A Neoclassical Analysis of The Korean Crisis*

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Abstract

In late 1997, Korea experienced a huge and unusual economic crisis. Three main features of this crisis are that output fell suddenly, output recovered rapidly, and consumption fell even more than output did. There is a large body of literature that explains the Korean crisis in terms of financial and monetary variables such as bankruptcies and exchange rates whereas this paper focuses on the fluctuation of real macroeconomic variables such as real GDP and consumption. A variation of the neoclassical model can quantitatively account for the crisis taking productivity and real interest rate shocks as exogenous.

1 Introduction

In late 1997, Korea experienced a severe economic downturn. Output, consumption, investment and labor divided by adult population dropped by 8%, 12%, 25% and 9% respectively between 1997 and 1998. The crisis was clearly a devastating event and at the same time embeds several puzzles within it. The three puzzling features of the Korean crisis are the sudden recession, the rapid recovery of output, and the consumption drop even greater than the output drop. This paper attempts to explain these puzzles with a canonical neoclassical model.

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The sudden output drop is puzzling since Korea was showing the strongest and most stable growth among the East Asian countries prior to the crisis. The average GDP per adult growth rate between 1980 and 1997 was 5.6% with a standard deviation of 1.76%. An 8% drop is over 7 standard deviation points away from the mean which is nearly a zero probability event.

The rapid bounce-back of output is striking since economies hit by such large shocks typically experience prolonged stagnation. In Thailand and Indonesia where output fell as much as Korea during the same period, GDP was still below trend level in 2002, while for Korea two years were enough to recover. In historical perspective, many studies on past depressions document the slow recoveries such as Cole and Ohanian (2002) for the US in its depression in the 1930s and the UK in the 1920s, Kydland and Zarazaga (2002) for Argentina's depression of the 1980s and Hayashi and Prescott (2002) for the Japanese lost decade in the 1990s. Thailand and Indonesia fit this empirical pattern of very slow recoveries from depressions whereas Korea clearly does not.

The fact that consumption fell more than output is surprising since it goes against the idea of consumption smoothing. Fundamental economic theory tells us that when there are temporary income shocks, people would want to smooth consumption by borrowing or saving. As stated above, the income shock was temporary and extremely large and thus implies that there should have been high motivation for consumption smoothing.

In this paper, I will address these three puzzles by quantitatively analyzing the effects of exogenous shocks to the Korean economy using a small open economy stochastic dynamic general equilibrium model. I will consider two shocks, productivity and real interest rate shocks, as there were important movements in these variables during the crisis. I feed these observed shocks into the model, compute the equilibrium, and compare the time paths of key variables generated by the model to data over the 1994 - 2002 period. The main finding is that the model, taking these two shocks as exogenous, can account for the three puzzles extremely well. Moreover, the depression and rapid recovery of output are explained mainly by productivity shocks whereas the real interest rate plays an important role in explaining the large drop in consumption.

Real interest rate and total factor productivity shocks showed dramatic changes during the crisis. The Korean real interest rate jumped up from 5% to almost 10% in 1998. Following Neumeyer and Perri (2005), I assume that Korea is a net debtor in the international financial market and that international lenders exogenously determine the country specific spread on loans made to Korea. Thus, the large jump in the real interest rate represents the reversal of foreign investors' belief in Korea which lead to the financial crisis. Total factor productivity was growing 3.1% on average between 1980 and 1997, suddenly fell 2.8% between 1997 and 1998 and then grew 4.6% and 4.9% the next two years. The possible sources of productivity shocks are discussed below.

Many studies on the Korean crisis deal with the financial turbulence and the fluctuation of the exchange rate. These studies focus on the cause and resolution of the financial crisis, i.e. the abrupt decline in capital inflow which caused the currency devaluation. For instance, Burnside, Eichenbaum and Rebelo (2000) argue that the prospective government debt reached an unsustainable level due to the ongoing banking crisis and led to the currency crisis. Shin and Hahm (1998) claim that contagious effects from South-East Asian crises and policy missteps to the effects as well as inherent instability in the international financial markets were the main cause of the financial crisis. However, there are hardly any quantitative studies that focus on fluctuations of real macroeconomic variables during the crisis[1]. This study complements the existing literature by quantitatively analyzing the effects of exogenous shocks to the Korean macroeconomy.

Quantitative results show that with a Cobb-Douglas preference function over consumption and leisure, the model cannot predict output the given the observed shocks in real interest rates and productivity. With Cobb-Douglas preference, the negative income effect on leisure both from the real interest rate rise and productivity drop is too strong such that the model predicts a counterfactual increase in labor and consequently output during the crisis. By using an alternative preference called GHH preference in which there is no income effect on labor supply, the model can account for all three of the striking features. The fact that the model performed extremely well is surprising since small open economy models are usually used to explain much smaller fluctuations and comovements of variables, not actual time paths of variables during crisis periods. The success of the model implies that market imperfections specific to the Korean economy, such as crony capitalism, restrictions, and regulations, outside of their affect on interest

[1] One exception is Cook and Deveraux (2002) that develops a sticky price small open economy dynamic general equilibrium model with real interest rate shocks which studies the reaction of real exchange rates and output in Korea, Indonesia and Malaysia.

rates or productivity, do not seem to be important for understanding the Korean crisis. The impacts of each shocks are also surprising. The depression and recovery of output and labor are mostly explained by productivity shocks while real interest rate shocks primarily affect the composition of output between consumption, investment and trade balance. High interest rates have been considered to be a key depressing shock on labor and output, as in Christiano and Eichenbaum (1992) whereas this not the case in my model. High real interest rates reduce investment which affects future output not current output. In order to explain the drop of current output, negative productivity shocks which depress current labor are needed.

I also conduct a deeper analysis on productivity shocks by assessing factors that may be causing these shocks. I examine models with endogenous capacity utilization and imported intermediate given real interest rate shocks and found that neither of these additional features are sufficient to explain the fluctuation of measured total factor productivity. I conjecture that corporate failures and the breakdown of bank lending may have temporarily reduced productivity by forcing firms to divert resources away from production operations to finding alternative business relationships as in Ohanian (2001).

The remaining of this paper is organized as follows. Section 2 shows recent macroeconomic performance of the Korean economy. Section 3 describes the standard neoclassical small open economy model and the quantitative method. Section 4 presents quantitative results. Section 5 introduces the working capital assumption on labor in order to consider the depressing effect of high real interest rates. Section 6 discusses possible sources of productivity shocks. The paper is concluded in section 7.

2 The Korean Economy

In this section, I will present the recent performance of the Korean economy. First I will specify the key features of the Korean crisis by presenting cyclical features of the domestic economy, and establish the uniqueness of the Korean case by comparing the Korean performance to other neighbor countries. Second, I will define real interest rates and total factor productivity, and show their large movements during the crisis.

2.1 The Macroeconomic Performance of Korea Since 1980

In order to explain the macroeconomic performance of Korea, I investigate the Korean economy from three different viewpoints. First, I look at the supply side of the economy by examining the fluctuations of production factors. Next, I check the demand side of the economy by studying the fluctuations of GDP expenditure components. Finally, I compare Korea with other East Asian economies focussing on output and consumption fluctuation.

2.1.1 The Supply Side

On the supply side of the economy, I consider two production factors, labor and capital stock. Both inputs move along with output while most of the output fluctuation is coming from labor fluctuation.

Figure 1 presents the fluctuation of Korean GDP, capital stock and labor. Labor consists of hours worked per worker and the number of workers. All variables shown here are in real terms and are divided by adult population, detrended by the Hodrick-Prescott filter and presented in the form of deviations from their trend. The downward spike of GDP in 1998 shows how suddenly output fell and how rapidly it recovered. The figure also shows that labor and capital stock are both procyclical. Capital stock moves smoothly because in general it takes time to remove or to build capital stock. On the other hand, labor moves instantaneously. Thus, most of the fluctuation of output seems to be coming from labor fluctuation. This implies that in order to explain output fluctuation, the model must explain labor fluctuation.

It is well known that the fluctuation of output cannot be fully explained by the fluctuation of inputs. The residual is known as the Solow residual or total factor productivity. I will discuss about this object in detail below.

2.1.2 The Demand Side

The demand side of the economy consists of consumption, investment and trade balance. Consumption and investment are both procyclical while trade balance is countercyclical where the volatilities of all three are larger than the volatility of output.

Figure 2 presents the fluctuation of Korean GDP and its components. This figure shows that both consumption and investment fell dramatically while trade balance improved during the crisis. The scale on the left axis is for output, consumption, and investment whereas the right axis is for trade balance. Consumption includes private consumption and government consumption of goods and services. Investment includes private and government fixed investment[2]. Trade balance is divided by GDP in order to make the series stationary.

The striking fact is that consumption is falling more than output during the crisis. This goes against the fundamental economic principle of consumption smoothing. The fact that consumption fluctuation is greater than output fluctuation in developing countries was pointed out by Neumeyer and Perri (2005). However, there are no studies on the fact that this holds also during a crisis period where fluctuations are enormous.

2.1.3 International Comparison

One reason I focus on the Korean crisis is because it was the most surprising case among East Asian countries. This is because Korea was the most rapidly growing and least volatile East Asian economy since 1980, while it had the one of the deepest and most volatile recessions as well as the largest drop of consumption relative to output drop.

Table 1 shows the mean and standard deviation of the growth rates of GDP per adult for Hong Kong, Indonesia, Malaysia, Singapore, Thailand, and Korea during the 1980-1997 period. This shows that the annual growth rate of Korean GDP per adult was highest on average at 5.6% and had the lowest standard deviation at 1.76%. Clearly, Korea showed the strongest growth and highest stability through the period among all rapidly growing East Asian economies. Thus, Korea seemed to be the least likely candidate for such a severe economic downturn.

Table 2 shows the summary statistics of the six Asian countries during the Asian crisis. The first column shows GDP per adult relative to the Hodrick-Prescott trend level. The Korean GDP per adult was 8.7% below trend which is the lowest among the countries[3]. The second column shows the growth rate of consumption relative to the growth rate of GDP between 1997 and 1998. Both GDP and consumption growth rates were negative so the ratio is positive in all countries. Korea has the highest ratio which means

[2]This will cause an omission of inventory investment in the resource constraint. However, I will not adjust for this fact given that the amount of inventory investment is small.

[3]Indonesia and Thailand show larger drops in terms of GDP growth rates.

that consumption fell the most relative to GDP in Korea during the crisis. Finally, the last column shows the growth rate of GDP per adult between 1998 and 1999. Korean GDP per adult grew 9.2% at 1998 whereas the other five countries averaged at 1.7%. Clearly, Korea was the only country that showed such a rapid recovery.

Figure 3 shows GDP per adult and consumption per adult detrended by the Hodrick-Prescott filter for the six East Asian countries. The stability through 1980-1997, the sudden drop, and the rapid recovery in Korea can be seen clearly. Indonesia, Malaysia, and Thailand also show a significant drop in real GDP per adult. The sharp drop in consumption can be seen in Korea as well as Indonesia, Malaysia, and Thailand.

In short, Korea was a country that showed the strongest growth and highest stability but experienced one of the most severe economic downturns in East Asia. Nonetheless, among the countries that were suffering, Korea was the only country to show a rapid recovery. Also, consumption fell the most relative to GDP among the East Asian countries during the crisis.

2.2 Real Interest Rates and Productivity

Now that the main features of the Korean crisis are established, I introduce real interest rate and productivity shocks which I consider as the two main shocks to the Korean economy during the crisis.

2.2.1 Real Interest Rates

Figure 4 shows the Korean real interest rate, which is defined as the real lending rate, and GDP per adult detrended by Hodrick-Prescott filter. The figure shows that the real interest rate rose by nearly 5 percentage points between 1997 and 1998. This represents the sudden drop of the willingness to lend to Korean firms which led to the financial crisis in Korea. While many papers discuss the cause and resolution of the financial crisis in Korea, such as Shin and Hahm (1998), I take the fluctuation of real interest rate as exogenous and deduce its impact on the Korean economy.

The real interest rate is the difference between the nominal interest rate and the expected inflation rate. The minimum annual lending rate of the deposit money banks[4] was chosen as the nominal interest rate. Since this is

[4]Deposit money banks consolidates the commercial banks, excluding trust accounts and overseas branches of commercial banks, and the specialized banks. Commercial banks

the minimum rate a domestic firm will face when borrowing from a domestic or foreign bank in the country, it is the relevant measure of the nominal interest rate for my analysis[5]. The expected inflation rate was computed as the average of the current year realization and four preceding years of inflation in the GDP deflator[6].

There are several studies that analyze the effects of real interest rate shocks on emerging market business cycles. The empirical regularity that motivated these studies was that real interest rates are counter-cyclical in emerging economies. Neumeyer and Perri (2005) and Uribe and Yue (2003) use a general equilibrium small open economy model with a 'working capital' assumption such that firms in emerging economies have to borrow foreign credit in order to hire labor. Since the labor cost is a function of the real interest rate, shocks to the real interest rate will directly affect the labor demand and will cause the economy to fluctuate. Cook and Devereux (2003) use a sticky price dynamic general equilibrium small open economy model with interest rate shocks to explain the currency crisis in Korea, Thailand, and Malaysia. The interest rate shock will affect domestic absorption through income and substitution effects and cause a contraction in the nontradable sector and consequently a depreciation of the real exchange rate.

In this paper, I focus on the incentive effect the real interest rate has on consumption. A sudden rise of real interest rate should cause a negative intertemporal substitution effect on current consumption as well as a negative income effect since Korea was a net debtor. Therefore, real interest rate shocks seems to be able to explain the huge drop in consumption.

comprise nationwide banks, local banks, and foreign banks. Specialized banks comprise the industrial bank of korea, the credit and banking sectors of the agricultural fishery, and livestock cooperatives.

[5] Neumeyer and Perri (2005) use secondary market prices of emerging market bonds to recover nominal U.S. dollar interest rates and obtain real rates by subtracting expected U.S. inflation. Their nominal interest rates were constructed as the 90 day U.S. T-bill rate plus the J.P. Morgan Emerging Market Bond Index (EMBI) Global Spread. The movement of their real interest rate measure is close to the measure in this paper and thus the selection of real interest rate measure will not change the main result of this paper.

[6] This assumption on expected inflation rate is arbitrary and will not affect the results except that the fluctuation of real interest rate will be greater as the lags are reduced.

2.2.2 Productivity

Figure 5 shows total factor productivity and GDP per adult. Both series were detrended by Hodrick-Prescott filters. Clearly, there is a positive relationship between productivity and GDP during the crisis. The Real Business Cycle literature shows that productivity shocks are a powerful source of economic fluctuation. Thus, it seems worthwhile investigating to what extent productivity shocks can explain the Korean crisis.

It is well known that the growth of an economy can be decomposed into the growth of inputs and the growth of total factor productivity. I will assume a Cobb-Douglas production function,

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

where Y_t is real output per adult, K_t is real capital stock per adult, X_t is the labor augmenting technical progress, l_t is labor input per adult[7], and θ is the capital share set as 0.297[8]. z_t is detrended productivity which is one of the main objects in this paper and what I will refer to as 'productivity' further on. Taking the log difference of (1) between two periods, we can get an approximation,

$$\%\Delta Y_t = \%\Delta SR_t + \theta\%\Delta K_t + (1-\theta)\%\Delta l_t. \tag{2}$$

where $SR_t = z_t X_t^{1-\theta}$ is known as the Solow residual or total factor productivity (TFP). I will assume $X_t = (1+\gamma)X_{t-1}$ so that the technical progress is constant and that the trend of TFP growth is coming from γ while all of the fluctuation of TFP about the trend is coming from z_t. According to the neoclassical theory, per adult values of output, capital, consumption, and investment grow at the same rate as labor augmenting technical progress along the balanced growth path.

The trend growth rate γ is estimated with a regression of the log of Solow residuals on a linear trend and a constant[9]. By definition, the residuals of the

[7] Labor was computed as

$$\frac{h_t}{16 * 7} * \frac{e_t}{N_t}$$

where h_t is average weekly hours worked, e_t is employed workers, N_t is adult population. l_t is restricted to be between zero and one given that the average weekly hours worked never exceeds $16 * 7$ hours.

[8] This value is borrowed from Young (1994).

[9] The regression is presented in the appendix.

regression is productivity shocks $\ln z_t$. The Solow residuals were computed from the non-detrended per adult population data.

3 The Benchmark Model

The model is a canonical small open economy neoclassical model. Cole and Ohanian (1999) define the neoclassical model as, "the optimal growth model in Cass 1965 and Koopmans 1965 augmented with various shocks that cause employment and output to deviate from their deterministic steady-state paths as in Kydland and Prescott 1982". They show that productivity shocks alone cannot explain the slow recovery during the Great Depression and that the government policies toward monopoly and the distribution of income are to blame. This study broke the taboo of Real Business Cycle literature and applied the neoclassical model to large economic fluctuations such as the Great Depression. In this section, I will follow their method using a small open economy standard neoclassical model as the benchmark model in order to analyze the Korean crisis.

The economy is a small open economy which consists of a representative household, firm and foreign investors. The household has preference over a single storable consumption good and labor. The household is facing an incomplete capital market where he can issue debt with a one period non-state-contingent international discount bond at a given rate of return to foreign investors[10]. There is a firm that produces the single good using capital and labor with a Cobb-Douglas production function. For simplicity, there is no government sector[11]. There are adjustment costs on both capital stock and international debt. Adjustment cost on capital stock is necessary in order to limit the fluctuation of investment to a reasonable level. Introducing adjustment cost on international debt is one way to induce stationarity in a small open economy model with incomplete markets. The shocks to the economy are real interest rate and productivity shocks. All variables are detrended by the trend growth X_t except for labor in order to make the

[10] Throughout this paper, I will assume Korea to be a net debtor for every period. That is, $d_{t+1} > 0$ for all t. This is true until the second quarter of 2000. The fact that Korea turned into a net foreign creditor after 2000 doesn't affect my analysis of the crisis so I will not adjust for this fact.

[11] It turns out that shocks to government purchases are trivial during the crisis. Therefore I do not separately include government sector in the model.

economy stationary.

3.1 Household

The representative household chooses how many hours to work, and how much to consume. The lifetime utility of the representative agent depends on the utility from consumption and disutility from labor;

$$\max U = E_t \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \tag{3}$$

where c_t is consumption and l_t stands for labor input and is the fraction of total hours available allocated to work.

For the functional form of $u(\bullet)$, I consider two cases. One is the Cobb-Douglas preference function which is widely used in macroeconomic literature and the other is the GHH preference function which has recently been used in the small open economy literature.

Case 1. Cobb-Douglas Preference:

$$u(c_t, l_t) = \frac{(c_t^{\Psi}(1-l_t)^{1-\Psi})^{1-\sigma}}{1-\sigma} \tag{4}$$

where $1-l_t$ is leisure, $0 \leq \sigma < \infty$ is the curvature parameter which represents the relative risk aversion and $0 < \Psi < 1$ governs the weights the households assign to consumption and leisure.

Case 2. GHH Preference:

$$u(c_t, 1-l_t) = \frac{(c_t - \chi l_t^{\nu})^{1-\sigma}}{1-\sigma}. \tag{5}$$

GHH preference was named after Greenwood, Hercowitz, and Huffman (1988) who introduced this preference function to the dynamic general equilibrium model. It is known that this preference function can be considered as a reduced form of a preference function on consumption and leisure with home production[12]. In this interpretation, labor supplied to the market is a

[12] Greenwood, Rogerson, and Wright (1995) show the mapping from a home production model to a GHH model.

perfect substitute of labor allocated to home production. Thus, market labor is costly since it reduces both leisure and home production. The parameters χ and ν adjust for the level and curvature of this cost respectively.

The representative agent maximizes (3) subject to the budget constraint,

$$w_t l_t + r_t k_t + \frac{\Gamma d_{t+1}}{R_t} = c_t + i_t + d_t + \Phi(\Delta k_t) + \Pi(d_{t+1}) \tag{6}$$

and capital law of motion

$$\Gamma k_{t+1} = i_t + (1-\delta)k_t \tag{7}$$

where k_t is capital stock, i_t is the investment, d_t is the foreign debt, $1 - \frac{1}{R_t}$ is the real interest rate for d_t, w_t and r_t are wage and rental rates respectively. The lower-case letters c_t, k_t, i_t, and d_t are all detrended per adult variables. 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.

The country is a small open economy so it takes R_t as given. It is common to assume adjustment cost for capital stock in small open economy models because otherwise the volatility in investment will be too high. I assume the functional form of the capital adjustment cost function $\Phi(\Delta k_t)$ to be $\phi\frac{(k_{t+1}-k_t)^2}{2}$. $\Pi(d_{t+1})$ is debt adjustment cost which I assume to have the functional form $\pi\frac{(d_{t+1}-d)^2}{2}$ where d is the steady state level of foreign debt. One well known fact is that the solution to a small open economy model will include a unit root for international asset holdings. This debt adjustment cost is one of several ways to remove this random walk component introduced by Schmitt-Grohe and Uribe (2003)[13]. I choose π to be arbitrarily small such that this portfolio adjustment cost will not affect the short run dynamics of the model.

The first order conditions for the household are, the labor first order condition;

$$\frac{u_{1-l_t}}{u_{c_t}} = w_t \tag{8}$$

the Euler equation for capital;

[13]They introduce models with endogenous discount factor, debt elastic interest rates, portfolio adjustment cost, and complete asset markets. They claim that all models deliver virtually identical results.

$$u_{c_t}(\Gamma + \phi(k_{t+1} - k_t)) = \beta E_{t+1}\left[u_{c_{t+1}}\left\{r_{t+1} + 1 - \delta + \phi(k_{t+2} - k_{t+1})\right\}\right] \quad (9)$$

and the Euler equation for international debt;

$$u_{c_t}\left(\frac{\Gamma}{R_t} - \pi(d_{t+1} - d)\right) = \beta E_{t+1} u_{c_{t+1}}. \quad (10)$$

where the marginal utilities of consumption and leisure for the Cobb-Douglas case are;

$$\begin{aligned} u_{c_t} &= \Psi c_t^{\Psi(1-\sigma)-1}(1-l_t)^{(1-\Psi)(1-\sigma)} \\ u_{1-l_t} &= (1-\Psi)\, c_t^{\Psi(1-\sigma)}(1-l_t)^{(1-\Psi)(1-\sigma)-1} \end{aligned} \quad (11)$$

while for the GHH case they are;

$$\begin{aligned} u_{c_t} &= (c_t - \chi l_t^{\nu})^{-\sigma} \\ u_{1-l_t} &= (c_t - \chi l_t^{\nu})^{-\sigma} \chi \nu l_t^{\nu-1}. \end{aligned} \quad (12)$$

3.2 Firm

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

$$y_t = z_t k_t^{\theta} l_t^{1-\theta} \quad (13)$$

where y is the detrended per adult output, and z_t is the productivity. Thus, the firm's problem is,

$$\max \pi_t = y_t - w_t l_t - r_t k_t. \quad (14)$$

The optimality conditions are,

$$r_t = \theta \frac{y_t}{k_t} \quad (15)$$

and

$$w_t = (1-\theta)\frac{y_t}{l_t}. \quad (16)$$

3.3 International Capital Market

The country is a small open economy such that it cannot affect the real interest rate. Thus, all interest rate shocks are given to the economy by the international financial market. The fluctuation of real interest rates can come from the world interest rate or the country specific interest rate premium. Hence,

$$R_t = R_t^* S_t$$

where R_t^* is the real world interest rate and S_t is the country specific spread. It turns out that the observed world interest rate[14] is not important in explaining the fluctuation of any variable of interest. Therefore, I assume that the world interest rate is constant for simplicity. In other words, I assume that all of the fluctuation of real interest rates comes from the country specific spread. Following Neumeyer and Perri (2005), domestic private borrowers always pay back in full but each period the local government can confiscate the interest payments to foreign lenders. Therefore, the default risk is bared solely by the international lenders.

The assumption such that foreign investors determine the real interest rate may seem to be inconsistent with the definition of real interest rates as real domestic lending rate. Cook and Devereux (2003) make a distinction between the exogenous country specific risk premia determined by foreign investors and domestic real interest rate where the two are connected through a monetary policy rule. In Korea, real interest rates using country specific risk premium data computed by Neumeyer and Perri (2005) and domestic lending rate both show similar fluctuations during the crisis. This reflects the fact that the Korean government took tight monetary policy during the financial crisis in order to contain the currency crisis. For simplicity, in this paper I assume no freedom for monetary policy by allowing foreign investors to directly decide domestic real interest rates.

3.4 Shock Process

Real interest rates and productivity shocks are assumed to follow an autoregressive process;

[14] I used the real interest rate of 3 months US treasury bills as the real world interest rate.

$$\begin{pmatrix} \ln z_t \\ \ln S_t \end{pmatrix} = \begin{pmatrix} \rho_z & 0 \\ 0 & \rho_s \end{pmatrix} \begin{pmatrix} \ln z_{t-1} \\ \ln S_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{zt} \\ \varepsilon_{st} \end{pmatrix} \tag{17}$$

$$\begin{pmatrix} \varepsilon_{zt} \\ \varepsilon_{st} \end{pmatrix} \sim N(0, V)$$

where the errors are allowed to be correlated[15]. The variance-covariance matrix of the errors looks like,

$$V = \begin{pmatrix} \sigma_z^2 & \sigma_{zs} \\ \sigma_{zs} & \sigma_s^2 \end{pmatrix}.$$

The shocks are expected to be persistent because of the auto-regressive parameters ρ_z and ρ_s which are between zero and one. Future shocks are anticipated using this process given current shocks.

3.5 Competitive Equilibrium

A competitive equilibrium is, $\{c_t, l_t, k_{t+1}, d_{t+1}, y_t, i_t, w_t, r_t, R_t\}_{t=1}^{\infty}$ such that; (1) Households optimize given $\{w_t, r_t, R_t\}_{t=1}^{\infty}$ and d_1, k_1, (2) Firm optimizes given $\{w_t, r_t, z_t\}_{t=1}^{\infty}$, (3) Markets clear, (4) The resource constraint holds:

$$y_t = c_t + i_t + tb_t + \phi\frac{(k_{t+1} - k_t)^2}{2} + \pi\frac{(d_{t+1} - d)^2}{2} \tag{18}$$

where the trade balance is defined as

$$tb_t = -\Gamma\frac{d_{t+1}}{R_t} + d_t, \tag{19}$$

and (5) The shocks follow the process (17).

[15] I estimated the unrestricted process;
$\begin{pmatrix} \ln z_t \\ \ln S_t \end{pmatrix} = \begin{pmatrix} \rho_{zz} & \rho_{zs} \\ \rho_{zs} & \rho_{ss} \end{pmatrix} \begin{pmatrix} \ln z_{t-1} \\ \ln S_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{zzt} \\ \varepsilon_{sst} \end{pmatrix}.$
However, The results show that the cross terms of the persistence matrix are statistically insignificant. Therefore I assumed the cross terms to be zero. The error terms are negatively correlated which is consistent with Neumeyer and Perri (2005).

4 Quantitative Analysis

The main objective of this paper is to assess how well the neoclassical model predicts the fluctuation of key variables as a reaction to exogenous shocks during the 1994-2002. In this section, first I present the values of parameters defined in the model. Next, I explain the simulation method. Finally I present the simulation results.

4.1 Parameter Values

The benchmark parameters are listed in Table 4. θ was borrowed from Young (1994). All other parameters were obtained from the 1980-2002 data. n, l, $\frac{y}{k}$, and $\frac{tb}{y}$ were directly calculated as the average of the data. γ was estimated by the regression presented in the appendix. δ is the average of δ_t calculated from the capital accumulation equation

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

where N_t is the adult population at date t. β was calibrated from the steady state capital Euler equation combining equations (9) and (15),

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

Ψ was calibrated from the steady state labor first order condition combining equations (8) and (16)

$$\frac{1-\Psi}{\Psi} = (1-\theta)\frac{y}{cl}.$$

The values of χ and ν for GHH preference were calibrated to match the elasticity of labor to that in the Cobb-Douglas case for $\sigma = 1$[16]. d was calibrated by equations (18) and (19). ρ_z and ρ_S were estimated by equation (17). ϕ was chosen to match the volatility of investment to data.

4.2 Simulation Method

One basic assumption is that the economy is growing along a balanced growth path during the 1994-2002 period where the fluctuation is calculated as the

[16] The calibration of χ and ν are shown in the appendix.

deviation from this path. The quantitative analysis was done by using linearized versions of equilibrium conditions. I used the method introduced by Uhlig (1997) to compute linear decision rules of endogenous variables. The decision rules depend on state variables – capital stock, foreign debt, and exogenous shocks. Exogenous shocks are the residuals from regressions of real interest rates and productivity respectively on linear trends and constants for 1994-2002. I substitute these linearly detrended shocks into linear decision rules to compute fluctuations of endogenous state variables assuming that they are in their steady state values in the initial period 1994. Then I simulate the fluctuation of the other endogenous variables by plugging the exogenous shocks and simulated endogenous state variables into their linear decision rules. Finally, the simulated series are detrended by the Hodrick-Prescott filter in order to make them comparable to detrended data.

The virtue of this method is that the effects of exogenous shocks can be separately analyzed. That is, the model can be simulated with only productivity shocks, only real interest rate shocks or both. The following section will show the quantitative results for each case.

4.3 Quantitative Results

In this section, I present the simulation results. First I discuss the results with only productivity shocks where I set real interest rate as a constant. Next I discuss the results with only real interest rate shocks where I set productivity as a constant. Finally the results with both shocks are discussed.

4.3.1 Results with only Productivity Shocks

The model with only productivity shocks reduces to a small open economy real business cycle model. The results show that while the model prediction improves dramatically by introducing GHH preference it still fails to quantitatively account for the fall of consumption. The result such that GHH preference works better than Cobb-Douglas preference is consistent with earlier literature such as Correia, Neves and Rebelo (1995).

Figure 6 shows the simulation results for the benchmark model with only productivity shocks where σ is set at $\sigma = 1$. CD stands for the Cobb-Douglas case while GHH stands for the GHH case. The key results are as follows.

Case 1: Cobb-Douglas Preference with $\sigma = 1$

1. The model can explain 86% of the fluctuation of output and 74% of labor.

2. The model can account for only 6% of the fluctuation of consumption during the crisis at all and trade balance moves to the opposite direction.

Being able to explain 86% of the volatility of output means that the standard deviation of output from the model is 86% of that from data. The result that productivity can explain output fluctuation well is consistent with RBC literature such as Cooley and Prescott (1995) in which they use a standard closed economy RBC model and conclude that 78% of the postwar US output fluctuation can be attributed to productivity shocks[17]. However, when we consider result 2, the model doesn't explain the Korean crisis well. This is related to a well known fact that small open economy RBC models tends to predict excessive consumption smoothing and procyclical trade balance. It turns out that this result depends on the functional form of the preference function. In the following, I will explain why the model fails to account for the fluctuation of consumption and trade balance.

The fact that consumption doesn't fluctuate much is because with Cobb-Douglas preference, there is a trade-off between fluctuation of consumption and fluctuation of labor due to the income effect of labor. Procyclical trade balance is related to low consumption fluctuation since there is a trade-off between fluctuation of consumption and fluctuation of trade balance. These can be shown by using the linearized versions of equilibrium conditions. First, from the bond Euler equation (10), consumption and labor fluctuate to the same direction as long as $\sigma > 1$ due to intratemporal substitution of consumption and leisure. Given that the real interest rate is constant in this case, the marginal utility of consumption is virtually the same on expectation in every period[18]. Totally differentiating u_c and setting it as a constant gives the condition

$$\widetilde{c_t} = \frac{(1-\Psi)(1-\sigma)}{\Psi(1-\sigma)-1}\frac{l}{1-l}\widetilde{l_t}$$

which says that consumption and labor supply will move to the same direction as long as $\sigma > 1$. Also, the higher the σ the higher the volatility of

[17]The results cannot be directly compared since the time frames and the frequencies of periods are different.

[18]Since π is set arbitrarily small, the fluctuation in portofolio adjustment cost is negligible.

consumption relative to the volatility of labor. Next, using this relationship, we can see that shocks to wage will cause fluctuation in consumption and labor and that there is a trade-off between the two. This can be seen by the labor-leisure first order condition (8). For the benchmark model, the linearized version of the labor-leisure first order condition is,

$$\widetilde{w}_t = \widetilde{c}_t + \frac{l}{1-l}\widetilde{l}_t.$$

This condition says that when there is a shock to wage, consumption and labor will fluctuate and there is a trade off between the fluctuation of the two. For instance, when a negative productivity shock causes wage to fall, the consumer will reduce consumption from both income and substitution effects. However, the effect on labor is ambiguous since substitution effect causes leisure to increase while income effect causes leisure to decrease. The second effect depends on consumption. Since consumption will fall, the marginal rate of substitution of leisure for consumption $\frac{1-\Psi}{\Psi}\frac{c_t}{1-l_t}$ declines and leisure will be less attractive than before and thus the income effect causes labor to increase. When $\sigma > 1$, consumption and labor will move to the same direction so when wage falls, both consumption and labor should decrease. This means that the substitution effect dominates the income effect on leisure. When $\sigma = 1$, the preference (4) will take the log form and will be separable between consumption and leisure as $u = \Psi \log(c_t) + (1-\Psi)\log(1-l_t)$. In this case, u_c depends only on consumption so consumption should be almost flat[19]. Therefore the trade-off between the fluctuation of consumption and labor implies that the lower the σ the lower the fluctuation of consumption and the higher fluctuation of labor.

The trade-off between the fluctuation of consumption and trade balance can be shown by the resource constraint,

$$y\widetilde{y}_t = c\widetilde{c}_t + i\widetilde{i}_t + tb\widetilde{tb}_t.$$

The drop in productivity reduces the expected marginal product of capital so that investment must decrease in order to maintain equations (9) and (10). Since the volatility of investment is fixed to match data, the fluctuation of consumption and trade balance must adjust such that the resource constraint holds. It turns out that the fluctuation of domestic absorption is less than

[19] On expectation, consumption should follow a flat path since portfolio adjustment cost is neglectable.

the fluctuation of output because of the low fluctuation of consumption. This is why trade balance is procyclical in the case of Cobb-Douglas preference. Thus, the procyclicality of trade balance is simply the other side of the coin of low consumption fluctuation. In order to have countercyclical trade balance, the fluctuation of consumption must be higher.

The fact that a small open economy model with Cobb-Douglas preference predicts excessive consumption smoothing is a well known problem. Mendoza (1991) introduced GHH preference to the small open economy model in order to focus on the interaction of foreign assets and domestic capital as alternative vehicles of savings and consequently generated countercyclical trade balance. Correia, Neves, and Rebelo (1995) pointed out that the problem with Cobb-Douglas preference in a small open economy model is that it tends to underestimate the fluctuation of consumption and as a result will generate procyclical trade balance and that GHH preference solves this problem. Raffo (2005) shows that even in a more general setting, a two-country model, GHH preference can generate counter cyclical trade balance by increasing volatility in consumption without resorting to counterfactual terms of trade effects. These studies indicate that this preference assumption is crucial to understand open economy dynamics.

Case 2: GHH Preference with $\sigma = 1$

1. The model can explain 92% of the fluctuation of output and 87% of labor.

2. The model can explain 60% of the fluctuation of consumption.

A striking result with GHH preference is that the volatility of both consumption and labor increased compared to the Cobb-Douglas preference case, which is the main reason GHH preference is used in small open economy RBC models. This is due to the fact that there is no income effect on labor with GHH preference. In addition, the model correctly predicts countercyclical trade balance. These can be shown by linearized equilibrium conditions.

As in the Cobb-Douglas preference case, setting u_{c_t} to be constant gives the condition

$$\widetilde{c_t} = \frac{\chi \nu l^{\nu}}{c} \widetilde{l_t}.$$

This says that consumption and labor will move to the same direction regardless of the value of σ.

Unlike in the Cobb-Douglas case, there is no trade-off between the fluctuation of consumption and labor. For the GHH model the linearized labor-leisure first order condition (8) is,

$$\widetilde{w}_t = (\nu - 1)\widetilde{l}_t.$$

As in the Cobb-Douglas case, when there is a negative shock to wage, the substitution and income effects reduce consumption. However, now the marginal rate of substitution of leisure for consumption is $\chi \nu l_t^{\nu-1}$ and doesn't depend on consumption. Therefore, although labor income decreases and agents reduce consumption, this does not affect the labor-leisure decision. In other words, since there is no income effect on leisure, there is no trade-off between the fluctuation of consumption and labor. Thus, both consumption and labor will fluctuate more than in the Cobb-Douglas case. The results do not depend on σ since labor is determined solely by (8) so consumption is determined by (10) and the real interest rate independently from σ[20].

We can also see that the GHH preference generates countercyclical trade balance through high consumption volatility. From the resource constraint (18), since the reaction of consumption is sufficiently large, trade balance moves to the opposite direction of consumption to keep the equation to hold.

Although the model can account for many features of the crisis, it still cannot predict the fall in consumption to be greater than the fall in output. Therefore, the GHH model only with productivity shocks is not enough to explain the Korean crisis.

4.3.2 Result with only Real Interest Rate Shocks

The sudden rise of real interest rate in 1998 reflects the reversal of the foreign investors' willingness to lend to Korea. In this sense, the high real interest rate is directly related to the financial crisis. The key channel through which the interest rate affects the model is the household's incentive to borrow from foreign investors. The results show that real interest rate shocks alone cannot account for the fluctuation of output.

[20] As mentioned above, GHH preference is a reduced form of home production where market labor is a perfect substitute of labor allocated to home production. The huge drop of market labor corresponds to an increase in home labor. Thus, the model implies that the decrease of consumption was compensated by home production.

Figure 7 shows the simulation results for the benchmark model with only real interest rate shocks where σ is set at $\sigma = 1$. The key results are as follows.

Case 1: Cobb-Douglas Preference with $\sigma = 1$

1. The model generates the fluctuation of labor and output in the opposite direction.

2. The model can predict 141% of the fluctuation of consumption.

The opposite output fluctuation comes from the opposite labor fluctuation due to the income and intertemporal substitution effect on labor. Since Korea is assumed to be a net debtor, a rise in real interest rate causes a negative income effect. At the same time, current goods become relatively expensive which causes a negative intertemporal substitution effect on current consumption and leisure. This can be seen in the bond Euler equation. When the interest rate increases, u_{c_t} should increase relative to $u_{c_{t+1}}$ which means that current consumption and leisure should decrease and future consumption and leisure should increase. From both effects labor and hence output increases during the crisis. When σ is lower, the household is willing to allow the period by period utility to fluctuate more so consumption and leisure will be more sensitive to this shock to the real interest rate.

Since the return on foreign debt is high during the crisis, the household will reduce international borrowing which leads to an improvement of the trade balance. Investment will decrease during the crisis since the expected return on capital must be equal to the real interest rate in order to hold the two Euler equations equal[21].

The result such that output will increase during a financial crisis is consistent with the result of Chari, Kehoe, and McGrattan (2005) in which they show that when a country faces sudden stops of foreign capital inflows the economy will expand. They assess effects of sudden stops implicitly using collateral constraints on foreign borrowing. The binding collateral constraint has the same effect as the real interest rate shock in my model[22]. They conclude that in order to generate an output drop during a sudden stop period, the model also needs a shock that depresses production. It turns out

[21] The adjustment cost on capital and international bonds are both small and negligible.

[22] In a general equilibrium model, the lagrangian multiplier on the binding constraint will appear in the bond Euler equation in a similar fashion as the real interest rate.

that even with productivity shocks, the model with Cobb-Douglas preference cannot predict an output drop during the financial crisis.

Case 2: GHH Preference with $\sigma = 1$

1. The model can account for only 13% of the fluctuation in output and labor

2. The model can account for only 43% of the fluctuation in consumption

The reason why the model cannot generate fluctuation in labor and output is because of the feature of GHH preference such that there is no income effect on labor. Therefore with only real interest rate shocks, labor and output do not react in the period the shock occurs but does only from one period after the shock. This can be shown with the linearized equilibrium conditions.

First, from the production function and the labor first order condition, it can be shown that real interest rate shocks cannot generate fluctuation in current labor and output with GHH preference. The production function (13) gives

$$\widetilde{y_t} = \widetilde{z_t} + \theta \widetilde{k_t} + (1-\theta)\,\widetilde{l_t}.$$

Since $\widetilde{z_t} = 0$ and k_t is predetermined, $\widetilde{y_t} = (1-\theta)\,\widetilde{l_t}$. Combining the household labor-leisure first order condition (8) and the firm first order condition (16) gives

$$\widetilde{y_t} = \nu \widetilde{l_t}.$$

Given that $\nu \neq (1-\theta)$, the only solution to the two equations is $\widetilde{y_t} = \widetilde{l_t} = 0$. Thus, labor and output will not react to real interest rate shocks in the current period. In other words, there are no income nor intertemporal substitution effects on current labor from the real interest rate shock.

Second, the relationship between the fluctuation of future output and capital stock can be shown by the production function (13), labor first order condition (8), and the firm first order condition (16). Combining the equations for period $t+1$ and again setting $\widetilde{z_{t+1}} = 0$,

$$\widetilde{y_{t+1}} = \frac{\nu\theta}{\nu+\theta-1}\widetilde{k_{t+1}} = \nu\widetilde{l_{t+1}}$$

where $\frac{\nu\theta}{\nu+\theta-1} < 1$. Thus, when there is an increase in real interest rate, in order to make both capital and Foreign debt Euler equations (9) and (10) to hold, current investment will fall and make the expected return on capital equal to the real interest rate. Therefore, as capital stock in the future falls, output and labor in the future falls as well. Hence, the real interest rate shocks does not affect current labor and output but effects the future labor and output through the effect on future capital stock.

4.3.3 Result with Productivity and Real Interest Rate Shocks

Now combining the two shocks, the results show that the model with Cobb-Douglas preference cannot predict the economic downturn during the crisis. On the other hand, the model with GHH preference can account for all three features of the Korean crisis.

Figure 8 shows the simulation results for the benchmark model with both productivity and real interest rate shocks where σ is set at $\sigma = 1$. The key results are as follows.

Case 1: Cobb-Douglas Preference with $\sigma = 1$

1. The model predicts output and labor to fluctuate in the opposite direction during the crisis.

2. The model can explain 145% of the fluctuation of consumption.

The model fails to account for the fluctuation of output and labor because of the income effect on labor from both shocks. From the previous results, the negative productivity shock causes labor to drop while the rise in real interest rate causes labor to increase. In my setting, the income effect from both productivity and real interest rate shocks dominates the substitution effect from the productivity shock so that labor increases. The increase of labor dominates the direct negative effect of productivity drop and causes output to increase during the crisis. Hence, even with productivity shocks, the model predicts expansion during the financial crisis.

The model correctly predicts the drop in investment during the crisis. From both shocks, investment unambiguously falls during the crisis. Given that output is increasing and both consumption and investment are decreasing, trade balance improves in order to fill in the gap between domestic absorption and aggregate supply and maintain the resource constraint.

Case 2: GHH Preference with $\sigma = 1$

1. The model can explain roughly 96% of the fluctuation of output and 90% of labor.

2. The model can explain 103% of the fluctuation of consumption and generate a consumption series more volatile than the output.

All variables react to real interest rate and productivity shocks through the same mechanism as in the single shock cases with GHH preference. Labor and output are mainly affected by changes in productivity since there is no income effect nor intertemporal substitution effect on current labor. Hence, labor will fall solely in response to the fall in productivity through the substitution effect. Output will unambiguously fall because of the direct effect of productivity drop and the decrease of labor. Real interest rate does not affect current output because with the GHH preference there is no income nor intertemporal substitution effects on current labor. The main impact the real interest rate has on the economy is shifting the division of output between consumption, investment and trade balance. In particular, high real interest rates cause consumption and investment to fall and trade balance to improve. In addition, the lower the σ, the more of consumption fluctuation the model can explain. In fact, for $\sigma = 1$ the model can actually explain more than 100% of the fluctuation of consumption. Since the intertemporal elasticity of substitution is high when σ is low[23], the consumer allows consumption to fluctuate more. Labor and output do not depend on σ because the degree of consumption smoothing does not affect labor supply.

The main finding is that with GHH preference, the model can explain all three key features of the Korean crisis extremely well given both real interest rate and productivity shocks. Moreover, most of the depression and recovery of labor and output is explained by productivity shocks whereas real interest rate primarily affects the economy through the division of output between consumption, investment and trade balance. The result such that real interest rate does not affect current labor or output is surprising because conventional wisdom says that high real interest rates have large depressing effects on the economy. In the following section I will show that the potential roll of this effect is limited.

[23]The intertemporal elasticity of substitution is not exactly $\frac{1}{\sigma}$ in this model because the periodical utility function includes both consumption and labor.

5 Working Capital on Labor

In this section I will introduce a model that possesses a feature such that high real interest rates have depressing effects on current output. I show that this channel did not play an important role in quantitatively explaining the output drop during the crisis compared to productivity shocks.

High real interest rates depress investment which in turn tends to depress the economy in the future. However, as seen in results for the model with only real interest rate shocks, this channel cannot account for the output drop during the crisis in Korea. In order to explain the output drop, the real interest rate must have a depressing effect on current labor and output. Christiano and Eichenbaum (1992) introduced the 'working capital' assumption on labor in a closed economy setting and created a labor market distortion which depends on real interest rate. They assume that firms have to borrow a fixed fraction of the wage-bill from abroad in the beginning of the period due to a friction in technology to process the wage payment to the household. When the real interest rate is high, hiring labor becomes costly so that labor demand falls. Neumeyer and Perri (2004) adopted this structure into the small open economy model and generated business cycles that are negatively correlated to real interest rate fluctuations which is consistent with data in developing countries. I will follow their setting and investigate whether this channel can help understanding the Korean crisis.

The fraction of wage that must be paid in advance is fixed at $0 \leq \Omega \leq 1$ such that the firm will borrow $\Omega w_t l_t$ in the beginning of the period and payback $(1 + (1 - \frac{1}{R_t}))\Omega w_t l_t$ at the end of the period. This additional cost accrues within the period so the firm's problem remains static. The firm's problem is now

$$\max \pi_t = z_t k_t^{\theta} (l_t)^{1-\theta} - (1 + (1 - \frac{1}{R_t})\Omega) w_t l_t - r_t k_t \tag{20}$$

rather than (14). As a result, the Firm's optimality condition for labor will be

$$w_t = \frac{(1-\theta)R_t}{R_t + (R_t - 1)\Omega} \frac{y_t}{l_t} \tag{21}$$

rather than (16). Trade balance is redefined as

$$tb_t = -\Gamma \frac{d_{t+1}}{R_t} + d_t + \frac{(1-\theta)(R_t - 1)\Omega}{R_t + (R_t - 1)\Omega} y_t \tag{22}$$

rather than (19) where the additional term is the cost of the working capital, which is paid to international investors.

Figure 9 shows the prediction of the model with working capital on labor compared to the data. For all simulations, Ω is set at $\Omega = 1$ while productivity shocks are set at zero for all periods. With $\Omega = 0$, the model will reduce to the benchmark model presented in the previous section. The main results are as follows.

Case 1. Cobb-Douglas Preference with $\sigma = 1$

1. The model predicts labor and output to fluctuate in the opposite direction.

2. The model can explain 146% of the fluctuation of consumption.

With Cobb-Douglas preference, the model predicts an increase in labor during the crisis even in the limit case where $\Omega = 1$. The working capital on labor feature does have a depressing effect on labor. However, the income effect on labor is too strong such that labor and consequently output fluctuates in the opposite direction as in the benchmark model.

Case 2. GHH Preference with $\sigma = 1$

1. The model can explain 100% of the fluctuation of labor and 54% of output.

2. The model can explain 109% of the fluctuation of consumption.

With GHH preference, the model with working capital on labor matches the magnitude of labor fluctuation exactly. However, the model can only account for 54% of the output fluctuation. Intuitively speaking, setting productivity equal to zero for all periods forces the model to omit part of the output fluctuation.

From these results, the Cobb-Douglas preference case is once again unable to account for the crisis. Even with GHH preference, the model with real interest rate shocks and working capital on labor can explain only 54% of output fluctuation. In contrast, the model with productivity shocks can explain over 90% of output fluctuation without working capital on labor.

Therefore, productivity is the key shock for output fluctuation.[24] In the following section, I will take a closer view at productivity shocks during the Korean crisis.

6 Productivity Shocks

In this section, I extend the model to deepen the understanding of productivity shocks during the Korean crisis. The benchmark model is modified in order to assess whether the sudden increase of real interest rates, i.e. the financial crisis, can cause a fall of measured productivity during the crisis.

First I will introduce endogenous capacity utilization with working capital on labor. In this model high real interest rates reduce labor demand which reduces the marginal product of effective capital stock. This in turn gives incentive to reduce capital utilization which appears as a reduction of total factor productivity. Second, I will introduce working capital on intermediate goods. In this model high real interest rate makes the intermediate good expensive and causes a shift in the production mix which shows up as a drop in productivity. The results show that quantitative impact of real interest rates on measured productivity through these two channels are limited. I conjecture that the fluctuation of productivity can be explained by a temporary loss of organizational capital due to the banking crisis and corporate failures.

6.1 Endogenous Capacity Utilization

One can argue that during the financial crisis, firms cut back the utilization of existing capital stock which appears as a fall in measured productivity. In this section, I will introduce endogenous capacity utilization in order to quantify the effect of this channel.

Endogenous capacity utilization was formalized by Greenwood, Hercowitz and Huffman (1988). In their setting capacity utilization will increase production but is also costly because the higher the utilization, the faster the of capital stock depreciates. In their model, an exogenous disturbance to

[24] The working capital on labor model with GHH preference and both shocks can account for the fluctuation of labor and output almost perfectly. However, the gain is trivial since the model without working capital on labor already explains more than 90% of the output fluctuation.

the marginal return on investment affects the marginal return on utilization and causes the economy to fluctuate. Instead, in my model presented in this section, real interest rate shocks will affect labor demand because of the working capital assumption on labor and thus, affects the marginal return on capacity utilization.

The firm faces a working capital requirement on labor as in the previous section. The profit maximization problem is now

$$\max \pi_t = y_t - w_t(1 + (1 - \frac{1}{R_t})\Omega)l_t - r_t u_t k_t \tag{23}$$

rather than (14) where u_t is capacity utilization and

$$y_t = (u_t k_t)^\theta l_t^{1-\theta} \tag{24}$$

rather than (13). Thus, the firm is hiring effective capital $u_t k_t$ for production. The optimality condition for effective capital is

$$\theta \frac{y_t}{u_t k_t} = r_t \tag{25}$$

rather than (15). The firm is indifferent between capacity utilization and capital stock because they are a linear product in both production and cost.

The household budget constraint changes to

$$w_t l_t + r_t u_t k_t + \frac{\Gamma d_{t+1}}{R_t} = c_t + i_t + d_t + \phi \frac{(k_{t+1} - k_t)^2}{2} + \pi \frac{(d_{t+1} - d)^2}{2} \tag{26}$$

rather than (6) assuming that the household is renting effective capital $u_t k_t$, where the capital accumulation equation is

$$i_t = \Gamma k_{t+1} - (1 - \delta u_t^\varpi) k_t \tag{27}$$

rather than (7). δu_t^ϖ is the endogenous depreciation rate where the value $\varpi = 1.42$ was borrowed from Greenwood, Hercowitz and Huffman (1988). The steady state value of u_t is chosen to be one in order to make the steady state depreciation rate equal to δ. The capital Euler equation (9) changes to

$$u_{c_t}(\Gamma + \phi(k_{t+1} - k_t)) = \beta E_{t+1} \left[u_{c_{t+1}} \left\{ r_{t+1} + 1 - \delta u_t^\varpi + \phi(k_{t+2} - k_{t+1}) \right\} \right]. \tag{28}$$

The optimality condition for utilization is

$$r_t = \delta \varpi u_t^{\varpi - 1}. \tag{29}$$

Everything else is the same as the model with working capital on labor presented in the previous section.

The model reduces to a single shock model where the only shock is real interest rate shocks while measured productivity fluctuates endogenously. The mechanism works as follows. Given the increase of the real interest rates, labor demand falls because of the working capital assumption. The fall of labor input reduces the marginal return of effective capital, $u_t k_t$. Since capital stock is predetermined, utilization will fall. The fall of utilization will reduce output since effective capital is an input.

Figure 10 shows the result for the simulation of this model. In addition to the five variables presented in previous sections, I also present both the data and the model prediction of the measured productivity fluctuation. In this model, the measured productivity is obviously u_t^θ from (13) and (24). The key findings are as follows.

Case 1: Cobb-Douglas Preference with $\sigma = 1$ and $\Omega = 1$

1. The model predicts output and labor to fluctuate in the opposite direction
2. The model can explain 138% of the fluctuation of consumption
3. The model predicts productivity to fluctuate in the opposite direction

With Cobb-Douglas preference, labor fluctuates in the opposite direction even in the limit case $\Omega = 1$ because the income effect from real interest rate shocks dominates the working capital cost as in the previous section. Labor increases during the crisis, which tends to increase the marginal product of effective capital. Thus, utilization increases which causes a further increase in output in addition to the direct effect from labor increase. Consumption, investment and trade balance can be explained as in the benchmark model with only real interest rate shocks.

Case 2: GHH Preference with $\sigma = 1$ and $\Omega = 0.6$

1. The model can explain 70% of the fluctuation of output and 100% of labor

2. The model can explain 101% of the fluctuation of consumption

3. The model can explain only 36% of the fluctuation of measured productivity

Ω was set at $\Omega = 0.6$ in order to match the volatility of labor to data. Although the fluctuation of labor is predicted well, the fluctuation of output cannot be explained well compared to when productivity shocks are taken as exogenous. The main reason is because in this model capacity utilization does not fluctuate enough to explain the fluctuation of measured productivity. Therefore, endogenous capacity utilization cannot explain the fluctuation of productivity and output well.

6.2 Intermediate Good Model

Next, I will consider a case in which real interest rate shocks affect the firm's measured productivity through an assumption of working capital on an intermediate good. Under this assumption, firms have to borrow from abroad in advance of production in order to pay for an intermediate good. The model presented in this section is a simplified version of the setting in Chari, Kehoe and McGrattan (2004) in which the inefficiency in borrowing is shown to be observed as a fall of productivity.

The firm produces aggregate gross output q_t from capital, labor and an intermediate good f_t which I will call foreign funds. For simplicity, I assume that the firm must borrow foreign funds from abroad in the beginning of the period. After production occurs, the firm pays back what they borrowed including the interest payment $(1 - \frac{1}{R_t})f_t$. Final output is defined as gross output q_t net of intermediate good f_t such that $y_t = q_t - f_t$.

The firm's problem will be

$$\max \pi_t = q_t - w_t l_t - r_t k_t - (1 + (1 - \frac{1}{R_t}))f_t \tag{30}$$

rather than (14), where

$$q_t = (\alpha^{\frac{1}{\epsilon}} f_t^{\frac{\epsilon-1}{\epsilon}} + (1-\alpha)^{\frac{1}{\epsilon}} (k_t^{\widehat{\theta}} l_t^{1-\widehat{\theta}})^{\frac{\epsilon-1}{\epsilon}})^{\frac{\epsilon}{\epsilon-1}} \tag{31}$$

where $\epsilon > 0$ is the elasticity of substitution between the intermediate and composite goods. The production function will become a Cobb-Douglas function $q_t = f_t^{\alpha}(k_t^{\widehat{\theta}} l_t^{1-\widehat{\theta}})^{1-\alpha}$ when $\epsilon = 1$. $\widehat{\theta}$ is no longer equal to the capital share θ in the national income accounting sense. I show the mapping from θ to $\widehat{\theta}$ in the appendix. The firms first order conditions will be

$$1 + (1 - \frac{1}{R}) = \left(\alpha \frac{q_t}{f_t}\right)^{\frac{1}{\epsilon}} \tag{32}$$

$$r_t = (1-\alpha)^{\frac{1}{\epsilon}} \widehat{\theta} \left(\frac{k_t^{\widehat{\theta}} l_t^{1-\widehat{\theta}}}{q_t}\right)^{\frac{\epsilon-1}{\epsilon}} \frac{q_t}{k_t} \tag{33}$$

rather than (15).

$$w_t = (1-\alpha)^{\frac{1}{\epsilon}} (1 - \widehat{\theta}) \left(\frac{k_t^{\widehat{\theta}} l_t^{1-\widehat{\theta}}}{q_t}\right)^{\frac{\epsilon-1}{\epsilon}} \frac{q_t}{l_t} \tag{34}$$

rather than (16).

The household's problem and resource constraint are identical to those in the GHH model. Trade balance is now defined as

$$tb_t = -\Gamma \frac{d_{t+1}}{R_t} + d_t + (1 - \frac{1}{R_t}) f_t$$

rather than (19).

As in the previous section, measured productivity[25] fluctuates endogenously. In this model, the financial crisis increases the cost of the intermediate good. This exogenous shock to the input cost will show up as a drop of measured productivity through the shift in factor allocation.

Figure 11 shows the results of the intermediate good model with $\epsilon = 1$ and $\alpha = 0.7$. I choose $\epsilon = 1$ for simplicity. Since there is no standard realistic counterpart for the parameter α, this value was chosen as large as possible so that the model has the best chance to explain the fluctuation of productivity. For higher values of α, the economy becomes too volatile such that the adjustment cost on capital cannot control the fluctuation of investment in both cases. The main results are as follows

[25] The computation of measured productivity fluctuation is provided in the appendix.

Case 1: Cobb-Douglas Preference with $\sigma = 1$, $\epsilon = 1$ and $\alpha = 0.7$

1. The model predicts output and labor to fluctuate in the opposite direction
2. The model explains 144% of the fluctuation of consumption
3. The model predicts 72% of the fluctuation of productivity

For the intermediate good model with Cobb-Douglas preference the key effects of the real interest rate rise are twofold. On one hand, high real interest rates make the intermediate good relatively costly compared to other inputs. On the other hand, as previous results, high real interest rates have income effects on labor. Once again the income effect on labor is so strong that the model predicts an increase in labor during the crisis. This increases the marginal product of the intermediate good. The direct effect on intermediate goods dominates the secondary effect in this case such that intermediate goods fall during the crisis. Hence, the measured productivity falls during the crisis[26]. In this setting, the labor increase dominates the effect of the drop in intermediate goods so that output increases.

Case 2: GHH Preference with $\sigma = 1$, $\epsilon = 1$ and $\alpha = 0.7$

1. The model can predict 153% of the fluctuation of output and 220% of labor
2. The model can predict 151% of the fluctuation of consumption
3. The model can predict 38% of the fluctuation of measured productivity

With GHH preference, the intermediate good model does predict the sudden drop of output and consumption more than enough. However, even with the highest α possible, the model can explain only 38% of the fluctuation of productivity. Also, the recovery of productivity and output are too slow relative to data.

The key effect of high real interest rates is that it reduces demand for the intermediate good and thus reduces marginal product of labor as it does in the Cobb-Douglas case. However, since there is no income effect on labor with

[26] The relationship between intermediate goods and measured productivity is stated in the appendix.

GHH preference, labor will fall. Together with the fall of intermediate goods this causes the drop of output during the crisis. In addition, high interest rates depress investment and consequently future capital stock which leads to low marginal product of intermediate goods in the future. This slows down the growth in productivity and thus output after the crisis[27].

The Cobb-Douglas production function is a special case of (31) where $\epsilon = 1$. When the elasticity of substitution is lower, the fluctuation of measured productivity is lower. Given high real interest rates, the firm will cut back on the intermediate good. Since the composite good is more complimentary to the intermediate good, the firm will reduce the composite good as well. Since output and the composite good are moving along tightly, the measured productivity doesn't fall so sharply. In contrast, when the elasticity of substitution is higher, the fluctuation of measured productivity is higher. High real interest rates cause the firm to reduce more intermediate goods and less composite goods. Hence, output will fall but the composite good will not fall so much which causes measured productivity to fall. Higher ϵ does increase the volatility of measured productivity but at the same time makes the other variables volatile as well. It turns out that for ϵ larger than 1.02, the adjustment cost on capital stock cannot match the volatility of investment to data.

In summary, neither endogenous capacity utilization nor working capital on intermediate goods alone can fully explain the fluctuation of productivity. However, I do not dismiss the idea such that the financial crisis affected productivity. In the next section, I will discuss how the financial crisis may explain the pattern of productivity fluctuation during the Korean crisis through affecting organizational capital.

6.3 Organizational Capital

The exercises above showed that the fluctuation of productivity during the Korean crisis can neither be fully explained by endogenous capacity utilization nor shifts in intermediate good allocation. In this section, I pursue alternative sources of productivity shocks by focussing on the relationship between 'organizational capital' and the existing literature on the Korean financial crisis.

[27] With lower α, this effect gets relatively stronger and for some cases the model predicts the trough at 1999 not 1998 as in the benchmark model with real interest rate shocks.

Ohanian (2001) conjectures that productivity fell during the Great Depression as a result of reduction in "the knowledge and know-how firms use to organize production", i.e. 'organizational capital'. He claims that a breakdown in either supplier or customer relationship can reduce efficiency by forcing managers to shift their labor from planning and organizing production to searching activity for new relationships. An argument in the same line may be plausible to explain the productivity fluctuation during the Korean crisis.

Korea suffered from a number of corporate failures in 1998. Figure 12 shows the percentage of dishonored bills among total bills issued. Clearly, the percentage suddenly increased in the first quarter of 1998. This should have caused a disruption in the supply chain and a loss of organizational capital. One popular argument on the cause of widespread corporate failures during the Korean crisis is that currency crisis hurt firms who had currency mismatches in their balance sheets as stated in Krugman (1999).

Another issue which may have contributed to the loss of organizational capital is the sudden drop of bank loans. Figure 13 shows the amount of real bank loans which were the primary source of private credit in Korea. As this figure shows, bank loans start to decline sharply in the fourth quarter of 1997. Koo and Kiser (2001) state that the credit crunch was mild in Korea compared to other Asian countries because the corporate sector was able to counter the reduction of bank loans with commercial bond and equity issues. Behind the shift from bank loans to other funding sources, there should have been a loss of managerial labor allocated to production while managers were busy raising funds.

Existing literature has been focussing on defaults and banking crises in relation with the currency crisis. However, I claim that these may also be important in explaining the fluctuation of productivity through organizational capital during the Korean crisis. The challenge for future literature would be to model and quantify the effects of corporate failures and banking crises reduction on organizational capital and consequently on measured total factor productivity.

7 Conclusion

After many years of very high growth and very little volatility, Korea has experienced a "roller-coaster" like macro activity in late 1990s. The three puzzles of the Korean crisis are the sudden recession, the rapid rebound of output, and the consumption drop even greater than the output drop. I construct a canonical small open economy dynamic general equilibrium model in order to address these puzzles. The main result is that the model with GHH preference taking real interest rate and productivity shocks as exogenous can account for all three features. Moreover, the quantitative analysis shows that the driving force of the depression and recovery of output and labor is productivity whereas real interest rate shocks are important to explain the large drop of consumption. Thus, if there is anything to blame for the economic downturn, it must be causing a temporary drop in productivity. As neither capacity utilization nor temporary misallocation of intermediate goods given real interest rate shocks can fully explain the fluctuation of productivity, I conjecture that a temporary loss of organizational capital can account for the temporary productivity drop during the Korean crisis. This study complements the existing literature by suggesting that corporate failures and the banking crisis can be important to explain the Korean crisis by temporarily reducing organizational capital and consequently total factor productivity.

This paper invites some possible extensions. First, it is essential to measure the change in organizational capital during the crisis. It is trivial to model an economy in which managerial labor is an imperfect substitute to regular labor where managerial output can be allocated either to production organization or non-production labor such as searching for new business relationships. However quantitative analysis is challenging given limited data on details of managerial output in Korea.

Second, it is interesting to see how well productivity and interest rate shocks account for the macro performance in other countries. As shown in section 2, while most of the Asian countries experienced a considerably large drop in consumption, they showed recovery patterns different from Korea after facing a downturn in late 1997 and early 1998. It is remained to be discussed to what extent the model with productivity and interest rate shocks can explain the differences and similarities in macroeconomic performances in these countries during the crisis.

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8 Appendix

8.1 Computation of Trend

TFP can be divided into fluctuation and trend as,

$$\ln SR_t = (1-\theta)\ln X_t + \ln z_t.$$

By definition of Labor Augmenting Technical Progress, $X_t = (1+\gamma)^t X_0$ so

$$\ln X_t = t\ln(1+\gamma) + \ln X_0.$$

Thus,

$$\ln SR_t = \alpha_1 + \alpha_2 t + \varepsilon_t$$

where

$$\begin{aligned}
\alpha_1 &= (1-\theta)\ln X_0, \\
\alpha_2 &= (1-\theta)\ln(1+\gamma), \\
\varepsilon_t &= \ln z_t.
\end{aligned}$$

Therefore, the growth rate of labor augmenting technical progress can be estimated by,

$$\gamma \approx \ln(1+\gamma) = \frac{\alpha_2}{1-\theta}.$$

8.2 Calibration of GHH Parameters

The parameter ν was calibrated to match the wage elasticity of labor in the GHH preference with that of the Cobb-Douglas preference following Correia, Neves, and Rebelo (1995). χ was calibrated to match the steady state level of labor.

Setting u_c constant and linearizing u_c for the Cobb-Douglas preference around the steady state yields,

$$\widetilde{c_t} = \frac{(1-\Psi)(1-\sigma)}{\Psi(1-\sigma)-1}\frac{l}{1-l}\widetilde{l_t}.$$

Next, linearizing the labor first order condition around the steady state and substituting the condition above yields,

$$\frac{\sigma l}{1-\Psi(1-\sigma)}\widetilde{l_t} = (1-l)\widetilde{w_t}.$$

Thus, the constant marginal utility of consumption wage elasticity of labor for the Cobb-Douglas preference is,

$$\left[\frac{\partial l_t}{\partial w_t}\right]_{\overline{u_c}}^{Cobb-Douglas} = \frac{1-\Psi(1-\sigma)}{\sigma}\frac{1-l}{l}.$$

On the other hand, the wage elasticity of labor for the GHH preference is,

$$\left[\frac{\partial l_t}{\partial w_t}\right]^{GHH} = \frac{1}{\nu-1}.$$

Setting these two equal,

$$\nu = 1 + \frac{\sigma}{1-\Psi(1-\sigma)}\frac{l}{1-l}. \tag{35}$$

Once we calibrate ν we can calibrate χ from the steady state version of the labor first order condition in equilibrium to get

$$\chi = \frac{1-\theta}{\nu}\frac{y}{l^{\nu}}. \tag{36}$$

8.3 Mapping Parameters from the GHH model to the Intermediate Good Model

In this section, I will show how some parameters can be mapped from the GHH model to the intermediate good model. I also show how the measured productivity can be computed.

8.3.1 $\widehat{\theta}$

I assume that β is equal in the GHH model and the intermediate good model. Therefore from (15) and (33),

$$(1-\alpha)^{\frac{1}{\epsilon}}\left(\frac{k^{\widehat{\theta}}l^{1-\theta}}{q}\right)^{\frac{\epsilon-1}{\epsilon}} = \frac{y}{q}\frac{\theta}{\widehat{\theta}} \tag{37}$$

Also, from (32)

$$\alpha^{\frac{1}{\epsilon}}\left(\frac{f}{q}\right)^{\frac{\epsilon-1}{\epsilon}} = \frac{\alpha}{(1+(1-\frac{1}{R}))^{\epsilon-1}}$$

And from the fact that $y = q - f$,

$$\frac{y}{q} = 1 - \frac{\alpha}{(1 + (1 - \frac{1}{R}))^{\epsilon}}.$$

Combining these with (31),

$$\widehat{\theta} = \frac{(1 + (1 - \frac{1}{R}))^{\epsilon} - \alpha}{(1 + (1 - \frac{1}{R}))^{\epsilon} - \alpha(1 + (1 - \frac{1}{R}))}\theta$$

where $\widehat{\theta} > \theta$.

8.3.2 $\widehat{\chi}$ and $\widehat{\nu}$

From (34) and (37),

$$w_t = (1 - \widehat{\theta})\frac{\theta}{\widehat{\theta}}\frac{y_t}{l_t}.$$

Thus, from (8) and (11)

$$\widehat{\Psi} = \frac{1}{1 + (1 - \widehat{\theta})\frac{\theta}{\widehat{\theta}}\frac{y}{c}\frac{1-l}{l}}.$$

χ and ν are adjusted accordingly as

$$\widehat{\nu} = 1 + \frac{\sigma}{1 - \widehat{\Psi}(1 - \sigma)}\frac{l}{1 - l}$$

and

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

8.3.3 Measured Productivity

The linearized version of (31) gives

$$y\widetilde{y_t} + f\widetilde{f_t} = \alpha^{\frac{1}{\epsilon}}q^{\frac{1}{\epsilon}}f^{\frac{\epsilon-1}{\epsilon}}\widetilde{f_t} + (1 - \alpha)^{\frac{1}{\epsilon}}q^{\frac{1}{\epsilon}}(k^{\widehat{\theta}}l^{1-\theta})^{\frac{\epsilon-1}{\epsilon}}(\widehat{\theta}\widetilde{k_t} + (1 - \widehat{\theta})\widetilde{l_t}).$$

Using (37), this can be rewritten as

$$y\widetilde{y_t} = \left(\left(\alpha\frac{q}{f}\right)^{\frac{1}{\epsilon}} - 1\right)f\widetilde{f_t} + y\frac{\theta}{\widehat{\theta}}(\widehat{\theta}\widetilde{k_t} + (1 - \widehat{\theta})\widetilde{l_t})$$

Thus, from linearized version of (13),

$$\widetilde{z}_t = \left(\left(\alpha\frac{q}{f}\right)^{\frac{1}{\epsilon}} - 1\right)\frac{f}{y}\widetilde{f}_t - (\frac{\widehat{\theta} - \theta}{\widehat{\theta}})\widetilde{l}_t.$$

9 Tables and Figures

Table 1. Growth and Stability of Asian Countries (1980-1997)[28]

	g^y	std
$HongKong$	3.87	3.31
$Indonesia$	4.11	2.07
$Malaysia$	4.00	3.11
$Singapore$	4.74	3.27
$Thailand$	4.63	3.23
$Korea$	5.60	1.76

Table 2. Summary Statistics of Asian Countries[29]

	y_{98}	g^c_{97}/g^y_{98}	g^y_{98}
$HongKong$	-0.050	1.11	1.31
$Indonesia$	-0.055	0.59	-1.38
$Malaysia$	-0.034	1.27	2.92
$Singapore$	-0.005	1.26	3.50
$Thailand$	-0.081	0.91	2.37
$Korea$	-0.087	1.44	9.19

[28] g^y stands for the average percentage growth rate of real GDP per adult. std stands for the standard deviation of GDP per adult growth rates.

[29] y_{98} stands for the deviation of GDP per capita in 1998 relative to its trend. g^c_{97}/g^y_{97} is the ratio of the growth rates of real consumption to real GDP per adult in 1997. g^y_{98} is the percentage growth rate of real GDP per adult in 1998.

Table 3. Parameter Values of The Benchmark Model

θ	Capital Share	0.297
β	Discount Factor	0.967
δ	Depreciation Rate	0.037
Ψ	Consumption-Leisure Parameter	0.263
Γ	Growth Trend	1.061
ν	Curvature Parameter of GHH Preference	1.34
χ	Level Parameter of GHH Preference	1.17
ρ_z	Persistence of Productivity Shock	0.80
ρ_s	Persistence of Real Interest Rates Shock	0.65

Figure 1. Korean Production Factors[30]

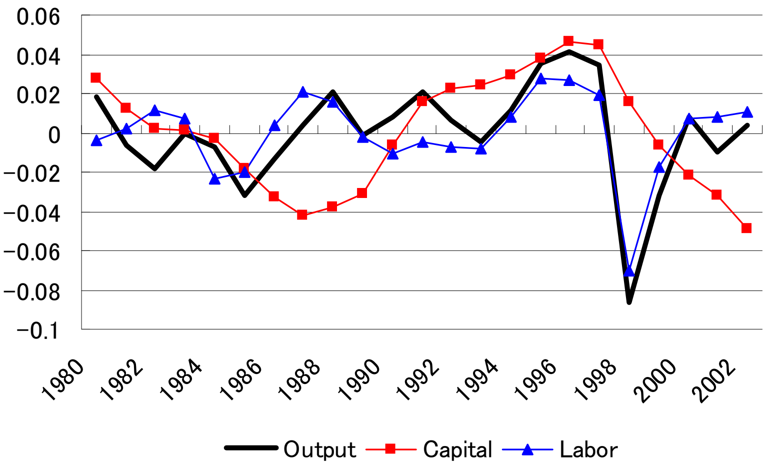
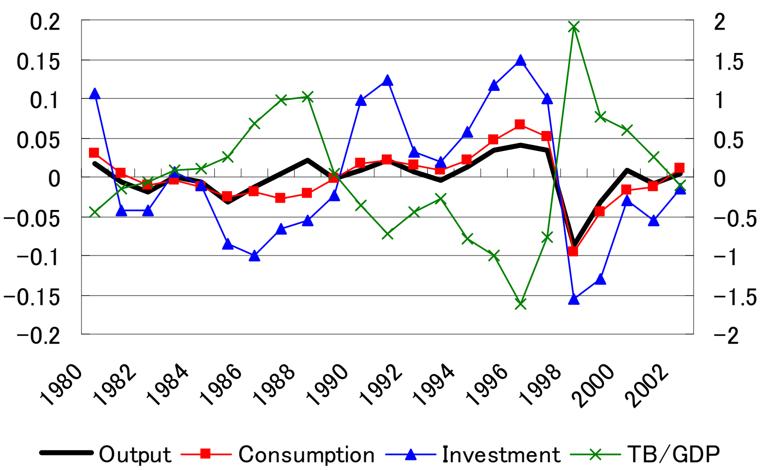


Figure 2. Korean GDP Components[31]



[30]Source: Pyo (2003) for capital stock Korea National Statistical Office Statistical Database (KOSIS) for labor.

[31]Source: Korea National Statistical Office Statistical Database (KOSIS)

Figure 3. Asian Output and Consumption (1980-2002)[32]

[32]Source: World Bank "World Development Indicators" except for Korea

Figure 4. Output and Real Interest Rate[33]

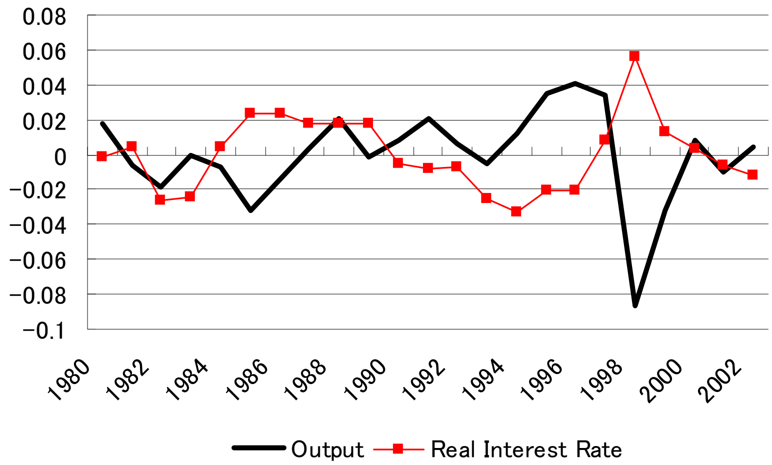
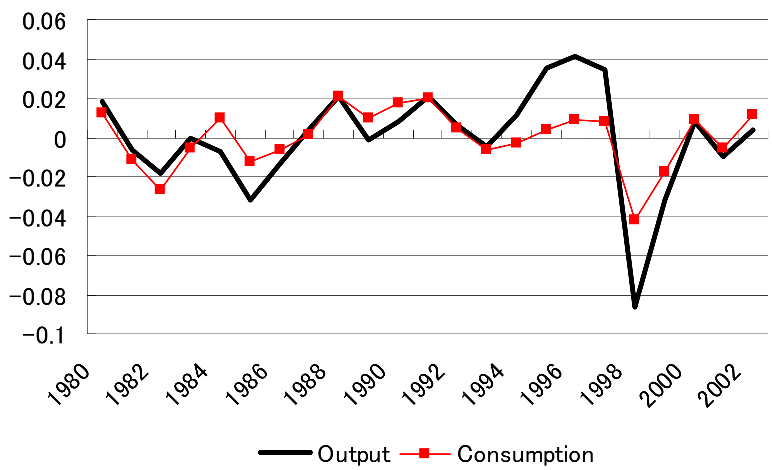


Figure 5. Output and Productivity[34]



[33]Source: Korea National Statistical Office Statistical Database (KOSIS) for output, IMF "International Financial Statistics" for real interest rate.

[34]Source: Korea National Statistical Office Statistical Database (KOSIS) for output, author's calculation for productivity.

Figure 6. Result: Benchmark Model with Productivity Shocks

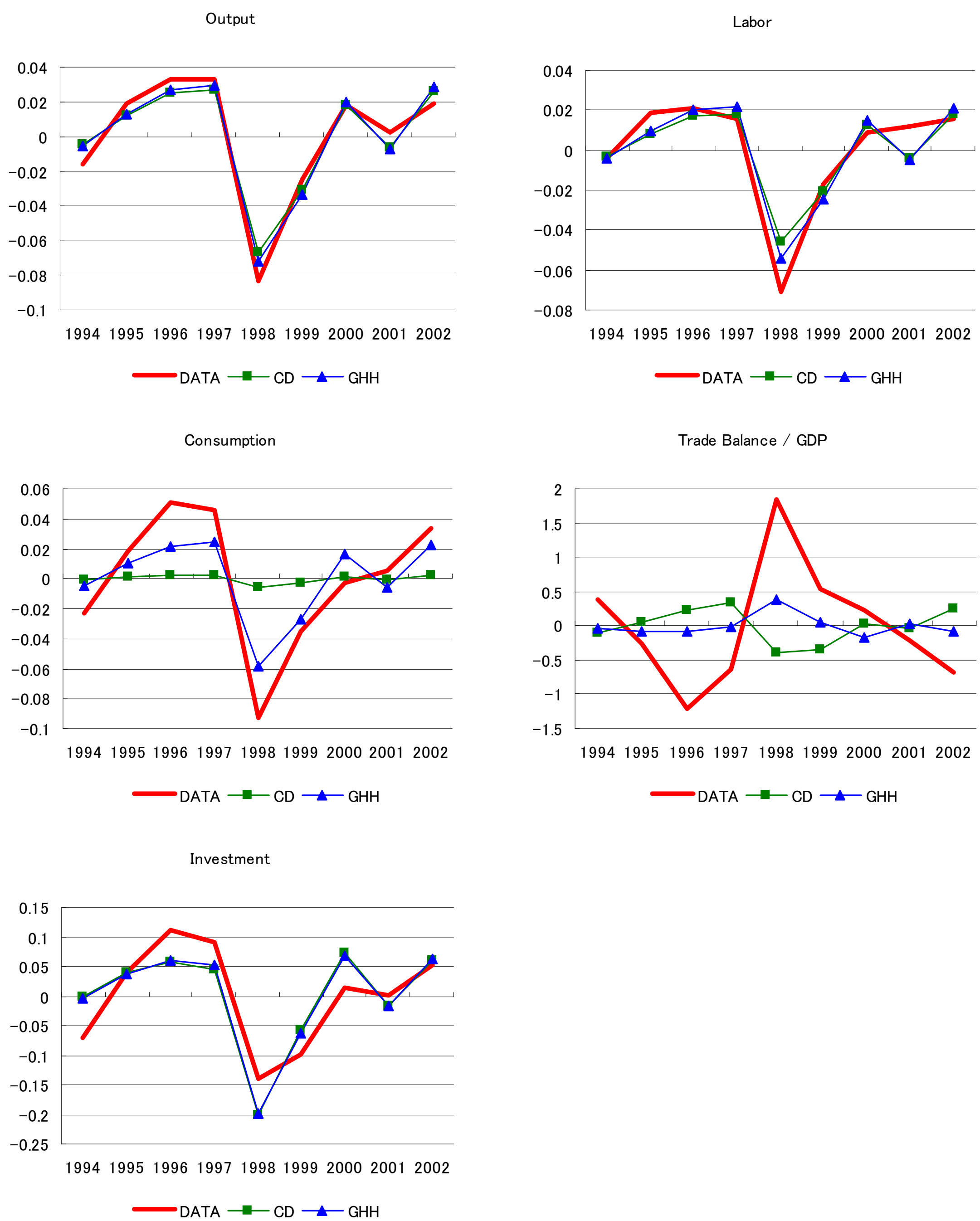


Figure 7. Result: Benchmark Model with Real Interest Rate Shocks

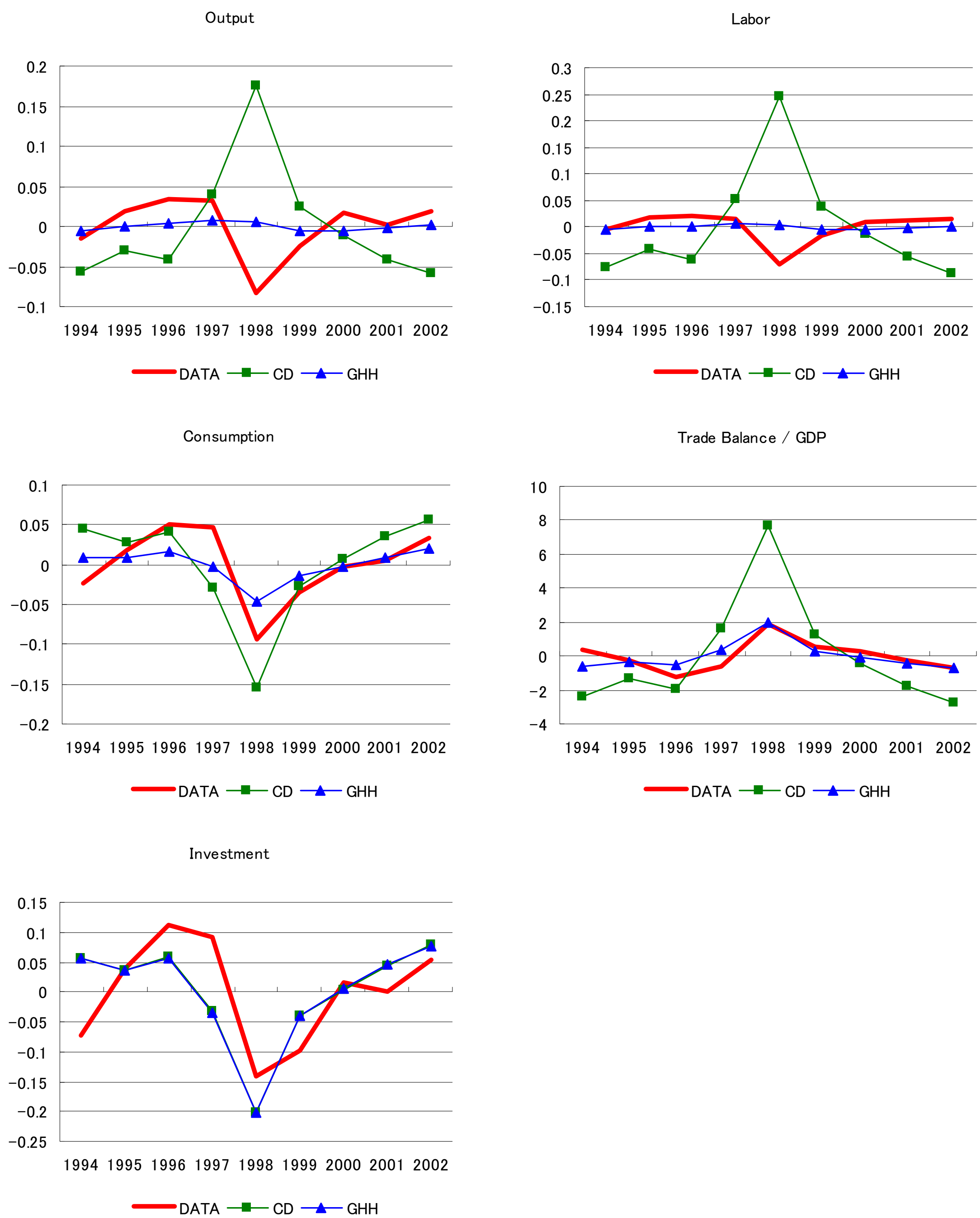


Figure 8. Result: Benchmark Model with Productivity and Real Interest Rate Shocks

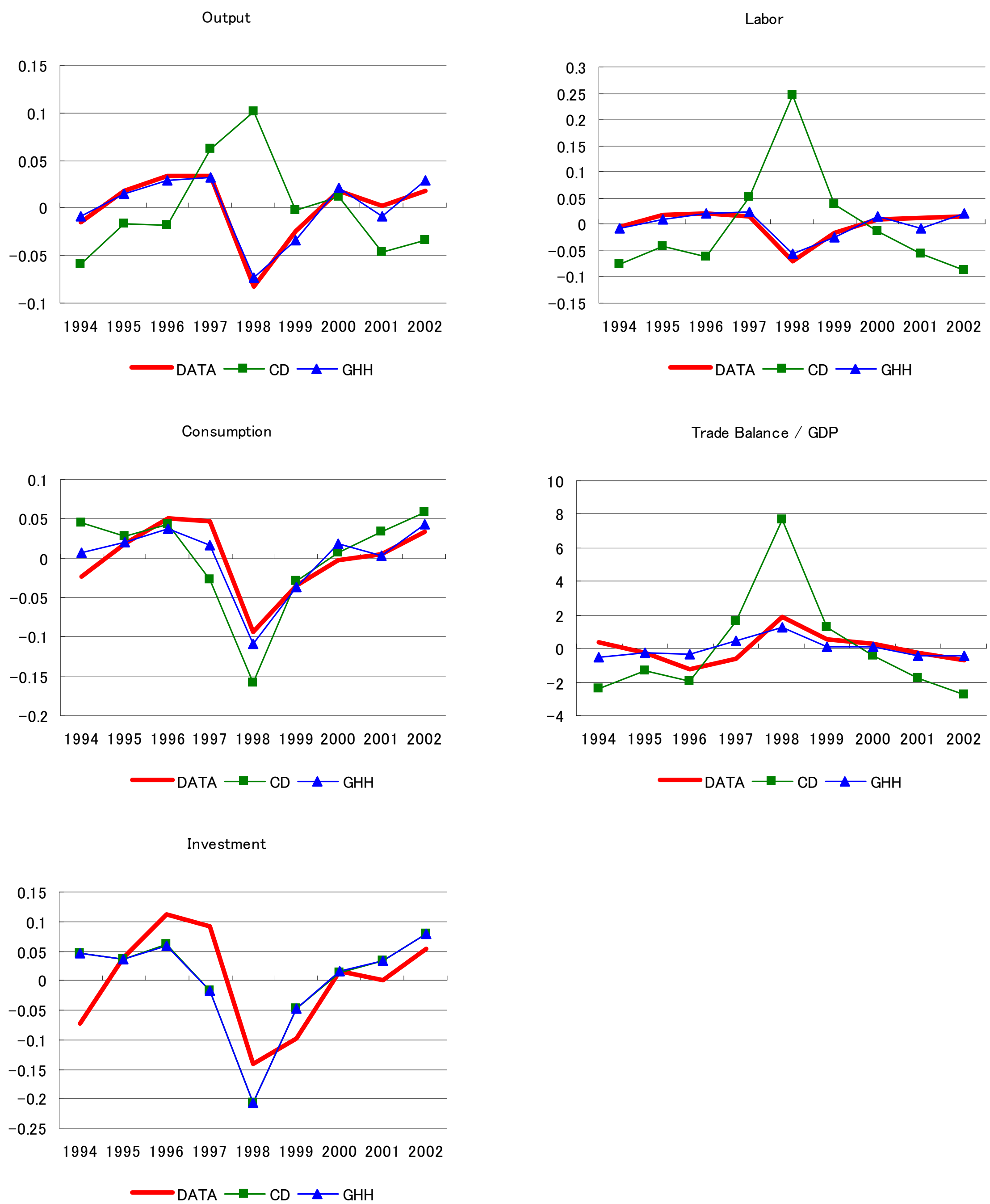


Figure 9. Result: Model with Working Capital on Labor

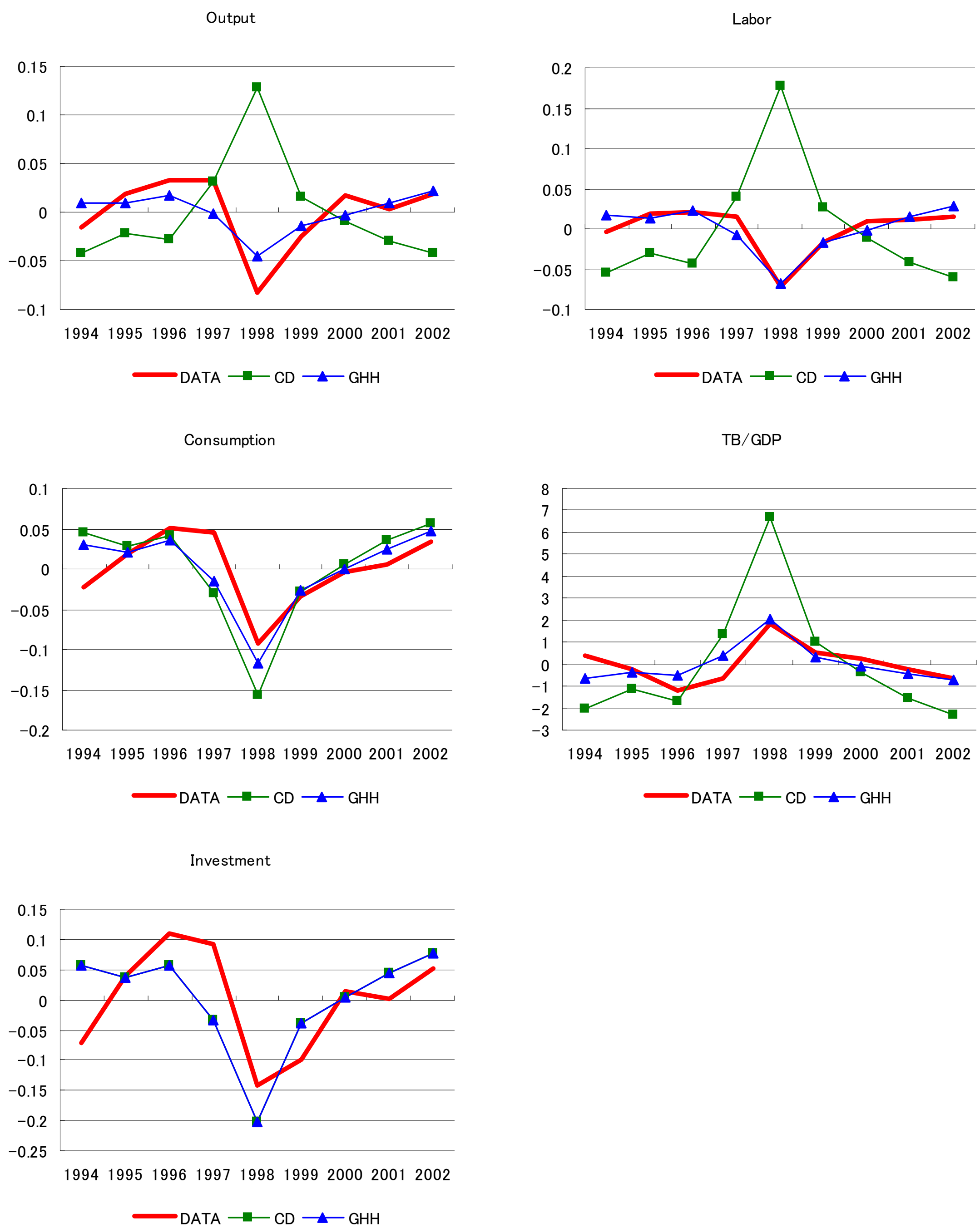


Figure 10. Result: Model with Endogenous Capacity Utilization

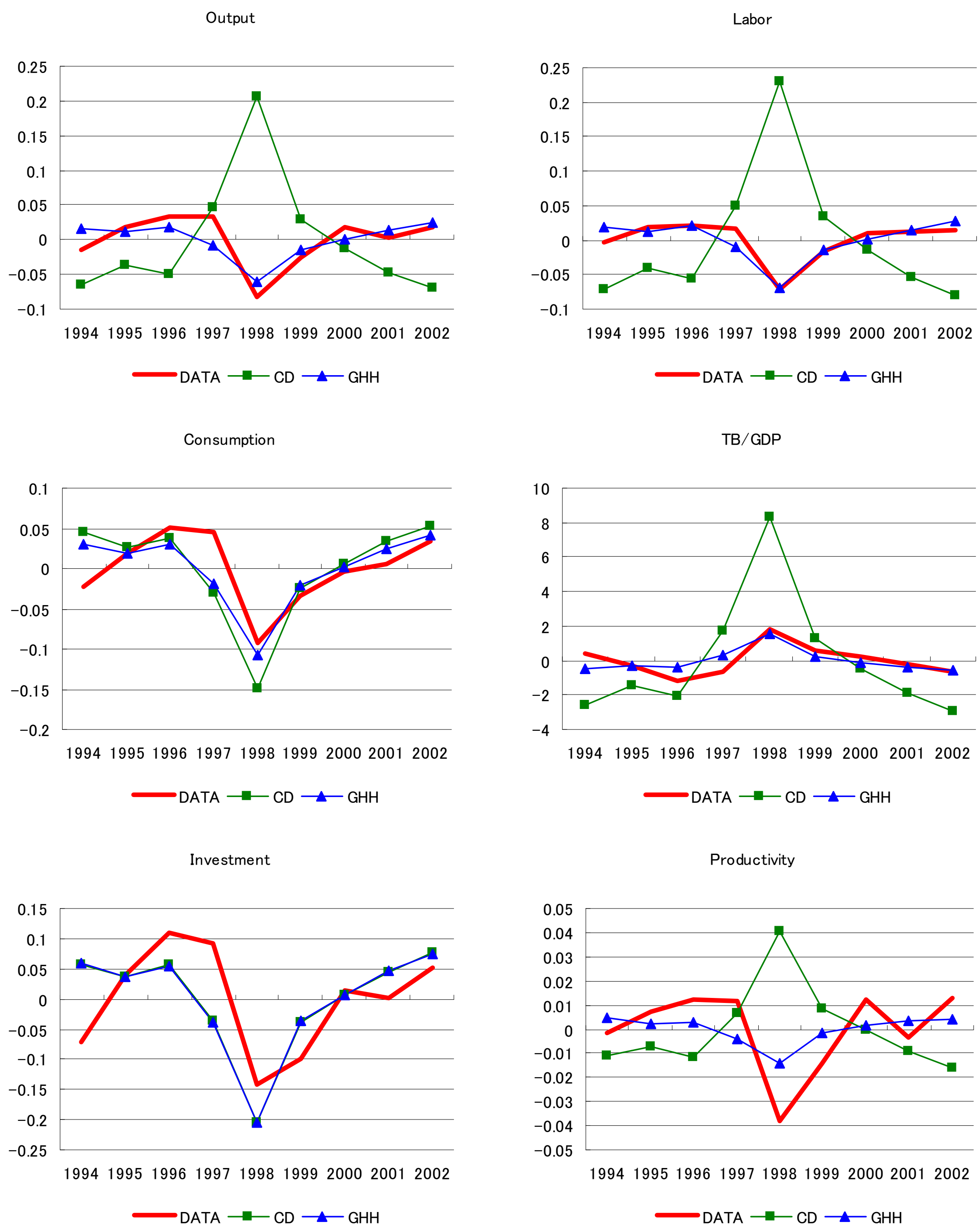


Figure 11. Result: Intermediate Good Model

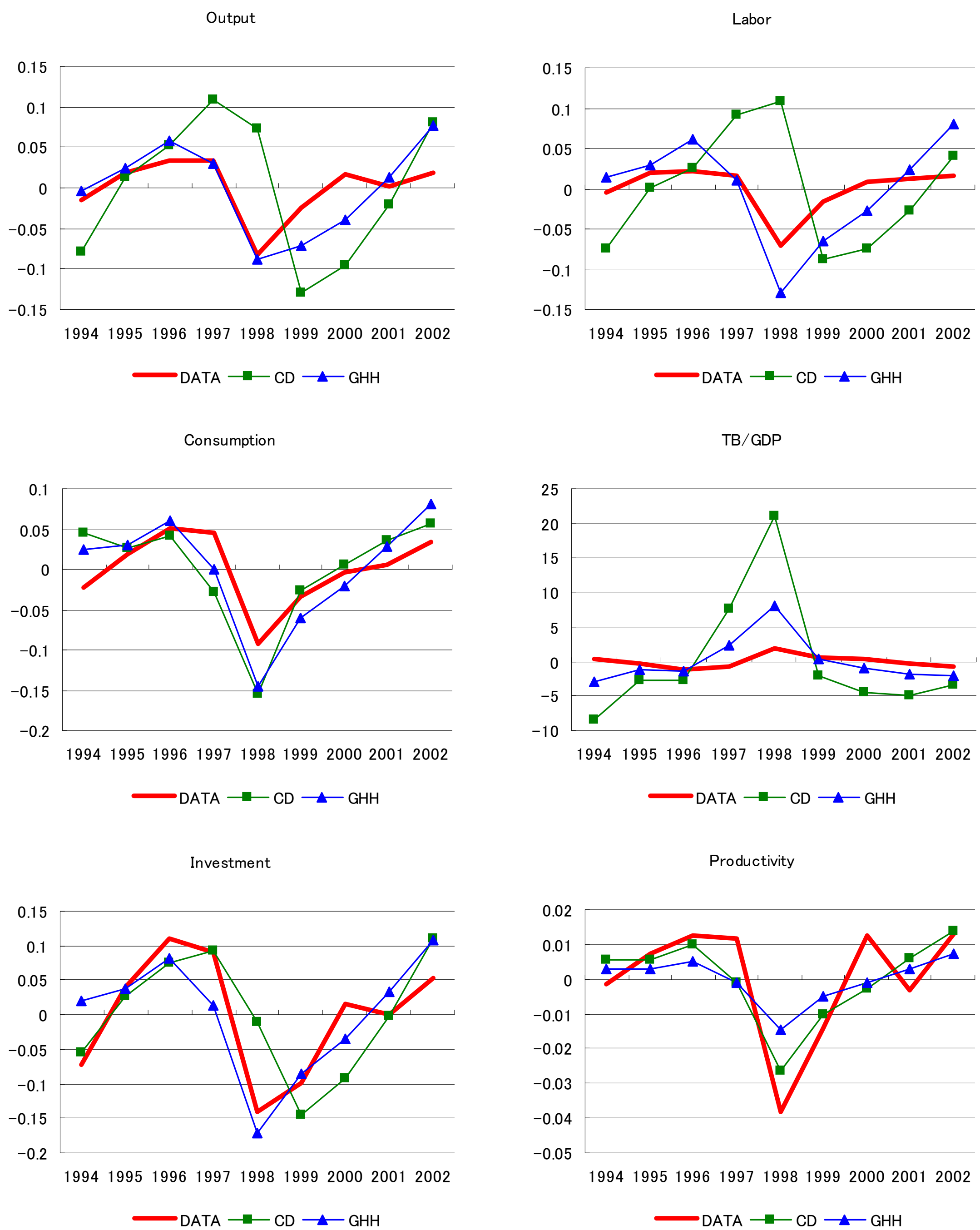


Figure 12. Percentage of Dishonored Bills[35]

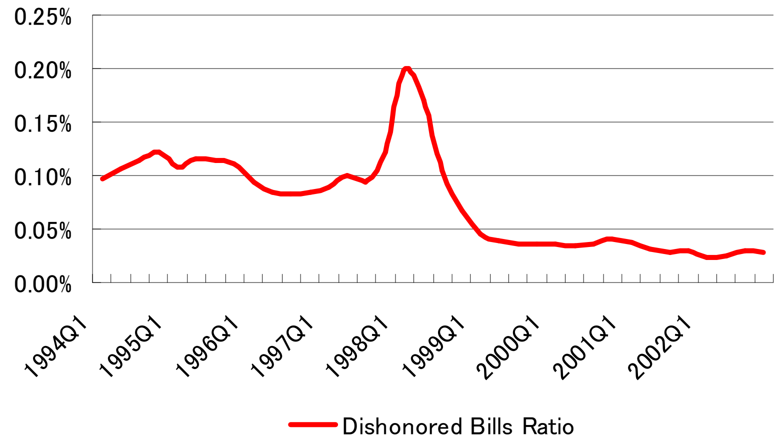
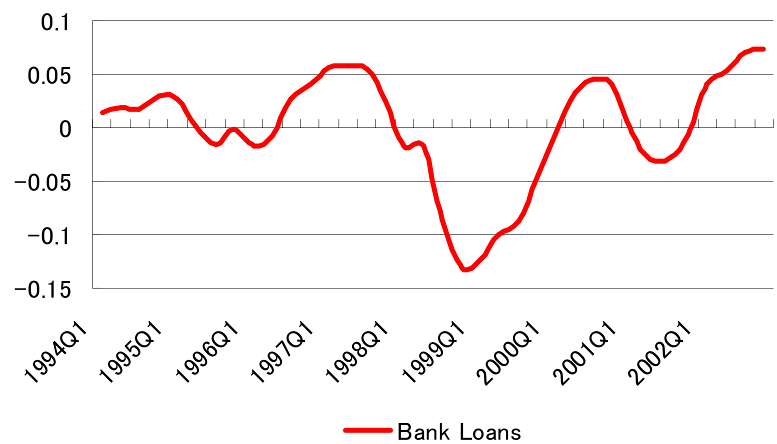


Figure 13. Bank Loans[36]



[35] Source: Korea National Statistical Office Statistical Database (KOSIS). $\frac{\text{Number of dishonored commercial bills}}{\text{Total amount issued}}$.

[36] Source: Korea National Statistical Office Statistical Database (KOSIS). Seasonally adjusted and detrended with Hodrick-Prescott filter.