# A Neoclassical Analysis of the Asian Crisis: Business Cycle Accounting for a Small Open Economy

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**Abstract**

This paper applies the business cycle accounting method to a standard neoclassical small open economy model and assesses the recent crises in Hong Kong, Korea, Singapore and Thailand. Quantitative results show that (a) distortions in production (TFP) are important in all countries in explaining the sudden output collapses, (b) unlike the closed economy literature, distortions in the labor market do not have contractionary effects, and (c) distortions in the foreign debt market are not important in explaining the recessions.

*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 key common feature of the crises in East Asian countries is the sudden economic contractions in terms of output, consumption, labor input and investment in 1998. This paper quantitatively analyzes the recession patterns in Hong Kong, Korea, Singapore and Thailand using a small

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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 speculative investors[1]. In contrast, there are fewer studies with quantitative analyses on the recession patterns in these countries. Therefore, there are open questions such as, "what are the key forces that caused the economic downturns?" 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 East Asian economies within 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 the firm, household, government and foreign sectors. 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), which can be considered as the degree of distortions in the production market. There is an infinitely-lived representative household who gains utility from consumption and disutility from labor. The household owns the physical capital stock and can also borrow from abroad with a non-state-contingent one-period discount bond at a given real interest rate. The government sector imposes distortionary labor income and investment taxes on the household. There are also distortions in the foreign debt market, in the form of shocks to the return on international debt, which is not present in the existing literature. 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.

[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.

I take the parameterized model, solve the model for linear decision rules, compute the wedges from the decision rules using data and simulate the model by feeding in the time paths of these 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, the main focus of this paper is to find "where" the important shocks are rather than "what" they are.

The key findings are (a) distortions in production (TFP) are important in explaining the sudden output collapses in all countries, (b) unlike the closed economy literature, labor wedges do not have contractionary effects, and (c) foreign debt wedges are not important in explaining the recessions.

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.

## 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 through lump-sum transfers. There are also distortions in the 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.

[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.

### 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). 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. GHH preferences are named after from Greenwood, Hercowitz and Huffman (GHH (1988)) which introduced this preference function to the general equilibrium model. The main feature of it is that there are no income effects on labor supply[6].

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

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

and the capital law of motion:

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

[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, Neves and Rebelo (1995) show that GHH preferences solve this issue due to the lack of income effects on labor. Result for with Cobb-Douglas preferences are available in the appendix.

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 $\gamma$ is the growth rate of labor augmenting technical progress and $n$ is the population growth rate. $\tau_t^d$, $\tau_t^l$ and $\tau_t^x$ 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 $\phi$ arbitrarily small so that this portfolio adjustment cost will not affect the short run dynamics of the model.

It is common to include capital adjustment cost, $\Pi(\Delta k_t)$, in small open economy models since otherwise the model will predict excessive volatility in investment. I assume the functional form of the capital adjustment cost function as $\frac{\pi(k_{t+1}-k_t)^2}{2}$.

## 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 $\tau_t$. 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, $\left\{c_t, l_t, k_{t+1}, d_{t+1}, y_t, x_t, tb_t, w_t, r_t, \tau_t^d, \tau_t^l, \tau_t^x, z_t\right\}_{t=0}^{\infty}$ such that;

1. Households optimize given $\left\{w_t, r_t, \tau_t^d, \tau_t^l, \tau_t^x\right\}_{t=0}^{\infty}$ and $d_0$, $k_0$.

2. Firm optimizes given $\{w_t, r_t, z_t\}_{t=0}^{\infty}$.

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

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

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 $\varepsilon_t = (\varepsilon_{dt}, \varepsilon_{lt}, \varepsilon_{xt}, \varepsilon_{zt})'$.

## 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[8].

### 3.6.1 Foreign Debt Wedges

Foreign debt wedges $\tau^d$ appear in the foreign debt Euler equation. They are defined as the difference between the intertemporal marginal rate of substitution and the rate of return on foreign debt[9]:

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

CKM (2006, 2007) claim that exogenous shocks to the trade balance are equivalent to government expenditure shocks. In CKM (2006) the sudden improvements in the trade balance during the financial crises represent sudden stops of capital inflows. Instead, in this paper, I follow the small open economy literature and consider the trade balance as an endogenous variable. I assume exogenous distortions in the foreign debt market as shocks to the effective real interest rates. In addition, for simplicity, I assume that foreign debt wedges are fully paid to foreigners so that wedges directly affect the trade balance as in (8).

[8] Thoughout this paper I deal with the wedges $s_t$ and not the innovations $\varepsilon_t$. One of the criticism of business cycle accounting made by Christiano and Davis (2006) is that the correlation of innovations should be important in explaining dynamics.

[9] Since $\phi$ is set very small, the foreign debt adjustment cost is negligible.

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

Foreign debt wedges may also capture domestic monetary and foreign exchange policy shocks. That is, real interest rates which the domestic household faces may not be equal to the rate of return on foreign debt. If the household does not have direct access to debt but can borrow only from a financial intermediary, the monetary authority can affect the domestic interest rate faced by the household through monetary policy. Although, in this case the name might be inappropriate.

#### 3.6.2 Labor Wedges

In equilibrium, labor wedges $\tau^l$ 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 value of labor income relative to consumption.

In Christiano and Eichenbaum (1992), labor wedges emerge from a working capital assumption on labor input. 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 the 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 $\tau^x$ appear in the capital Euler equation:

$$U_{ct}(\tau_t^x \Gamma + \pi(k_{t+1} - k_t)) = \beta E_t \left[ U_{ct+1} \left( \theta \frac{y_{t+1}}{k_{t+1}} + (1-\delta)\tau_{t+1}^x + \pi(k_{t+2} - k_{t+1}) \right) \right]. \quad (13)$$

It is straight forward to compute deterministic investment wedges since all of the arguments in a 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. The 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.

Obviously, the value of capital adjustment costs affects the value of investment wedges. I discuss how the capital adjustment cost is defined in the following section.

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

#### 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 equation (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 appear as shocks to aggregate TFP.

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.

# 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 $\theta$ is 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. I use this as the common capital income share for the Asian countries.

Other parameters were obtained from the 1960-2003 data. I set the long-run averages of $n$, $l$, $\frac{y}{k}$, and $\frac{tb}{y}$ as their steady state values. Steady state values of wedges are assumed to be one[11]. The trend growth rate $\gamma$ 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 nondetrended per capita output, capital and labor respectively. The depreciation rate $\delta$ is the average of $\delta_t$ calculated from the capital accumulation equation

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

using Nehru and Dhareshwar (1993) data, where $N_t$ is the adult population and $X_t$ is non-detrended per capita investment[12]. The discount factor $\beta$ is calibrated from the steady state capital Euler equation:

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

The labor disutility curvature parameter $\nu$ is 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 labor disutility level parameter $\chi$ 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

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

[12] Given that the data is on annual basis, the depreciation rates seem lower than convention. One possible reason might be because we do not include durable goods consumption in investment. Nonetheless, we do not adjust for this fact since the results are not sensitive to this parameter.

estimated following CKM (2007)[13]. The parameters to be estimated are the 16 persistence parameters in the $4 \times 4$ 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.

Since there is no real world counterpart for capital adjustment costs, I set the parameter $\pi$ such that the volatility of investment simulated from the model with only TFP shocks will match the data. This is a standard treatment in the small open economy real business cycle literature[14].

## 4.2 Simulation Method

Given all parameters values, 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 $\tau_t^x$ and $\tau_t^d$. Assuming that $\{y_t, c_t, l_t, x_t\}$ 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, the procedure goes as follows:

1. Assume $k_{1990} = d_{1990} = 0$.
2. Given $\{k, d\}_{1990}$, elicit $\left\{\tau^d, \tau^l, \tau^x, z\right\}_{1990}$ from $(y, c, l, x)'_{1990} = DR_{(4\times 6)} \left\{k, d, \tau^d, \tau^l, \tau^x, z\right\}'_{1990}$
3. Given $\left\{\tau^d, \tau^l, \tau^x, z\right\}_{1990}$, obtain $\{k, d\}_{1991}$ from $(k, d)'_{1991} = DR'_{(2\times 6)} \left\{k, d, \tau^d, \tau^l, \tau^x, z\right\}'_{1990}$
4. Given $\{k, d\}_{1991}$, elicit $\left\{\tau^d, \tau^l, \tau^x, z\right\}_{1991}$ from $(y, c, l, x)'_{1991} = DR_{(4\times 6)} \left\{k, d, \tau^d, \tau^l, \tau^x, z\right\}'_{1991}$ and so on.

[13] Instead of using MLE as in CKM (2007), I use Bayesian estimation with the Dynare package. Unfortunately, the labor data for Hong Kong, Korea, Singapore and Thailand start at 1985, 1970, 1982 and 1983 respectively. Thus, the estimation periods are short.

[14] Note that the value of $\pi$ affects not only the dynamics, but also the estimation of $P$. Also, in my model TFP shocks have feed back effects through expectations which depend on the $P$ matrix.

Next, in order to evaluate the effects of the wedges, 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 assume 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 wedges to future expected wedges, the effects of these wedges are complex. That is, a change in wedges today will affect the expectation of future wedges and the reactions of agents depend on these expectations. In the following, I limit my discussion to the direct effects of each wedge in order to build some intuition.

An interesting fact is that foreign debt wedges jumped up in Korea in 1998. The fact that this wedge in Korea increased implies that the disturbances in the foreign debt market suddenly increased during the crisis. An increase in foreign debt wedges affects the marginal rate of intertemporal substitution in (11), which tends to reduce current consumption[15]. This also reduces investment since the expected return on capital must be equated to the return on foreign debt according to (11) and (13). Thailand also experienced an increase in the foreign debt wedge, but to a much smaller extent. This is surprising since the Asian financial crisis originated in Thailand. On the other hand, foreign debt wedges in Hong Kong and Singapore increased in 1999.

Labor wedges fell sharply in all countries except for Korea. 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

[15] 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.

will increase through the substitution effect. Thus, the drops in labor wedges during the crises have expansionary effects in each country.

Investment wedges fell in 1998 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 reduces the marginal product of labor. This leads to a drop in real wage which reduces labor supply through the intratemporal substitution effect of leisure on consumption. Consumption also tends to fall from both income and substitution effects.

### 4.3.2 Individual Simulation Results

Figure 4 presents the results of each country with each type of wedges[16]. In Hong Kong, TFP wedges have contractionary effects whereas labor wedges have expansionary effects during the crisis. An important result is that TFP alone predicts output and labor 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 an expansionary labor wedge. As discussed above, investment wedges do not have strong effects on current labor or output. The increase in foreign debt wedges in 1999 is important to explain the drop in investment. TFP alone cannot explain the drop in investment after 1998.

In Korea, almost all of the drops in output, consumption, labor and investment can be explained by the drop in TFP[17]. The increase in foreign debt wedges and the decrease in the investment wedges help explaining the drop in consumption. Investment wedges tend to increase investment while foreign debt wedges tend to reduce investment during the crisis, while these two effects roughly cancel out each other.

In Singapore, TFP has contractionary effects while labor wedges have expansionary effects during the crisis, which fits the labor hoarding explanation as in Hong Kong. Also,

[16] Results of simulations with a combination of shocks are available upon request.
[17] This is consistent with the finding in Otsu (2006).

Singapore is the only country in which investment wedges have large contractionary effects on consumption.

In Thailand, as in Hong Kong and Singapore, the labor hoarding explanation seems to fit. In fact, labor supply did not fall at all during the crisis regardless of the huge drop in TFP. Investment and foreign debt wedges have little effect on output, consumption and labor. The two have impacts on investment which cancel out each other as in Korea.

# 5 Conclusion

In this paper, I conduct a stochastic business cycle accounting simulation using the standard neoclassical small open economy model calibrated to data of Hong Kong, Korea, Singapore and Thailand. I compute wedges from equilibrium conditions and investigate how they affected the East Asian economies over the 1990-2003 period focusing on the year of the crisis, 1998.

The main finding is that TFP is important in explaining the economic downturns in all countries. In Hong Kong, Singapore and Thailand, reduction in labor wedges counter the excessive contractionary effects of TFP whereas Korea is the only country in which the model with TFP alone predicts an output contraction close to data. Investment wedges as well as foreign debt wedges have little impact on output in all countries due to the lack of income effects on labor given GHH preferences.

The message of this paper is that sophisticated models of the Asian crisis should account for the sudden drop in TFP. If financial imperfections or speculative attacks are believed to be the sources of the output collapses in East Asia, these should cause drops in TFP. In this sense, understanding the characteristics of the variance and covariance matrix in these countries is the first step to further progress.

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# A Detrending

The business cycle accounting model is detrended with a deterministic 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 since this is the standard assumption in the small open economy literature. In this section, I assume Cobb-Douglas preferences as in CKM

(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 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 simply to point out that business cycle accounting results depend on the assumption on preferences[18].

Figure A1 shows the computed wedges. Compared to the GHH preference case, the main differences is that labor wedges jump up during the crisis in the Cobb-Douglas case. In addition, foreign debt wedges decrease during the crisis. Figure A2 shows the simulation results for Korea. Labor wedges have strong contractionary effects on the economy in contrary to the GHH preference case. The increase in labor wedges causes a positive intratemporal substitution effects on leisure which reduces labor and consumption. Obviously, labor wedges are much more important in explaining the business cycle with Cobb-Douglas preferences.

Clearly, the results do depend on the assumption on preferences. The business cycle accounting method is silent in terms of the plausibility of the preference function assumption.

# C Tables and Figures

Table 1. Steady State Parameter Values

| | Hong Kong | Korea | Singapore | Thailand |
|---|---|---|---|---|
| $\beta$ | 0.942 | 0.889 | 0.911 | 0.940 |
| $\delta$ | 0.023 | 0.018 | 0.018 | 0.026 |
| $\theta$ | 0.333 | 0.333 | 0.333 | 0.333 |
| $\chi$ | 1.134 | 1.008 | 1.089 | 1.052 |
| $\nu$ | 1.515 | 1.429 | 1.409 | 1.802 |
| $\Gamma$ | 1.064 | 1.051 | 1.052 | 1.058 |
| $\gamma$ | 0.038 | 0.029 | 0.023 | 0.030 |
| $n$ | 0.024 | 0.021 | 0.028 | 0.027 |

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

Table 2. Estimated Shock Process Parameters

$$P_{HK} = \begin{bmatrix} 0.720 & 0.032 & -0.081 & -0.064 \\ -0.031 & 0.944 & -0.065 & 0.077 \\ 0.149 & 0.028 & 0.885 & 0.070 \\ 0.278 & 0.010 & 0.048 & 0.884 \end{bmatrix}, Q_{HK} = \begin{bmatrix} 0.0006 & 0.0000 & -0.0000 & 0.0000 \\ 0.0000 & 0.0019 & 0.0001 & 0.0003 \\ -0.0000 & 0.0001 & 0.0013 & 0.0000 \\ 0.0000 & 0.0003 & 0.0000 & 0.0012 \end{bmatrix}$$

$$P_{KR} = \begin{bmatrix} 0.725 & -0.017 & 0.052 & -0.140 \\ -0.055 & 0.881 & -0.017 & 0.025 \\ 0.047 & 0.083 & 0.904 & 0.021 \\ 0.328 & -0.048 & 0.093 & 0.888 \end{bmatrix}, Q_{KR} = \begin{bmatrix} 0.0005 & 0.0000 & -0.0001 & -0.0000 \\ 0.0000 & 0.0008 & 0.0000 & 0.0001 \\ -0.0001 & 0.0000 & 0.0015 & 0.0000 \\ -0.0000 & 0.0001 & 0.0000 & 0.0007 \end{bmatrix}$$

$$P_{SP} = \begin{bmatrix} 0.731 & 0.046 & 0.010 & -0.111 \\ -0.095 & 0.864 & 0.014 & -0.002 \\ 0.054 & -0.009 & 0.899 & -0.050 \\ 0.250 & -0.044 & 0.098 & 0.909 \end{bmatrix}, Q_{SP} = \begin{bmatrix} 0.0007 & -0.0000 & -0.0001 & 0.0001 \\ -0.0000 & 0.0009 & 0.0001 & 0.0001 \\ -0.0001 & 0.0001 & 0.0030 & 0.0000 \\ 0.0000 & 0.0001 & 0.0000 & 0.0010 \end{bmatrix}$$

$$P_{TL} = \begin{bmatrix} 0.648 & -0.067 & -0.026 & 0.030 \\ -0.007 & 0.914 & -0.070 & 0.076 \\ 0.120 & 0.024 & 0.9953 & -0.060 \\ 0.117 & -0.049 & 0.018 & 0.892 \end{bmatrix}, Q_{TL} = \begin{bmatrix} 0.0004 & 0.0000 & -0.0000 & 0.0000 \\ 0.0000 & 0.0051 & 0.0001 & 0.0007 \\ -0.0000 & 0.0001 & 0.0010 & 0.0000 \\ 0.0000 & 0.0007 & 0.0000 & 0.0022 \end{bmatrix}$$

Figure 1. Production Factors

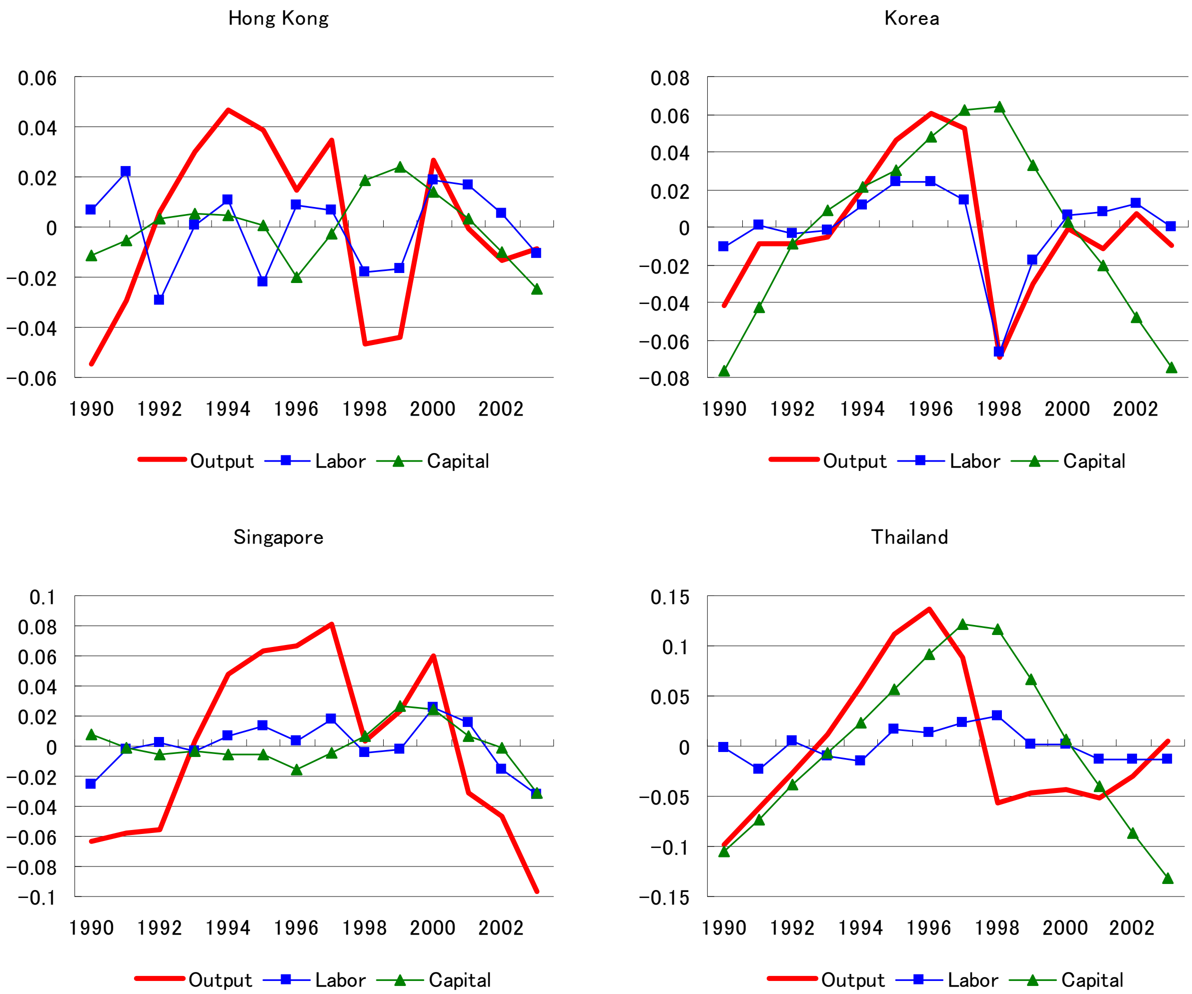

Figure 2. GDP Components

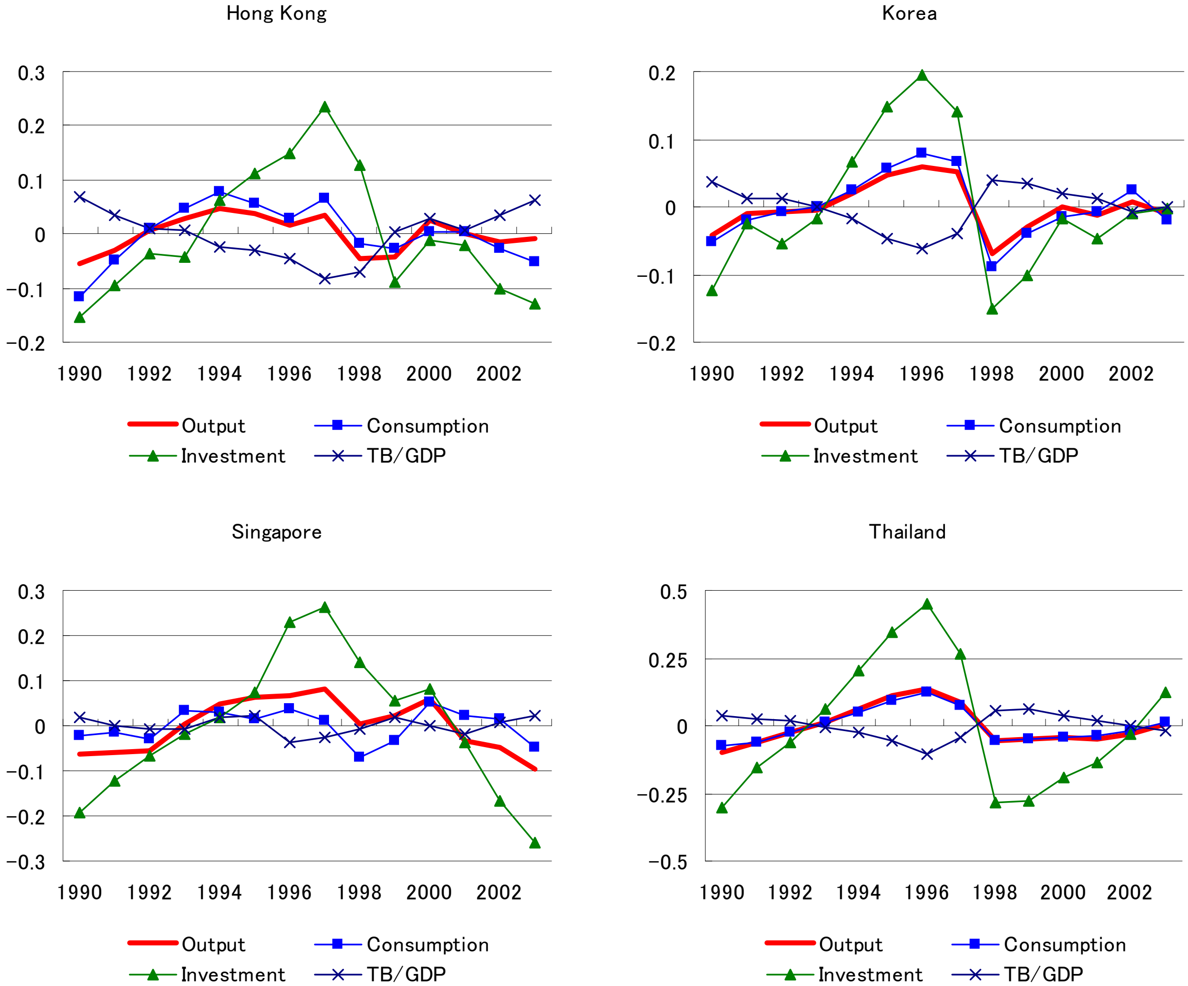

Figure 3. Wedges

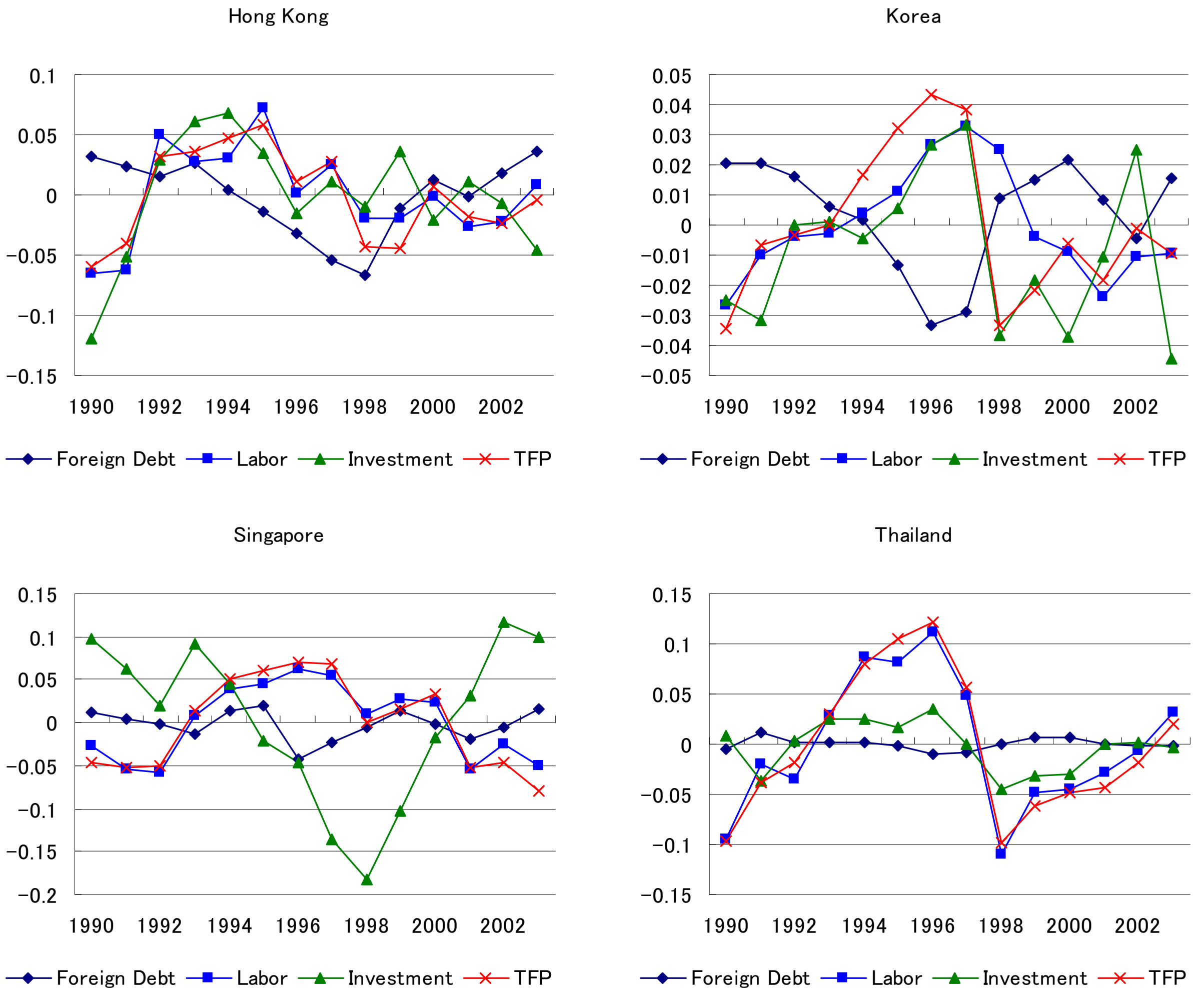

Figure 4a. Results: Hong Kong

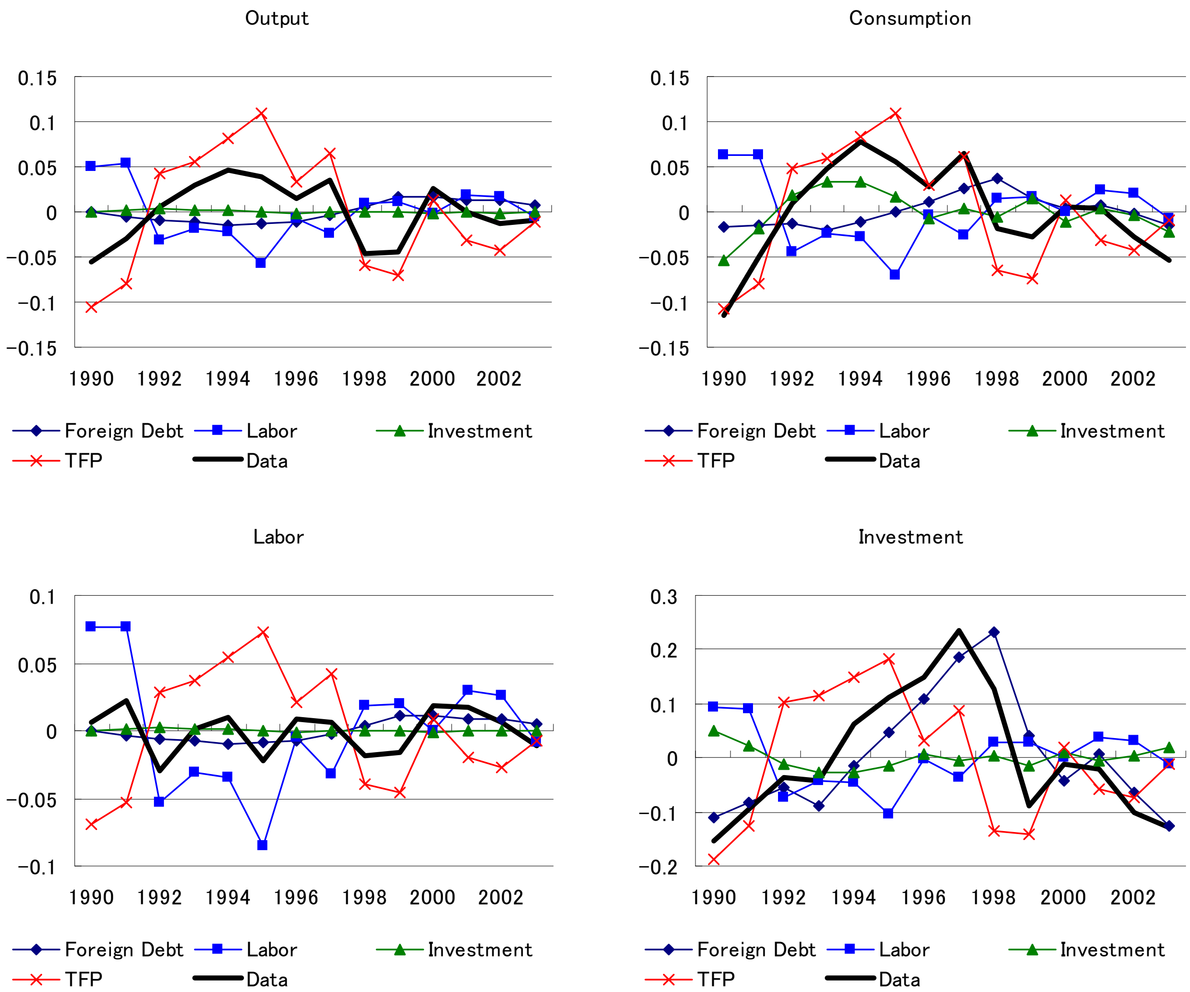

Figure 4b. Results: Korea

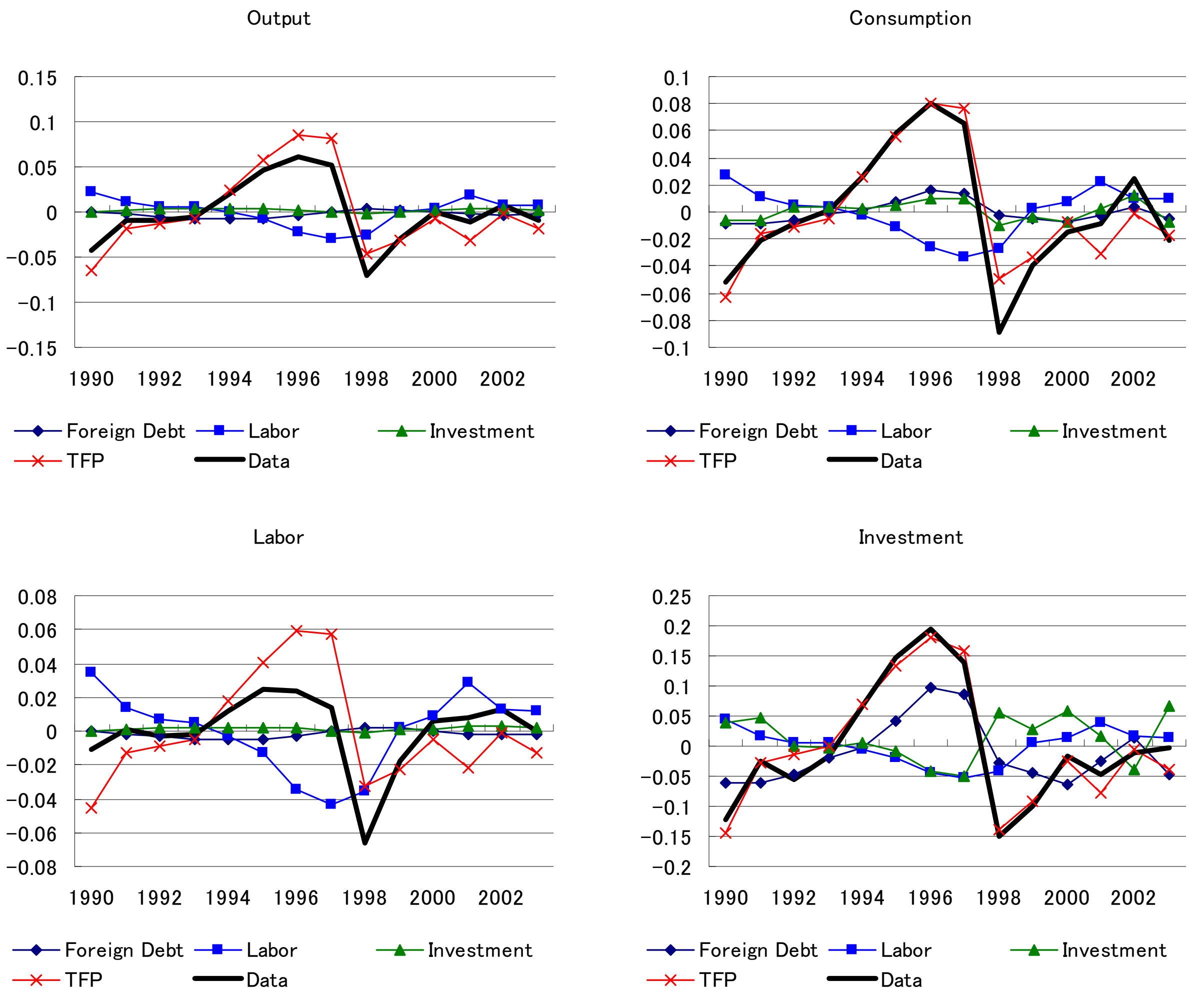

Figure 4c. Results: Singapore

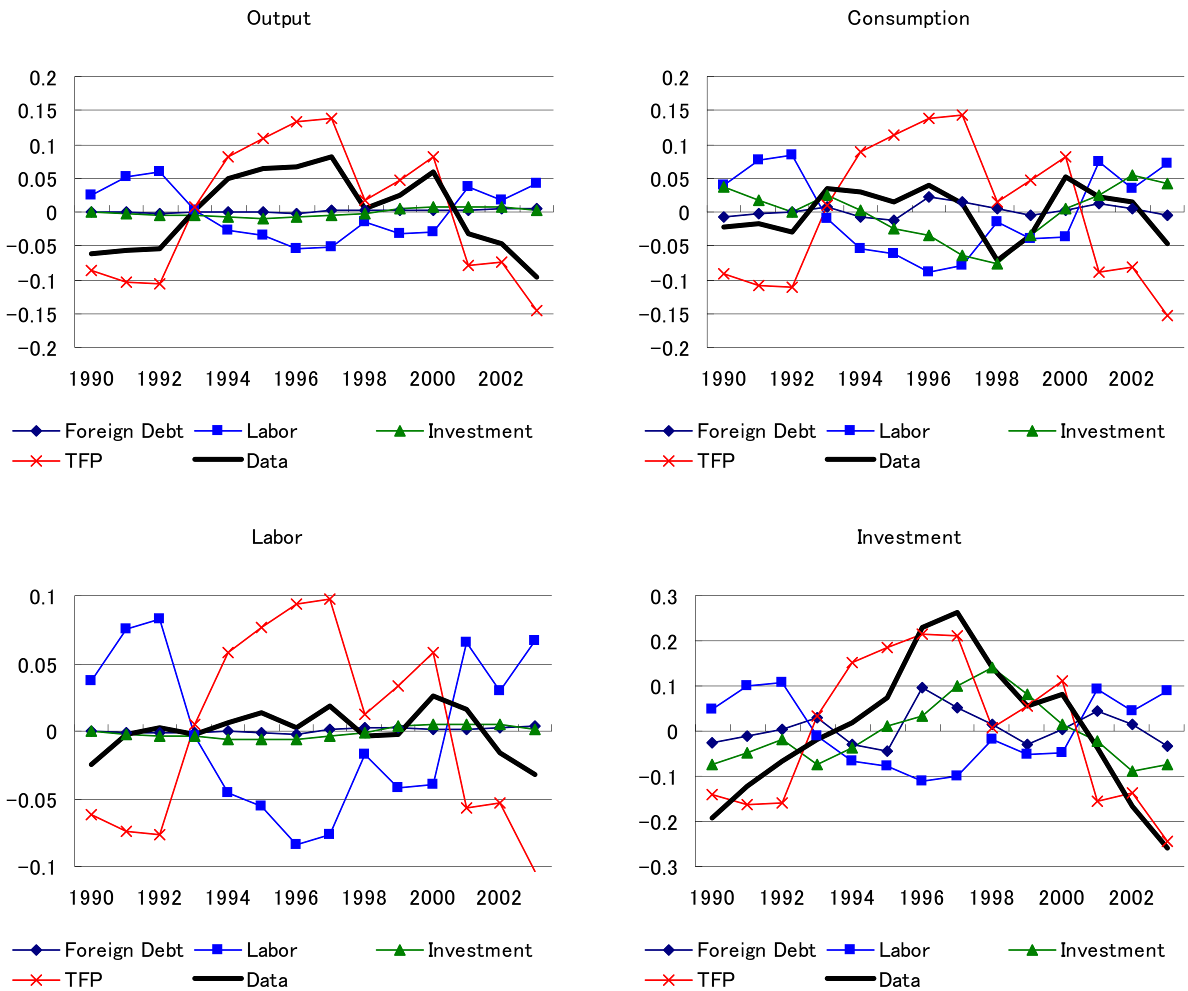

Figure 4d. Results: Thailand

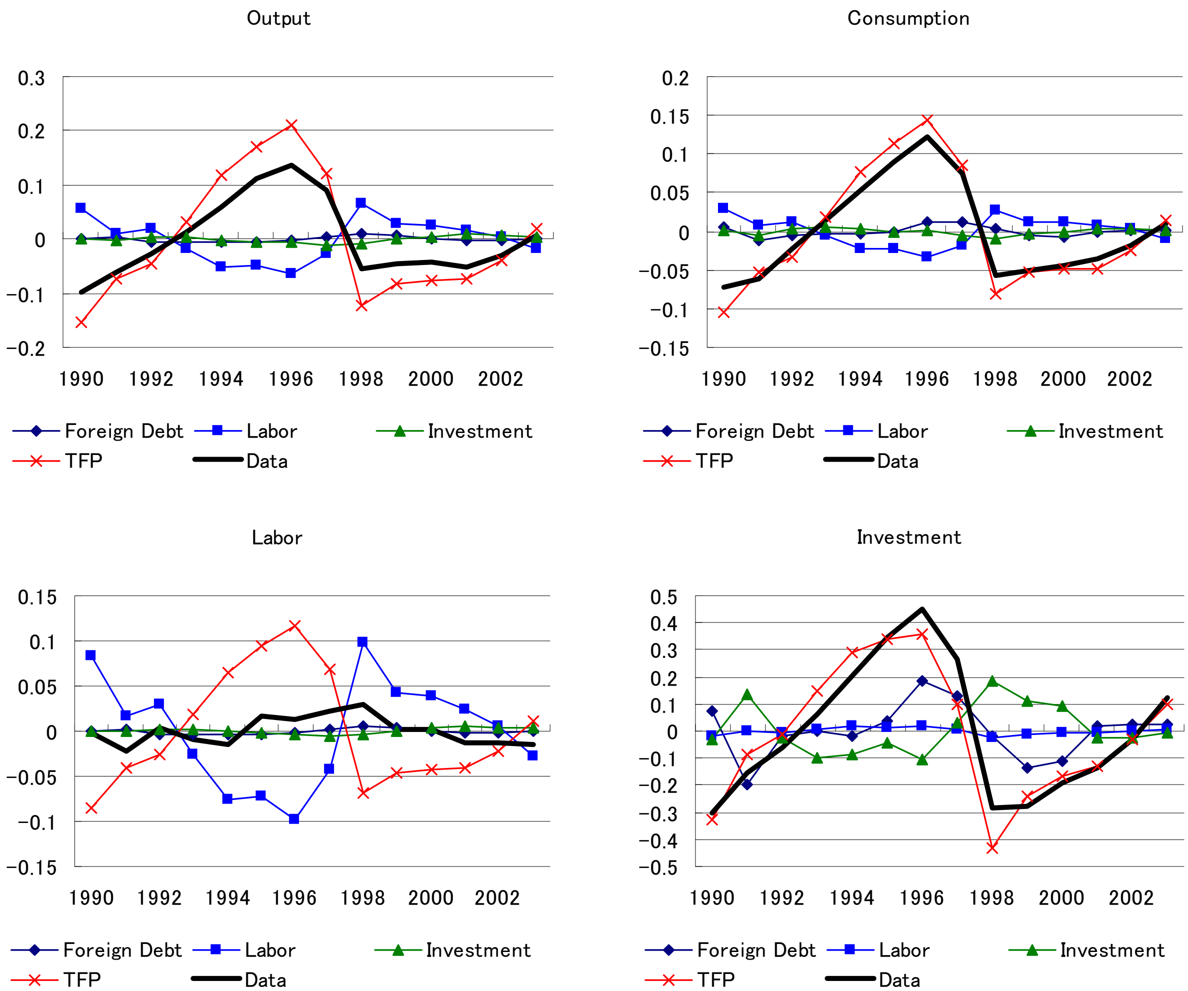

Table A1. Estimated Shock Process Parameters (Cobb-Douglas)

$$P_{KR} = \begin{bmatrix} 0.593 & 0.066 & 0.036 & -0.068 \\ -0.224 & 0.841 & 0.000 & -0.037 \\ 0.036 & 0.059 & 0.919 & 0.067 \\ 0.433 & -0.068 & 0.060 & 0.872 \end{bmatrix}, Q_{KR} = \begin{bmatrix} 0.0003 & -0.0000 & -0.0001 & 0.0000 \\ -0.0000 & 0.0010 & -0.0001 & -0.0000 \\ -0.0001 & -0.0001 & 0.0010 & 0.0001 \\ -0.0000 & -0.0000 & 0.0001 & 0.0008 \end{bmatrix}$$

Figure A1. Wedges (Cobb-Douglas)

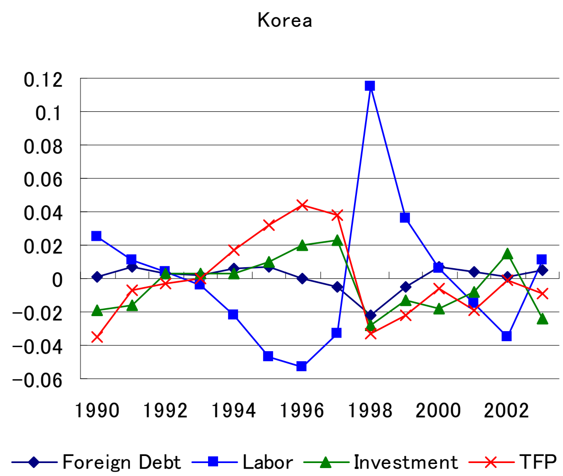

Figure A2. Results: Korea (Cobb-Douglas)