle correlations between Japan and Asia over the 1980s, 1990s and 2000s are -0.30, 0.50 and 0.84 respectively.
During the Asian crisis in the late 1990s, Japan experienced a domestic financial system crisis leading to a recession which resulted in a high business cycle correlation. The correlation is rising recently not only because of the global crisis in the late 2000s, 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 region, Japan and Asia, produces specialized tradable intermediate goods. They combine both intermediate goods using an aggregation technology and produce a common final good. The households in each region can trade international real state contingent claims among each other in the international financial market.

3.1 Intermediate-goods firm

Intermediate-goods firms combine labor $l_t$ and capital $k_t$ and produce intermediate goods. We assume that Japan produces good $a$ and Asia produces good $b$ so that

$$f_t^{JP}(s^t) = a_t^{JP}(s^t) + a_t^{AS}(s^t)$$
$$f_t^{AS}(s^t) = b_t^{JP}(s^t) + b_t^{AS}(s^t)$$

where $f_t^i$ is the production in region $i$ and $s^t$ is the state of the economy.

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

$$\max \pi_t^i(s^t) = p^i_{j,t}(s^t)f^i_t(s^t) - w^i_t(s^t)l^i_t(s^t) - r^i_t(s^t)k^i_t(s^t)$$

subject to

$$f^i_t(s^t) = z^i_t(s^t)(k^i_t(s^t))^\theta (l^i_t(s^t))^{1-\theta}$$

where $p^i_{j,t}$ 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 $i = AS$, $w^i_t$ and $r^i_t$ are the real wage and return on capital relative to final goods in each region, while $z^i_t$ is the efficiency wedge. Since $p^i_{j,t}(s^t)f^i_t(s^t)$ represents GDP, the Solow residuals, i.e. TFP, can be defined as $p^i_{j,t}(s^t)z^i_t(s^t)$ in our model.
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 $G(a, b)$. The detrended profit maximization of the final goods firm in each region is

$$\max \hat{\pi}_i(s^t) = G_i(a_i(s^t), b_i(s^t)) - p_{at}(s^t)a_i(s^t) - p_{bt}(s^t)b_i(s^t)$$  \hspace{1cm} (3)

subject to

$$G_{JP}^i(a_{JP}(s^t), b_{JP}(s^t)) = \left(\eta_{JP}(a_{JP}(s^t))^{\frac{\epsilon - 1}{\epsilon}} + (1 - \eta_{JP})(b_{JP}(s^t))^{\frac{\epsilon - 1}{\epsilon}}\right)^{\frac{1}{\epsilon - 1}}$$

$$G_{AS}^i(a_{AS}(s^t), b_{AS}(s^t)) = \left((1 - \eta_{AS})(a_{AS}(s^t))^{\frac{\epsilon - 1}{\epsilon}} + \eta_{AS}(b_{AS}(s^t))^{\frac{\epsilon - 1}{\epsilon}}\right)^{\frac{1}{\epsilon - 1}}$$  \hspace{1cm} (4)

where $\eta$ is the home bias parameter and $\epsilon$ is the elasticity of substitution among intermediate goods.

3.3 Household

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

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

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

The household receive after tax labor and capital income, the state contingent international claim $d_i^t$ and the lump-sum transfer from the government $tr_i^t$ 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

$$\left(1 - \tau_{hi}^t(s^t)\right)w_i^t(s^t)l_i^t(s^t) + \left(1 - \tau_{ki}^t(s^t)\right)r_i^t(s^t)k_i^t(s^{t-1}) + rer_i^t(s^t)d_i^t(s^t) + tr_i^t(s^t) = c_i^t(s^t) + x_i^t(s^t) + rer_i^t(s^t) \sum_{s_{t+1}|s^t} q_t(s^t+1|s^t) d_i^{t+1}(s^t+1|s^t),$$  \hspace{1cm} (5)

where $\tau_{hi}^t$ and $\tau_{ki}^t$ are the distortionary labor and capital income taxes. We assume that the international claims $d_i^t$ are denominated in Japanese final
goods so that the real exchange rates $rer_t^J$ are $rer_t^{JP} = 1$ and $rer_t^{AS} = rer_t$.

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:

$$
\Gamma^i k^i_{t+1}(s^t) = x^i_t(s^t) + (1 - \delta^i) k^i_t(s^{t-1}) + \Phi \left( \frac{x^i_t(s^t)}{k^i_t(s^{t-1})} \right) k^i_t(s^{t-1}),
$$

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

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

where $\Omega^i = \Gamma^i - (1 - \delta^i)$ so that there is no adjustment cost in the steady state.

### 3.4 Government Budget Constraint

The government collects labor and capital income taxes in order to pay for government expenditures and rebates the remaining through a lump-sum transfer. Therefore the government budget constraint is

$$
\tau^i_{lt}(s^t) w^i_t(s^t) l^i_t(s^t) + \tau^i_{kt}(s^t) r^i_t(s^t) k^i_t(s^{t-1}) = tr^i_t(s^t) + g^i_t(s^t)
$$

We consider government expenditure as exogenous and define it as government wedge.

### 3.5 International Transactions

In a standard two country model, the total accumulation of the international claims in the world should add up to zero. In this paper, following Otsu (2009) we assume that a physical cost $\tau_t$, which we call the international trade wedge, will be charged on any international transportation of resources. Therefore, the international capital account relationship is as follows:

$$
[q_t(s^{t+1}|s^t) d^J_{t+1}(s^{t+1}|s^t) - d^J_t(s^t)] + [q_t(s^{t+1}|s^t) d^{AS}_{t+1}(s^{t+1}|s^t) - d^{AS}_t(s^t)] = \tau_t(s^t).
$$

Since the accumulation of international claims, i.e. the capital account, should be equal to the trade balance in each region by definition, the international trade balance relationship is as follows:

$$
tb^J_t(s^t) + tb^{AS}_t(s^t) / rer_t(s^t) = \tau_t(s^t).
$$
where the trade balance in each region is
\[ \text{tb}^{JP}_t(s^t) = p^{JP}_{at}a^{AS}_t(s^t) - p^{JP}_{bt}b^{JP}_t(s^t) + \tau_t(s^t) \]
\[ \text{tb}^{AS}_t(s^t) = p^{AS}_{bt}b^{JP}_t(s^t) - p^{AS}_{at}a^{AS}_t(s^t). \]
For simplicity, we assume that all of the physical cost is paid by Japan. It turns out that this simplification does not affect any of the results.

The terms of trade \( \text{tot}_t \) is defined as the price of Japanese intermediate goods relative to that of Asian intermediate goods:
\[ \text{tot}_t = \frac{p^{JP}_{at}}{p^{JP}_{bt}} = \frac{p^{AS}_{at}}{p^{AS}_{bt}}. \tag{9} \]
The real exchange rate is defined as the price of Japanese final goods relative to that of Asian final goods:
\[ \text{rer}_t = \exp(p_t)\frac{p^{AS}_{at}}{p^{JP}_{at}} = \exp(p_t)\frac{p^{AS}_{bt}}{p^{JP}_{bt}} \]
where \( p_t \) is an international price wedge that causes disturbances in the conversion rate of resources in one region shifted to another.

### 3.6 Domestic Absorption and National Accounts

Combining the household budget constraint (5), firms’ profit (3) and (1), government budget constraint (7) and balance of payments accounts (8), we can derive the domestic absorption:
\[ G^i_t(a^i_t(s^t), b^i_t(s^t)) = c^i_t(s^t) + x^i_t(s^t) + g^i_t(s^t) + \text{tb}^i_t(s^t) + \tau^i_t(s^t) \tag{10} \]
where \( \tau^{JP}_t = \tau_t \) and \( \tau^{AS}_t = 0 \).

Gross domestic product in this model is defined as
\[ y^i_t = p^i_{jt}f^i_t = c^i_t(s^t) + x^i_t(s^t) + g^i_t(s^t) + \text{tb}^i_t(s^t) + \tau^i_t(s^t). \tag{11} \]

### 3.7 Equilibrium

The competitive equilibrium is a set of quantities \( \{k^i, y^i, c^i, x^i, l^i, b^i, a^i, b^i, f^i, tr^i\} \), prices \( \{w^i, r^i, q^i, p^i_a, p^i_b, \text{tot}, \text{rer}\} \) and wedges \( \{g^i, \tau^i_t, \tau^i_k, z^i, p, \tau\} \) such that, (i) the households in each region optimize taking \( \{w^i, r^i, q^i, \text{rer}, tr^i, \tau^i_t, \tau^i_k, p, \tau\} \)
as given, (ii) the final-goods firms and intermediate-goods firms in each region optimize taking \( \{w^i, r^i, p_a^i, p_b^i, z^i\} \) as given, (iii) the government budget constraint (7) holds, (iv) the domestic resource constraints (11) hold in each region, (v) the international resource constraint (8) holds, and (vi) the 10 exogenous variables \( s = \{\ln g^i, \tau^i_k, \tau^i_t, \ln z^i, p, \tau\} \) follow a stochastic process

\[
s_t = P_0 + P \cdot s_{t-1} + \varepsilon_t
\]

where \( \varepsilon = \{\varepsilon^i_g, \varepsilon^i_l, \varepsilon^i_k, \varepsilon^i_z, \varepsilon_p, \varepsilon_\tau\} \sim N(0, V) \).

The Equilibrium is characterized by the following set of equations: The capital Euler equation

\[
\Gamma^i(1 + \Phi'_t)^{\frac{1}{c_t^i}} = \beta^i E_t \left[ \frac{1}{c_{t+1}^i} \left( \frac{(1 - \tau^i_{kt+1})p^j_{jt,t+1} \theta^i_{kt+1}}{\kappa_{kt+1}} + (1 + \Phi'_t) \left( 1 - \delta^i - \Phi'_t \frac{z^i_{kt+1}}{\kappa_{kt+1}} + \Phi_{t+1} \right) \right) \right],
\]

the labor first order condition

\[
\frac{\Psi^i}{1 - \Psi^i} \frac{c_t^i}{1 - l^i_t} = (1 - \tau^i_{lt})p^i_{jt,t} (1 - \theta) \frac{f^i_t}{l^i_t},
\]

the international financial condition under complete markets

\[
rer_t = \frac{\Psi^{JP} c_t^{AS}}{\Psi^{AS} c_t^{JP}} = \exp(p_t) \frac{G_{a,t}^{AS}}{G_{a,t}^{JP}},
\]

the intermediate goods production function (2), the final goods firm production function (4), the capital law of motion (6), the international resource constraint (8), the domestic absorption (10), and the domestic resource constraint (11). Finally, the international prices are defined as

\[
\frac{MU_{c^t^{JP}}}{MU_{c^t^{AS}}} = \exp(p_t) \frac{G_{a,t}^{AS}}{G_{a,t}^{JP}} = rer_t
\]

\[
\frac{G_{a,t}^{JP}}{G_{b,t}^{JP}} = \frac{G_{a,t}^{AS}}{G_{b,t}^{AS}} = tot_t.
\]
4 Quantitative Analysis

4.1 Parameter Values

Most of the structural parameters are obtained through calibration using data such as the average consumption-output ratio, investment-output ratio, capital-output ratio, labor input and so on. Table 3 shows the list of key parameter values.

The capital share $\theta$ is defined as capital income plus imputed flow service of durable goods and government capital stock divided by GDP plus the imputed flow service. We set the growth trend $\Gamma$ so that the balanced growth path grows at an annual rate of 2%, which is equal to the average annual growth rate of the U.S. per capita output. The depreciation rate $\delta$ is calibrated from the steady state capital law of motion

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

The subjective discount factor is calibrated from the steady state capital Euler equation

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

The preference parameter $\Psi$ is calibrated from the steady state labor first order condition

$$\frac{1 - \Psi}{\Psi} = (1 - \tau_l)(1 - \theta)^2 \frac{y}{c} \frac{1 - l}{l}.$$  

The elasticity of substitution $\varepsilon$ is set at 1.5 following Backus, Kehoe and Kydland (1994). The home bias parameter $\eta$ is set at 0.5 in the benchmark case in order to consider a completely symmetric setting.

The persistence matrix $P$ is assumed to be orthogonal with the persistence of each shocks to be 0.8. In the sensitivity analysis section, we use the persistence matrix estimated using the maximum likelihood method. The main results are not sensitive to alternative assumptions on the persistence matrix.

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2\footnote{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 quarterly growth trend.}
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 $1 + \phi (\frac{x}{k} - \Omega)$. 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 which is 32.5.

### 4.2 Computing the Wedges

We follow the method of Chari, Kehoe and McGrattan (2007) in computing the wedges.

1. Solve the model for linear decision rules

   $$\{k_{i+1}^i, y_t^i, c_t^i, l_t^i, x_t^i, g_t^i\} = DR(k_t^i, g_t^i, \tau_{it}^i, \tau_{kt}^i, z_t^i, p_t, \tau_t).$$

2. Assuming $k_1^i = k_{ss}^i$, compute $\{g_1^i, \tau_{i1}^i, \tau_{k1}^i, z_1^i, p_1, \tau_1\}$ from

   $$\{y_1^i, c_1^i, l_1^i, x_1^i, g_1^i\} = DR(k_1^i, g_1^i, \tau_{i1}^i, \tau_{k1}^i, z_1^i, p_1, \tau_1).$$

3. Compute $k_2^i$ from

   $$k_2^i = DR(k_1^i, g_1^i, \tau_{i1}^i, \tau_{k1}^i, z_1^i, p_1, \tau_1).$$

4. Solve for $\{g_2^i, \tau_{i2}^i, \tau_{k2}^i, z_2^i, p_2, \tau_2\}$ from

   $$\{y_2^i, c_2^i, l_2^i, x_2^i, g_2^i\} = DR(k_2^i, g_2^i, \tau_{i2}^i, \tau_{k2}^i, z_2^i, p_2, \tau_2).$$

5. Repeat 4 and 5 for the whole period.

Figure 2 presents the computed wedges. The most dramatic feature of the wedges is that the efficiency wedge in Asia is rising rapidly with a sudden negative disturbance in late 1990s while that in Japan is gradually falling below the trend especially after 1990. One important note on this is that the efficiency wedge itself is not equivalent to the Solow residuals. The efficiency wedges are $z_t^i$ while the Solow residuals are $p_{t,t}^i z_t^i$. Since the growth in Asian
efficiency reduced the relative prices of its intermediate goods, the Solow residual in Japan does not have a downward trend as the efficiency wedge.\textsuperscript{3}

Labor wedges both in Japan and Asia are constantly rising. 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. Braun, Ikeda and Joines (2006) shows that when the household utility weight on consumption relative to leisure depends on the family size, the shrinking population in Japan leads to a decrease in labor supply. The same mechanism might be applicable to both Korea and Taiwan are known to have an even lower birth rate than in Japan.\textsuperscript{4}

Capital wedges in Japan fell dramatically in the late 1980s corresponding to the bubble economy period. This implies that there were shocks favorable to investment in the capital market. The Japanese capital wedge remained low during the lost decade in the 1990s and started to rise during the 2000s. In Asia, capital wedges fell dramatically in the late 1980s as in Japan and continued to fall throughout the early 1990s. This corresponds to the rapid growth period in South East Asia when capital market deregulation took place. The Asian capital wedge started to rise after the Asian economic crisis in 1998. In both regions, the capital wedge rapidly increased after 2008.

The government wedges in Japan and Asia are both increasing. This means that the government expenditure in both regions are growing faster than the balanced growth path. While the government expenditure to output ratio is growing in Japan, it is slightly falling in Asia. In Japan, the output is not growing as fast as it used to while government expenditure is growing mainly due to increasing social security and health related payments. Although the government expenditure is growing in Asia, the growth in the economy is outweighing it.

The international price wedge is rising throughout the period. This implies that there is a force in the international financial market that is causing an increase in the relative price of Japanese final goods.

\textsuperscript{3}Backus, Kehoe and Kydland (1994) infer the stochastic process of $z_t$ 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.

\textsuperscript{4}The 2008 figures of birthrate show that the birthrates of Japan, Korea, and Taiwan are 1.4, 1.2, and 1.0 in 2008-2009, while those are 1.75, 2.70, 2.52 in 1980, according to White Paper on Society with Fewer Children and the newspapers.
The international trade wedge is rising throughout the period. By definition, the international trade wedge is the trade surplus of Japan and Asia to the rest of the world. This can be considered as capturing the part of persistent trade deficit of the U.S.

4.3 Business Cycle Accounting

Figures 3a and 3b present the endogenous fluctuation of output in each region in response to each wedge. The two main factors that affect Japanese output are the Japanese and Asian efficiency wedges. The deteriorating Japanese efficiency wedges drag the Japanese output down. On the other hand, the growing Asian efficiency wedges leads to a growth in Japanese output. The growth in Asia leads to a fall in the price of Asian intermediate goods. This positive terms of trade effect offsets the deterioration of Japanese efficiency wedges. Labor wedges in each region also affects Japanese output. The rise in Japanese labor wedges leads to a drop in Japanese labor and thus Japanese output. The rise in Asian labor wedges also leads to a drop in Japanese output through a negative terms of trade effect. Figure 3b presents the results for Asian output. The responses of Asian output to efficiency wedges are symmetric to that of the Japanese results. Labor wedges in each region affects Asian output through the same mechanism as Japanese output.

We also investigate the short run features of the model by detrending the results with the HP filter. The results for output are presented in Figures 4a and 4b. The figures show that efficiency wedges in each region is important in accounting for short run fluctuations of output in each region. An interesting result is that the Asian efficiency wedges drop during the Asian crisis lead to a significant drop in Japanese output. Asian labor wedges are important in accounting for short run fluctuations in Asian output. However, Japanese labor wedges are not important in accounting for Japanese output fluctuations. Furthermore, capital wedges are not important in accounting for the recent crisis.

The results for consumption are presented in Figures 5c and 5d. Efficiency wedges seem as the most important contributor, however, other factors are also affecting consumption such as Asian efficiency wedges, Japanese labor wedges, and international price wedges. The fact that the international price wedge is affecting consumption implies that risk sharing between Japan and Asia is not perfect. Although identifying the source of imperfect risk sharing is beyond the scope of this paper, our results reconfirm the existence of some
international financial friction.

The results for labor and investment are also plotted in Figures 5e-5h. In both regions, labor wedges are important in accounting for labor while capital wedges are important in accounting for investment. Labor and capital wedges play a more important role in the open economy setting than in the closed economy setting. In an open economy model, inputs will increase in the relatively productive country and decrease in the other. Labor and capital wedges are important in offsetting these forces.

5 Sensitivity Analysis

5.1 The Effect of Wedge Spill-overs

We now abandon the assumption of the orthogonal persistence matrix of wedges. In this section, we estimate the $P$ matrix in equation (12). We set the orthogonal matrix as the initial guess for $P$ and use the maximum likelihood estimation.

The result for the estimation is

\[
P = \begin{bmatrix}
0.92 & -0.05 & -0.01 & 0.01 & 0.03 & 0.06 & 0.01 & 0.05 & 0.01 & -0.39 \\
-0.14 & 0.45 & -0.00 & 0.13 & 0.03 & 0.25 & -0.09 & 0.04 & 0.11 & 0.11 \\
-0.21 & 0.00 & 0.86 & -0.14 & -0.07 & -0.08 & 0.02 & -0.01 & -0.07 & 0.15 \\
-0.04 & -0.36 & -0.02 & 1.01 & 0.10 & -0.03 & -0.07 & 0.23 & -0.23 & 0.02 \\
-0.00 & -0.03 & -0.01 & 0.07 & 0.83 & 0.15 & 0.10 & -0.04 & 0.27 & -0.09 \\
-0.03 & 0.48 & -0.05 & -0.26 & 0.08 & 0.36 & -0.26 & 0.07 & -0.65 & 0.52 \\
0.07 & 0.06 & -0.01 & -0.08 & -0.03 & -0.05 & 0.95 & -0.14 & -0.06 & 0.55 \\
0.02 & 0.32 & 0.01 & -0.20 & 0.00 & -0.25 & -0.21 & 0.89 & -0.30 & 0.06 \\
0.00 & 0.01 & 0.01 & -0.03 & 0.01 & -0.01 & -0.06 & 0.06 & 0.90 & -0.35 \\
0.01 & 0.03 & 0.01 & -0.03 & 0.01 & -0.01 & -0.02 & -0.00 & -0.04 & 0.87
\end{bmatrix}
\]

Although we also estimate the variance covariance matrix $V$, we do not report it since it is not used in the linear approximated solution method.

The computed wedges are presented in Figure 5a. The main difference is that the capital wedges in both Japan and Asia are rising throughout the 1980s. The simulation results presented in Figures 5b and 5c are almost unchanged as the effect of capital wedges in our model are limited. Nonetheless, this counter-intuitive result should be investigated in detail.
5.2 The Transition Effect

Throughout the paper, we assumed that both Japan and Asia start at the steady state in 1980. This leads to a much higher ending point in Asian output that of Japan. Our constructed capital stock series implies that the Asian capital stock detrended by the 0.5% quarterly trend in 1980 was approximately 80 percent lower than the level in 2009. We use this value as a starting point and redo the simulations.\footnote{There are initial jumps in Asian wedges. Future versions of this paper will check for initial points that will avoid these jumps.} The computed wedges are presented in Figure 6a.

It turns out that the output simulations show in Figures 6b and 6c do not differ much from the baseline case except for the starting points of the plots. Since we use a linear approximation solution method, the level of Asian capital stock in the initial period does not make much difference except for the effect through the stochastic process (12).\footnote{Transition effects may play a larger role in a non-linear simulation such as Fujiwara, Otsu and Saito (2008).} That is, in this exercise Asia is converging to the trend naturally while in the baseline model it is diverging from the trend with unexpected shocks arriving every period. The fact that the shape of the plots do not differ much means that the impact of the shocks themselves when they actually realize is more important than their effects through expectation.

6 Conclusion

In this paper, we constructed a two-region two-good model in order to investigate the relationship between Japan and Asia. We find that shocks to production efficiency in each region are important in accounting for the growth and fluctuation of output in each region. Furthermore, Asian efficiency supported Japanese growth in the long run through a positive terms of trade effect whereas its sharp drop during the Asian crisis significantly hurt the Japanese economy. While the rapid long run growth of Asian efficiency can be attributed to technology diffusion, future study should attempt to identify the source of its drop during the crisis.

Future study should also consider the effect of other regions on the Japanese and Asian economies. For instance, US and China are undoubtedly important trade partners for both regions. Although we believe that our main
results in a two-region model will hold in an expanded multi-region model, it is interesting to see the relative importance of efficiency wedges in each region on the other regions.

References


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
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.

Some data adjustment was done for conducting theory-based empirical analysis. Consumption is defined as the sum of consumption on non-durables, services, and service flow from capital income from durable goods consumption and government capital stock. 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 is total hours worked defined as the product of average hours worked per worker and the number of workers.