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INVESTMENT-SPECIFIC TECHNOLOGY SHOCK IN AN INTERNATIONAL REAL BUSINESS CYCLE MODEL: THE KOREA CASE

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This paper investigates an international real business cycle model of a small open economy such as Korea. Our model is parameterized, calibrated, and incorporates the neoclassical framework with investment-specific technology shock. Our result supports that shocks to the marginal efficiency of investment are important for business fluctuations. Our model is able to duplicate many of the stylized facts of business cycles in Korea. Our analyses suggest that capacity utilization and investment-specific technology shock, together with productivity and world real interest rate shocks, provide a meaningful explanation to Korea economic fluctuations. The shock has positive effects on macroeconomic variables except for trade balance.

JEL Classification: E3, F4
Keywords: International real business cycles; Capacity utilization; Investment-Specific technology shocks

I. INTRODUCTION

Real business cycle theory, which was developed to the international real business cycle model by Backus, Kehoe, Kydland (1992), has extended to the real business cycle model of a small open economy. Mendoza (1991a, 1991b, 1995), Cardia(1991), Correa, Neves, Rebelo(1995), Schmitt-Grohe(1998), Senhadji (1998) developed the real business cycle model of a small open economy.

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Mendoza(1991a, 1991b) focused on two main aspects such as the ability of a small open economy to smooth consumption and investment, and the transmission effects from the foreign sector. Mendoza (1995) accounts for business cycle effects as well as the relationship between the trade balance (TB) and terms of trade (TOT) in a three-sector model. Senhadji(1998) built a small open economy with the endogenous terms of trade and import goods. He investigates the relation between the terms of trade and trade balance by using the S-curve, which is an S-shaped lead and lag correlation between the trade balance and terms of trade. Schmitt-Grohé(1998) also refers to the roles of the terms of trade in a small open economy.

Typically, real business cycle models have focused on exogenous shocks to the production function. Hence, they support a view that the main economic fluctuations can be explained by productivity shocks. In contrast, Greenwood, Hercowitz, and Krusell (1997, 2000) argue that it is shocks to the marginal efficiency of investment that are important in generating output fluctuations, rather than shocks to the production function. They show that a positive shock to marginal efficiency of investment stimulates the formation of "new" capital and more intensive utilization and accelerated depreciation of "old" capital. Therefore, their key conclusion suggests that shocks to the marginal efficiency of investment can be important elements for business cycles.

In this paper we adopt an international real business cycle model of a small open economy such as Korea. The distinguished features of our paper can be outlined in the following way. First, we incorporate important features of small open economy in our model. An important aspect of the model developed by Mendoza (1991a) is that the representative agent's consumption and savings can be smoothed through access to world financial markets. A small open economy such as Korea has an effect from the change of world financial markets. We incorporate the shock on world real interest rate in our model. The positive shock on world real interest rate raises the opportunity cost of consumption and investment, and thus decreases production, consumption and investment. Second, we incorporate investment-specific technology shock and capacity utilization in our model. The Korean economy has been rapidly developing during the past decades. One major factor of the achievement was the rapid capital accumulation. The capital accumulation has been realized by investment, in which investment specific technology is embodied. While the analyses by Greenwood, Hercowitz, and Krusell (1997, 2000) are based on a closed economy context, our model assumes a small open economy. In our model, the endogenous capacity utilization variable is also central to our model's ability to generate the positive intertemporal co-movement of macroeconomic variables.

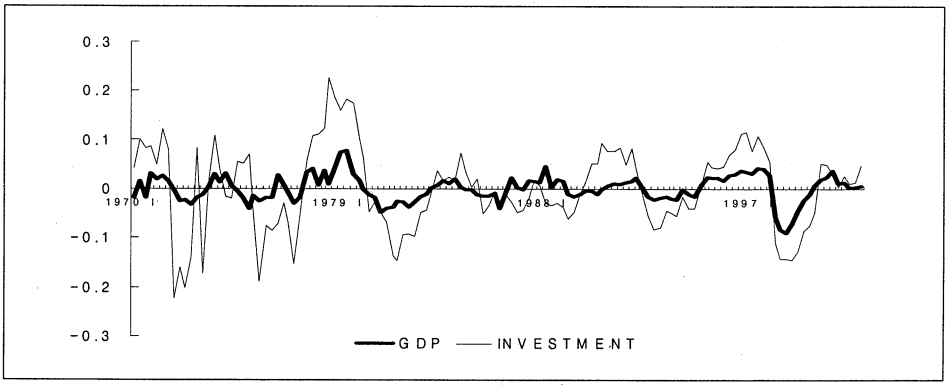
This paper consists of six sections. Section Ⅱ provides a full description of the dynamic stochastic model of a small open economy. Section Ⅲ sets benchmark parameters, solution techniques, and finds the steady-state conditions for optimal allocation in the dynamic programming problem. Section Ⅳ provides the key findings in the empirical analysis. Finally, concluding remarks are presented in Section Ⅴ.

Ⅱ. AN INTERNATIONAL REAL BUSINESS CYCLE MODEL

As can be seen from Figure 1, the volatility of investment has been higher than that of GDP, and also it is procyclical. Accordingly, we can infer that investment has an important explanation power for business fluctuations. A the dynamic stochastic model of a small open economy is developed to investigate shocks to productivity, investment specific technology and world interest rate. The structure of the model is built in which the economy is represented by large, infinitely-lived agents with the same preferences, and the same production technology. Our major concern is the role of investment-specific technology.

Our model has a few salient features. First, the model allows that an increase in the efficiency of newly produced investment goods stimulates the formation of "new" capital and more intensive utilization and accelerated depreciation of "old" capital. Second, we incorporate foreign financial assets with exogenous world real interest rate shocks as the alternative vehicles in smoothing the agent's consumption and savings.

[Figure 1] Korean GDP and Investment, Logged and Detrended by a HP Filter



2.1. Preference

Agents who are infinitely-lived with the same identical preferences allocate C_t (consumption) and N_t (labor supply) intertemporally to maximize stationary cardinal utility.

$$E_0\Big[\sum_{t=0}^{\infty}\{U(C_t-G(N_t))\}\exp\Big\{-\sum_{\tau=0}^{t-1}\upsilon(C_\tau-G(N_\tau))\Big\}\Big] \qquad (1)$$

The instantaneous utility and time-preference functions are as follows:

$$U(C_t - G(N_t)) = \frac{\left[C_t - \frac{N_t^{1+\theta}}{1+\theta}\right]^{1-\gamma} - 1}{1-\gamma} \tag{2}$$

$$v(\cdot) = \beta \ln\left(1 + C_t - \frac{N_t^{1+\theta}}{1+\theta}\right), \quad G(\cdot) = \frac{N_t^{1+\theta}}{1+\theta} \tag{3}$$

$$\begin{aligned} & U(\cdot)<0, \quad U'(\cdot)>0, \quad U'(0)=\infty, \quad 1+\theta>1, \quad \gamma>1 \\ & v(\cdot)>0, \quad v'(\cdot)>0, \quad v''(\cdot)<0, \quad \beta>0 \\ & G(\cdot)>0, \quad G'(\cdot)>0, \quad G''(\cdot)>0, \\ & U'(\cdot)\exp(v(\cdot)) \text{ nonincreasing.} \end{aligned}$$

The parameter β is referred to as the consumption elasticity of the rate of time preference. The parameter θ is the inverse of the intertemporal elasticity of substitution in labor supply. The parameter γ is known as the coefficient of relative risk aversion. The distinct features of preferences are as follows: first, the intertemporal discount rate equalizes to the world's real interest rate in the steady-state equilibrium. Second, in equilibrium, the marginal product of labor should be equal to the marginal disutility of labor, which implies that the labor supply is separated from the dynamics of consumption.

2.2. Production and Technology

Output is given by the following Cobb-Douglas production function using capital and labor. However, it differs from the standard neoclassical specification solely by the inclusion of a variable rate of capacity utilization[1] (h_t)

$$Y_t = Z_t(K_t h_t)^{\alpha} N^{1-\alpha} \tag{4}$$

where Y_t is the output of the single good in period t, K_t is the capital stock, and N_t is labor input in period t. The parameter α is referred to as the capital share. The variable h_t determines the flow of capital services ($K_t h_t$) and represents the intensity of the use of capital, that is, the speed of operation

[1] We use a capacity utilization variable for two reasons. First, a higher utilization rate causes a faster depreciation of capital stock, either because wear and tear increase with use or because less time can be devoted to maintenance. Second, from the first-order condition of the business cycle model with investment-specific technology shock, if capacity utilization does not exist in the model, labor supply expresses as a function of only capital stock, which means labor supply is independent of investment-specific technology shock. Accordingly, by incorporating capacity utilization into the business model, the effect of the shock is transmitted to labor supply *intratemporarily*.

or the number of hours per period the capital is used. Z_t is productivity shock, and follows the first-order Markov distribution function.

2.3. Capital Accumulation and Financial Structure

The law of motion for capital stock follows:

$$K_{t+1}=K_t[1-\delta(h_t)]+e_{1t}i_t \tag{5}$$

$$\text{and} \quad \delta(h_t)=\frac{h_t^{\omega}}{\omega} \qquad \omega>1$$

where i_t denotes gross investment and δ is *not* a constant rate of depreciation but a non-negative function of capacity utilization (h_t). ω is an elasticity of depreciation with respect to capacity utilization. The capital accumulation and production capacity in period $t+1$ depend on both investment and technology shocks (e_{1t}) affecting the productivity of new capital goods. The technology shocks (e_{1t}) also follow the first order Markov distribution function.

The financial structure has links with the trade balance, which is assumed by one good trade. The financial structure assumes that an agent in the economy is a small participant and has access to a perfectly competitive intertemporal financial asset market. Holdings of foreign financial assets (A_{t+1}) evolve according to:

$$A_{t+1}=TB_t+(1+e_{2t}r^*)A_t \tag{6}$$

where A_t denotes the holdings of foreign financial assets in period t. TB_t is the balance of trade, and r^* is the world real interest rate, which is determined exogenously. The shocks on the world real interest rate (e_{2t}) follow the first order Markov distribution function.

2.4. Resource Constraint

The model is completed with a resource constraint as follows:

$$C_t+\frac{K_{t+1}}{e_{1t}}-\left(1-\frac{1}{\omega}h_t^{\omega}\right)\frac{K_t}{e_{1t}}+A_{t+1}-(1+e_{2t}r^*)A_t\leq$$

$$Z_t(K_th_t)^{\alpha}N_t^{1-\alpha}-\frac{\phi\left(\frac{K_{t+1}}{e_{1t}}-\frac{K_t}{e_{1t}}\right)^2}{\frac{K_t}{e_{1t}}} \tag{7}$$

where ϕ is parameter to restrict the adjustment costs. The aggregate resource constraint of the economy describes that the sum of consumption, investment, and trade balance cannot exceed gross domestic product.

Ⅲ. DYNAMIC PROGRAMMING PROBLEM, SOULUTION TECHNIQUES AND PARAMETER CALIBRATIONS

The social planner selects paths of consumption and labour supply to maximize the life-time utility. To solve the dynamic programming problem, the agent's optimal intertemporal decisions choose the control variables ($K_{t+1}, A_{t+1}, C_t, h_t, N_t$) in period t, given the state of the economy as described by K_t, A_t, Z_t, e_{1t} and e_{2t}. To solve the dynamic programming problem of the model, the Lagrangian problem is constructed as follows:

$$L=\sum_{t=0}^{\infty}\prod_{\tau=0}^{t-1}\left(1+C_\tau-\frac{N_\tau^{1+\theta}}{1+\theta}\right)^{-\beta}\left\{\frac{\left(C_t-\frac{N_t^{1+\theta}}{1+\theta}\right)^{1-\gamma}-1}{1-\gamma}\right.$$
$$+\lambda_{1t}\left(Z_t(K_th_t)^\alpha N_t^{1-\alpha}-C_t-\frac{K_{t+1}}{e_{1t}}+\left(1-\frac{1}{\omega}h_t^\omega\right)\frac{K_t}{e_{1t}}\right. \tag{8}$$
$$\left.\left.-A_{t+1}+(1+e_{2t}r^*)A_t-\frac{\phi\left(\frac{K_{t+1}}{e_{1t}}-\frac{K_t}{e_{1t}}\right)^2}{\frac{K_t}{e_{1t}}}\right)\right\}$$

The first-order conditions for utility maximization are:

$$(C_t):\ V_{ct}=\lambda_{1t} \tag{9}$$

$$(K_{t+1}):\lambda_{1t}\left[\frac{2\phi\left(\frac{K_{t+1}}{e_{1t}}-\frac{K_t}{e_{1t}}\right)}{K_t}+\frac{1}{e_{1t}}\right]=\lambda_{1t+1}B(t)\left[\alpha\frac{Y_{t+1}}{K_{t+1}}+\right. \tag{10}$$
$$\left.\left(1-\frac{1}{\omega}h_{t+1}^\omega\right)\frac{1}{e_{1t+1}}+\frac{2\phi\left(\frac{K_{t+2}}{e_{1t+1}}-\frac{K_{t+1}}{e_{1t+1}}\right)}{K_{t+1}}+\frac{\phi\left(\frac{K_{t+2}}{e_{1t+1}}-\frac{K_{t+1}}{e_{1t+1}}\right)^2}{\frac{K_{t+1}^2}{e_{1t+1}}}\right]$$

$$(N_t):N_t^\theta=(1-\alpha)\frac{Y_t}{N_t} \tag{11}$$

$$(h_t):\alpha Y_t=\frac{1}{e_{1t}}K_th_t^\omega \tag{12}$$

$$(A_{t+1}): \lambda_{1t} = \lambda_{1t+1} B(t)(1 + e_{2t} r^*) \tag{13}$$

$$(\lambda_{1t}): Z_t(h_t K_t)^{\alpha} N_t^{1-\alpha} - C_t - \frac{K_{t+1}}{e_{1t}} + (1 - \frac{1}{\omega} h_t^{\omega}) \frac{K_t}{e_{1t}} - A_{t+1} + (1 + e_{2t} r^*) A_t - \frac{\phi \left(\frac{K_{t+1}}{e_{1t}} - \frac{K_t}{e_{1t}} \right)^2}{\frac{K_t}{e_{1t}}} = 0 \tag{14}$$

where $B(t) = \exp(-\upsilon(C_t - G(N_t)) = \exp\left(-\beta \ln(1 + C_t - \frac{N_t^{1+\theta}}{1+\theta})\right) = \left(1 + C_t - \frac{N_t^{1+\theta}}{1+\theta}\right)^{-\beta}$, $V_{ct} = \left(C_t - \frac{N_t^{1+\theta}}{1+\theta}\right)^{-\gamma} - \beta\left(1 + C_t - \frac{N_t^{1+\theta}}{1+\theta}\right)^{-\beta-1} (U(t+1) + B(t+1)U(t+2) + B(t+1)B(t+2)U(t+3) + \cdots\cdots)$

A feature of these first-order conditions is that this model reflects the property of a small open economy business cycle model. The variable intertemporal discount rate is a convex function as follows: $B(\cdot)>0$, $B'(\cdot)<0$ and $B''(\cdot)>0$. This feature induces consumption and labour to smooth from economic shock. In other words, if consumption increases, the increased consumption decreases the intertemporal discount rate, and in turn the decreased discount rate reduces the utility of current consumption compared with future consumption, and thus decreases current consumption. This interaction causes consumption to smooth even though the effect is small.

3.1. Solution Technique and Calibration

To solve the dynamic program problem by using an undetermined coefficient solution method, we need to linearize above first-order conditions around the steady-state values (Christiano 1998). We use economic theory as the basis for restricting the general framework for finding numerical values for parameters. The benchmark parameter values from Table 1 are computed as follows:

[Table 1] Benchmark Parameter Values

Parameters	Definition	Value
β	Consumption elasticity of the rate of time preference	0.085
γ	Coefficient of relative risk aversion	2.0
θ	Inverse of the intertemporal elasticity of substitution in labour supply	0.34
α	Capital share in output	0.5395
ω	Elasticity of depreciation with respect to utilization	1.4
r^*	World's real interest rate	0.01
δ	Depreciation rate of capital	0.025
ϕ	Adjustment cost coefficient of capital	4.0

Under the restriction that the average ratio of net foreign interest payments to GDP is around 2%, the consumption elasticity of the rate of time preference (β) is computed as 0.085 from the steady-state condition which equates the world real interest rate with the discount rate of preference. The coefficient of relative risk aversion (γ) is estimated from 1.02 to 11.23 for south America countries by Rossi(1988). We set as 2.0, which is conventionally used. The inverse of the intertemporal elasticity of substitution in labour supply (θ) is calculated at 0.34 by using the restriction that steady state labour supply is 0.33. The relevant parameters of production are calculated from national income data. An average quarterly value of 0.5395 over the 1970:1-2001:4 period is used for capital share (α) from the national account. The elasticity of depreciation with respect to utilization (ω) is set as 1.4 under the restriction that the depreciation rate (δ) of capital is 0.025 in a deterministic steady state. The world's real interest rate (r^*) is set to 0.01, which is computed from average value of Prime Bank Lending Rate of US less inflation of US. By following the way conducted by Park (1999), adjustment cost coefficient is set as 4.0, which equates the volatility of investment in model data to that in Korean data.

3.2. Shock Process

Our model has three shocks, which are the shocks to productivity, investment-specific technology and the world real interest rate. The parameters of productivity shock process are estimated from Solow residuals of GDP, and parameters of investment-specific technology process are estimated using the values that are filtered by linear time trend.

$$\ln q_t = \text{constant} + \text{trend} \times \ln \gamma_q + e_{1t}$$

Where, q_t is defined by the ratio of consumer price index to producer price index of machinery and equipment.[2] The shock process of world real interest rate, which is defined by Prime Bank Lending Rate of US minus US inflation, is also estimated using the values that are filtered by linear time trend. It is assumed that the shock processes follow the first-order Markov distribution function, and the processes are estimated by VAR (vector autoregression) as follows:

[2] Greenwood et al. (1997, 2000) define the relative price of equipment as the ratio between a price index of quality-adjusted equipment and a price index for consumption. They also argue that the relative price of equipment is negatively correlated with investment, which implies that the relative price of equipment reflects the technology change in investment. In Korea, the relative price of equipment decreases in reflecting the technological improvement of capital goods.

$$\begin{bmatrix} Z_{t+1} \\ e_{1t+1} \\ e_{2t+1} \end{bmatrix} = \begin{bmatrix} 0.99 & 0.0 & 0.0 \\ 0.0 & 0.97 & 0.0 \\ 0.0 & 0.0 & 0.92 \end{bmatrix} \begin{bmatrix} Z_t \\ e_{1t} \\ e_{2t} \end{bmatrix} + \begin{bmatrix} w_{1t+1} \\ w_{2t+1} \\ w_{3t+1} \end{bmatrix}$$

The correlation-covariance matrix of the innovation is:

$$\begin{bmatrix} 0.000409 & 0.000054 & -0.000002 \\ 0.000054 & 0.001802 & -0.000004 \\ -0.000002 & -0.000004 & 0.000005 \end{bmatrix}$$

and the percentage standard deviations are 2.02%, 4.25% and 0.02%, respectively.

Ⅳ. EMPIRICAL FINDINGS

4.1. Simulation and Sensitivity Analysis

Table 2 represents the major features of the real economy and the benchmark economy. The standard deviations of the real data from Table 2 provide that investment, 8.44, is more volatile than output, 2.70, and consumption, 2.28. Trade balance, 2.21, is lower than consumption. The standard deviation of capital stock shows the lowest value at 1.25. The highest standard deviation is shown from foreign financial assets at 28.72.

The standard deviations of the benchmark economy are similar to real data[3] in consumption (2.28, 2.31), labour supply (1.84, 2.02), investment (8.44, 8.61) and trade balance (2.21, 2.09). In the case of first order serial correlation, the benchmark economy fairly well mimics the real data. For instance, the autocorrelations of consumption are similar at 0.76 and 0.71 in the real data and the benchmark economy, respectively.

Moreover, the autocorrelations of investment (0.75, 0.71), capital stock (0.93, 0.96), labour supply (0.68, 0.72) and trade balance (0.78, 0.71) prove that the benchmark economy fairly well replicates the real economy. The correlations of macroeconomic variables with output mimic the benchmark economy in trade balance (-0.53, -0.90). In addition, trade balance shows well countercyclical effects with output. The correlation of capacity utilization with output shows procyclical effects at 0.95, reflecting the ability to generate the positive intertemporal co-movement of macroeconomic variables. Namely, the shocks can

[3] To exclude the effects of oil shocks, we compute the second moments of macroeconomic variables in the period of 1980:1 to 2001:4. When the beginning year is altered from 1970:1 to 1980:1, the standard deviation of GDP is changed from 2.70 to 2.68, which is a negligible change. Consumption increases from 2.28 to 2.61, whereas investment declines from 8.44 to 6.46. Trade balance rises from 2.41 to 2.48. Overall, the volatilities of consumption and external sector increases, but investment become relatively stable. However, serious changes in the economic structure are not shown.

not affect directly current capital stock, but they affect capacity utilization, and then increase capacity utilization rate and the use of capital stock.

[Table 2] Statistical Moments: Korean Data and the Benchmark Model

Variable	Korean data 1970:1-2001:4			Benchmark model		
	σ_x	$\rho_{xt,xt-1}$	$\rho_{xt,GDPt}$	σ_x	$\rho_{xt,xt-1}$	$\rho_{xt,GDPt}$
Output	2.70 (0.236)	0.74 (0.065)	1.0	2.70 (0.167)	0.72 (0.043)	1.0
Consumption	2.28 (0.268)	0.76 (0.139)	0.78 (0.042)	2.31 (0.143)	0.71 (0.044)	0.99 (0.001)
Investment	8.44 (0.572)	0.75 (0.062)	0.71 (0.047)	8.61 (0.534)	0.71 (0.044)	0.95 (0.009)
Capital Stock	1.25 (0.096)	0.93 (0.011)	-0.04 (0.110)	0.54 (0.030)	0.96 (0.007)	0.02 (0.086)
Capacity Utilization	-	-	-	2.61 (0.161)	0.69 (0.046)	0.95 (0.009)
Labour Supply	1.84 (0.154)	0.68 (0.097)	0.66 (0.061)	2.02 (0.125)	0.72 (0.043)	0.99 (0.001)
Interest Payment	28.72 (2.054)	0.59 (0.076)	-0.30 (0.091)	4.04 (0.232)	0.85 (0.030)	0.03 (0.088)
Trade Balance	2.21 (0.252)	0.78 (0.072)	-0.53 (0.086)	2.09 (0.130)	0.71 (0.044)	-0.90 (0.017)

Notes: The Korean data are obtained from the Database of Bank of Korea, divided by the 15+ population, logged and detrended by a Hodrick-Prescott filter with the smoothing parameter set at 1600. Output is real GDP, consumption and investment are total real values based on 1970:1-2001:4 period at constant prices in 1995. Labor supply is calculated by multiplying the average weekly working hours by the number of employed. Capital stock is gross capital stock, and interest payments are the net of foreign interest paid and received. Trade balance is divided by GDP. For each variable, σ_x is the percentage standard deviation, $\rho_{xt,x-t1}$ is the first-order autocorrelation, and $\rho_{xt,GDPt}$ is the contemporaneous correlation with GDP. σ_x and $\rho_{xt,xt-1}$ of the benchmark models are re-adjusted by those of GDP in real data. The values in parenthesis represent the standard deviations estimated by GMM (Generalized Method of Moment) using the Hansen-Heaton-Ogaki gauss program (Ogaki, 1993). The model statistics are based on sample average values of 100 simulations of 128 quarters.

Table 3 presents the findings of simulation when major parameters except for ϕ, γ and δ change by 10%. When capital adjustment costs (ϕ) change from 4.0 to 2.3, the volatility of investment increases from 8.61 to 11.70, and that of trade balance rises from 2.09 to 3.32. The change of the relative risk aversion coefficient (γ) affects the volatility of consumption rather than other variables. The changes of depreciation rate (δ) and adjustment costs(ϕ) have effects on the volatility of investment. In general, the macroeconomic variables of the benchmark model are stable to the change of parameters.

[Table 3] Sensitivity Analysis

	Volatility				First-order serialcorrelation				Correlation with output			
	C	I	N	TB	C	I	N	TB	C	I	N	TB
Baseline model	2.31	8.61	2.02	2.09	0.71	0.71	0.72	0.71	0.99	0.95	0.99	-0.90
γ=1.01	2.59	8.61	2.02	2.22	0.71	0.71	0.72	0.71	0.99	0.95	0.99	-0.92
3.0	2.22	8.61	2.02	2.05	0.71	0.71	0.72	0.71	0.99	0.95	0.99	-0.89
δ=0.018 ω=1.55	3.59	11.93	2.02	3.57	0.71	0.71	0.72	0.71	0.99	0.92	0.99	-0.90
ϕ =2.3	2.30	11.70	2.02	3.32	0.71	0.71	0.72	0.71	0.99	0.92	0.99	-0.87
β	2.42	8.61	2.02	2.16	0.71	0.71	0.72	0.71	0.99	0.95	0.99	-0.90
θ	2.43	8.66	1.97	2.19	0.71	0.71	0.72	0.71	0.99	0.95	0.99	-0.90
α	2.83	8.70	2.02	2.62	0.71	0.71	0.72	0.71	0.99	0.96	0.99	-0.90
r^*	2.12	8.20	2.02	1.80	0.71	0.71	0.72	0.71	0.99	0.95	0.99	-0.88

Note: The parameters except for γ, δ and ϕ are increased by 10% compared to the parameter values of baseline model. C: Consumption, I: Investment, N: Labour supply, TB: Trade balance.

4.2. Impulse Response Analysis

This section presents the impulse responses of economic variables to three shocks, which are productivity shock, investment-specific technology shock and world real interest rate shock. Impulse response analysis is useful to assess the dynamic characterisation of an economic system and to measure the magnitude of the effects of economic variables to the shock.

Figure 2 shows the impulse response of each variable to 1% positive shocks. A positive productivity shock causes an income effect to the economy. An increase in productivity raises output and then induces consumption and investment to increase. The impulse response functions indicate that positive shocks in productivity are followed by positive responses in output, consumption and investment. The responses shown in Figure 2 are quite similar in output, consumption and labour supply; however, investment, and capacity utilization differ in pattern and in magnitude, and trade balance shows a negative effect. It is noticeable that a positive shock in productivity increases the efficiency of investment and has two effects on the economy. First, it augments the demand for investment. Second, an increase in the efficiency of investment reduces the cost of capital utilization and thus induces a higher capacity utilization. A distinguished feature is that the convergence of output and consumption are slow, whereas investment and capacity utilization converge quickly to the equilibrium. Moreover, the initial shock increases consumption and investment, and then raises imports more than exports, and thus decreases trade balance as can be seen from Figure 2.

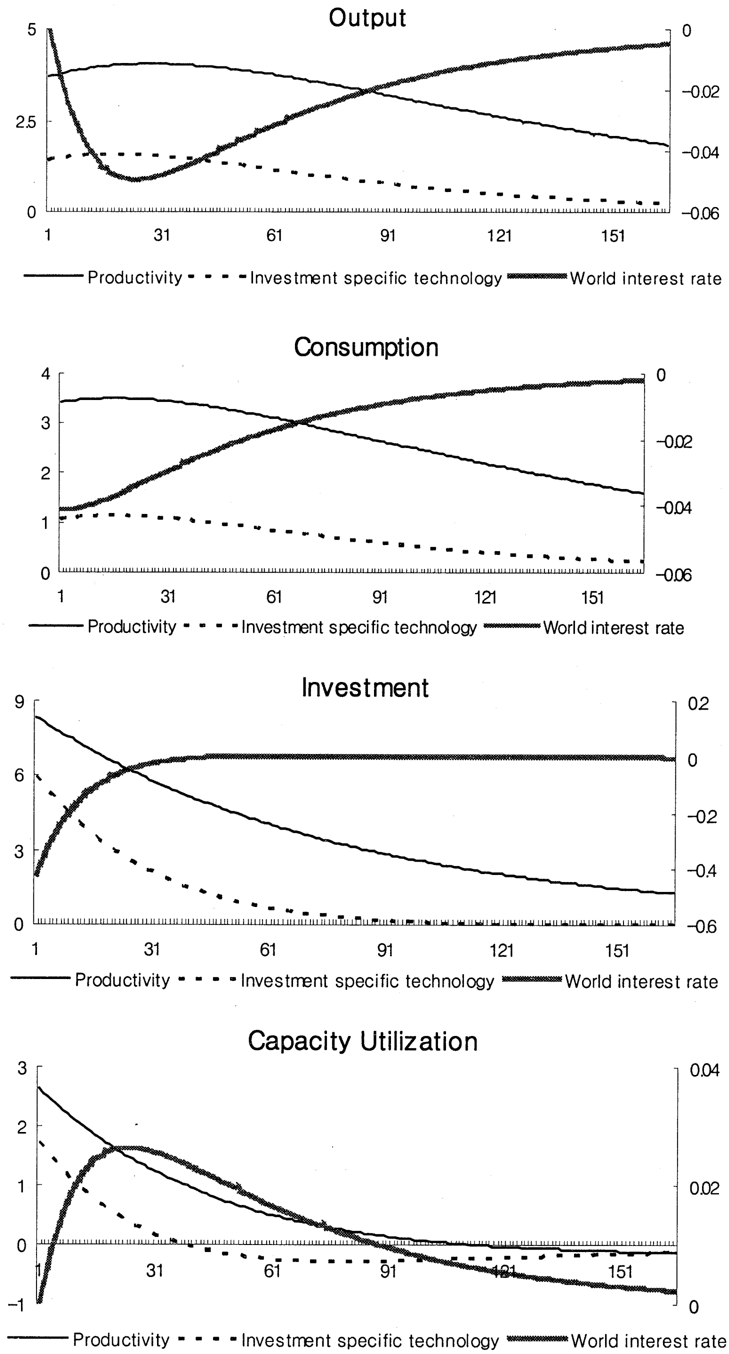
As can be seen from Figure 2, a positive investment-specific technology shock has a positive effect on investment and output. However, the effect of the shock on consumption can be ambiguous because consumption has positive income effect and negative substitution effect. The shock on the investment increases the efficiency of investment, and thus the substitution from consumption to investment happens. From Figure 2, the positive income effect overwhelms the negative substitution effect. Accordingly, the effect of the shock on consumption is smaller than the effect of the shock on GDP, even though consumption responds positively to the shock. On the other hand, the effect of the shock on investment is more than the effects on GDP, consumption, and capacity utilization. A positive investment-specific technology shock increases GDP, and then raises exports. However, the increased GDP also raises imports. Consequently, the shock raises imports more than exports, and the trade balance decreases. Differently from productivity shock and investment-specific technology shock, the shock on world interest rate decreases GDP, consumption, investment and labour supply, but increases trade balance. The positive shock on world real interest rate raises the borrowing cost from world financial markets. Hence, the marginal utility of consumption and the marginal production of capital should increase, and thus consumption and investment decrease. The shock on world real interest rate has an opposite effect of productivity shock even though the size in magnitude of the effects is different.

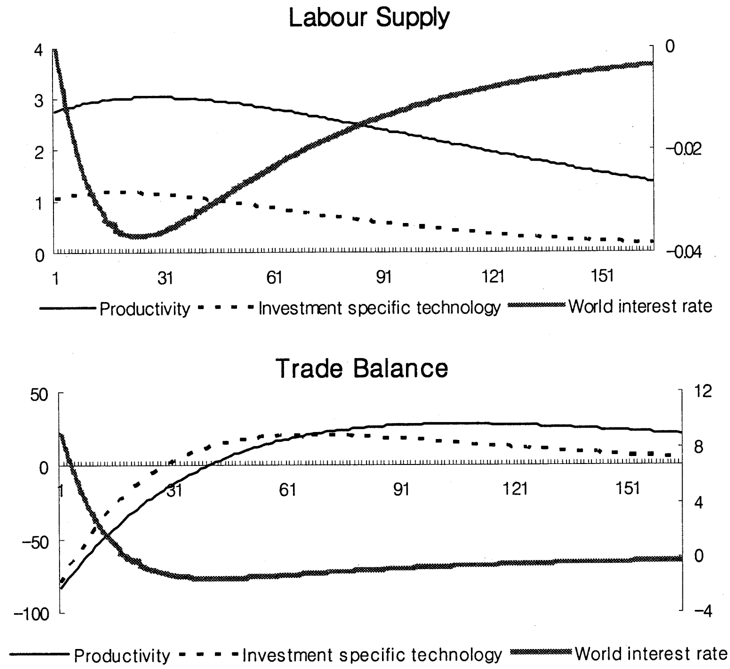
In general, the productivity shock and investment-specific technology shock have positive effects on macroeconomy, while the shock in world real interest rate has negative effects on macroeconomy.

Although productivity shock has stronger effects on macroeconomy than investment-specific technology shock, if we consider that the volatility of investment specific technology shock (4.25%) is over two times as much as that of productivity shock (2.02%), the investment specific technology shock is considered as the meaningful source of Korea's business fluctuations. For example, from Figure 3, the impulse response of each variable to standard deviation shocks shows the increase in relative magnitude in the case of investment specific technology shock. Especially, the initial effects of investment specific technology shock on investment, capacity utilization and trade balance overwhelm those of productivity shock.

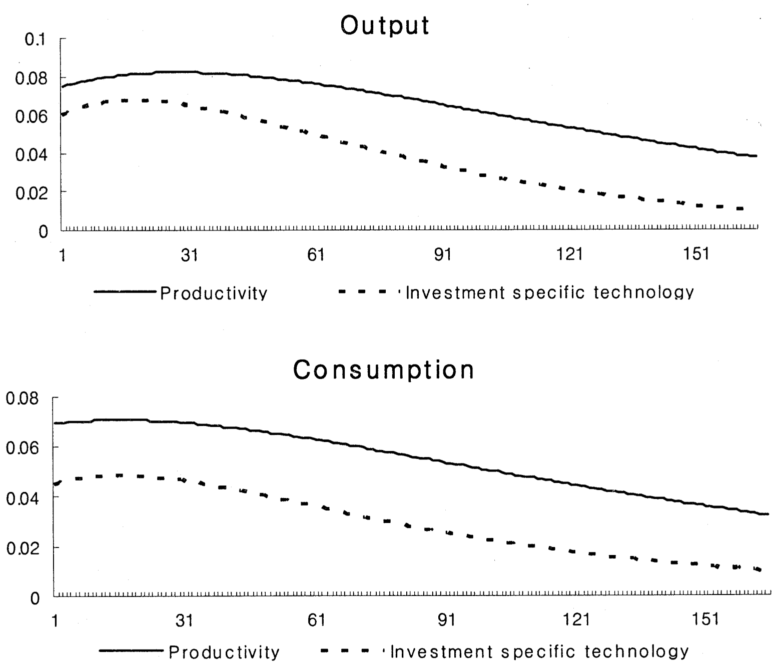
In other words, Investment-specific technology shock increases the efficiency of investment, and thus raises capacity utilization more than productivity shock. As a result, the shock accelerates the depreciation of old capital and increases new investment. Moreover, the efficiency of investment causes substitution effect from consumption to investment. Accordingly, investment specific technology shock shows stronger effects on capacity utilization and investment than productivity shock in Figure 3.

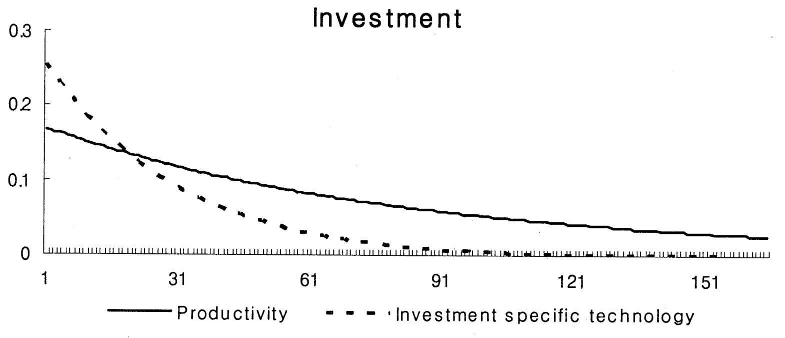
[Figure 2] Impulse Responses to 1% Shocks of Productivity, Investment-Specific Technology and World Interest Rate

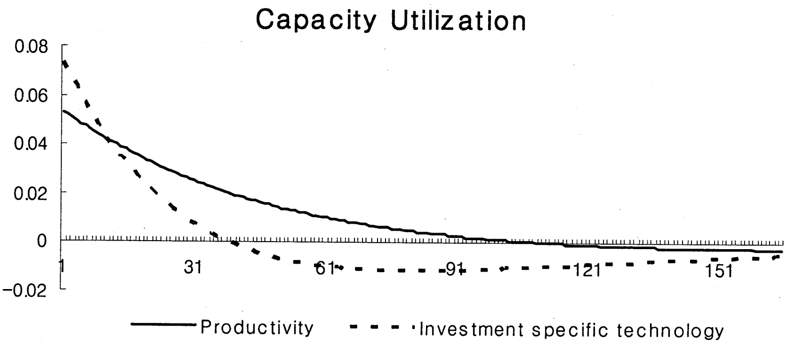


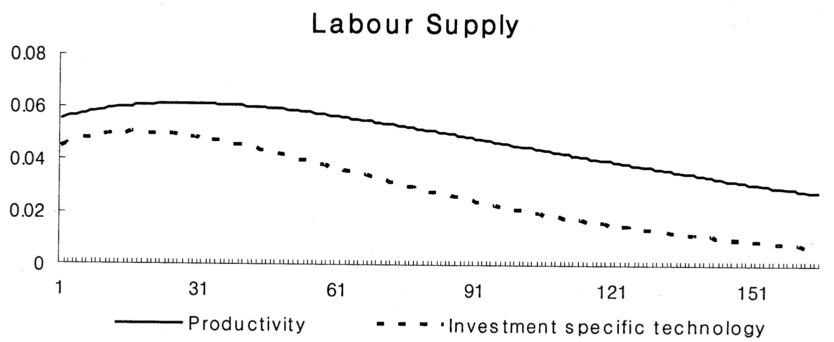


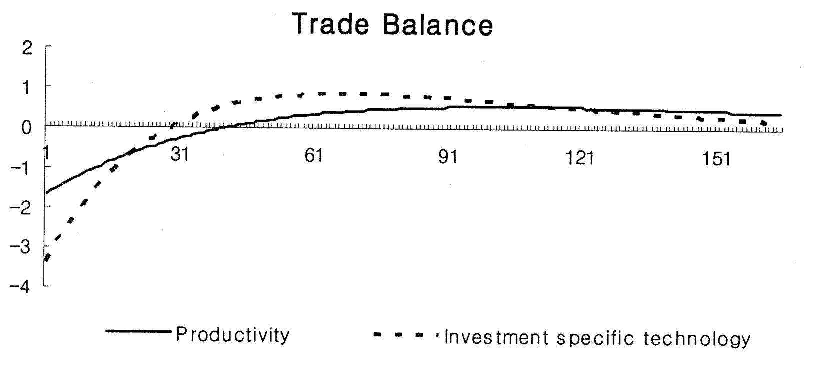
[Figure 3] Impulse Responses to the Standard Deviation Shocks of Productivity and Investment-Specific Technology




Investment
0.3
0.2
0.1
0
1
31
61
91
121
151
Productivity
Investment specific technology


Capacity Utilization
0.08
0.06
0.04
0.02
0
-0.02
1
31
61
91
121
151
Productivity
Investment specific technology


Labour Supply
0.08
0.06
0.04
0.02
0
1
31
61
91
121
151
Productivity
Investment specific technology


Trade Balance
2
1
0
-1
-2
-3
-4
1
31
61
91
121
151
Productivity
Investment specific technology

V. CONCLUDING REMARKS

Our paper analyzes an international real business cycle model of a small open economy such as Korea. Under the assumption that the model of the economy has productivity shock, investment-specific technology shock and world real interest rate shock, our paper especially investigates the central issue of how the economic variables fluctuate in response to the shocks. Specifically, we try to find out the role of investment-specific technology shock and world real interest rate shocks on the Korean economy, which has been developed by export driven policy based on continuous investment acceleration.

We conducted the quantitative analysis on the effects of shocks using the Korean data. The model economy fairly well replicates the real economy features in properties of second moments. The finding of sensitivity analysis supports that the model is stable. The elasticity of substitution in consumption affects relatively strongly the variables. From impulse response analysis, productivity and investment specific technology shocks increase output, consumption and investment, while the shocks decrease trade balance even though investment-specific technology shock has weaker effects on the Korean economy than productivity shock. However, by considering the volatility of investment-specific technology shock is higher than productivity shock, we find out that investment-specific technology shock is a meaningful source of the business fluctuations in Korea. On the other hand, a positive world rela interest rate shock has negative effects on macroeconomy.

APPENDIX : DATA

The Korean real data are mainly obtained from the database of the Bank of Korea. All series are composed of quarterly observations from 1970:1 to 2001:4 and adjusted seasonally by X-12 ARIMA. *Output*: real GDP, 1995 price. *Consumption*: final consumption expenditure, 1995 price. Investment: gross fixed capital formation, 1995 price. *Capital stock*: gross capital stock, 1995 price. *Labor supply*: the number of employed laborers × weekly hours worked. *Population*: population aged 15 years and over. *Interest payments*: (nominal investment income to overseas-nominal investment income from overseas) ÷ GDP deflator. *Trade balance*: (exports of goods and services-imports of goods and services)/ GDP. *World interest rate*: prime bank lending rate of USA

REFERENCE

Backus, D.K., Kehoe, P.J., Kydland, F.E. (1992), "International real business cycles," *Journal of Political Economy*, 100, pp.745-775.

Cardia, E. (1991), "The dynamics of a small open economy in response to monetary, fiscal, and productivity shocks," *Journal of Monetary Economics*, 28, pp.411-434.

Christiano, L.J. (1998), "Solving Dynamic Equilibrium Models by a Method of Undetermined Coefficients," Technical working paper, 225, National Bureau of Economic Research.

Correia, I., Neves, J.C., Rebelo, S. (1995), "Business cycles in a small open economy," *European Economic Review*, 39, pp.1089-1113.

Greenwood, J., Hercowitz, Z. and Huffman, G.W. (1988), "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, 78, pp.402-417.

Greenwood, J., Hercowitz, Z. and Krusell, P. (1997), "Long-Run Implication of Investment-Specific Technological Change," *American Economic Review*, 87, pp.342-362.

Greenwood, J., Hercowitz, Z. and Krusell, P. (2000), "The Role of Investment-Specific Technological Change in the Business Cycle," *European Economic Review*, 44, pp.91-115.

Keynes, J. M. (1936), The General Theory of Employment, Interest and Money (London: Macmillan).

Kim, J.Y. (1996), "Gross Capital Stock in Korea: Capital Stock Estimation in Private and Government Sectors," Korean Economy Research Institute, in Korean.

Mendoza, E.G. (1991a), "Capital Controls and the Gains from Trade in a Business Cycle Model of a Small Open Economy," IMF staff papers, 38, pp.480-505.

Mendoza, E.G. (1991b), "Real Business Cycles in a Small Open Economy," *American Economic Review*, 81, pp.797-818.

Mendoza, E.G. (1995), "The terms of trade, the real exchange, and economic fluctuation," *International Economic Review*, 36, pp.101-137.

Ogaki, M. (1993), "GMM: A User Guide," RCER working paper, No. 340, University of Rochester.

Park, H.S. (1999), "Real business cycle model in Korea," Economic Analysis 1, Financial Research Institute, Bank of Korea, in Korean.

Rossi, N. (1988), "Government spending, the real interest rate, and the behaviour of liquidity-constrained consumers in developing countries," IMF Staff Papers, 35, pp.104-140.

Senhadji, A.S. (1998), "Dynamics of the trade balance and the terms of trade in LDCs: the S-curve," *Journal of International Economics*, 46, pp.105-131

Schmitt-Grohe, S. (1998), "The international transmission of economic fluctuations: effects of U.S. business cycles on the canadian economy," *Journal of International Economics*, 44, pp.257-287.