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Inspecting Driving Forces of Business Cycles in Korea*

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This paper sets up a new Keynesian model with external habit to explore the role of each shock over business cycles in Korea. The estimated model via maximum likelihood shows that the productivity shock plays a pivotal role in explaining the output variations before and after the financial crisis since mid-1970s. It also shows that the model with external habit is more successful in explaining the business cycles in Korea after the Asian financial crisis than the model without habit. The monetary policy shock which dominates by accounting for more than 70 percent of the unconditional variance of the inflation rate before the financial crisis is less important in the inflation rate fluctuations after the financial crisis. This partly reflects the regime change of the monetary policy to the inflation targeting rule after the financial crisis.

Keywords: Business Cycles, Maximum Likelihood Estimation, Sticky Price, Habit, Korea
JEL Classification: E21, E32, E52

I. INTRODUCTION

Developments in macroeconomics since mid-1990s led to a new generation of small-scale monetary business cycles, generally referred to as new Keynesian models. The new models, embedding imperfect competition and nominal rigidities in a dynamic general equilibrium economy, attempt to explore empirical issues such as the relationship between money, inflation over business cycles. Needless to say that the models have yielded many genuinely new insights about the role of monetary policy over business cycles, and the desirability of alternative monetary policies by utilizing an explicit-based welfare analysis.

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With these theoretical developments in macroeconomics, many authors try to address the critical issues in macroeconomics by comparing the empirical or quantitative performance of the models with those of standard Vector Autoregressions (VARs). For example, Christiano, Eichenbaum and Evans (2005) estimate the deep parameters in new Keynesian models by minimizing some distance between the theoretical and empirical impulse response to a monetary shock, and then evaluate the performance of the model. In contrast to this weak econometric interpretation, some authors attempt to provide a full characterization of the observed data with strong econometric interpretation. For example, Ireland (2003, 2011) estimates the deep parameters of the sticky model using classical maximum likelihood methods with Kalman filtering. Smets and Wouters (2007) also utilize a Bayesian approach as in Otrok (2001) and Schorfheide (2000) to compare the performance of the theoretical model with full set of structural shocks with those of the Bayesian VARs.

At the core of the new Keynesian models including the heterogeneous agent new Keynesian (HANK hereafter) model stands the new Keynesian Phillips curve in which the short-run monetary policy effect is derived from assuming frictions in price adjustment on the part of imperfectly competitive firms (e.g. Rotemberg (1982), Yun (1996), Woodford (2003)). The new Keynesian Phillips curve (NKPC hereafter) postulates that the price decisions of imperfectly competitive firms lead to a relation linking to current inflation rate to current marginal cost and expected future inflation rate. The NKPC is widely used in the workhorse model such as the Two Agent New Keynesian (TANK) and HANK model which address the interaction between an income or consumption inequality and monetary and fiscal policy by extending the so-called expectational IS curve.

Needless to say that the new Keynesian model shares many features with the real business cycle models as well as the traditional Keynesian models. To uncover the role of the technology shock in the business cycle which is the driving main force of the real business cycle model, Clarida, Gali, and Gertler (1999), Smets and Wouters (2007), and Steinsson (2003) add other shocks such as a preference shock and a cost-push shock or an exogenous disturbance to firm's desired markups of prices over marginal costs, to the new Keynesian model. Ireland (2003, 2011) sets up a new Keynesian model in which both preference and cost-push shocks compete with the technology shock in accounting output and inflation rate in the U.S. business cycle. Smets and Wouters (2007) explores the sources of the U.S business cycle by applying the Bayesian likelihood approach to a fully-fledged DSGE model. Ireland (2003) estimates the key parameters with quarterly data from the postwar U.S. employing maximum likelihood. He shows that the cost-push shock is far more important than the technology shock in explaining the behavior of output, inflation, and interest rates in the postwar U.S. business cycles. Comparing the Great Recession and its predecessors, 1991 and 2001 recession, Ireland (2011) finds that the preference shock as well as the technology shock play an important role.

This paper sets up a canonical new Keynesian model with external habit to address the following questions. Which shock drives the business cycle in Korea? Specifically, is the technology shock still important in explaining the business cycle in Korea after the Asian financial crisis? If so, how much does it contribute the behavior of output and inflation rates? Though it is also interesting to address how the Great Recession has shaped the business cycles in Korea, I will focus on the Asian crisis for lack of space.

For this purpose, I first set up a canonical new Keynesian model with three structural equations and three shocks such as a technology shock, a monetary shock, and a preference shock. Then, I estimate the key parameters with quarterly data from Korea employing maximum likelihood along with Ireland (2003, 2011). For this purpose, I split the sample into two sub-periods following the literature. The first encompasses the era of rapid economic growth (1976:3 - 1996:3), while the second corresponds to the periods with economic slow- down after the Asian financial crisis in Korea at 1997. The second sample is also related to the so-called consumption volatility puzzle period in Korea, where the consumption volatility is larger than the volatility of output. Finally, I evaluate the relative importance of each shock over the business cycle and discuss the implied monetary policy role from the data.

The main findings of this paper can be summarized as follows. First, the model with external habit is more successful in explaining business cycles in Korea after the Asian financial crisis than the model without habit, while the former cannot be said to be better than the latter in explaining the business cycle before the crisis. The model with catching up with the Joneses which entails excessive consumption response is more useful in generating the volatile consumption fluctuation, i.e. the so-called consumption volatility puzzle in emerging economies[1] than the model without external habit. Second, a technology shock, i.e. a productivity shock is far more important than a demand or a monetary policy shock in explaining the behavior of the detrended output

[1] The consumption volatility puzzle is observed in Korea after the financial crisis.

over Korean business cycle since mid-1970s. The monetary policy shock contributes more than 50 percent of the inflation rate variations over the Korean business cycle before the Asian financial crisis, but the monetary shock plays minor role in explaining the inflation rate fluctuations since the Asian financial crisis when the Bank of Korea adopted the inflation targeting rule. Finally, the estimated monetary policy from the call money interest rate implies that the monetary authority has responded actively to stabilize the inflation.

This paper is composed as follows. In section 2, I specify a sticky price model with an external habit formation. In section 3, I derive an equilibrium and discuss the implications of the model related to interest rates and real activities. In section 4, I discuss the quantitative implications of the model. Finally, section 5 is a concluding remark.

II. THE MODEL

1. Households

The economy consists of a continuum of identical infinite-lived households. The household chooses consumption, labor hours, and portfolios to maximize its lifetime objective

$$E_t\left[\sum_{j=0}^{\infty}\beta^j \exp\left(s_{t+j}\right)\left(\frac{(C_{t+j}-bH_{t+j})^{1-\sigma}-1}{1-\sigma}-\frac{N_{t+j}^{1+\nu}}{1+\nu}\right)\right], \sigma\neq 1,\ \ 0<\beta<1 \quad (1)$$

where β is the household's discount factor, and E_t denotes the conditional expectations operator on the information available at time *t*. C_{t+j} and N_{t+j} represent the household's consumption and labor supply at time *t+j*. Here H_t summarizes the influence of past consumption levels on today's utility and $0\leq b<1$ measures the degree of external habit persistence. The state of the economy, x_t evolves according to a Markov process described by a density function $f(x_{t+1}, x_t)$. The preference shock s_t follows the following AR(1) process

$$s_t=\rho_s s_{t-1}+\varepsilon_{s,t}, \quad (2)$$

where $-1<\rho_s<1$ and $E[\varepsilon_{s,t}]=0$ and $\varepsilon_{s,t}$ is i.i.d. over time.

The utility of a representative household depends on that of the difference between consumption and habit. The stochastic sequence of habits $\{H_t\}_{t=0}^{\infty}$ is regarded as exogenous by the household and tied to the stochastic sequence of aggregate consumption $\{C_t\}_{t=0}^{\infty}$ as follows:

$$H_t = \tilde{C}_{t-1},$$

where $\tilde{C}_{t-1}$ is aggregate past consumption. Since there is a representative agent, aggregate consumption equals the household's consumption in equilibrium:

$$C_t = \tilde{C}_t.$$

It is assumed that there is a riskless one-period discount bond market. Let B_{t+1} denote the household's holdings of the bond with price R_t^{-1} per unit. The household that has decided its current consumption starts with nominal bonds, carried over from period *t-1*, and wages and dividends received from firms and lump-sum transfers from the government. Then the household faces the budget constraint given by

$$P_t C_t + \frac{B_{t+1}}{R_t} \leq B_t + W_t N_t + \Pi_t + T_t. \tag{3}$$

where N_t, Π_t, and W_t denote the hours worked, the firm's nominal profits, and nominal wages given to the household at time *t*, respectively. Finally, T_t represents the lump-sum taxation or subsidy at time *t*.

2. Firms

1) Final goods-producing firms

The representative final goods-producing firm uses $Y_t(i)$ units of each intermediate goods, purchased at the price $P_t(i)$ to produce Y_t units of final goods according to the constant-returns-to scale technology given by

$$Y_t \leq \left[\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{4}$$

where ϵ is the constant elasticity of substitution among varieties as in Dixit and Stiglitz (1977).

The profit maximizing condition implies that $Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\epsilon} Y_t$, $P_t = \left[\int_0^1 P_t(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$.

2) Intermediate goods-producing firms

Suppose that there are a continuum of firms producing differentiated intermediate goods, and each firm indexed by i, $0 \le i \le 1$, produces its product with constant returns to scale technology. Each firm *i* takes P_t and the aggregate demand as given, and chooses its own product price $P_t(i)$. Since the input markets are perfectly competitive, the demands for labor and capital are determined by its cost minimization as follows,

$$C(W_t, Y_t(i)) = min._{N_t(i)} W_t N_t(i) \quad (5)$$
$$\text{s.t. } Y_t(i) \le \exp(z_t) N_t(i).$$

Here $\exp(z_t)$ is the technology process at period *t*. $Y_t(i)$ is the output of the *i*th firm. It is assumed that the technology shock follows an AR(1) process :

$$z_t = (1-\rho_z)z + \rho_z z_{t-1} + \varepsilon_{z,t}, \ \ 0 < \rho_z < 1, \quad (6)$$

where $E[\varepsilon_{z,t}] = 0$, and $\varepsilon_{z,t}$ is i.i.d. over time.

From the firm's first order condition, the demand for labor is given by

$$W_t = MC_t(i) \exp(z_t). \quad (7)$$

3) Staggered price setting

Many papers have studied the price decision rules in monopolistically competitive product markets. In this subsection, the Calvo (1983) -Yun (1996) type of staggered price setting is considered. Since the intermediate goods substitute imperfectly for one another in producing the final goods, the intermediate goods-producing firms behave as monopolistically competitive firms in the market. The probability that a monopolistic competition firm i in the domestic product markets keeps its price fixed in a given period is α, while the probability that the firm sets its new price P_t^*(i)) optimally is (1-α), where the probability draws is i.i.d. over time. The firm's maximization problem can be written as follows.

$$\max.\, E_t\left\{\sum_{k=0}^{\infty}\alpha^k Q_{t,t+k}\left[(1+\tau)P_t^*(i)Y_{t,t+k}(i)-MC_{t+k}Y_{t,t+k}(i)\right]\right\} \quad (8)$$

subject to

$$Y_{t,t+k}(j)=\left(\frac{P_t^*(i)}{P_t}\right)^{-\epsilon}Y_{t+k}$$

where $P_{t,t+k}=P_t^*(i)_{H,t}$ with a probability of α^k. $Q_{t,t+k}=\frac{\beta^k\Lambda_{t+k}P_t}{\Lambda_t P_{t+k}}$, and Λ_t and Λ_{t+k} are the marginal utility of wealth in periods t and t+k with $k=0,1,2,\ldots,\infty$. Here MC_t is the nominal marginal cost at time t and the sales tax τ is introduced to neutralize the market power distortions in the steady state, τ=(1/(ϵ-1)).

Since $P_t^*(i)$ is the same for the reoptimizing firms, the optimal price setting equation in the Calvo-Yun type model can be written as

$$E_t\left\{\sum_{k=0}^{\infty}\alpha^k Q_{t,t+k}\left(\frac{P_t^*}{P_t}\right)^{-\epsilon}Y_{t+k}[(1+\tau)^{-1}\mathcal{M}MC_{t+k}-P_t^*]\right\}=0, \quad (9)$$

where $\mathcal{M}=\frac{\epsilon}{\epsilon-1}$ is the steady-state gross mark-up. The price level also satisfies the recursive form such that

$$P_t^{1-\epsilon}=(1-\alpha)(P_t^*)^{1-\epsilon}+\alpha P_{t-1}^{1-\epsilon}. \quad (10)$$

3. Monetary Policy Rule

In literature, may leading macroeconomists follow Taylor (1993)'s recommendation of a simple interest rule or its variant such as interest smoothing policy to evaluate the effect of monetary policy. In this paper, I employ an interest rate smoothing rule to evaluate the model.

Assume that nominal interest rates R_t are set according to simple Taylor rule with a partial adjustment term as in Clarida et al. (1999, 2000):

$$\frac{R_t}{R_{ss}} = \exp(\varepsilon_{r,t}) \left(\frac{R_{t-1}}{R_{ss}}\right)^{\rho_r} \left(\left(\frac{1+\pi_t}{1+\pi_{ss}}\right)^{a_\pi} \left(\frac{Y_t}{Y_{ss}}\right)^{a_y}\right)^{1-\rho_r}, \tag{11}$$

where ρ_r measures the degree of interest rate smoothing and $\mathrm{E}[\varepsilon_{r,t}] = 0$, and $\varepsilon_{r,t}$ is i.i.d. over time. Here X_{ss} is the steady state value of the corresponding variable X_t.

III. EQUILIBRIUM

1. Symmetric Equilibrium

The competitive equilibrium conditions consist of the efficiency conditions and the budget constraint of the households and firms, and the market clearing conditions of each goods market, labor market, money, and bond market. Then, the symmetric equilibrium is an allocation of $\{C_t, N_t, Y_t\}_{t=0}^{\infty}$, a sequence of prices and costate variables $\{P_t^*, P_t, MC_t, R_t\}_{t=0}^{\infty}$ such that (1) the households' decision rules solve their optimization problem given the states and the prices; (2) the demands for labor solves each firm's cost minimization problem and price setting rules solve its present value maximization problem given the states and the prices; (3) each goods market, labor market, and bond market are cleared at the corresponding prices, given the initial conditions for the state variables, and the exogenous shock processes $\{z_t, s_t, \varepsilon_{r,t}\}_{t=0}^{\infty}$ as well as the fiscal and monetary policies $\{T_t, R_t\}_{t=0}^{\infty}$.

The symmetric equilibrium conditions for nine variables are given by

$$E_t \left[\frac{R_t \exp(s_{t+1} - s_t)}{1+\pi_{t+1}} \left(\frac{C_{t+1} - bC_t}{C_t - bC_{t-1}}\right)^{-\sigma}\right] = 1, \tag{12}$$

$$N_t^{\nu} (C_t - bC_{t-1})^{\sigma} = \exp(z_t) \frac{MC_t}{P_t}, \tag{13}$$

$$E_t \left\{\sum_{k=0}^{\infty} \alpha^k Q_{t,t+k} \left(\frac{P_t^*}{P_t}\right)^{-\epsilon} Y_{t+k}[(1+\tau)^{-1} \mathcal{M} MC_{t+k} - P_t^*]\right\} = 0, \tag{14}$$

$$Y_t = \frac{\exp(z_t) N_t}{\Delta_t}, \tag{15}$$

$$Y_t = C_t, \tag{16}$$

$$\frac{R_t}{R_{ss}} = \exp(\varepsilon_{r,t}) \left(\frac{R_{t-1}}{R_{ss}}\right)^{\rho_r} \left(\left(\frac{1+\pi_t}{1+\pi_{ss}}\right)^{a_\pi} \left(\frac{Y_t}{Y_{ss}}\right)^{a_y}\right)^{1-\rho_r}, \tag{17}$$

and (10). Here where $\Delta_t = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di$ is the relative price distortion for the goods price in period *t*.

2. Dynamics around Steady State

First, I will represent the economy system in a state space to explore the dynamics of the economy. Next, I will analyze the response of the economy to exogenous shocks using essentially the method of King, Plosser, and Rebelo (1988). That is, I restrict my attention to the case of small fluctuations of the endogenous variables around a steady state growth path. Assuming that the fiscal authority implements a tax/ subsidy at sales to ensure the efficient steady-state, then the dynamics of the economy can be simplified in terms of three endogenous variables $\{\hat{y}_t,\ \hat{\pi}_t,\ \hat{r}_t\}$ and three exogenous variables $\{\hat{s}_t,\ \hat{z}_t,\ \varepsilon_{r,t}\}$ as follows:

$$\sigma E_t[\hat{y}_{t+1} - (1+b)\hat{y}_t + b\hat{y}_{t-1}] = (1-b)\{\hat{r}_t - E_t[\hat{\pi}_{t+1}] - (1-\rho_s)\hat{s}_t\}, \tag{18}$$

$$\hat{\pi}_t = \beta E_t[\hat{\pi}_{t+1}] + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}[\sigma(1-b)^{-1} + \nu)\hat{y}_t - \sigma(1-b)^{-1}\hat{y}_{t-1} \\ -(1+\nu)\hat{z}_t], \tag{19}$$

$$\hat{r}_t = \rho_r\hat{r}_{t-1} + (1-\rho_r)\left[a_\pi\hat{\pi}_t + a_y\hat{y}_t\right] + \varepsilon_{r,t}, \tag{20}$$

$$\hat{s}_t = \rho_s\hat{s}_{t-1} + \varepsilon_{s,t}, \tag{21}$$

$$\hat{z}_t = \rho_z\hat{z}_{t-1} + \varepsilon_{z,t}, \tag{22}$$

Where $x_{ss} = \ln\left(\frac{X_t}{X_{ss}}\right)$.

In this system, the state vector at period *t*, x_t consists of a previous interest rate ($\hat{r}_{t-1}$), a (log) technology shock ($\hat{z}_t$), a preference shock ($\hat{s}_t$), and a monetary shock ($\varepsilon_{r,t}$).

IV. ESTIMATION RESULTS

1. Estimation Methods

To make the maximum likelihood procedure more transparent, a subset of the model's parameters is fixed in advance. The values of π_{ss} and r_{ss} are taken from the steady state inflation rate and nominal interest rate. The value of Y_{ss} is taken from the average level of detrended, per-capita GDP in the data. The time discount factor β is determined from the condition that the model's steady-state nominal interest rate r_{ss} equals (1+π_{ss})/β.

First, assume that the elasticity of intertemporal substitution and the Frisch labor supply elasticity equal 0.5 and 1, i.e. σ=2 and ν=1 as in Gali (2008). Next, I will choose ϵ=11, implying a steady-state markup of 10 percent as in Woodford (2003).

Equations (18) - (22) and an i.i.d. monetary policy shock constitute a system of six equations in three observable variables - output, inflation, and the nominal interest rate - and three unobservable variables. One can apply the methods of Blanchard and Khan (1980) to solve the model. Since the equilibrium solution of this system takes the form of state-space econometric model, the Kalman filtering techniques can be applied to estimate the model's key parameters via maximum likelihood.

The model has ten parameters, $\rho_r, a_y, a_\pi, \rho_s, \rho_z, \sigma_s, \sigma_z, \sigma_r, b, \alpha$. Let the state vector $s_t = [r_{t-1}, y_{t-1}, \pi_{t-1}, s_t, z_t, \varepsilon_{r,t}]'$, and let $y_t = [\hat{y}_t, \hat{\pi}_t, \hat{r}_t]'$ the vector of the observed variables whose values are the logarithmic deviations of detrended output, inflation, and the short-term nominal interest rates from their average. Then the log-linearized equilibrium systems can be stated as the state-space representation.

$$s_{t+1} = As_t + B\varepsilon_{t+1}, \tag{23}$$

$$y_t = Cs_t, \tag{24}$$

where A, B, C are matrices of parameters of dimension 6×6, 6×3, and 3×6. Here $\varepsilon_{t+1} = [\varepsilon\_(s,t), \varepsilon\_(z,t), \varepsilon\_(r,t)]'$ is assumed to be normally distributed with zero mean and diagonal covariance matrix $V = \mathrm{diag}(\sigma_s^2,\ \sigma_z^2,\ \sigma_r^2)'$. To estimate the values of unknown parameters in the system on the basis of the observations, the Kalman filter are used many times to form the log-likelihood function. Along the lines of Hamilton (1994), denote $\hat{s}_{t|t-j} = E[s_t|y_{t-j}, y_{t-j-1}, \dots, y_1]$ and $\Sigma_{t|t-j} = E(s_t - \hat{s}_{t|t-j})(s_t - \hat{s}_{t|t-j})'$, and $\hat{y}_{t|t-j} = E[y_t|y_{t-j}, y_{t-j-1}, \dots, y_1]$. Then,

$$\hat{s}_{t+1} = A\hat{s}_t + \mathrm{P}_t \mathrm{v}_{t+1}, \tag{25}$$

$$y_t = C\hat{s}_t + \mathrm{v}_t, \tag{26}$$

where $\mathrm{v}_t = y_t - y_{t|t-1}\}$ and $\mathrm{Ev}_t\mathrm{v}_t' = C\Sigma_t C'\Omega_t$. Here the sequence for P_t and Σ_t can be generated recursively using the formula

$$\mathrm{P}_t = \mathrm{A}\Sigma_t C'(C\Sigma_t C')^{-1},$$
$$\Sigma_{t+1} = BVB' + A\Sigma_t A' - A\Sigma_t C'(C\Sigma_t C')^{-1} C\Sigma_t \mathrm{A}.$$

The innovations $\{\mathrm{v}_t\}_{t=1}^{T}$ are used to form the log-likelihood function for $\{y_t\}_{t=1}^{T}$ as

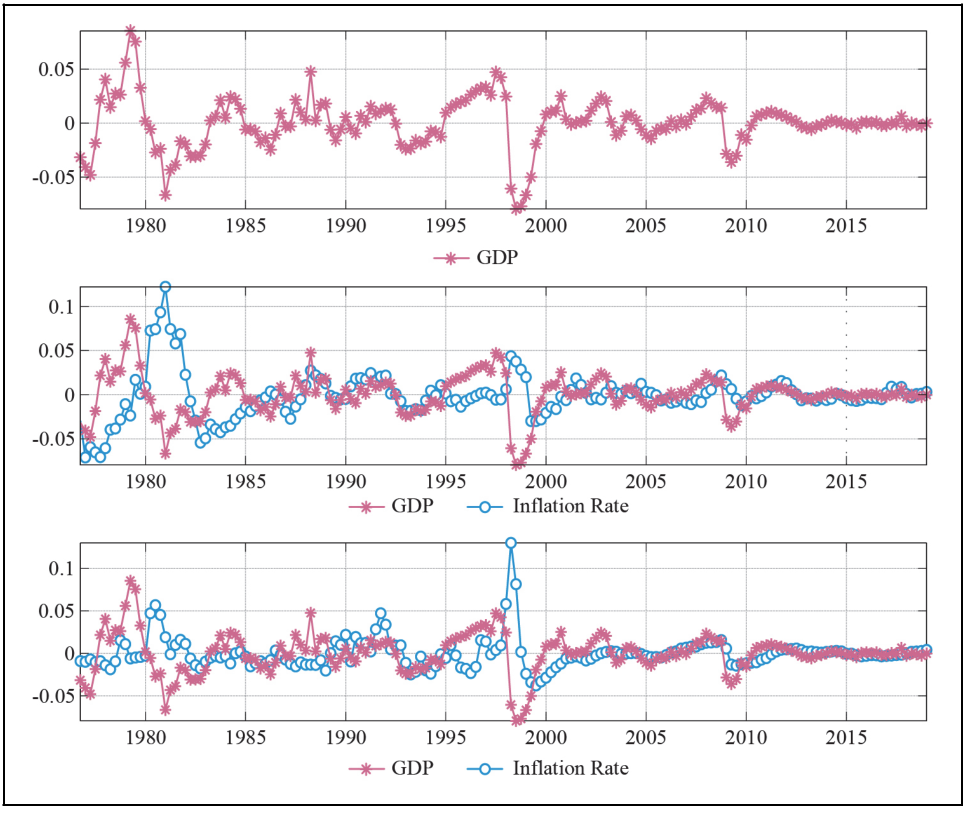
$$\mathrm{lnL} = -\left(\frac{3T}{2}\right)\ln(2\pi) - \frac{1}{2}\Sigma_{t=1}^{T}\ln|\Omega_t| - \frac{1}{2}\Sigma_{t=1}^{T}\mathrm{v}_t'\Omega_t\mathrm{v}_t.$$

2. Results

The data used in this exercise is running from 1976:3 through 2018:3. Figure 1 which presents the HP-filtered GDP, inflation, and interest rate shows that the fluctuations of relevant variables have been moderated over after the Asian financial crisis. This can reflect either the success of economic policy or a good luck associated with exogenous shock. To analyze the driving force of business cycles in Korea, first, seasonally-adjusted figures for real GDP, converted to log-quadratically detrended, are used to measure output fluctuation. Quarterly changes in the seasonally-adjusted CPI give the measure of inflation, and quarterly averages of daily readings on the one-day call rate yield the measure of the nominal interest rate.

The Kalman filter can be used to construct the other parameter values, ρ_r, $a_y, a_\pi, \rho_s, \rho_z, \sigma_s, \sigma_z, \sigma_r, b,$ and α with their standard errors as explained above. The sample is divided into two sub-periods. The first encompasses the era of rapid economic growth (1976:3 - 1996:3), while the second corresponds to the periods with economic slow-down after the Asian financial crisis in Korea at 1997.

Figure 1. Fluctuations of Key Macroeconomic Variables



The calibrated parameter values used in this paper are reported in Table 1. Table 2 presents key parameter presents maximum likelihood estimates of these values in the first sub-period (1976:3-1996:3) when the relative risk aversion parameter is set to 2. The standard errors are computed by taking the square roots of the diagonal elements of minus one times the inverted matrix of second derivatives of the maximum log-likelihood function. In the interest rate rule, lagged interest rate and inflation rate enter significantly as determinants of the current interest rate, while output does not. The high estimates of ρ_s and ρ_z imply that both productivity and preference shocks are highly persistent. Moreover, the large estimate of σ_z implies that the productivity shock plays more important role in the business cycle than other shocks. The estimates for b and α show that there is a modest degree of catching up with the Joneses and firms with market power set their prices every three quarter.

Table 1. The Calibrated Parameters

Parameter	Values	Definition and Description
ϵ	11	Elasticity of demand for a good with respect to its own price
σ	2	Relative risk aversion parameter
ν	1	Inverse of elasticity of labor supply

Table 2. Estimates and Standard Errors (1976:3-1997:3)

	Model	With Habit	Model	Without Habit
Parameter	Estimate	Standard Error	Estimate	Standard Error
ρ_r	0.8956	0.0104	0.6629	0.0179
a_y	-0.0001	0.0153	0.0001	0.0238
a_π	1.4815	0.0852	1.5124	0.0340
ρ_s	0.9887	0.0009	0.9895	0.0003
ρ_z	0.9900	0.0030	0.9901	0.0087
σ_s	0.0493	0.0015	0.0261	0.0007
σ_z	0.0412	0.0057	0.0253	0.0021
σ_r	0.0040	0.0004	0.0080	0.0007
A	0.6964	0.0403	0.2522	0.0128
b	0.3671	0.0486	-	
L_i	782.71		779.31	

Note: $L_i(\mathrm{i} = \mathrm{u}, \mathrm{c})$ denotes the maximized value of the model's log-likelihood function.

The estimate of the external habit degree b shows that there was a modest degree of catching up with the Joneses in Korean economy before the financial crisis. Under the null hypothesis that b=0, the likelihood ratio statistic $\mathrm{LR} = 2(L_u - L_c)$ is asymptotically distributed as a chi-square random variable with one degree of freedom, where L_u is the maximized value of the unconstrained log likelihood function and L_c is the maximized value of the constrained log likelihood function. Table 1 indicates that $L_c = 779.31$and $L_u = 782.71$, implying that $\mathrm{LR} = 6.80$. Since the 0.1 percent critical value for LR is 10.8, the null hypothesis cannot be rejected by the data. That is, the model with external habit cannot be evaluated to be more successful in explaining business cycles in Korea before the financial crisis than the model without habit.

Table 3. Forecast Error Variance Decompositions

Quarters Ahead	Preference Shock	Technology Shock	Policy Shock
Output			
1	1.30	85.94	12.76
4	0.46	95.14	4.40
8	0.21	97.76	2.02
12	0.14	98.53	1.33
20	0.09	99.08	0.83
40	0.05	99.47	0.48
∞	0.03	99.71	0.26
Inflation			
1	11.32	20.40	68.28
4	13.62	19.01	67.37
8	14.94	19.85	65.21
12	15.78	20.61	63.61
20	17.07	21.88	61.05
40	19.17	24.05	56.78
∞	21.99	27.83	50.18
Interest Rate			
1	3.98	7.16	88.86
4	19.68	25.93	54.39
8	31.31	36.50	32.19
12	36.23	40.66	23.11
20	40.31	44.27	15.42
40	43.12	47.37	9.51
∞	43.51	50.96	5.53

Table 3 decomposes forecast variances in detrended output, inflation, and the nominal interest rate into components attributable to each of the model's three orthogonal disturbances: $\varepsilon_{s,t}$, $\varepsilon_{z,t}$, $\varepsilon_{r,t}$. The table shows that at short and long horizons, the productivity shock contributes heavily in generating output fluctuations, while the monetary policy shock accounts for about 10 percent of the unconditional variance of the detrended output at short horizon. The monetary policy shock dominates by accounting for more than 50 percent of the unconditional variance of the inflation rate at short and long horizons, while the productivity and preference shocks account for about 10~20 percent of the unconditional variance of the inflation rate at short and longer horizons. The contributions of the productivity and policy shock to output and inflation rate fluctuations may reflect the stance of monetary authority to accommodate these shocks.

Table 4. Maximum Likelihood Estimates and Standard Errors (1998:1-2018:3)

	Model	With Habit	Model	Without Habit
Parameter	Estimate	Standard Error	Estimate	Standard Error
ρ_r	0.9378	0.0073	0.9250	0.0287
a_y	0.0001	0.0083	0.0000	0.0656
a_π	1.9887	0.0219	1.5261	0.0025
ρ_s	0.9887	0.0008	0.9893	0.0010
ρ_z	0.9897	0.0025	0.9896	0.0234
σ_s	0.0298	0.0013	0.0206	0.0008
σ_z	0.0441	0.0050	0.0191	0.0027
σ_r	0.0009	0.0001	0.0009	0.0001
A	0.5086	0.0400	0.7191	0.0296
b	0.8631	0.0053	-	-
L_i	991.97		982.63	

Note: $L_i(\mathrm{i} = \mathrm{u}, \mathrm{c})$ denotes the maximized value of the model's log-likelihood function.

Table 4 presents maximum likelihood estimates of these values in the second sub-period (1998:3-2018:3). Comparing the estimate for b in Table 2 and 4 shows that households are more willing to catch up with their neighbors after the Asian financial crisis than before the crisis. The estimate for the degree of nominal price rigidities also shows that firms on average set their optimal prices every five to six quarter in the second sub-period. The high estimates of ρ_s and ρ_z imply that the model's exogenous shocks are highly persistent. The persistent and large estimate of the productivity shock z_t implies that the productivity shock plays still the most important role in the business cycle after the Asian financial crisis.

The estimate of the degree of external habit b in Table 4 shows that there was a substantial degree of catching up with the Joneses in Korean economy before the financial crisis. Table 4 indicates that $L_u = 991.87$ and L_c =982.63, implying that LR=18.48. Since the 0.1 percent critical value for LR is 10.8, the null hypothesis is rejected by the data. That is, the model with external habit can be said to be more successful in explaining business cycles in Korea after the financial crisis than the model without habit.

Table 5. Forecast Error Variance Decompositions (1998:1-2018:3)

Quarters Ahead	Preference Shock	Technology Shock	Policy Shock
Output			
1	2.31	93.92	3.77
4	1.22	96.82	1.96
8	0.63	98.37	1.00
12	0.40	98.97	0.63
20	0.24	99.40	0.36
40	0.13	99.67	0.20
∞	0.07	99.82	0.11
Inflation			
1	14.99	71.37	13.64
4	17.05	69.33	13.62
8	18.04	69.40	12.56
12	18.43	69.85	11.72
20	18.77	70.55	10.68
40	19.10	71.59	9.31
∞	19.18	73.31	7.51
Interest Rate			
1	2.86	13.62	83.52
4	11.63	47.67	40.70
8	17.19	65.08	17.73
12	19.23	70.45	10.32
20	20.58	73.84	5.58
40	21.18	75.88	2.94
∞	20.66	77.80	1.54

Table 5 decomposes forecast variances in detrended output, inflation, and the nominal interest rate into components attributable to each of the model's three orthogonal disturbances. The table shows that at short and long horizons, the productivity shock contributes heavily in generating output fluctuations, while the preference shock and monetary policy shock accounts for less than 5 percent of the unconditional variance of the detrended output. In this sub-period, the productivity shock also dominates by accounting for more than 50 percent of the unconditional variance of the inflation rate, while the monetary policy shock accounts for about 30 percent of the unconditional variance of the inflation rate at short and longer horizons, which mirrors the inflation targeting regime. The relatively small contributions of a monetary policy shock to inflation fluctuations during the second sub-period implies that the monetary authority has tried to follow a rule rather than a fine-tuning in implementing a monetary policy.

Figure 2. Impulse Response Function to Each Shock before and after the Asian Crisis

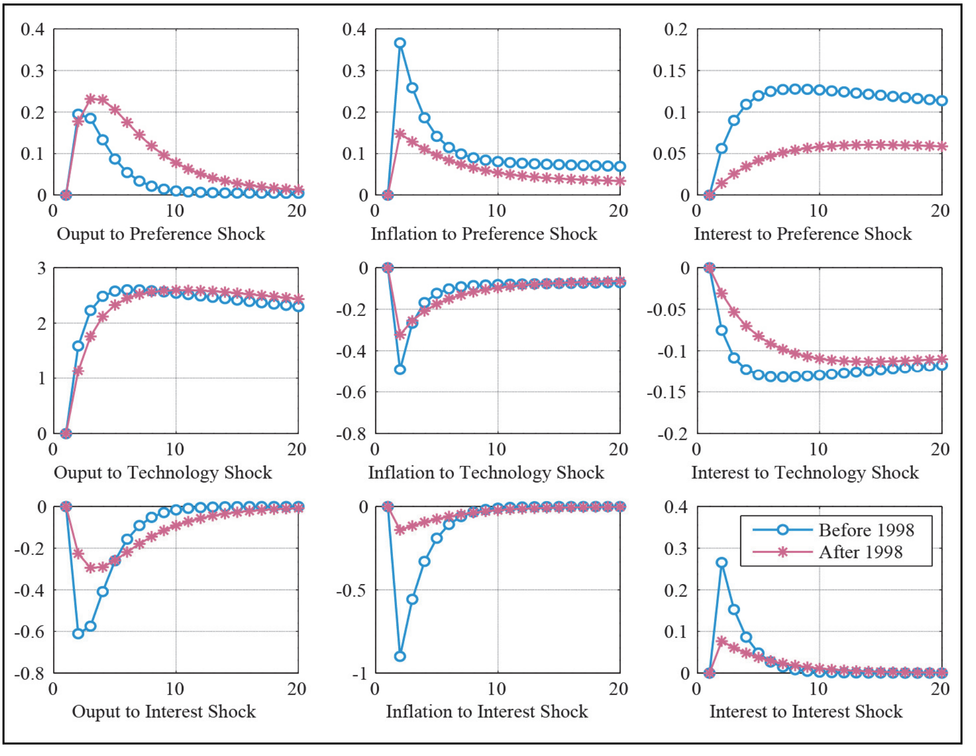


Figure 2 shows the impulse response function of each shock to output, the inflation rate, and the interest rate before and after the Asian financial crisis. Consider first the impulse response function before the crisis. The circle lines (o-) in Figure 2 represent the response of relevant variables to each shock before the crisis. Output responds strongly to the productivity shock, while inflation responds strongly to the monetary policy shock as Table 3 shows. The response of output to the productivity shock is greater than the response of output to the preference shock, which implies that the supply shock plays more important role in the fluctuations of output in Korea than the demand shock. However, the effect of the monetary policy shock on the inflation rate is more persistent and greater than productivity and preference shocks. Next, consider the impulse response after the crisis. The star lines (*-) in Figure 2 represent the impulse response function of output, the inflation rate, and the interest rate to each shock after the crisis. Output and inflation responds strongly to the productivity shock as Table 4 shows. Figure 2 shows that inflation is more stabilized after the crisis than before the crisis. This partly reflects the change of monetary policy regime from a kind of fine tuning with discretion to the inflation targeting rule. Note that the estimated monetary policy from the call money interest rate in Table 5 implies that the monetary authority has responded actively to stabilize the inflation.

V. CONCLUDING REMARKS

This paper specifies a sticky price model with the preference shock, real shock, and monetary shock, and then investigates the role of each shock over the business cycles in Korean economy via maximum likelihood estimation. The paper finds that the model with external habit is more successful in explaining the business cycles in Korea after then Asian financial crisis than the model without habit. Furthermore, the productivity shock is far more important than the preference or monetary policy shock in explaining the behavior of the detrended output over business cycles in Korea since mid-1970s. The productivity shock contributes more than 70 percent of the output variations over the business cycle, and it also plays an important role in explaining the inflation rate fluctuations after the Asian financial crisis. The monetary policy shock is very important in explaining the inflation rate fluctuation in the first sub-period, i.e. before the Asian financial crisis, but its role in the inflation fluctuations declined over time which reflects the monetary policy regime change in Korea.

In the future research agenda, it is desirable to extend the closed economy model into either an open economy context or into the heterogeneous agent model and address the consumption volatility puzzle by uncovering the relative role of each shock over the business cycles in Korea.

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