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Abstract

This paper applies the business cycle accounting method à la Chari, Kehoe and McGrattan (2007) to a standard neoclassical small open economy model and assesses the recent crises in Hong Kong, Korea, Singapore and Thailand. The key common features of these crises are the sudden output collapses and consumption drops as large as the output drops. Quantitative results show that the sudden drops in total factor productivity are important in explaining the output drops. Distortions in the foreign debt market are important in Korea and Thailand whereas distortions in the domestic capital market are important in Hong Kong and Singapore in explaining the large consumption drops.

Keywords: Business Cycle Accounting; Small Open Economy; Asian Crisis
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1 Introduction

In late 1997, several East Asian countries experienced massive economic downturns. The two key common features of the Asian crisis are the sudden output collapses and consumption drops as large as the output drops. This paper quantitatively analyzes the recession patterns in Hong Kong, Korea, Singapore and Thailand using a small open economy version of the business cycle accounting method developed by Chari, Kehoe and McGrattan (CKM (2007)).

Broad literature covering the Asian crisis focuses on the causes and the procedures for resolution of the financial and currency crises in which the currencies pegged to US dollars were attacked by investors[1]. In contrast, there are few studies with quantitative analyses on the depression patterns in these countries. Therefore, there are open questions such as, "what are the key forces that caused the economic downturn?" and "what are the channels through which they operated?" In this paper I address these issues by applying the business cycle accounting method to the small open economy framework.

The model's foundation is the standard small open economy optimal neoclassical growth model à la Mendoza (1991) and Correia, Neves and Rebelo (1995) which consists of a firm, household, government and foreign sector. The firm produces a final good from capital and labor using constant returns to scale production technology which fluctuates according to exogenous changes in total factor productivity (TFP). There is an infinitely-lived representative household who receives utility from consumption and disutility from labor. The household owns the physical capital stock and can also borrow from abroad with a non-

[1] Burnside, Eichenbaum and Rebelo (2000) and Corsetti, Pesenti and Roubini (1999) claim that implicit government guarantees to companies and banks led to the crisis by increasing the future government cost. Chang and Velasco (2000) claims that financial liberalization in emerging markets attracted large short term loans, which led to liquidity mismatch as in typical bank-run models. Krugman (1999) argues that capital outflow forced the foreign debt relying corporate sector to reduce investment while real exchange rate depreciation increased the value of existing debt, forced firms to further reduce investment and led to a debt crisis.

state-contingent 1-period discount bond at a given real interest rate. The government sector imposes distortionary taxes on the household. I assume that there are also distortions in the foreign debt market which appear as shocks to the return on international debt. The distortions in the foreign debt, labor, investment and production markets are computed as "wedges" in equilibrium conditions and are taken as exogenous.

The model includes utility function parameters, production function parameters and parameters governing the stochastic shock process. I choose values for these parameters based on data over the 1960-2003 period for each country following the CKM (2007) method. I take the parameterized model, solve the model for linear decision rules, compute the wedges and simulate the model by feeding in the time paths of the wedges one by one. I then visually compare output, consumption, labor and investment from the model to data over the 1990-2003 period focusing on the sharp recessions in 1998.

There are several closely related quantitative studies that analyze the Asian crisis using dynamic general equilibrium models. Meza and Quintin (2007) shows that TFP and factor hoarding are important in explaining recent episodes of economic downturns during financial crises in emerging economies. Otsu (2006) shows that exogenous TFP alone can explain the sudden drop and rapid recovery of Korean output while real interest rate shocks are important in explaining the consumption drop. Cook and Devereux (2006) shows that the exogenous rise in nominal interest rate premiums in Korea, Malaysia and Indonesia can account for the output drop in these countries mainly through a contraction in the nontradable sector within a sticky price setting. Gertler, Gilchrist and Natalucci (2006) also uses a sticky price model and shows that the financial accelerator was important in amplifying the depressing effect of real interest rate shocks under the fixed exchange rate regime on aggregate demand in Korea. While these studies deduce the impact of certain primary shocks on the economy, this paper focuses on “where” the important shocks are rather than “what” they are.

The key findings are as follows. Distortions in production (TFP) are important in all countries in explaining the sudden output collapses. Distortions in the foreign debt market are important in explaining the consumption drops in Korea and Thailand whereas distortions in the domestic capital market are important in Hong Kong and Singapore. Thus, advanced models should be aimed to reveal the relationship between TFP and foreign debt wedges in the Korean and Thailand cases, and TFP and investment wedges in the Hong Kong and Singapore cases.

The remaining sections are organized as follows. Section 2 discusses the facts of the East Asian crisis. Section 3 describes the business cycle accounting model. Section 4 presents quantitative results. Section 5 concludes the paper.

2 Asian Crisis

In this section, I document the similarities and differences of the recession patterns in Hong Kong, Korea, Singapore and Thailand from both the production and demand sides using data over the 1990-2003 period. The key similarities are that in all countries output suddenly dropped in 1998 and consumption dropped as much as output did. The main differences are the magnitudes of the economic downturns and their durations in each country.

2.1 Production Side

Figure 1 shows the fluctuation of GDP and production factors per member of adult population in each country from 1990 to 2002. Each series are linearly detrended. GDP and adult population data are from the World Bank World Development Indicators (WDI) database. I computed the capital stock series using the perpetual inventory method and data from Nehru and Dhareshwar (1993)[2]. Labor (total hours worked) is calculated from the number of employed workers and average weekly hours worked per workers. Labor data is from the International Labor Organization LABORSTA database.

GDP per adult fell 6.7%, 8.3%, 4.1% and 12.6% respectively. The fluctuation in capital lags the business cycle, which is typical since in general it takes time to replace or install capital stock. On the other hand, labor reacts instantaneously to exogenous shocks. Thus, in general, the fluctuation in labor is important in explaining the business cycle. This is true in Korea during the crisis where the labor series spikes down in 1998. However, labor does not drop much compared to output in the other countries, which implies an extraordinarily large drop in TFP in these countries[3].

All four countries experienced GDP collapses in 1998 whereas the magnitudes of economic downturns are quite different ranging from 4.1% to 12.6%. Also, the recovery patterns are quite different. In Hong Kong, output remained over 5% below trend until 1999 and then rapidly recovered to trend level. In Korea, output immediately recovered from the drop in 1998 and returned to trend level in 2000. In Singapore, output recovered immediately and experienced a boom in 2000 but fell below trend level again in 2001. In Thailand, it took until 2002 to return to its trend level.

[2]First, I compute the average depreciation rate from the Nehru and Dhareshwar (1993) data for total capital stock and fixed investment over the 1960-1990 period. Next, with the computed depreciation rate, investment data from WDI and capital stock in 1960 adjusted for prices, I extrapolate the capital stock series until 2003.

[3]This fact is explained in Meza and Quintin (2007). They claim that in Thailand and Indonesia the large fluctuation in TFP would predict too much fluctuation in output compared to data and that factor hoarding is important in explaining this gap.

2.2 Demand Side

Figure 2 shows the fluctuation of GDP and its components. The data are from WDI. Consumption includes private and government consumption[4]. Investment includes private and government fixed investment. For simplicity, inventory investment is included in the trade balance. The trade balance is divided by GDP in order to stationarize the series. The unit of each series is log deviations from the trend except for the trade balance to GDP ratio.

Both consumption and investment are procyclical whereas the trade balance is countercyclical during the crisis in all countries. The interesting fact is that in all countries consumption fell as much as output. The annual consumption drops in Hong Kong, Korea and Singapore from 1997 to 1998 were 7.2%, 12.0%, and 5.1%, which are greater than the output drops in each country. Thailand, which experienced the largest GDP drop, also experienced a large drop in consumption by 11.4%.

3 Business Cycle Accounting Model

The economy is a small open economy in which the representative household can borrow from abroad by issuing a 1-period international discount bond to foreigners at a given rate of return. The household owns labor and physical capital stock, and owes debt to foreigners. Given labor and capital income net of debt payment, the household chooses how much to work, invest, consume, and borrow. The firm produces a final good from capital and labor using a Cobb-Douglas production function which fluctuates according to changes in TFP. The government collects distortionary taxes on labor income and investment from the household, and fully rebates the revenue using lump-sum transfer. There are also distortions in the

[4] Ideally we would like to focus on household non-durable consumption. However, since this data is not available for most countries, I use total final consumption expenditure instead.

foreign debt market which is exogenously determined by foreign creditors. Following the business cycle accounting method in CKM (2007), the distortions are treated as exogenous.

3.1 Household

The lifetime utility for the representative agent depends on utility from consumption and disutility from labor;

$$\max U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \tag{1}$$

where $\beta (0 < \beta < 1)$ is the subjective discount rate, c_t is consumption, and l_t is labor supply which is the fraction of total hours available allocated to work[5]. For the periodical preference function, $u(\bullet)$, I assume GHH preferences which are commonly used in the small open economy real business cycle literature such as Mendoza (1991) and Correia, Neves and Rebelo (1995). GHH preferences are named after from Greenwood, Hercowitz and Huffman (GHH (1988)) which introduced this preference function to the general equilibrium model. The functional form is

$$u(c_t, l_t) = \log\left(c_t - \chi l_t^{\nu}\right) \tag{2}$$

where parameters $\chi (> 0)$ and $\nu (> 1)$ represent the level and curvature of the utility cost of labor respectively. The main feature of this preference function is that there are no income effects on labor supply[6].

[5] In specific, labor was computed as

$$l_t = \frac{h_t}{14 * 7} * \frac{e_t}{N_t}$$

where h_t is the average weekly hours worked per worker, e_t is the number of employed workers and N_t is adult population. l_t is restricted to be between zero and one given that the average weekly hours worked never exceeds $14 * 7$ hours.

[6] One well known fact in the small open economy real business cycle literature is that with Cobb-Douglas preferences over consumption and leisure, the model will predict too much consumption smoothing. Correia,

The representative agent maximizes the lifetime utility (1) subject to the budget constraint:

$$\frac{w_t}{\tau_t^l} l_t + r_t k_t + \tau_t + \frac{\Gamma d_{t+1}}{R \tau_t^d} = c_t + \tau_t^x x_t + d_t + \Phi(d_{t+1}) \tag{3}$$

and the capital law of motion:

$$\Gamma k_{t+1} = x_t + (1 - \delta) k_t \tag{4}$$

where k_t is capital stock, x_t is investment, d_t is foreign debt, w_t are real wages and r_t are real capital rental rates respectively. The lower-case letters c_t, k_t, x_t, and d_t are all detrended per adult variables. I explain the detrending procedure in the appendix. For simplicity, I assume that the population growth rate is constant and define $\Gamma = (1+\gamma)(1+n)$ where γ is the growth rate of labor augmenting technical progress and n is the population growth rate. τ_t^d, τ_t^l and τ_t^x represent wedges in foreign debt, labor and investment markets.

I assume the functional form of the debt adjustment cost function, $\Phi(d_{t+1})$, as $\frac{\phi(d_{t+1}-d)^2}{2}$ where d is the steady state foreign debt. The debt adjustment cost is one of several ways to remove the random walk component in the Euler equation for international asset holdings that are introduced by Schmitt-Grohe and Uribe (2003). They also introduce models with an endogenous discount factor, debt elastic interest rates and complete asset markets, and conclude that all models deliver virtually identical quantitative results. I set ϕ arbitrarily small so that this portfolio adjustment cost will not affect the short run dynamics of the model.

Neves and Rebelo (1995) show that GHH preferences solve this issue because of the lack of income effects on labor.

3.2 Firm

The firm produces a single storable good with a Cobb-Douglas production function,

$$y_t = z_t k_t^{\theta} l_t^{1-\theta} \tag{5}$$

where y_t is the detrended per adult output, and z_t is TFP. The firm's profit maximization problem is,

$$\max \pi_t = y_t - w_t l_t - r_t k_t. \tag{6}$$

3.3 Government

The government collects distortionary taxes and fully rebates them to the household using lump-sum transfer τ_t. Thus, the government budget constraint

$$\tau_t = \left(1 - \frac{1}{\tau_t^l}\right) w_t l_t + \left(\tau_t^x - 1\right) x_t \tag{7}$$

holds for all periods. For simplicity, I do not consider government expenditure shocks since they do not affect the main results. Instead, I include government purchases into consumption and government fixed investment into total investment.

3.4 Foreign Sector

One key difference from CKM (2007) is that I explicitly introduce the foreign sector. Since international debt is issued to the foreign sector, the small open economy must repay whatever it borrowed from abroad. The trade balance is defined by

$$tb_t = d_t - \frac{\Gamma d_{t+1}}{R\tau_t^d} + \frac{\phi(d_{t+1} - d)^2}{2}. \tag{8}$$

That is, I assume that all costs including foreign debt wedges and adjustment costs are paid to the foreign sector[7].

3.5 Competitive Equilibrium

The competitive equilibrium is, $\left\{c_t, l_t, k_{t+1}, d_{t+1}, y_t, x_t, tb_t, w_t, r_t, \tau_t^d, \tau_t^l, \tau_t^x, z_t\right\}_{t=1}^{\infty}$ such that;

1. Households optimize given $\left\{w_t, r_t, \tau_t^d, \tau_t^l, \tau_t^x\right\}_{t=1}^{\infty}$ and d_1, k_1.

2. Firm optimizes given $\{w_t, r_t, z_t\}_{t=1}^{\infty}$.

3. Markets clear and the government budget constraint (7) holds.

4. The resource constraint holds:

$$y_t = c_t + x_t + tb_t. \tag{9}$$

5. Shocks follow the process

$$s_t = P_{0(4\times1)} + P_{(4\times4)}s_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0_{(4\times1)}, Q_{(4\times4)}) \tag{10}$$

where $s_t = \left(\ln\tau_t^d, \ln\tau_t^l, \ln\tau_t^x, \ln z_t\right)'$ and $\varepsilon_t = (\varepsilon_{dt}, \varepsilon_{lt}, \varepsilon_{xt}, \varepsilon_{zt})'$.

[7] It is not important whether the foreign sector receives these or not. What matters is that these resources exit the small open economy.

3.6 Wedges

The business cycle accounting method interprets wedges as distortions in each relevant market. In this section I define the wedges and discuss potential sources of them. Nonetheless, the main focus of this paper is to assess the quantitative impact of these wedges and not to reveal the identity of them.

3.6.1 Foreign Debt Wedges

Foreign debt wedges τ^d appear in the foreign debt Euler equation. They are defined as the difference between the intertemporal marginal rate of substitution and the rates of return on foreign debt[8]:

$$U_{ct}\left(\frac{\Gamma}{R}\frac{1}{\tau_t^d}-\phi(d_{t+1}-d)\right)=\beta E_t\left[U_{ct+1}\right]. \tag{11}$$

CKM (2006, 2007) claim that shocks to the trade balance are equivalent to government expenditure shocks. In CKM (2006) the trade balance is exogenously given and the sudden improvements during the financial crises represent sudden stops of capital inflows. In this paper, I consider the trade balance as an endogenous variable following the small open economy literature. I assume exogenous distortions in the foreign debt market as shocks to the effective real interest rates[9].

Foreign debt wedges capture shocks to the country specific real interest rate premium. Neumeyer and Perri (2005) and Uribe and Yue (2005) claim that the fluctuation in real interest rates is a powerful source of business cycles in developing countries. In their setting, the real interest rate premium is determined by foreign investors either independent from

[8] Since ϕ is set very small, the foreign debt adjustment cost is negligible.

[9] A same kind of wedge can be defined in a closed economy as domestic bond wedges. In this case the domestic real interest rate is endogenous and the net supply of bonds should be zero in all periods.

domestic situations or as a reaction to changes in domestic policy and circumstances.

Foreign debt wedges also capture domestic monetary and foreign exchange policy shocks. That is, real interest rates the domestic household faces may not be equal to real interest rates on foreign debt. If the household does not have access to the bonds directly but can borrow only from some intermediary, the monetary authority can affect the intertemporal terms of trade through monetary policy. Nonetheless, for simplicity, I assume that foreign debt wedges are fully paid to foreigners so that wedges directly affect the trade balance as in (8).

3.6.2 Labor Wedges

In equilibrium, labor wedges τ^l appear as the difference between the consumption-leisure marginal rate of substitution and the marginal product of labor:

$$(1-\theta)\frac{y_t}{l_t}\frac{1}{\tau_t^l} = \chi\nu l_t^{\nu-1}. \tag{12}$$

CKM (2007) shows that a monetary model with sticky wages à la Cole and Ohanian (2002) can be mapped into a prototype real business cycle model with labor wedges. Cole and Ohanian (2002) assumes that nominal wages are set in the beginning of the period by labor unions and do not react to monetary shocks which occur subsequently. This creates distortion in the labor market.

Cooley and Hansen (1989) generates labor wedges with a cash-in-advance constraint on consumption goods in a monetary model. This model subdivides a period into two. In the first sub-period the goods market opens and in the second sub-period the asset market opens. The household needs cash in order to consume goods in the goods market whereas it uses income to accumulate money and financial assets for the next period. Inflation creates distortions in the consumption-leisure choice by deflating the relative value of labor income.

In Christiano and Eichenbaum (1992), labor wedges emerge from a working capital assumption on labor supply. Since firms must borrow credit in the financial market in order to pay wages, labor cost includes the borrowing cost in addition to wage payment. Therefore, exogenous shocks to borrowing rates create distortions in the labor market. Neumeyer and Perri (2005) applies this framework to a small open economy setting.

In Rotemberg and Woodford (1995), the markup of monopolistically competitive firms shows up as labor wedges. The key feature of New Keynesian models is that central bank can neutralize the effects of short-run markup shocks with monetary policy under the assumption of sticky prices.

3.6.3 Investment Wedges

Investment wedges τ^x appear in the capital Euler equation:

$$\tau_t^x \Gamma U_{ct} = \beta E_t \left[U_{ct+1} \left(\theta \frac{y_{t+1}}{k_{t+1}} + (1-\delta)\tau_{t+1}^x \right) \right]. \tag{13}$$

It is straight forward to compute investment wedges in a deterministic model since all of the arguments in the deterministic Euler equation are observable. However, investment wedges will erroneously include all expectational errors in this case. In a stochastic model, the estimation of the expected variables and the computation of the wedges must be done simultaneously, taking into account the fact that future variables are not correctly predicted. This procedure is described in the following section.

In GHH (1988), investment wedges arise from shocks to investment efficiency. In their setting, high investment efficiency enables the household to accumulate more capital stock for a given investment level. This can be interpreted as low investment wedges in the business cycle accounting model.

CKM (2007) shows that models with financial frictions such as Bernanke, Gertler and Gilchrist (1999) and Carlstrom and Fuerst (1997) can be mapped into a prototype business cycle accounting model with investment wedges. They also show that the model with capital wedges à la Christiano and Davis (2006)[10] produces similar simulation results as those of the model with investment wedges.

In general, small open economy models include adjustment costs on capital stock in order to limit the volatility of investment in the model, which will otherwise be overstated. The adjustment costs show up as investment wedges. For instance, high investment adjustment cost that prevents investment to fall during a crisis can be considered as a drop in current investment wedge and a rise in the future investment wedge.

3.6.4 TFP

By definition, TFP is a wedge in the production process since it is computed as the residual from the production function (5). CKM (2007) shows that a multisector model with input-financing frictions can be mapped into a prototype model with TFP shocks. Under their setting, intermediate-goods producers are facing financial borrowing constraints that create differences in borrowing rates across producers who have different productivity levels. Since intermediate-goods are not perfect substitutes, shocks to these firm specific borrowing rates cause shifts in the input mix of final-good production which appears as a shock to aggregate TFP.

[10] Capital wedges are interpreted as tax on capital income that shows up in the Euler equation.

Ohanian (2001) conjectures that the huge drop in TFP during the US Great Depression was caused by the loss of organizational capital, i.e. "the knowledge and know-how firms use to organize production". When there are failures of intermediate goods suppliers, managers must shift time away from production to searching for new suppliers. Since the organizational capital is not used for production, this will appear as a drop in TFP.

Mismeasurement of inputs will also appear as changes in TFP. In GHH (1988), endogenous capital utilization causes fluctuation in aggregate TFP. Burnside, Eichenbaum and Rebelo (1993) introduces labor hoarding as mismeasurement in labor supply which leads to an overstatement of TFP. Meza and Quintin (2007) shows that factor hoarding explains why in several emerging market financial crisis episodes output did not fall as much as a canonical real business cycle model predicts.

Obviously, there is no guarantee that a model with exogenous TFP would yield the same quantitative results as these endogenous TFP models. In context of business cycle accounting, this implies that endogenous TFP models might accompany wedges in other equilibrium conditions. One of the strengths of the business cycle accounting method is that it can identify "where" the wedges are in preparation for effectively modeling "what" these distortions are.

4 Quantitative Analysis

4.1 Parameter Values

In order to simulate the model, the parameter values must be pinned down. The structural parameters were chosen by calibration and estimation to match the model to data over the 1960-2003 period. The parameter values are listed in tables 1 and 2.

The capital income share parameter θ was set at 1/3 for all countries. Gollin (2002) shows that after adjusting for self-employment income the mean capital share over 41 sample countries is approximately 1/3. Thus, I use this as the common capital income share for the Asian countries.

All other parameters were obtained from the 1960-2003 data. Means of the data are used for the steady state values of n, l, $\frac{y}{k}$, and $\frac{tb}{y}$. Steady state values of wedges were assumed to be one[11]. The trend growth rate γ is estimated by a regression of the log of Solow residuals

$$\ln SR_t = \ln Y_t - \theta \ln K_t - (1-\theta) \ln L_t$$

on a linear trend and a constant where Y_t, K_t, and L_t are non-detrended per capita output, capital and labor respectively. The depreciation rate δ is the average of δ_t calculated from the capital accumulation equation

$$N_{t+1}K_{t+1} = N_t X_t + (1-\delta_t) N_t K_t,$$

where N_t is the adult population and X_t is nondetrended per capita investment. The discount factor β was calibrated from the steady state capital Euler equation:

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

the labor disutility curvature parameter ν was computed by equating the elasticity of labor supply computed from the model $\left(\frac{1}{\nu-1}\right)$ to the Frisch labor supply elasticity computed from the model with Cobb-Douglas preferences following Correia, Neves and Rebelo (1995). The

[11] The results are not sensitive to variations of these steady state values.

labor disutility level parameter χ was calibrated from the steady state labor first order condition:

$$(1-\theta)y = \chi\nu l^{\nu}.$$

Since investment and foreign debt wedges are defined by expectational Euler equations which include unobservable state variables, the parameters in the shock process (10) are estimated with maximum likelihood estimation following CKM (2007)[12]. The parameters to be estimated are the 16 persistence parameters in the 4×4 matrix P and the 4 standard deviations and 6 pairwise correlation coefficients of the errors in the variance-covariance matrix Q. I do not estimate the values of P_0 since they are determined by steady state equations. I use linearly detrended data on output, consumption, investment and labor for the estimation since there are 4 shocks to be estimated.

4.2 Simulation Method

Given that all parameters are specified, the model can be solved quantitatively. I use a linear solution method à la Uhlig (1999) to solve for the linear decision rules. Having obtained the decision rules, I compute the unobserved exogenous variables τ_t^x and τ_t^d. Since $\{y_t, c_t, l_t, x_t\}$ are observable, the values of $\left\{\tau_t^d, \tau_t^l, \tau_t^x, z_t\right\}$ can be computed using the linear decision rules

$$(y_t, c_t, l_t, x_t, k_{t+1}, d_{t+1})' = DR_{(6\times 6)}\left\{k_t, d_t, \tau_t^d, \tau_t^l, \tau_t^x, z_t\right\}'$$

where DR is a matrix containing the corresponding linear decision rule coefficients. In specific,

[12]The Dynare package for Matlab offers user-friendly programs for not only MLE but also Bayesian estimation. I follow CKM (2007) and use MLE.

1. I assume $k_{1990} = d_{1990} = 0$.

2. Given $\{k, d\}_{1990}$, I elicit $\{\tau^d, \tau^l, \tau^x, z\}_{1990}$ from $(y, c, l, x)'_{1990} = DR_{(4\times6)} \{k, d, \tau^d, \tau^l, \tau^x, z\}'_{1990}$

3. Given $\{\tau^d, \tau^l, \tau^x, z\}_{1990}$, I obtain $\{k, d\}_{1991}$ from $(k, d)'_{1991} = DR'_{(2\times6)} \{k, d, \tau^d, \tau^l, \tau^x, z\}'_{1990}$

4. Given $\{k, d\}_{1991}$, I elicit $\{\tau^d, \tau^l, \tau^x, z\}_{1991}$ from $(y, c, l, x)'_{1991} = DR_{(4\times6)} \{k, d, \tau^d, \tau^l, \tau^x, z\}'_{1991}$
   and so on.

Next, in order to evaluate the effects of the wedges separately, I plug each type of wedges into the model one by one and compute the fluctuation of endogenous variables using the linear decision rules. The method is identical to CKM (2007) except that I use foreign debt wedges rather than government wedges. When plugging each type of wedges into the model, I do not change the estimated stochastic process. That is, the off-diagonal terms in the persistence matrix are kept non-zero. Obviously, plugging in all of the wedges will produce a simulated series that perfectly matches the data.

4.3 Quantitative Results

4.3.1 Wedge Analysis

Figure 3 presents the values of wedges in each country over the 1990-2003 period. Since matrix P relates current shocks to future expected shocks, the effects of these shocks are complex. That is, a shock today will affect the expectation of future shocks and the reactions of agents depend on these expectations. In the following, I limit my discussion to the direct effects of each shock in order to build some intuition.

An interesting fact is that foreign debt wedges jumped up in Korea and Thailand in 1998 while the fluctuations of them in Hong Kong and Singapore were decimal. The fact that these wedges in Korea and Thailand are large implies that the disturbances in the foreign debt market during the crisis were high in these countries. An increase in foreign debt wedges reduces borrowing, which improves the trade balance. At the same time, this affects the marginal rate of intertemporal substitution in (11), which tends to reduce current consumption[13]. This also reduces investment since the expected return on capital must be equated to the return on foreign debt according to (11) and (13).

Labor wedges fell sharply in all countries except for Korea in which they fell only mildly. Labor wedges primarily affect labor supply and consumption by changing the effective real wage as in (12). A decline in labor wedges will cause consumption to increase through both income and intratemporal substitution effects. Since there are no income effects on labor with GHH preferences, labor will increase through the substitution effect. Thus, the drops in labor wedges during the crises have expansionary effects in each country.

Investment wedges fell sharply in all countries. A drop in investment wedges stimulates investment since they represent the prices of investment relative to consumption. This tends to decrease current consumption through substitution effects but has little effect on current labor supply or output due to the lack of income effects on labor. Instead, it affects future output and labor through increasing future capital stock.

TFP fell sharply in all countries. A drop in TFP leads to a drop in output while it also lowers the marginal product of labor. This leads to a drop in real wage which reduces labor supply through the substitution effect. Consumption also tends to fall from income and substitution effects.

[13] The intertemporal substitution effect of a rise in foreign debt wedge on current consumption is negative while the sign of the income effect depends on whether the country is a net borrower or lender. If the country is a borrower, the income effect is also negative.

4.3.2 Individual Simulation Results

Figure 4 presents the results of individual simulations with each type of wedges[14]. In Hong Kong, TFP and investment wedges have contractionary effects whereas labor and foreign debt wedges have slightly expansionary effects during the crisis. As discussed above, investment wedges do not have strong effects on current labor or output. The increase in investment wedges in 1997 reduces capital stock in 1998 which has contractionary effects on labor and output. Investment wedges are also important in explaining the drop in consumption during the crisis. An important result is that TFP alone predicts output to fall too much. This is consistent with the finding of Meza and Quintin (2007) that labor hoarding is important in explaining why labor and output did not fall as much as the theory would predict. In context of business cycle accounting, labor hoarding overstates the drop in TFP and will appear as a reduction in labor wedge.

In Korea, TFP and foreign debt wedges have contractionary effects whereas labor and investment wedges have slightly expansionary effects during the crisis. Almost all of the drop in output can be explained by the drop in TFP. The increase in foreign debt wedges helps explaining the drop in consumption. However, TFP and foreign debt wedges predict an excessive fall in investment during the crisis. Thus, without the expansionary effects from investment wedges in 1999, output, consumption and labor will all hit a trough in 1999[15].

In Singapore, TFP have contractionary effects while the other wedges have slightly expansionary effects during the crisis. Investment wedges are important in explaining the drop in consumption during the crisis. In addition, TFP alone will predict too much drop in GDP as in Hong Kong.

[14] Results of simulations with a combination of shocks are available upon request.

[15] In Otsu (2006), investment adjustment costs prevent investment to fall too much during the crisis so that TFP alone can predict the sudden drop and rapid recovery of output in Korea.

In Thailand, TFP and foreign debt wedges have contractionary effects during the crisis. Again, TFP alone predicts an excessive drop in output as in Hong Kong and Singapore. In fact, labor supply did not fall at all during the crisis. This is an extreme case that strongly supports the labor hoarding explanation of Meza and Quintin (2007).

Overall, the similarity across the Asian crisis is that the drop in TFP is important in explaining the economic downturn. In fact, in all countries except for Korea, TFP predicts too much drop in output. One key difference is that in order to explain the consumption drop during the crisis, foreign debt wedge is important in Korea and Thailand while investment wedge is important in Hong Kong and Singapore. I conjecture that this is because Korea and Thailand were net debtors whereas Hong Kong and Singapore were net creditors when the crisis occurred.

5 Conclusion

In this paper, I conduct a stochastic business cycle accounting simulation using the wedges computed from equilibrium conditions as exogenous shocks and investigate how they affected the East Asian economies over the 1990-2003 period. The standard neoclassical small open economy model was calibrated to data for Hong Kong, Korea, Singapore and Thailand over the 1960-2003 period.

I find that TFP is important in explaining the economic downturns in all countries. I also find that distortions in the foreign debt market are important in Korea and Thailand whereas investment wedges are important in Hong Kong and Singapore in explaining the large consumption drops. Future study should focus on revealing the relationship between TFP and foreign debt wedges in indebted countries and the relationship between TFP and investment wedges in net creditor economies.

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A Detrending

Business cycle accounting model is detrended with the growth trend. Consider a non-detrended per adult production function:

$$Y_t = z_t K_t^{\theta} (X_t l_t)^{1-\theta} \tag{14}$$

where z_t is detrended TFP and X_t is the labor-augmenting technical progress. I assume that the growth rate of X_t is constant:

$$X_t = (1+\gamma) X_{t-1}.$$

According to neoclassical growth theory, per adult variables Y_t, K_t, and $X_t l_t$ should be growing at the same rate as X_t along the balanced growth path. Thus, we obtain (5) from

$$\frac{Y_t}{X_t} = z_t \left(\frac{K_t}{X_t}\right)^{\theta} \left(\frac{X_t l_t}{X_t}\right)^{1-\theta}$$

where $\frac{Y_t}{X_t} \equiv y_t$ and $\frac{K_t}{X_t} \equiv k_t$.

A notable assumption is made for the preference function. The detrended preference function (2) is derived from a non-detrended preference function

$$u(C_t, l_t) = \log(C_t - \chi X_t l_t^{\nu}). \tag{15}$$

The growth of labor disutility can be justified as follows. Greenwood, Rogerson and Wright (1995) shows that GHH preferences are equivalent to a reduced form of a preference function with consumption, leisure, and home production. If we assume that home production uses the same technology as market-goods production, disutility from the loss of home-goods should have the same growth trend as market-goods.

B Cobb-Douglas Preference

In this paper, I assume GHH preferences because it is the standard assumption in the small open economy literature. In this section, I will introduce an alternative preference specification, Cobb-Douglas preferences, that were used in Chari, Kehoe and McGrattan (2007). The functional form is

$$u(c_t, l_t) = \Psi \log c_t + (1 - \Psi) \log(1 - l_t).$$

This preference function is widely used in closed economy macroeconomic literature. The key difference between the Cobb-Douglas and GHH preferences is that the Cobb-Douglas preferences have income effects on labor. The procedure is the same as the GHH preference case. In order to save space, I will only present the simulation results for Korea in this section[16].

Figure A1 shows the computed wedges for all countries. Compared to the GHH preference case, the main differences is that labor wedges jump up during the crisis in the Cobb-Douglas case (except for in Thailand). As a result, labor wedges have a strong contractionary effect on the economy in contrary to the GHH preference case. Figure A2 shows the simulation results for Korea. The contractionary effect of labor wedges on output is stronger than TFP during the crisis. Also, foreign debt wedges have expansionary effects during the crisis. This is closely related to the results of Chari, Kehoe and McGrattan (2006) that sudden stops

[16] Figures for other countries are available upon request.

of capital inflows cause income effects which tends to increase labor. Similarly, an increase in foreign debt wedge causes income effects on labor that were absent in the GHH case. Nonetheless, it is still true that foreign debt wedges in Korea and Thailand have depressing effects on consumption.

Clearly, the results depend on the assumption on preferences. The business cycle accounting method is silent in terms of the plausibility of the preference function assumption. I use GHH preferences as a benchmark because it is the standard assumption in the small open economy literature.

C Tables and Figures

Table 1. Steady State Parameter Values

	Hong Kong	Korea	Singapore	Thailand
β	0.942	0.889	0.911	0.940
δ	0.023	0.018	0.018	0.026
θ	0.333	0.333	0.333	0.333
χ	1.134	1.008	1.089	1.052
ν	1.515	1.429	1.409	1.802
Γ	1.064	1.051	1.052	1.058
γ	0.038	0.029	0.023	0.030
n	0.024	0.021	0.028	0.027

Table 2. Estimated Shock Process Parameters

$$P_{HK} = \begin{bmatrix} 0.839 & -0.119 & 0.062 & 0.026 \\ -0.589 & 0.000 & 0.250 & 0.655 \\ 0.610 & 0.136 & 0.990 & -0.124 \\ 0.603 & -0.398 & 0.473 & 0.836 \end{bmatrix}, Q_{HK} = \begin{bmatrix} 0.0001 & -0.0000 & -0.0002 & -0.0000 \\ -0.0000 & 0.0019 & 0.0016 & 0.0017 \\ -0.0002 & 0.0016 & 0.0024 & 0.0014 \\ -0.0000 & 0.0017 & 0.0014 & 0.0017 \end{bmatrix}$$

$$P_{KR} = \begin{bmatrix} 1.225 & -0.032 & 0.129 & -0.193 \\ -1.371 & 0.295 & -0.373 & 0.898 \\ 0.007 & 0.090 & 0.854 & 0.105 \\ 0.729 & -0.084 & 0.222 & 0.632 \end{bmatrix}, Q_{KR} = \begin{bmatrix} 0.0002 & -0.0001 & -0.0006 & -0.0000 \\ -0.0001 & 0.0007 & 0.0008 & 0.0006 \\ -0.0006 & 0.0008 & 0.0028 & 0.0007 \\ -0.0000 & 0.0006 & 0.0007 & 0.0007 \end{bmatrix}$$

$$P_{SP} = \begin{bmatrix} 1.080 & -0.023 & -0.022 & 0.037 \\ -1.459 & 0.902 & 0.108 & -0.176 \\ 0.908 & 0.214 & 1.079 & -0.313 \\ -1.468 & 0.096 & 0.220 & 0.541 \end{bmatrix}, Q_{SP} = \begin{bmatrix} 0.0000 & -0.0001 & -0.0001 & -0.0001 \\ -0.0001 & 0.0008 & 0.0006 & 0.0008 \\ -0.0001 & 0.0006 & 0.0007 & 0.0005 \\ -0.0001 & 0.0008 & 0.0005 & 0.0010 \end{bmatrix}$$

$$P_{TL} = \begin{bmatrix} 0.694 & -0.099 & -0.005 & 0.029 \\ 0.075 & 0.725 & -0.042 & 0.133 \\ 0.857 & 0.206 & 1.037 & -0.266 \\ 0.247 & -0.161 & 0.046 & 0.957 \end{bmatrix}, Q_{TL} = \begin{bmatrix} 0.0002 & -0.0002 & -0.0007 & -0.0001 \\ -0.0002 & 0.0008 & 0.0009 & 0.0006 \\ -0.0007 & 0.0009 & 0.0023 & 0.0005 \\ -0.0001 & 0.0006 & 0.0005 & 0.0009 \end{bmatrix}$$

Figure 1. Production Factors

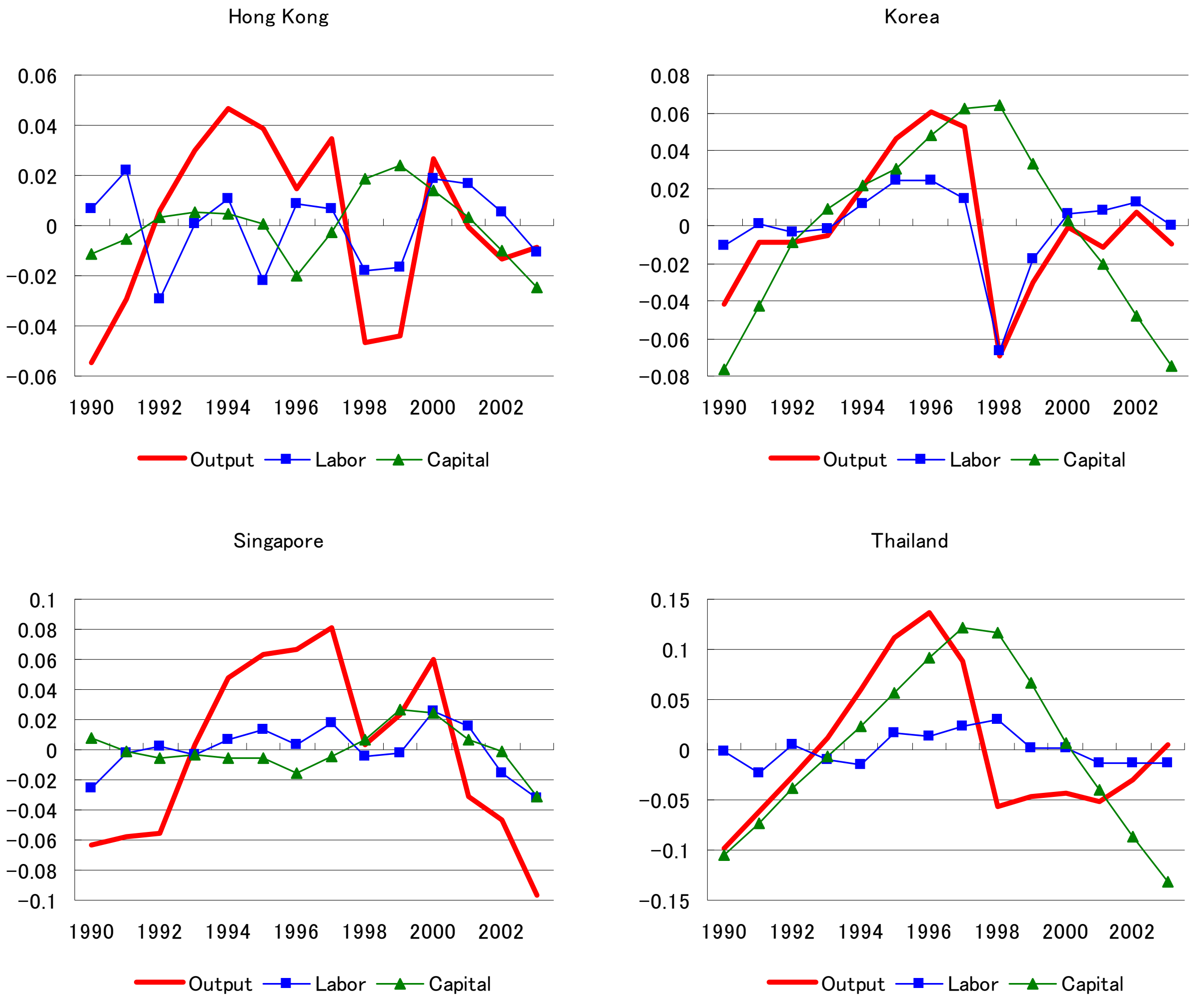

Figure 2. GDP Components

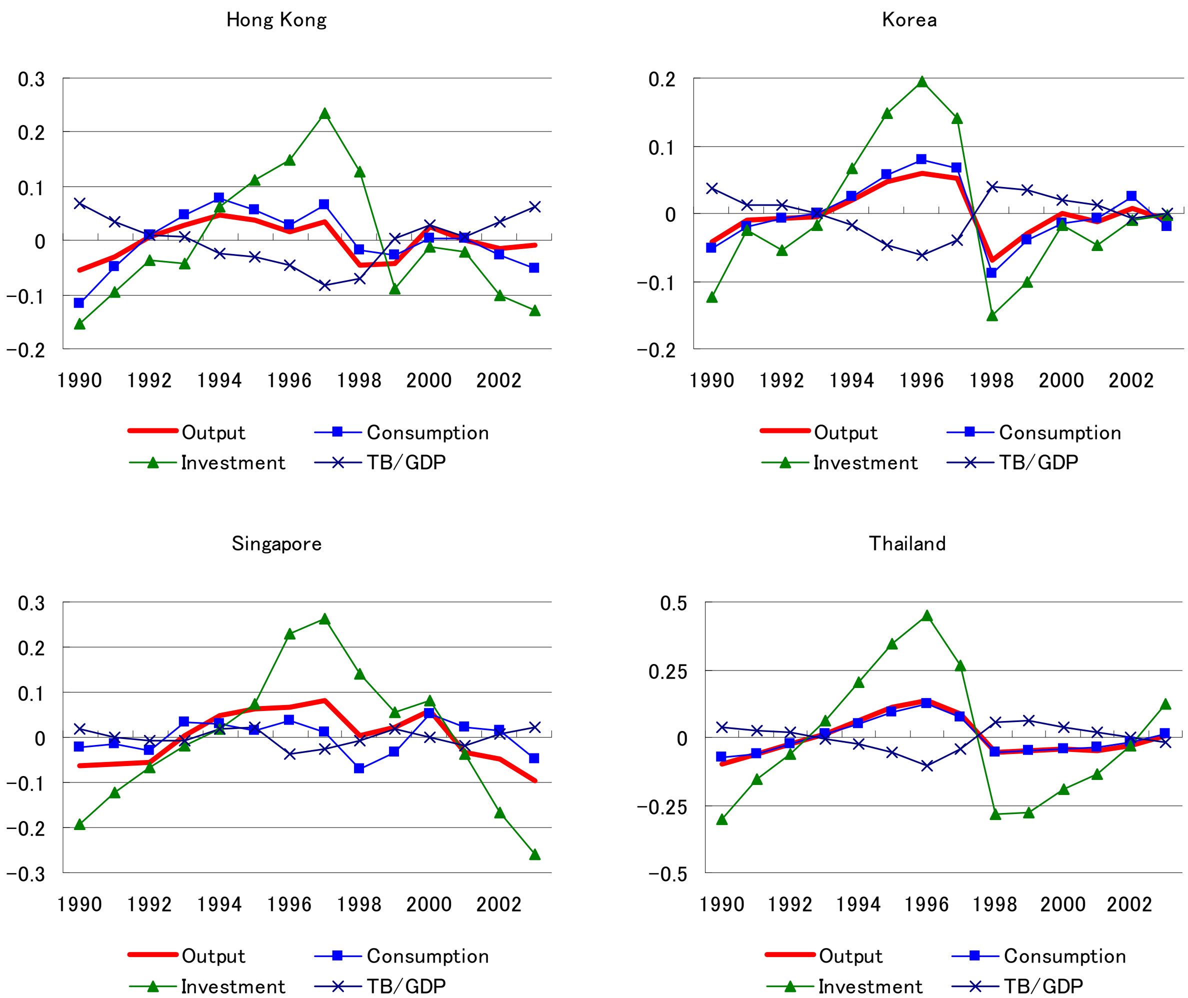

Figure 3. Wedges

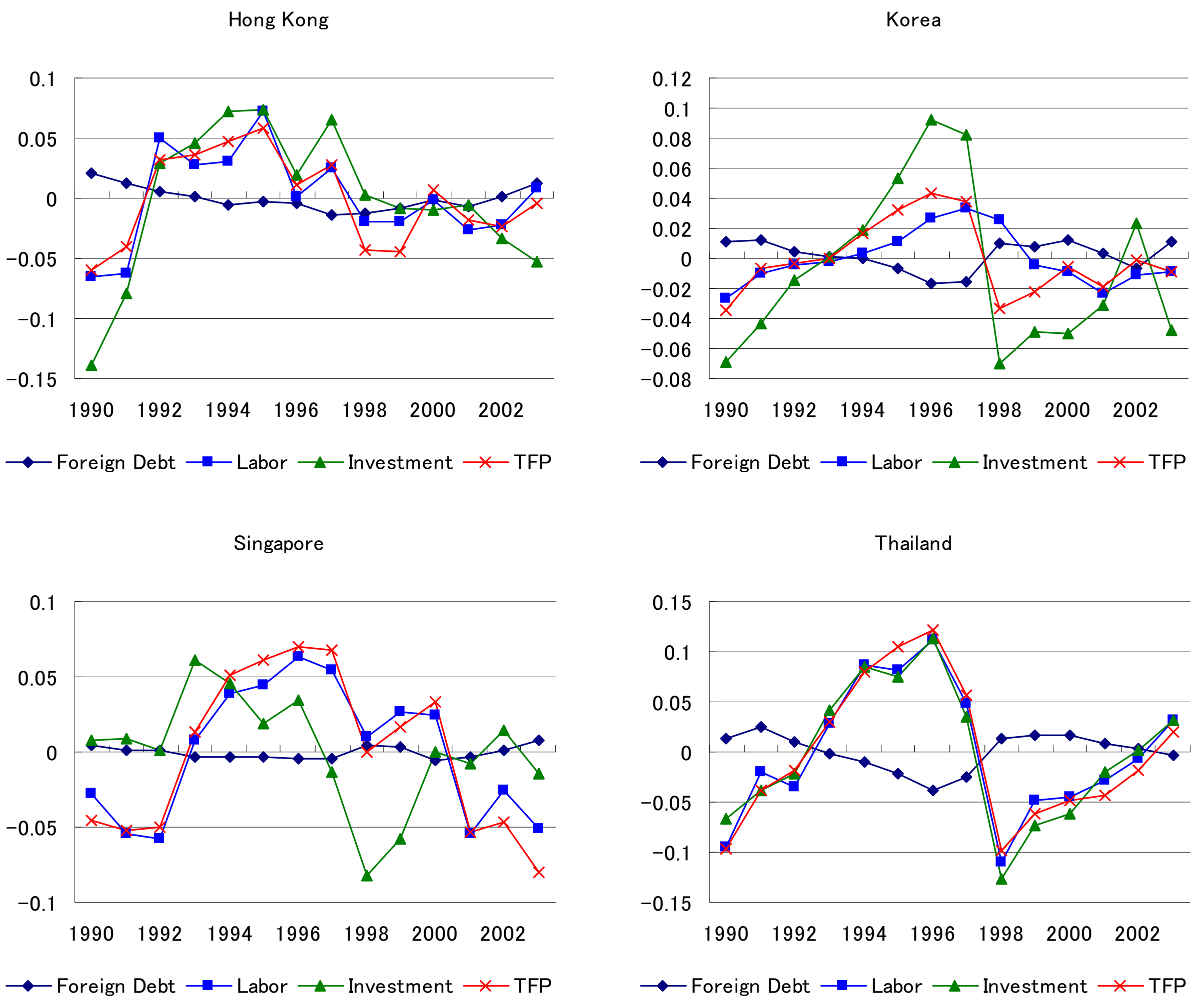

Figure 4a. Results: Hong Kong

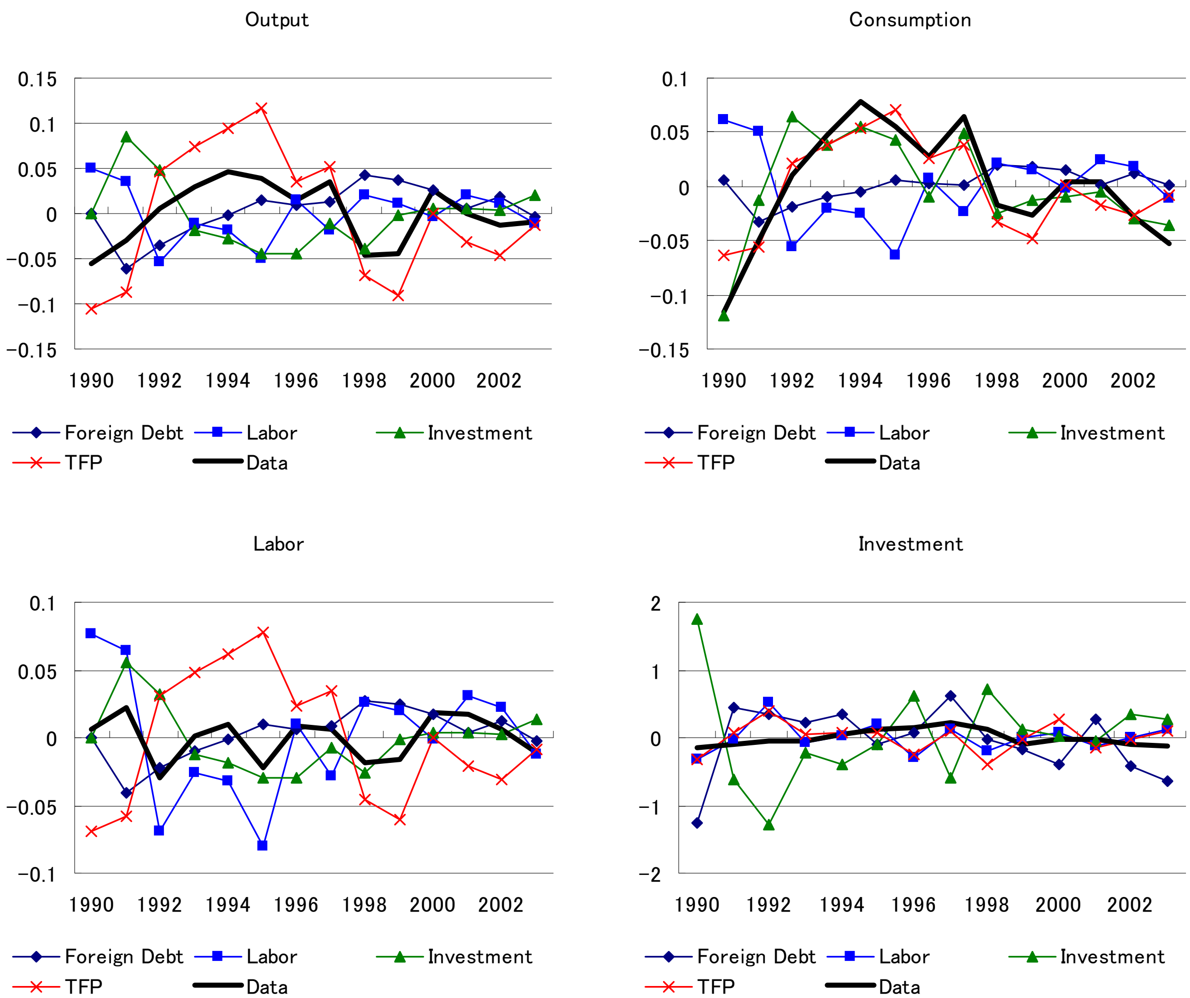

Figure 4b. Results: Korea

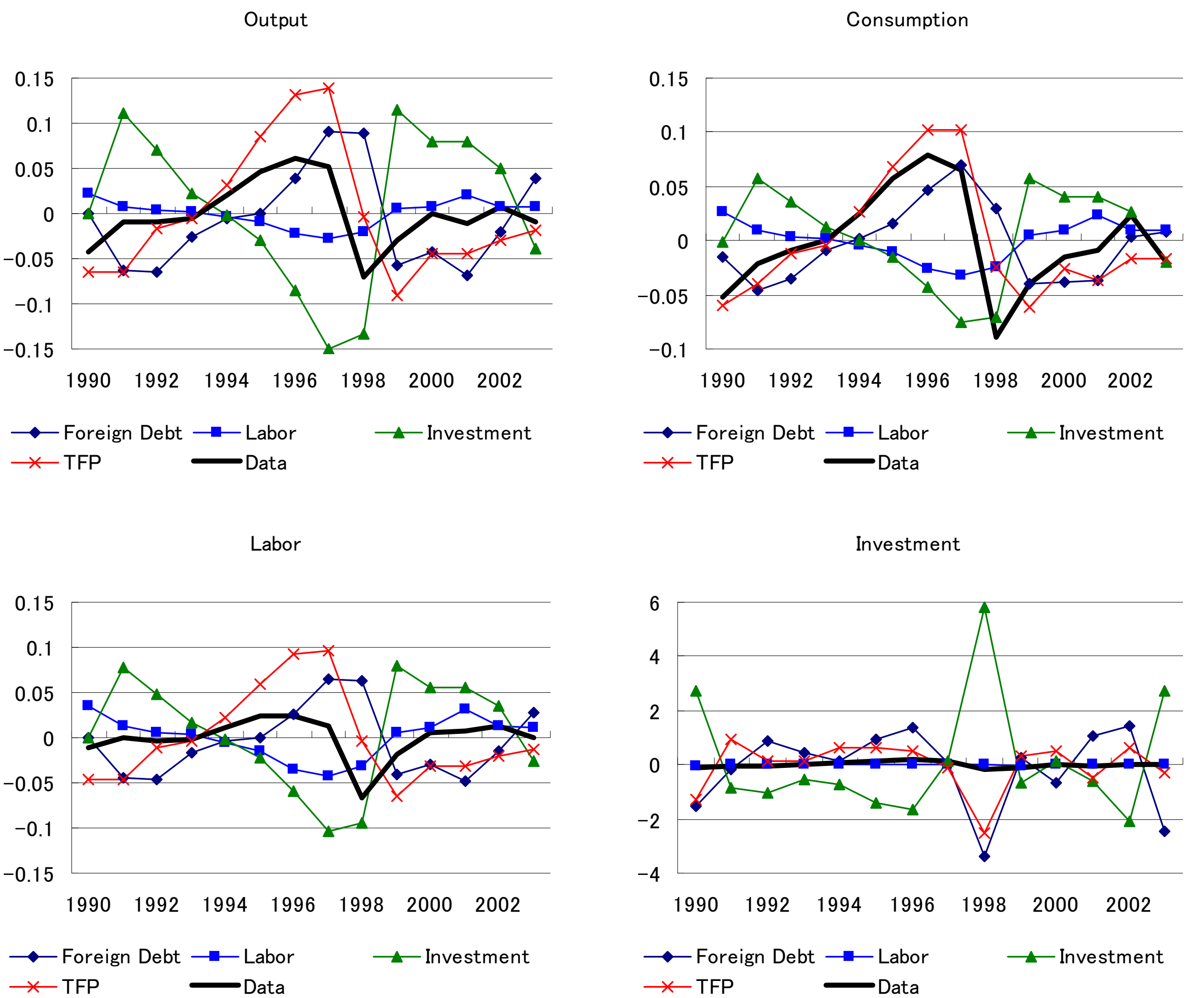

Figure 4c. Results: Singapore

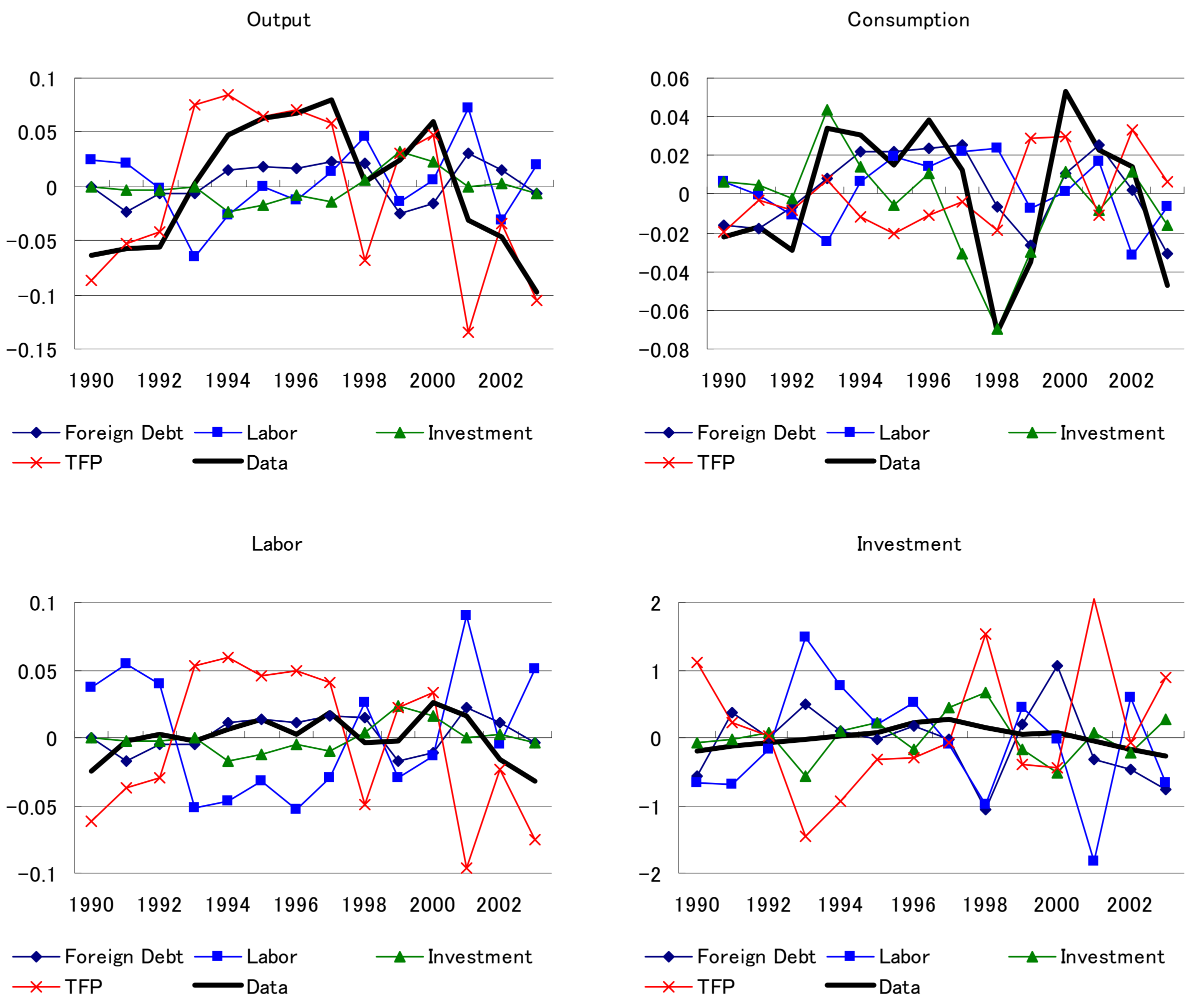

Figure 4d. Results: Thailand

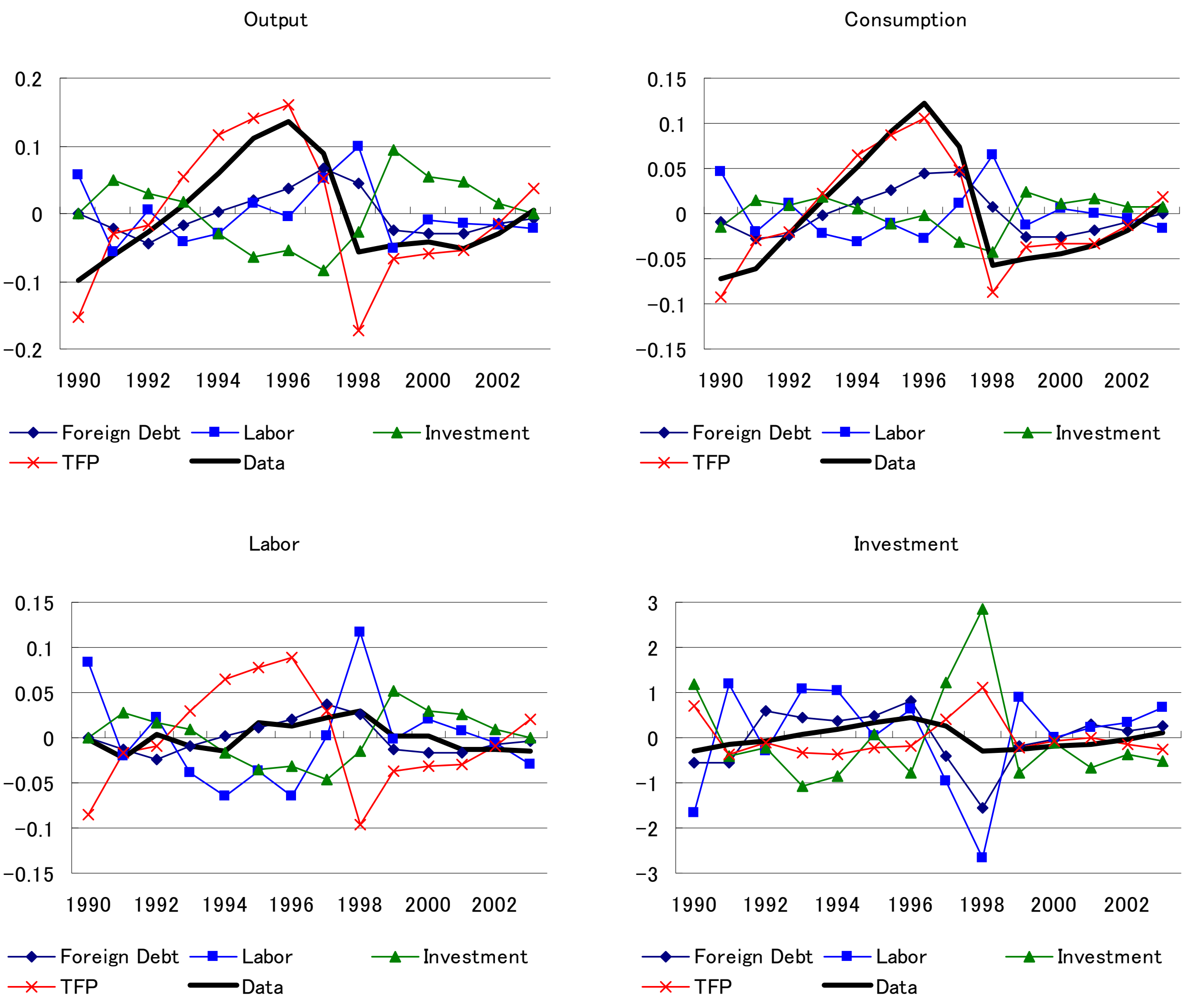

Table A1. Estimated Shock Process Parameters (Cobb-Douglas)

$$P_{HK} = \begin{bmatrix} 0.831 & 0.057 & 0.089 & -0.086 \\ 0.875 & 0.000 & -0.428 & 0.337 \\ 0.479 & 0.019 & 1.032 & -0.065 \\ 1.045 & -0.239 & 0.410 & 0.626 \end{bmatrix}, Q_{HK} = \begin{bmatrix} 0.0000 & 0.0000 & -0.0001 & -0.0000 \\ 0.0000 & 0.0008 & -0.0004 & 0.0003 \\ -0.0001 & -0.0004 & 0.0011 & 0.0010 \\ -0.0000 & 0.0003 & 0.0010 & 0.0016 \end{bmatrix}$$

$$P_{KR} = \begin{bmatrix} 1.028 & -0.257 & 0.055 & -0.129 \\ 0.201 & 0.252 & 0.009 & -0.096 \\ 0.089 & 0.360 & 0.990 & 0.0011 \\ 0.901 & -0.294 & 0.144 & 0.688 \end{bmatrix}, Q_{KR} = \begin{bmatrix} 0.0002 & 0.0003 & -0.0003 & -0.0000 \\ 0.0003 & 0.0007 & -0.0005 & 0.0001 \\ -0.0003 & -0.0005 & 0.0012 & 0.0006 \\ -0.0000 & -0.0001 & 0.0006 & 0.0007 \end{bmatrix}$$

$$P_{SP} = \begin{bmatrix} 0.942 & -0.086 & 0.016 & -0.018 \\ 0.367 & 0.576 & 0.017 & -0.050 \\ 0.095 & 0.251 & 0.993 & -0.146 \\ 0.940 & -0.205 & 0.064 & 0.865 \end{bmatrix}, Q_{SP} = \begin{bmatrix} 0.0001 & 0.0001 & -0.0002 & -0.0000 \\ 0.0001 & 0.0004 & -0.0002 & -0.0000 \\ -0.0002 & -0.0002 & 0.0006 & 0.0002 \\ -0.0000 & -0.0000 & 0.0002 & 0.0009 \end{bmatrix}$$

$$P_{TL} = \begin{bmatrix} 0.629 & -0.115 & 0.111 & -0.041 \\ 0.061 & 0.566 & -0.059 & 0.152 \\ 0.654 & 0.118 & 0.912 & -0.087 \\ 0.943 & -0.155 & 0.144 & 0.886 \end{bmatrix}, Q_{TL} = \begin{bmatrix} 0.0002 & 0.0001 & -0.0002 & -0.0001 \\ 0.0001 & 0.0023 & 0.0006 & 0.0012 \\ -0.0002 & 0.0006 & 0.0006 & 0.0006 \\ -0.0001 & 0.0012 & 0.0006 & 0.0013 \end{bmatrix}$$

Figure A1. Wedges (Cobb-Douglas)

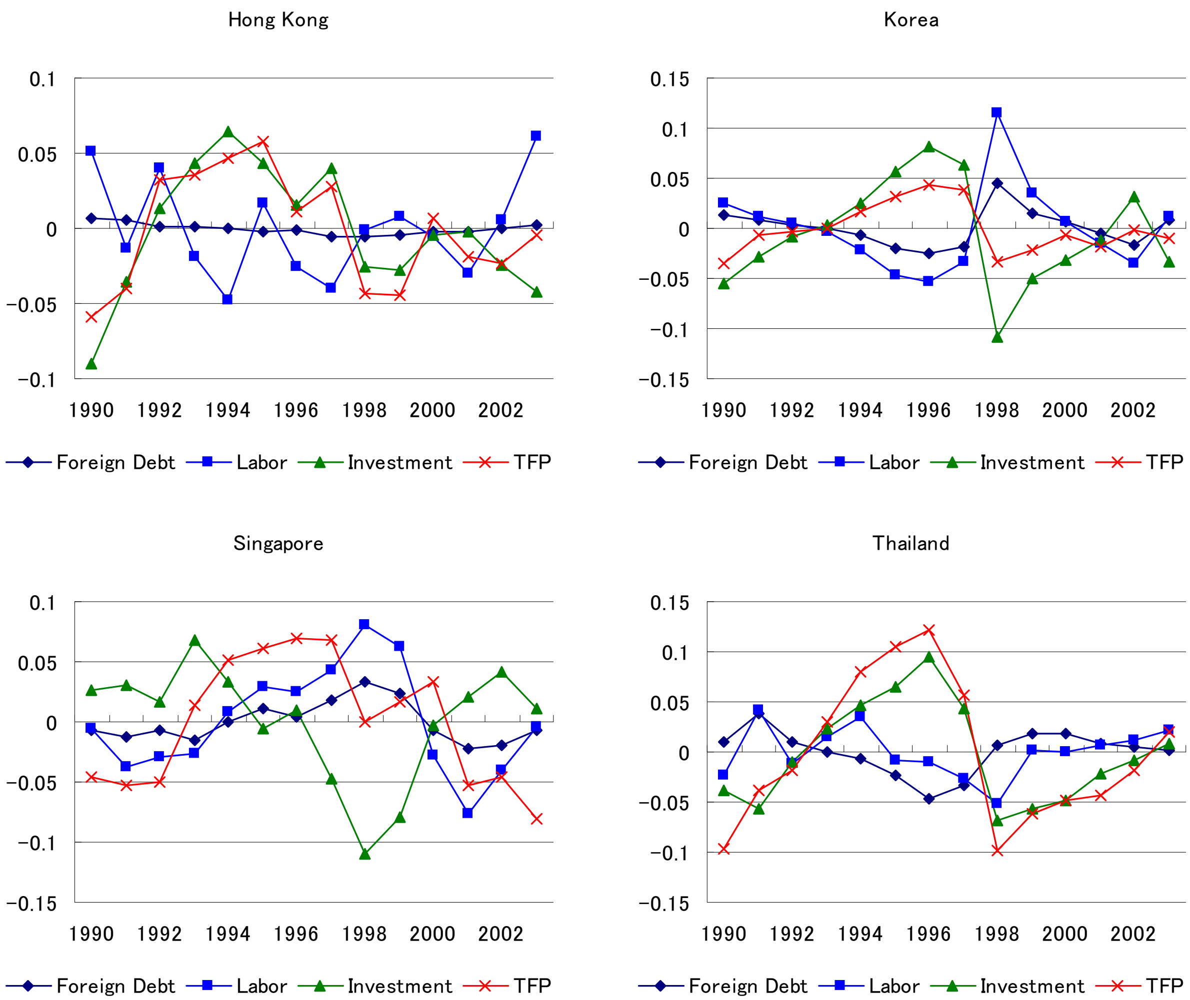

Figure A2. Results: Korea (Cobb-Douglas)