Dynamics of Business Cycles in Korea:
The Role of External Shocks

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외부충격이 한국의 경기변동에 미치는 영향에 관한 연구

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ABSTRACT

Using a multi-sector dynamic stochastic general equilibrium model, we investigate the dynamic effects of a variety of shocks to a small open economy. In particular, we calibrate the model to match the main characteristics of business cycles in Korea and analyze the effects of external shocks: the terms of trade and world real interest rate shocks. Business cycles in Korea more closely follow those of the G7 countries rather than Asian countries. The simulation results suggest that an improvement in the terms of trade has positive impact on investment, output and consumption, while a decrease in the world interest rate has a significant and positive effect on investment. This paper concludes that external shocks significantly influence business cycle fluctuations in Korea.

　본 논문은 소규모 개방경제 모델을 이용하여 여러 가지 실물부문의 충격이 한 국경제의 주요 거시변수에 미치는 영향을 동태 시뮬레이션 방법을 이용하여 분석하였다. 보다 현실적인 실물경제를 반영하기 위하여 기존의 경기변동 모델에 우리 경제의 특징적인 요소 몇 가지를 더하였다. 예를 들어, 수출재, 수입재 및 비교역재가 있는 재화시장과 채권시장을 통한 국제간 자본이동이 가능한 모델을 도입하였다. 특히 본 논문에서는 생산성 충격, 정부지출 충격 등의 국내 내부의 충격요인과 외부 금리 및 교역조건충격 등의 외부 충격요인의 상대적인 역할을 비교하였다. 시뮬레이션 결과에 의하면, 교역조건의 개선은 투자, 생산 및 소비를 늘리고, 국제금리 인하는 국내 투자에 상당한 정도의 긍정적인 효과가 있는 것으로 나타난다. 결론적으로, 본 논문은 우리 경제의 경기변동 정도가 아직도 외부충격에 의해 큰 영향을 받는다는 것을 보여준다.

I. Introduction

External shocks, such as shocks on the world interest rate, exchange rate, and the terms of trade, can notably influence business cycles in small open economies. Many researchers have empirically examined the effects of external shocks on business cycles using various time series estimation methods including the Vector Autoregressive (VAR) estimation. However, the estimation analysis lacks a systematic and theoretical interpretation of estimation results, which necessitates an analysis based on dynamic stochastic general equilibrium (DSGE) models. A number of papers have examined business cycle properties of developed countries using DSGE models.[1] However, there are few serious studies on Korean business cycles using DSGE models.[2]

This paper constructs a fully expanded DSGE model for a small open economy and calibrates the model to match business cycle statistics in Korea. We aim to explain the dynamic effects of internal and external shocks on key macroeconomic variables in Korea. In particular, we address the following questions: (1) What are the dynamic effects of sectoral productivity shocks on aggregate output, consumption, investment, and external accounts?; (2) How do macroeconomic variables respond to changes in the U.S. interest rate and in the terms of trade? Answering these questions is essential to formulating policies to stabilize the economy in a volatile economic environment.

The model used in this paper reflects several key characteristics of small open economies. First, we specifically consider three goods in the model—exportables, importables and nontraded goods. Second, production activities take place in the exportable and nontraded sectors, where each sector has its own physical capital accumulation process. Third, the production in the export sector uses imported intermediate goods. Fourth, the model explicitly formulates world financial markets where domestic households can trade risk-free international bonds (incomplete markets economy). Finally, agents in the model face several stochastic shocks. Domestic shocks are represented by changes in government spending and movements in productivities in the exportable and nontraded sectors. There are two external shocks in the model: the terms of trade shocks (or real exchange rate shocks) and the world real interest rate shocks. Since Korea is a small open economy with export-oriented industry structure and liberalized financial markets, this model is well suited to analyze stylized facts of business cycles in Korea as well as cyclical effects of external shocks.

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[1] For DSGE models on small open economies, see Mendoza (1991), Cardia (1991), and Kollmann (1995, 1998, 2001). Two-country DSGE models include Backus et. al (1995), Baxter (1995), Kim (1997), and Kose (2002).

[2] There are a number of empirical papers on business cycles in Korea. Yoo (1990) employed VAR and Yoo (1992, 1995), Park (1997), and Kim (1994) used Structural VAR models to analyze the effects on macroeconomic variables induced by real shocks to the Korean economy. Some employed closed-economy DSGE models to explain business cycles in Korea, including Jo (1991, 1997) and Lee (1996). Using a simple open economy setup, Park (1999) analyzed the role of external shocks on business cycles in Korea. Existing real business cycle studies on other open economies include Correia et al. (1992) for Portugal, Bruno and Portier (1995) for France, Harjes (1997) for Germany, and Tantitemit (2001) for Thailand.

Due to the highly nonlinear nature of the model, it is impossible to solve it directly using nonlinear solution methods. We therefore solve this model by applying a numerical approximation method suggested by Sims (2002) which is based on the linearization of the first-order conditions around the steady-states. The simulation results suggest that an improvement in the terms of trade has positive effects on investment, output and consumption, while a decrease in interest rate has a significant and positive effect on investment. External shocks significantly impact business cycle fluctuations in Korea.

The remaining sections are organized as follows. In section 2, we document the main characteristics of business cycles in Korea and compare them with other Asian and G7 countries. In section 3, we construct the model and provide a detailed solution. Section 4 explains how we calibrate the model parameters using the Korean data. In section 5, we compare the properties of the business cycles generated by the model with those actually observed in Korea in order to find the fit of the model. In section 6, we analyze the impulse responses of key macroeconomic variables to exogenous shocks, in particular, productivity, the terms of trade and world interest rate shocks, to study the propagation mechanisms generated by these shocks. Finally, section 7 offers the conclusion of the paper.

II. Properties of Business Cycles in Korea

In this section, we document the main characteristics of business cycles in Korea and compare them with those in OECD and other Asian countries. In particular, we investigate the second moments of main macroeconomic variables: volatility, persistence and co-movement with output. Volatility measures the amplitude of fluctuations; persistence indicates the amount of inertia in business cycles; and co-movement provides information on whether a series behaves pro-cyclically or counter-cyclically.

We use annual data from 1960 to 1996. We do not include data between 1997 and 2001 since the Asian crisis in 1997 makes the data during 1997-2001 outliers of the sample and the inclusion of this period would distort the statistics. We also present the statistics of the second half of the sample period from 1985 to 1996 because of potential structural changes in the Korean economy.[3] All of the data are properly treated and detrended. We use the Hodrick-Prescott filtering for detrending.[4]

Table 1 reports the business cycle statistics of Korea. In general, Korea's business cycle statistics match the main characteristics of business cycles reported in the literature[5]: (1) consumption is less volatile and investment is more volatile

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[3] A significant shift in policies towards capital flows occurred in the mid-1980s due to capital account liberalization (Kim et al. 2003).

[4] We set the value of smoothing parameter at 100, which is the conventional value used for annual data in the literature.

[5] See Backus and Kehoe (1992) for the stylized facts on business cycles in major economies.

<Table 1> Business Cycle Statistics of Korea

	Volatility		Relative Volatility		Persistence		Co-movement with Y	
	1960~96	1985~96	1960~96	1985~96	1960~96	1985~96	1960~96	1985~96
Y	3.05	2.14	1	1	0.55	0.57	1	1
C	2.27	1.71	0.74	0.80	0.44	0.51	0.38	0.41
I	11.36	6.50	3.72	3.03	0.56	0.63	0.45	0.60
G	7.86	2.38	2.58	1.11	0.59	0.50	0.23	0.21
EX	10.96	9.14	3.59	4.27	0.35	0.54	0.22	0.32
IM	8.71	5.09	2.86	2.38	0.40	0.46	0.11	0.24
NX	10.48	7.58	3.43	3.54	0.31	0.41	0.14	0.22
CPI	6.58	2.03	0.66	0.54	*	*	-0.63	-0.40
M	14.62	2.09	4.79	0.98	0.71	0.52	0.33	0.70

Notes: (1) Y: output, C: consumption, I: investment, G: government spending, EX: exports, IM: imports, NX: net exports, CPI: consumption price index, and M: money supply.
(2) All data in the tables are real at 1990 prices and logged and detrended using the Hodrick-Prescott filter with the smoothing parameter set at 100. Volatility is measured by the standard deviation and persistence is measured by the first order autocorrelation coefficient of the filtered series. Contemporaneous co-movement with output is measured by the correlation between the filtered series and filtered output. The reported statistic of persistence for the 60-96 period is significant at the 5% level if it lies outside of [-0.32 , 0.32].

(three to four times more) than output. Both exports and imports are more volatile than output; (2) All macroeconomic series are highly persistent; (3) Consumption and investment are procyclical. There are some exceptions: the correlation between consumption and output is quite small and the correlation between net export and output is positive. Usually, net export and output are negatively correlated as can be seen in the statistics for other countries in Table 2.[6]

Comparing the statistics from the whole period with those from the second half of the sample periods 1985-1996, we make several important observations. In particular, volatility of all macroeconomic variables significantly decreased in the second period. Several factors provide the explanation: first, the measures of fiscal and monetary policy variables, such as government expenditure and money stock, appear to be less volatile in the second period, suggesting a higher degree of stabilization in economic policy formation. Second, as financial markets have developed in Korea, the set of financial instruments used for hedging against different types of shocks and for providing a variety of risk-sharing opportunities has expanded. This, in turn, has reduced the volatility of business cycles. Third, global economic shocks, such as the global expansion in the 1960s, breakdown in the international financial order, oil price shocks in the 1970s, and the debt crisis in the early 1980s, were much stronger in the first period.

In Table 2, we compare the main characteristics of business cycles in Korea with those of Asian and G7 countries. We select seven Asian countries—Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan, and Thailand—to derive the

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[6] Other studies (Park, 1999) also reported that net exports are procyclical. This result, however, is sensitive to the selection of estimation period. Using data in different periods, we find that the net export-output correlation can be negative in some periods.

<Table 2> Comparison with Other Countries

<Relative Volatility>

	Korea	Asian average	G7 average
Y (volatility)	2.14	2.00	2.16
C	0.80	1.84	0.91
I	3.03	4.39	3.33
G	1.11	2.97	0.98
EX	4.27	3.62	3.08
IM	2.38	3.69	3.41
NX	3.54	2.95	2.45
CPI	0.54	0.54	0.73
M	0.98	2.35	2.34

<Correlation with Output>

	Korea	Asian average	G7 average
C	0.41	0.46	0.90
I	0.60	0.58	0.92
G	0.21	0.25	0.10
EX	0.32	0.32	0.19
IM	0.24	0.49	0.55
NX	0.22	-0.24	-0.57
CPI	-0.40	-0.05	0.06
M	0.70	0.39	0.41

Note: refer to table 1 for definition of variables. Data period is 1985-96. For Y, the numbers reported are actual volatility (standard deviation), not relative volatility.

average business cycle statistics for Asian countries.[7] Note that all the statistics in Table 2 are from the 1985-1996 period.

In terms of output volatility, Korea and other countries (both Asian and G7 countries) are similar with a standard deviation of approximately 2%.[8] However, other variables show that the volatilities are much lower in the G7 countries than in Asia. We find that the statistics of Korea are more similar to those of the G7 countries than with the Asian countries. In particular, consumption volatility in Korea is very low at approximately 0.8, which is almost at the level of the G7 countries (around 0.91), whereas the average volatility in Asia is high (1.84).

Concerning co-movements with output, G7 countries show a very high correlation between output, consumption and investment (around 0.9), while Korea and other Asian countries show a low correlation of approximately 0.4-0.5. One distinctive feature, mentioned previously, is that the correlation between net exports and output is negative in other Asian and G7 countries, while it is positive in Korea. An increase in output (a boom in the economy) usually worsens the trade balance by increasing investment or spending on imported goods.

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[7] These statistics are taken from Kim, et al. (2003). The appendix also explains the detailed sources of data.
[8] In the 1960s and 1970s data, output is less volatile in G7 countries than in Asia.

III. Model

There are three goods consumed in this small open economy: exportables (*x*), importables (*m*), and nontraded goods (*n*). Two goods (exportables and nontraded goods) are domestically produced. A representative agent solves

$$\max \ E_0 \sum_{t=0}^{\infty} \beta^t U_t, \ \text{and} \ U_t = \frac{\left(c_t - \frac{(1-l_t)^\theta}{\theta} \right)^{1-\sigma}}{1-\sigma}, \tag{1}$$

where l_t is leisure and c_t is a composite consumption good that consists of the three goods.

Our momentary utility formulation implies that the elasticity of substitution associated with leisure is zero. This utility function (hereafter "GHH preference") is introduced by Greenwood, Hercowitz, and Huffman (1988) and is widely used in open economy DSGE models.[9]

We can separate the nontraded good out of the budget constraint. We use the importable good as a numeraire. Then the budget constraint with incomplete financial markets becomes

$$B_{t+1} + \frac{\Phi}{2}(B_{t+1} - \overline{B})^2 = nx_t + (1+r_t)B_t, \tag{2}$$

where B_t is international bond with interest rate r_t and nx_t is net exports, which is described below. $\overline{B}$ is the steady state bond holdings. B_t is denominated in terms of import good. Φ represents the magnitude of bond holding adjustment costs that is proportional to the amount of international lending or borrowing. Using the bond holding adjustment costs allow us to avoid the nonstationarity problem in the small open economy model with incomplete markets.[10] We also assume that this bond holding adjustment cost is paid to a certain international institution and therefore disappears from the national budget constraint.[11]

The net exports can be expressed as

$$nx_t = p_{xt} y_{xt} - p_{xt} c_{xt} - c_{mt} - i_{xt} - i_{nt} - s_t, \tag{3}$$

where p_{xt} is the price of exportables and s_t is the imported intermediate input that is used to produce an exportable good. We assume that the production of exportables and nontraded goods requires imported capital goods. That is, both i_{xt}

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[9] See Correia, et al. (1995) and Crucini (1999) for the comparison of dynamic implications of the GHH utility function with those of the Cobb-Douglas utility function.

[10] See Mendoza (1991) and Kim and Kose (2003) for a detailed discussion on this issue.

[11] In the closed economy, one should have the bond holding adjustment costs transfer back to the household to close the national accounting system.

and i_{nt} are imported.

The resource constraint in the nontraded sector becomes

$$y_{nt} = c_{nt} + G_{nt},$$ (4)

where G_{nt} is government spending in nontraded goods. The price of a nontraded good is denoted as p_{nt}.

Composite good c_t consists of consumption on three goods, c_m, c_n, and c_x as follows:

$$c_t = \left[b_x c_{xt}^{1-\gamma} + b_m c_{mt}^{1-\gamma} + b_n c_{nt}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}, b_x + b_m + b_n = 1.$$ (5)

Total expenditure on consumption can be expressed as the sum of expenditure on each good:

$$p_t c_t = c_{mt} + p_{nt} c_{nt} + p_{xt} c_{xt},$$ (6)

where p_t is the price of composite good c_t. All the prices are normalized in terms of importables (p_{mt})-which means that p_{xt} is the price of exportables in terms of importables.

Maximizing (5) subject to (6) yields an equilibrium expression for relative demand for each consumption good and the price of the composite consumption good:

$$\frac{c_{xt}}{c_t} = b_x^{\frac{1}{\gamma}} \left(\frac{p_{xt}}{p_t} \right)^{-\frac{1}{\gamma}},$$ (7)

$$\frac{c_{mt}}{c_t} = b_m^{\frac{1}{\gamma}} \left(\frac{1}{p_t} \right)^{-\frac{1}{\gamma}},$$ (8)

$$\frac{c_{nt}}{c_t} = b_n^{\frac{1}{\gamma}} \left(\frac{p_{nt}}{p_t} \right)^{-\frac{1}{\gamma}},$$ (9)

$$p_t = \left[b_x^{\frac{1}{\gamma}} p_{xt}^{\frac{\gamma-1}{\gamma}} + b_m^{\frac{1}{\gamma}} + b_n^{\frac{1}{\gamma}} p_{nt}^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}.$$ (10)

Production functions for the exportable and nontraded goods are

$$y_{xt} = A_{xt} h_{xt}^{\omega} \left[a(k_{xt})^{1-z} + (1-a)(s_t)^{1-z} \right]^{\frac{(1-\omega)}{1-z}},$$ (11)

$$y_{nt} = A_{nt} h_{nt}^{\sigma_1} (L_t)^{\sigma_2} (k_{nt})^{1-\sigma_1-\sigma_2},$$ (12)

where L_t is land that is exogenously given.

Capital accumulation equations are

$$k_{x,t+1} = (1-\delta_x)k_{xt} + k_{xt}\phi\left(\frac{i_{xt}}{k_{xt}}\right),\tag{13}$$

$$k_{n,t+1} = (1-\delta_n)k_{nt} + k_{nt}\phi\left(\frac{i_{nt}}{k_{nt}}\right),\tag{14}$$

where δ denotes depreciation rate and $\phi(.)$ represents the standard adjustment cost function with $\phi(.) > 0$, $\phi(.)' > 0$, and $\phi(.)'' < 0$ (see Baxter and Crucini, 1993).

Labor hours are subject to the following constraint, in which the sum of working hours and leisure is normalized to one:

$$h_{xt} + h_{nt} + l_t = 1 .\tag{15}$$

There are five exogenous shocks that we can incorporate into the model. They are sectoral productivity shocks (A_{xt}, A_{nt}), government spending shock (G_{nt}), the world real interest rate shock (r_t), and the terms of trade shock (p_{xt}).

Since the model cannot be solved analytically, we solve the model numerically using linearization.[12] The linearized equation system can be cast into the set matrix system,

$$\Gamma_0\hat{x}_{t+1} = \Gamma_1\hat{x}_t + \Gamma_2\varepsilon_{t+1} + \Gamma_3(\hat{x}_{t+1} - E_t\hat{x}_{t+1}),\tag{16}$$

where the hat variable is the percentage deviation from its steady state. Note that the coefficient matrices, $(\Gamma_0,\Gamma_1,\Gamma_2,\Gamma_3)$, are nonlinear functions of the deep parameters. The system is solved following Sims (2002), whose method is a generalization of Blanchard and Khan (1980).[13]

If there is a unique equilibrium, the solution takes the following form:

$$\hat{x}_{t+1} = \Psi_1\hat{x}_t + \Psi_2\varepsilon_{t+1}.\tag{17}$$

where there is no expectations term. The coefficient matrices (Ψ_1,Ψ_2) are functions of the deep parameters and thus, the solution is a restricted VAR. We can interpret Ψ_1 as persistence of variables and Ψ_2 as effects of current shocks on the model variables.

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[12] The detailed sets of first order conditions, steady state equations and the linearized first order conditions are explained available upon request.

[13] We use a modified version of the MATLAB program gensys. The program reads ($\Gamma 0,\Gamma 1,\Gamma 2,\Gamma 3$) as inputs and writes ($\Psi 1,\Psi 2$) as outputs.

IV. Calibration

We calibrate the structural parameters to correspond to the existing real business cycle literature and to be consistent with the long-run features of the Korean economy. We fix the value of β at 0.954 to match the annual steady state world real interest rate at 4.8 % which is the average rate calculated using the U.S. three-month T-Bill rate deflated with CPI inflation. Following Mendoza (1991), the elasticity of substitution, *w*, is set to 1.455. The value of risk aversion parameter σ is set at 2.61 following Ostry and Reinhart (1992).

The value of γ is set at 0.93 to match the elasticity of substitution in the aggregate consumption function at 1.07 which is the average value used in Ostry and Reinhart (1992). As γ decreases, consumption responds more to the changes in relative prices. The bond holding adjustment costs is set to match the volatility of the trade balance (or the current account). Shares parameters (b_m, b_n, b_x) in the CES form consumption function are set to match the actual consumption shares in the data. The data show that the export good share is 11%, import good share is 21% and the nontraded good share is 68%.[14]

We set the depreciation rate at 13% for both production sectors, which is estimated by the Bank of Korea and also within a range of commonly used values in the literature. Labor share in the export good production ω is set at 0.48 following the Bank of Korea Annual Statistics. Others have used numbers ranging from 0.12 to 0.45 (Kouparitsas, 1997). Share of capital against the imported intermediate good is set at 0.55 (Kose, 2002). Elasticity of substitution between capital and imported intermediate good z is set at 1.35 following Kose (2002). Labor share in nontraded good production α_1 is set at 0.38 and the share of capital in nontraded good production is set at 0.4, following Kose (2002).

The adjustment cost parameters in capital accumulation equations are chosen so that the steady state of the model is the same as one without adjustment costs. This implies that $\phi(i/k) = i/k$ and $\phi'(i/k) = 1$. The steady state value of i/k is equal to the depreciation rate δ. The elasticity of the marginal adjustment cost function, $\eta = -(\phi'/\phi'')(i/k)^{-1}$, is set to 10, to match the volatility of investment in the data (cf. Baxter and Crucini 1993). We set the steady state land share in terms of nontraded output at 25% and the share of government expenditure in terms of nontraded output at 20%.

The next step is to calibrate the shocks. For the productivity measures for the exportable and nontraded sectors, we use the Solow residuals derived from the Cobb-Douglas production function without capital input following Backus et al. (1992) and Glick and Rogoff (1995).[15] For the elasticity of substitution in

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[14] We take the averages of the shares between 1985 and 1996 to be consistent with the sample period in the stylized facts section. Details of how we construct the sectoral production and employment data are reported in the appendix.

[15] Glick and Rogoff (1995) argued that adjusting for capital inputs should not produce radically different results since, if one explores the U.S. data, short-term movements in capital are small relative to short-term movements in labor. One might argue that the problems in constructing comparable capital stock measures in cross-country data are so severe that attempts to adjust for capital inputs are not that reliable.

production function, we use the value from Stockman and Tesar (1995) and Park (2000). For other shock variables, we follow the standard definitions. Detailed descriptions of the data are in the appendix.

<Table 3> Calibration

Parameter	Description	Parameter Values
Preferences		
β	Discount factor, $r = (1/\beta) - 1$	0.954
R	Real interest rate	4.8% (annual)
Γ	Coefficient of intratemporal elasticity of substitution between consumption goods	0.93
σ	Coefficient of relative risk aversion	2.61
θ	Intertemporal elasticity of substitution in labor supply	1.455
b_m	Weight of imported goods (in consumption)	0.21
b_x	Weight of exported goods	0.11
b_n	Weight of nontraded goods	0.68
Technology		
Export Goods Sector		
ω	Share of labor income	0.48
z	Coefficient of intratemporal elasticity of substitution between capital and imported intermediate inputs	1.35
a	Weight of capital input in the CES composite	0.55
δ_x	Depreciation rate	0.13 (annual)
η_x	Elasticity of marginal adjustment cost function $\eta_x = -(\phi'/\phi'')/(i_x/k_x)$	10
Nontraded Goods Sector		
a_1	Share of labor income	0.38
a_2	Share of land income	0.22
δ_n	Depreciation rate	0.13 (annual)
η_n	Elasticity of marginal adjustment cost function $\eta_n = -(\phi'/\phi'')/(i_n/k_n)$	10
Other steady state values		
yn	Share of land in y_n	0.25
g_{yn}	Share of government expenditure in y_n	0.20
b_{yx}	Share of initial financial asset position in y_x	0
p_x	Initial terms of trade (index)	1
Φ	Adjustment cost of asset holdings	1e-4

<Table 4> Characteristics of Exogenous Shocks

Persistence (AR(1) Coefficients)

Productivity shock (export sector) : A_{xt}	0.95
Productivity shock (nontraded sector) : A_{nt}	0.96
Terms of trade shock : p_{xt}	0.55
World real interest rate shock : r_t	0.70
Government spending shock : G_{nt}	0.95

Standard deviation (correlation coefficient)

	A_{xt}	A_{nt}	p_{xt}	r_t	G_{nt}
A_{xt}	0.0824				
A_{nt}	0.8727	0.0112			
p_{xt}	0.3520	0.2210	0.0137		
r_t	-0.4113	-0.5145	-0.5639	0.0127	
G_{nt}	0.0037	-0.1954	-0.0167	-0.0830	0.0094

Note: The diagonal terms are standard deviations and the off-diagonal terms of correlation coefficients.

All five shocks that we consider in the model are assumed to follow an AR(1) process. We estimate the AR(1) coefficients from OLS regressions of the shock variables, which are reported in Table 4. We calculate the correlation coefficients-standard deviation matrix of the five shocks and they are also reported in the table.

. Comparing the Second Moments

In this section, we compare the business cycle moments generated by the model with the actual statistics from the data reported in section 2. We simulate the model for 50 periods with our benchmark parameterization and report the average moments over 500 simulations. All results refer to the moments of Hodrick-Prescott (HP 100) filtered variables (cf. Hodrick and Prescott, 1997).

Table 5 reports the statistics from the data and the model. In general, the model successfully matches the moments. In relative volatility, the model produces more volatile investment (relative volatility of 3.52) and less volatile consumption (relative volatility of 0.98) than output, which correctly captures the data statistics in Korea. The export series from the model (and therefore net exports as well) are not as volatile as in the data, partly because of the GHH preference structure where the amount of production and export are directly determined by the amount of labor input. However, these statistics are consistent with the stylized fact that export and import series are more volatile than output in general.

<Table 5> Simulated Second Moments

	Relative Volatility		Persistence		Co-movement with Y	
	Data	Model	Data	Model	Data	Model
Y	1	1	0.57	0.61	1	1
C	0.80	0.98	0.51	0.54	0.41	0.98
I	3.03	3.52	0.63	0.22	0.60	0.54
EX	4.27	1.03	0.54	0.68	0.32	0.98
IM	2.38	2.28	0.46	0.34	0.24	0.71
NX	3.54	1.30	0.41	0.57	0.22	-0.24

In terms of persistence, the model matches the data very well. For co-movements with output, the model predicts an excessively high correlation between consumption and output, and between export and output. Again, this is due to the GHH preference structure as explained above. GHH preference is known to generate negative correlation between output and net exports. Even though the Korean data shows a positive correlation between the two variables, it is an exception. As seen in Table 2, all other Asian and G7 countries show a significantly negative correlation between output and net exports. Even for the Korean data, using different sample periods produces a negative correlation.

In conclusion, we can safely argue that this model explains the main statistical properties of Korea's business cycles and we can use this model to perform our main analysis of the study—impulse responses to external shocks—in the next section.[16]
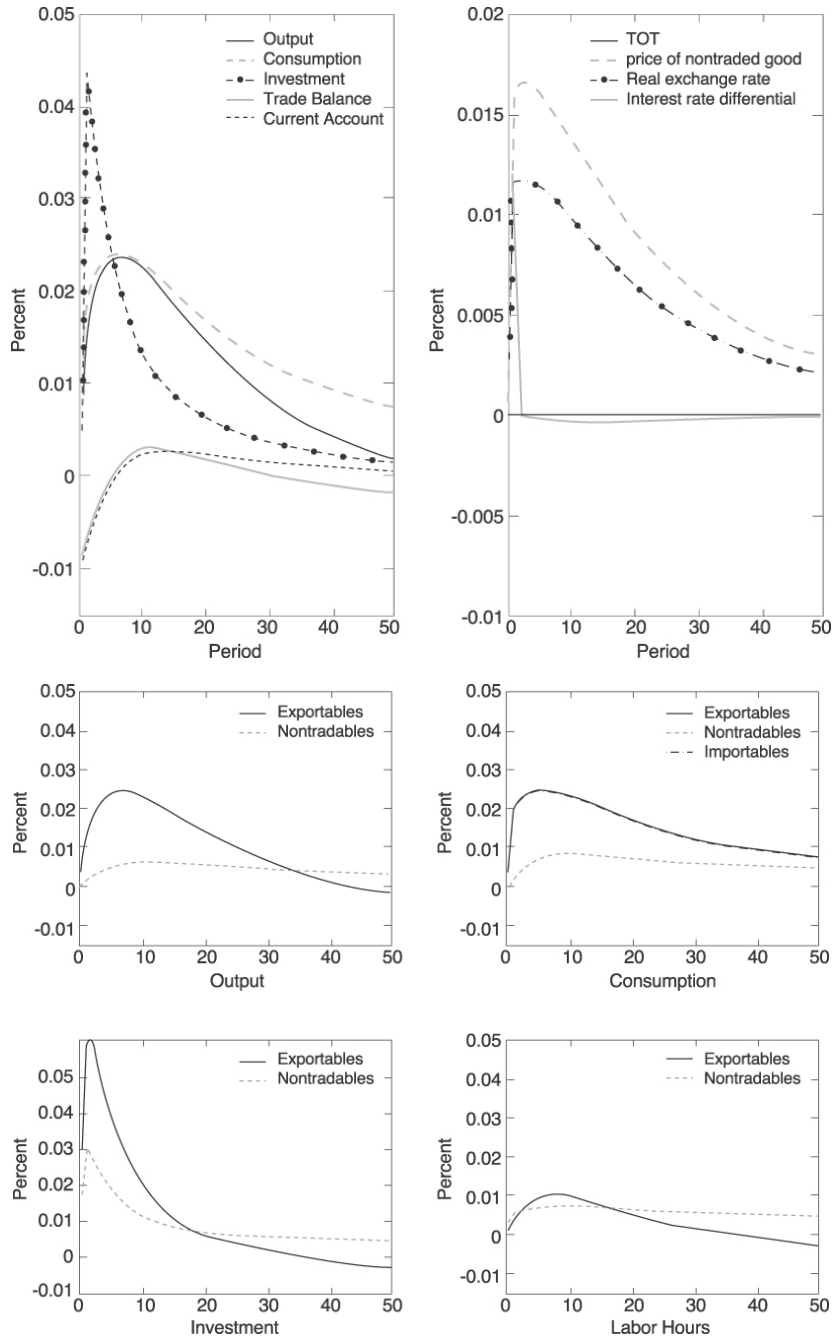
VI. Impulse Responses

In this section, we analyze the effects of each shock in the model on aggregate and sectoral variables. We use the same model and parameter specification and investigate how each macroeconomic variable responds to shocks.

1. Productivity shocks

Figure 1 presents the impulse responses to productivity shock in the exportable sector, a 1% increase in productivity at the initial period with $\rho = 0.95$ (persistence). We trace the responses up to 50 periods. The first set of graphs shows the

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[16] We did several sensitivity analyses. First, we reduce all shock correlations to zero and calculate second moments. Absolute volatility of variables slightly decreases but main properties of second moments do not change much. Second, we increase the persistence of shocks (TOT and interest rate shock) to 0.95. Volatility of variables slightly increases but other properties (persistence and correlation) remain almost unchanged.

[Figure 1] Impulse Responses to a 1% Increase in Productivity (export sector)

responses of aggregate variables and price variables: output, consumption, investment, trade balance, current account, price level, real exchange rate and interest rate differentials. Aggregate variables are constructed by taking a weighted average of the sectoral variables. The real exchange rate is represented by the general price of the economy (p_t) because foreign price is the numeraire of the economy. In this case, an increase in the real exchange rate denotes a real appreciation of domestic currency.

The model economy responds to a positive productivity shock by increasing investment, consumption and output. With temporary but persistent productivity shocks, households, knowing that positive productivity shocks are short-lived, work and produce more in the present. Although consumption grows, it does not grow as much as the increase in output and households save the remaining output by accumulating bonds over time. The net exports (or trade balance) decrease at impact because the agent borrows from the rest of the world to increase its capital stock and, in turn, utilizes the increase in productivity. In other words, the pro-borrowing effect initially dominates the pro-saving effect inducing a fall in the net exports. As the agent starts accumulating foreign assets, the net exports increase, but then decrease in the long run. This is because in the new steady state, agents enjoy interest income from holding foreign bonds and this allows them to have deficits in trade balance. Since the current account reflects income from asset holdings, it follows similar steps as the trade balance during the transitional period but it converges to zero in the long run.

An increase in the production of exportables increases the relative price of nontradables because of the relative scarcity of nontradables produced. The graph shows that the increase is around 1.5% during the initial period. An increase in the price of nontradables also increases the real exchange rate, indicating a real appreciation in the domestic currency.

The second set of graphs in Figure 1 shows the responses of sectoral output, investment, consumption and labor input. Since the positive productivity shock is in the export sector, all four variables in the export sector increase. In particular, the response of the investment is the largest, showing an initial increase of approximately 7%. Because of the income effect, there is a complementarity in the production of exportables and nontraded goods. Therefore, the production and consumption of nontraded goods increase as well. Note that the impulse responses can be sensitive to certain parameter values such as the discount rate and shock persistence, in particular, under the current incomplete financial market structure (see Kim et al., in press).

Figure 2 shows the impulse responses to a 1% increase in productivity in the nontraded sector. The graph of aggregate variables shows a similar response to the case of productivity shock in the exportable sector. The only difference is the magnitude of change: the size of increase in this case is smaller than in the case of the exportable sector shock. Since the price of nontradables also decreases with the impact, the weight of the nontraded good in deriving the aggregate variables decreases. An important difference is observed in the responses of the price variables. An improvement in productivity lowers the price of nontradables and therefore depreciates the domestic currency in real terms. As the nontraded sector

[Figure 2] Impulse Responses to a 1% Increase in Productivity (nontraded sector)

output increases, its price decreases.

Figures for sectoral variables show that output and consumption in the nontraded sector increase more than those in the tradable sector, which observation is explained by the fact that productivity increases in the nontraded sector. In particular, consumption of nontradables dramatically increases because of the additional favorable price effects. However, the responses of factor inputs, in particular labor, reveal that the exportable sector responds more than the nontraded sector. This is due to the shape of the production function and parameter values.
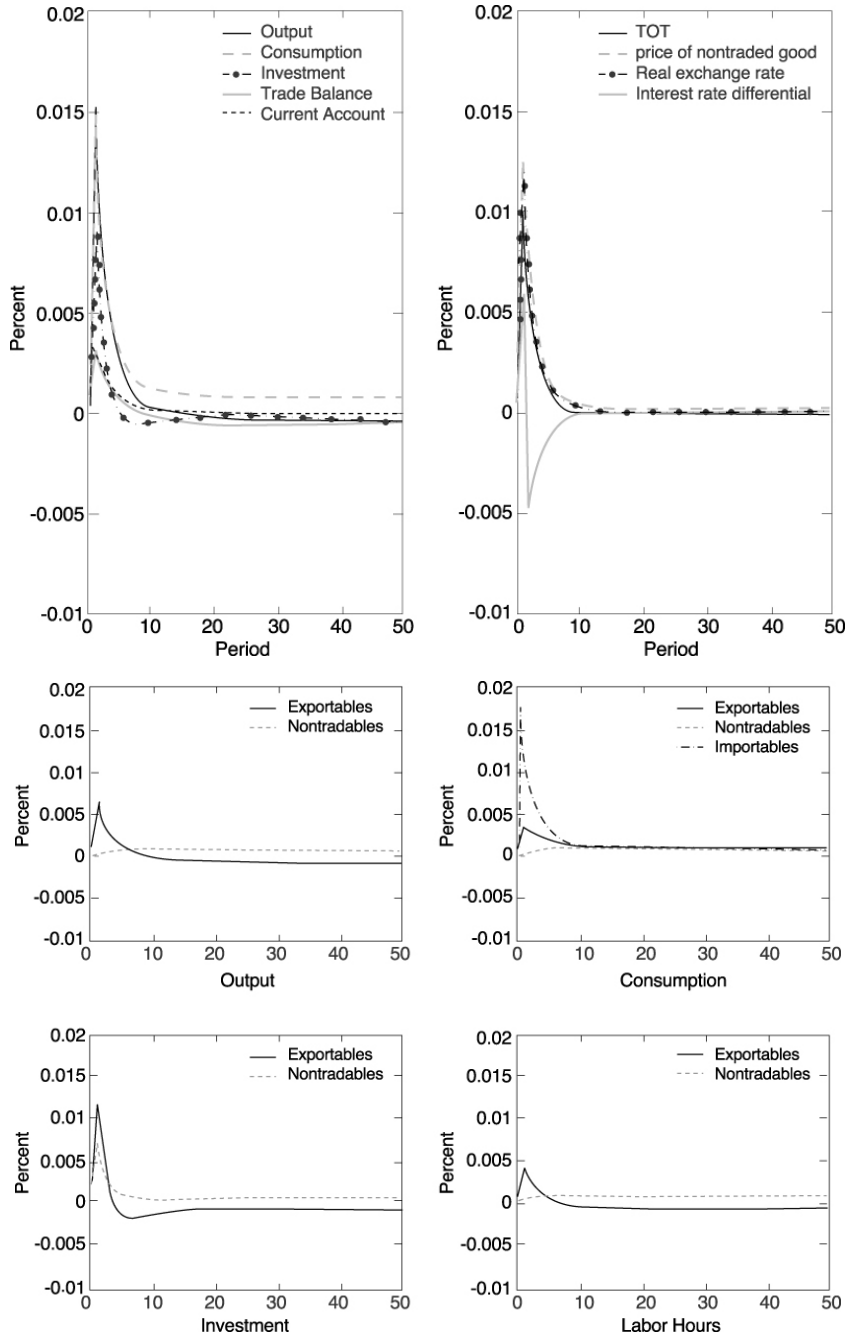
2. Terms of trade (TOT) shock

Figure 3 shows the impulse responses to a 1% increase in the terms of trade (TOT) with $\rho = 0.55$ (persistence). This implies an improvement in the terms of trade meaning that the relative price of exportables increases. The graphs show that there are favorable effects on aggregate variables. All aggregate variables positively respond to an improvement in the TOT. Because of the increase in the price of exportables, agents produce more exportable goods, which generates similar responses of aggregate variables as in the case of a positive productivity shock in the exportable sector. It increases the price of nontraded good and the real exchange rate. The difference is that the trade balance shows an improvement. Although the amount of exports decreases, the total value of exports increases because of an increase in the price of exportables. One notable observation is that consumption of importables sharply increases during the first several periods due to the decrease in the relative price of importables. As imported capital goods become cheaper, investment in both sectors increases.

This result is consistent with the proposition called the Harberger-Laursen-Metzler effect. Introduced in the 1950s, this proposition postulates that real income and savings fall with TOT deterioration. However, more recent papers based on the intertemporal approach with forward-looking savings behavior suggest a different story. By adopting a Uzawa-type utility function, Obstfeld (1982) shows that the deterioration of the TOT can increase savings. Svensson and Razin (1983) analyze the effects of the TOT of final and intermediate goods on savings and investment. A temporary deterioration in the TOT of final goods lowers the discount factor. The lower discount factor, in turn, increases investment but has ambiguous effects on consumption. The deterioration in the TOT also reduces the real value of domestic output in terms of consumption and eventually lowers consumption. However, the theoretical predictions are inconclusive because the results depend greatly on the specifications of shocks and the structure of the model economy.

3. World interest rate shocks

In figure 4, we examine the impulse responses of the model variables to a 0.25%

[Figure 3] Impulse Responses to a 1% Increase in the Terms of Trade

increase in the world real interest rate. The persistence is set at 0.7. Since capital stock is predetermined in the period of impact, labor supply does not respond immediately, and output remains constant. Changes in investment and consumption in the first period trigger changes in output, labor input and capital stock in the following period. The most significant impact is on investment, where investment decreases approximately 4% with a quarter point increase in the interest rate. Correspondingly, output decreases by 0.5% and consumption decreases less than that. Most previous studies including Park (1999) concluded that the effects of world interest rate shock on domestic economy are quite small. This is because that assumed that capital goods are domestically produced. In this paper, we assume that capital goods are imported and therefore the effects of world interest rate shocks are quite large.

An increase in the interest rate provides an incentive for domestic agents to accumulate foreign assets. Combined with a decrease in investment demand, asset accumulation corresponds with an increase in net exports. Since the interest rate affects both sectors to a similar degree, there is not much change in the relative price and exchange rate, as can be seen in the figure 4. The sectoral responses reveal that both sectors respond negatively to an increase in the interest rate. A decrease in investment is observed equally in both sectors but the amount of output loss is more severe in the exportable sector.
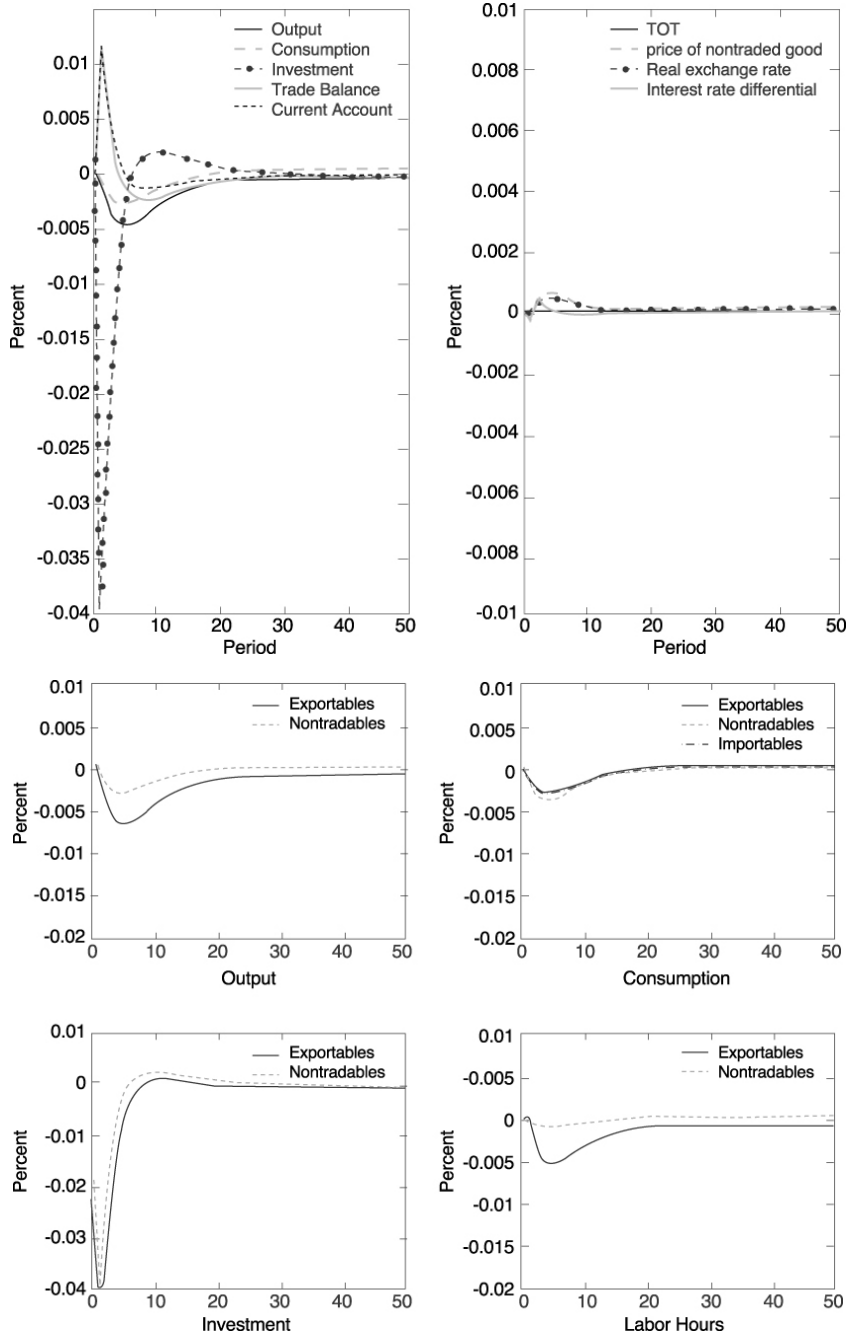
VII. Conclusion

In this paper, we constructed a multi-sector dynamic stochastic general equilibrium model that can be readily used to analyze business cycles in a small open economy. We calibrated the model to match the main characteristics of business cycles in Korea. Using this model, we examined the dynamic effects of various shocks on the macroeconomic variables, in particular external shocks such as the terms of trade and world real interest rate shocks.
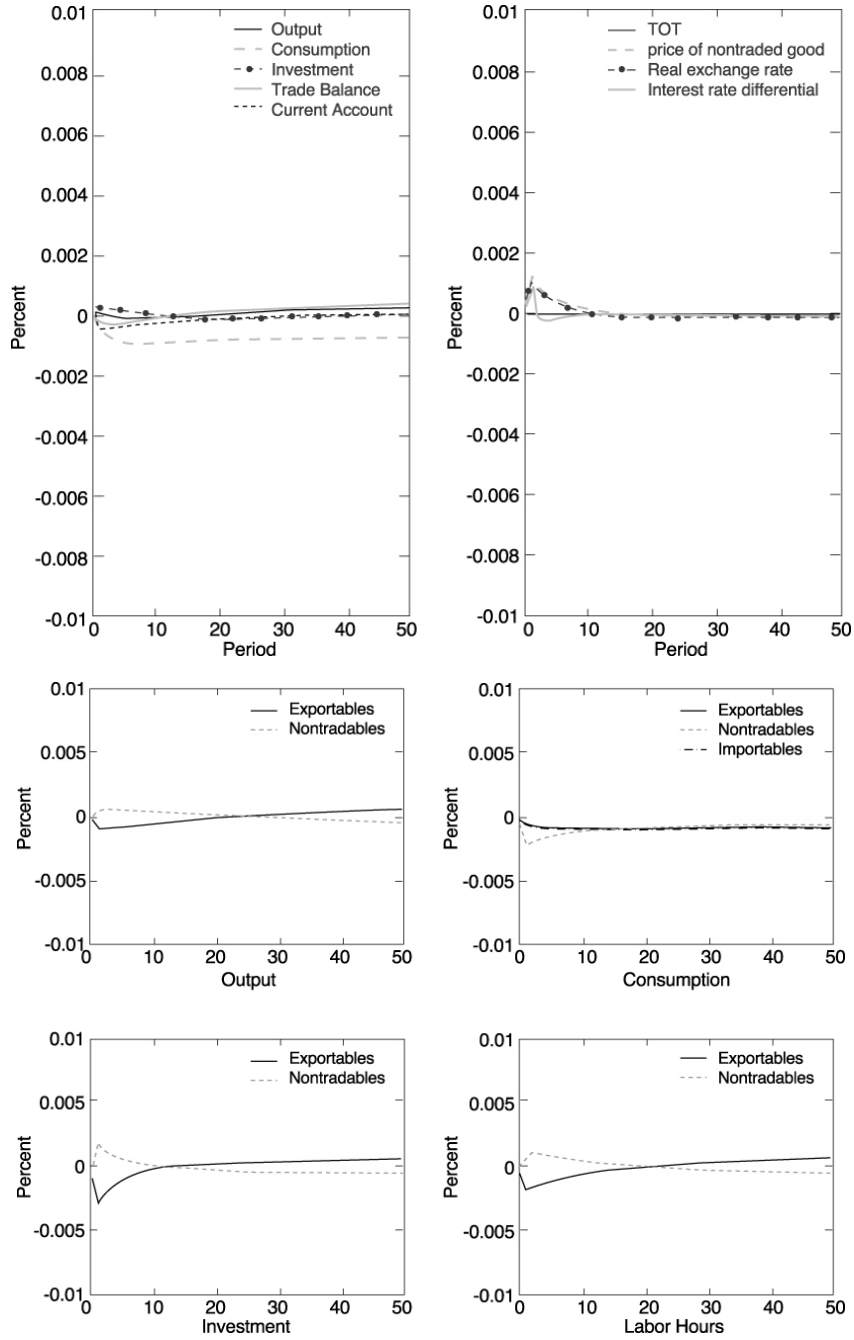
Korea's business cycle statistics match most of the stylized facts: consumption is less volatile than output and investment and external balances are more volatile than output. Consumption and investment are procyclical. The statistical analysis also reveals that the pattern of business cycles in Korea is more similar to the patterns in the G7 countries than in the Asian countries. We also investigate the fit of the model by comparing the second moments from the data with those from the model simulations. In general, this model does a good job of matching the second moments. However, the results are sensitive to the parameter values and model specifications.

Impulse response analysis provides several interesting findings. First, compared to other studies that have analyzed business cycles in a single-good framework, this model provides important insights regarding the responses of the economy to productivity shocks. Although the aggregate variables respond in a similar manner to the productivity shocks in the exportable and nontraded sectors,

[Figure 4] Impulse Responses to a 0.25% Increase in Interest Rate

[Figure 5] Impulse Responses to a 1% Increase in Government Spending

the price variables respond in a totally opposite manner. A positive productivity shock in the exportable sector increases domestic price and appreciates real exchange rate. However, when a positive shock occurs in the nontraded sector, then the domestic price decreases and the real exchange rate depreciates. This feature cannot be captured in a single-good model. Second, an improvement in the terms of trade has positive effects on investment, output and consumption. The current increase in world oil price can be viewed as a negative TOT shock and this model predicts that one percent decrease in the TOT initially decreases output and consumption about 1.5% and investment about 0.7%. These negative effects last at least for one year. Finally, a decrease in the world interest rate has a significant and positive impact on investment. A quarter percentage point decrease in world interest rate immediately increases investment about 4%, while output and consumption increase with some time gap (two-four quarters) by about 0.5% and 0.25%, respectively. The large effects of world interest rate shock are due to the assumption that capital goods are imported.

These simulation results can provide important policy implications by providing some quantitative analysis on the responses of the Korean economy to changes in external economic environments such as changes in world interest rate and oil price. As Korea is more integrated with world financial markets, changes in world interest rate would have more significant effects on Korean economy. This paper uses a model that incorporates integrated financial and goods markets (domestic residents can trade international bonds and capital goods are imported) and therefore can provide realistic implications for cyclical effects of external shocks. Appropriate monetary and fiscal policies can reduce the negative effects from adverse external shocks, which should be based on the accurate structural analysis of the Korean economy. This model provides such framework.

For future works, it would be interesting to include more realistic financial market structure such as trading of domestic and foreign equities as well as debt securities. Including risk premium in bond pricing can also be a good addition. Comparison of business cycles and the underlying shocks in pre- and post-crisis period (1997 currency crisis) would be interesting and can provide important policy implications in dealing with possible financial crisis. Despite all these potential additions to the model, the current model still well serves as a basic framework for analyzing small open economies such as Korea.

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Appendix. Data Sources and Definitions

Most data series are taken from the International Financial Statistics (IFS). Unless indicated, the data series are from 1960 to 1996.

Output: Output is measured as Gross Domestic Product (GDP) at 1990 prices (*line 99b.p or 99b.r*). Gross Domestic Product (*line 99b*) is generally presented in the IFS as the sum of final expenditure.

GDP Deflator: GDP deflator is the ratio of nominal GDP *(line 99b)* to real GDP (*line 99b.p or 99b.r*). All the nominal variables are deflated by the GDP deflator.

Private Consumption: Private consumption series are from the IFS (*line 96f*).

Investment: Investment is measured as gross fixed capital formation (*line 93e*).

Government Consumption: Government consumption series are from the IFS (*line 91f*).

Exports: Exports are measured as exports of goods and services of national accounts (*line 90c*).

Imports: Imports are measured as imports of goods and services of national accounts (*line 98c*).

Money: We use M2 which is is defined as M1 plus quasi-money.

CPI: Consumer Price Index (CPI) series are from the IFS (*line 64*). The CPI series of Korea starts from 1963.

Export Price: Index for unit value of exports is Laspeyres with weights derived from the data for transactions (*line 74*). The export and import price series of Korea are from 1963 to 1996.

Import Price: Index for unit value of imports is Laspeyres with weights derived from the data for transactions (*line 75*).

Terms of Trade: Terms of trade is defined as export price divided by import price.

Sectoral data for output, consumption, investment, labor, and capital stock are collected from the annual report on the survey of service industries and to classify the tradables and nontradables, we utilize the study of Sang-Yirl Nam (2001)[1], which presents tables on the share of total trade in domestic consumption in the manufacturing sectors. We define tradables as the manufacturing sectors where the share of total trade in domestic production is greater than 30 percent. Nontradables are defined as the manufacturing sectors where the share is below 30 percent and also include the agricultural and service sectors. Importables are defined as the manufacturing sectors where the share of imports on domestic consumption is greater than 50 percent. Exportables are defined as the manufacturing sectors where the share is below 50 percent.

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[1] Nam's study (2001) follows the classification of Korea standard Industry Classification (KSIC) where the Industries are classified as 2 digit, 36 sectors. The manufacturing consist of 23 sectors. Before 1990, manufacturing industries were classified in 2digit 9 industries. Therefore, we made an appropriate adjustment to match the new classification system.

\<Table A.1\> Sectoral Composition of Industries

Exportables (8)	Textiles, Except Sewn Wearing Apparel (17), Sewn Wearing Apparel & Fur Articles (18), Tanning & Pressing of Leather (19), Computers and Office Machinery (30), Radio, TV and Communication Equipment (32), Medical, Precision & Optical Investments (33), Manufacture of other Transport Equipment (35), Furniture; Articles n.e.c (36)
Importables (6)	Wood Products of Wood & Cork (20), Coke, Refined Petroleum Products (23), Chemicals and Chemical Products (24), Manufacture of Basic Metals (27), Manufacture of other Machinery (29), Electrical Machinery n.e.c (31)
Nontraded goods (8)	Manufacture of Food Products & Beverage (15), Manufacture of Tobacco Products (16), Pulp, Paper & Paper Products (21), Publishing, Printing & Reproduction (22), Rubber and Plastic Products (25), Non-metallic Mineral Products (26), Fabricated Metal Products (28), Motor Vehicles & Trailers Manufacturing (34), Service, Agriculture, Mining Sectors.

Note: The classification is based on Korea Standard Industry Classification (KSIC) revised in 1991.