The Korean Economic Review
Volume 38, Number 1, Winter 2022, 109-139.
DOI : 10.22841/kerdoi.2022.38.1.004

Inspecting Business Cycles in Korea through the Lens of the TANK Model

Yongseung Jung*

This paper extends the small open new Keynesian model in Galí and Monacelli (2005) by incorporating financial frictions with constrained households into the model to explore the sources of business cycles in Korea since the mid-1970s. The estimated model via maximum likelihood shows a substantial fraction of constrained households whose variation plays a pivotal role over business cycles in Korea. The contribution of the foreign productivity shock to the fluctuation of output has decreased over time, while the relative importance of the domestic factor in business cycles in Korea has increased. The monetary policy, which has been very loose to accommodate the high demand for liquidity during a high economic growth era, became proactive in controlling inflation after the Asian financial crisis as the Bank of Korea adopted the inflation targeting rule in 1998.

JEL Classification: E32
Keywords: Business Cycles, Maximum Likelihood, Open Economy, TANK

I. Introduction

Literature on the heterogeneous agent New Keynesian (HANK hereafter) models has proliferated in the last few years. Market incompleteness and heterogeneity have been incorporated into dynamic stochastic general equilibrium models. The HANK models have been used to improve our understanding of the transmission of monetary and fiscal policy (Kaplan et al., 2018; Auclert et al., 2018) and the forward guidance puzzle (McKay et al., 2016). In particular, Kaplan et al. (2018) point out that while the monetary policy multiplier occurs through the indirect income effect or general effect in the data, it is entirely dictated by the direct effect, i.e. the intertemporal substitution in the representative new Keynesian (RANK hereafter) model. The HANK models are successful in delivering the

Received: Oct. 19, 2020. Revised: April 21, 2021. Accepted: July 2, 2021.
* Professor, Department of Economics, Kyung Hee University, E-mail: jungys@khu.ac.kr. I thank two anonymous referees for useful comments.

general equilibrium effect of monetary policy comparable to that in the data. However, the HANK models are analytically intractable because of the computational burden to track the distribution of wealth, which is an infinite-dimensional of the state variable. Although some studies have matched the micro and macro moments by estimating the HANK model (Auclert et al., 2020), the lack of analytical tractability associated with HANK models introduces difficulties to and limits our understanding of the mechanisms behind the driving forces of business cycles (Alves et al., 2020).

Early empirical studies have shown that consumption tightly keeps track of current income for a substantial fraction of US households. For example, Campbell and Mankiw (1989) estimated that 40–50 percent of the US population merely consumed their current income. Micro studies using asset holdings data also show that a small share of the US population holds assets. Kaplan et al. (2014) estimate the fraction of hand-to-mouth (HtM hereafter) households using the Survey of Consumer Finance for 1989–2010 to find that approximately one-third of the US population are HtM. No exception found was in the European countries (Carroll et al., 2014).

The quantitative HANK models explicitly consider account heterogeneity and the feedback effects from equilibrium distributions to aggregates that depend on the asset and labor market. However, solving for the equilibrium of HANK economies, which requires the use of nontrivial computational techniques to keep track of the wealth distribution, is very challenging. To preserve the analytical tractability and consider the heterogeneity between agents, we will set up a two-agent New Keynesian (TANK hereafter) model that is useful in understanding and quantifying the implications of market incompleteness and heterogeneity for aggregate variables as in Bilbiie (2008), Debortoli and Galí (2018), and Galí et al. (2007). Debortoli and Galí (2018) show that the TANK models can generate similar equilibrium responses in response to monetary policy and other shocks under comparable redistribution schemes as in the HANK models. In the TANK model, two types of households are included. The first type is unconstrained households that satisfy the Euler equation as the households in the RANK model. The second type is constrained or HtM households that cannot have access to the financial market and consume all of their income each period. Constrained households cannot respond to the change in the interest rate or any variables other than their labor income.

The closed economy TANK model is isomorphic to the closed economy RANK model in that both models can be expressed in terms of the familiar three equations, i.e. the new Keynesian Phillips curve (NKPC hereafter), the aggregate demand, and the monetary policy equations. The aggregate demand equation in a TANK model, however, differs from that in a RANK model in that the response of output gap depends on the share of constrained households and the redistribution policy in place in the TANK model. In the open economy perspective, an additional difference arises between the RANK and TANK models. In the TANK model, only unconstrained households can share risk with foreign households in the international financial market, even though constrained households are also exposed to the exchange rate risk. Hence, the consumption gap between unconstrained households and constrained households generates trade imbalances in the TANK economy with the so-called Cole-Obstfeld preference and efficient productivity shocks.[1]

Some policymakers and students in academia have been skeptical about the future of the Korean economy. They have voiced the criticism that a substantial fraction of economically neglected households in the economy is heavily dependent on foreign countries. This paper re-exposes and reexamines the relative importance of foreign countries in shaping the business cycles in Korea by incorporating HtM households that are closely related to the economically neglected households into the canonical small open economy model as in Galí and Monacelli (2005). For this purpose, we introduce the foreign productivity shock in addition to domestic shocks such as domestic productivity shock, cost-push shock, and monetary shock into the small open economy TANK model. We first estimate the deep parameters with quarterly data from the Korean economy by using the MLE methodology along with Ireland (2011). Then, we evaluate the fraction of constrained households and the relative importance of each shock in the business cycle of Korea.

The contributions of the current paper are as follows.

First, a substantial fraction of constrained households in Korea has been observed since the mid-1970s. The fraction of constrained households is estimated at more than 0.5 in the sample period running from 1976:3 to 2018:4. The share of constrained households has increased over time with the Asian financial crisis and then moderately decreased. The estimate of the share of constrained households equals 0.54 in the first subsample period, namely, 1976:3–1996:4 before the Asian financial crisis. The estimate has significantly increased to 0.65 in the second subsample period, namely, 1998:32007:2 after the Asian financial crisis as the credit card crisis hit the Korean economy in 2003 with the macroprudential policy in place. The fraction of constrained households has moderately decreased to 0.60 in the third subsample period, namely, 2007:3–2018:4, i.e. during the Great Recession. The estimates of the share of constrained households are similar to those of the HtM households from the Korea Labor Institute Panel Survey in Jung (2019).

Second, the foreign productivity shock has played a more important role in explaining the variation of output than any other shock in the first subsample. The domestic productivity shock has also heavily contributed to the variation of output

[1] The intertemporal and intratemporal elasticity of substitutions equal one in the Cole–Obstfeld preference.

in the third subsample period. The contribution of the foreign productivity shock to the fluctuation of output is nil in the third subsample, implying that the relative importance of the domestic factor in business cycles in Korea has increased over time.

Third, the monetary policy, which has been very loose to accommodate the high demand for liquidity during the first subsample period, became proactive in controlling inflation during the second subsample period as the Bank of Korea adopted an inflation targeting rule after the Asian financial crisis. The effect of a monetary policy shock on the Korean economy has been negligible after the Asian financial crisis. The empirical result that the effect of monetary policy on output and the real exchange rate is nil in the third subsample period implies that the Korean economy could be in the liquidity trap near a zero-lower bound.

Finally, the cost-push shock has heavily contributed to the variation of output. Furthermore, the foreign productivity shock and the policy shock have played the most important role in explaining the variation of inflation and the real exchange rate in the Korean economy after the Asian financial crisis. The recent dominance of the cost-push shock and the foreign productivity shock to the fluctuation of output and inflation shows why the Korean government has attempted to transform its economic structures to be dependent on domestic markets than foreign markets, with an emphasis on price stability, in the era when a rapid economic growth has faded away.

The remainder of the paper is structured as follows. In section II, we specify a canonical two-agent new Keynesian model and derive an equilibrium. We also discuss the implications of the model related to interest rates and real activities. In section III, we present the empirical implications associated with the model. In section IV, we conclude.

II. The Model

This section sets up a variant of the new Keynesian model with simple heterogeneity in households applied to an open economy. The world is composed of two countries, home (H) and foreign (F) with population size n and $1-n$ respectively. In this paper, the small open economy is characterized as a limiting-case approach as in Galí and Monacelli (2005) and De Paoli (2009) by assuming that $n \to 0$.

A share of $1-\lambda$ of the continuum of households—referred to as unconstrained or Ricardian households—have access to financial markets, while the remaining share λ of the households—constrained or HtM households—cannot have access to financial markets and simply consume their period-income.

2.1. Households

2.1.1. Unconstrained Household

An unconstrained household chooses its consumption, asset holdings, and labor supply to maximize the expected lifetime utility function

$$\mathcal{W}_{U,t} = E_t[\sum_{k=0}^{\infty} \beta^k U(C_{U,t+k}, N_{U,t+k})],\ 0 < \beta < 1. \tag{1}$$

Here, $U(C_{U,t}, N_{U,t}) = \frac{C_{U,t}{}^{1-\sigma} - 1}{1-\sigma} - \frac{N_{U,t}^{1+\nu}}{1+\nu}$ for $\sigma \neq 1$, and $U(C_{U,t}, N_{U,t}) = \ln(C_{U,t}) - \frac{N_{U,t}^{1+\nu}}{1+\nu}$ for $\sigma = 1$. β is the household's discount factor and $C_{U,t}$ and $N_{U,t}$ represent the unconstrained household's consumption and working hours in period t, respectively. $C_{U,t}$ is a composite consumption index defined by

$$C_{U,t} \equiv \left[(1-\chi)^{\frac{1}{\eta}} C_{H,Ut}^{\frac{\eta-1}{\eta}} + \chi^{\frac{1}{\eta}} C_{F,Ut}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta-1}{\eta}},\ \eta \neq 1, \tag{2}$$

where $\chi \equiv (1-n)\theta$ is the share of domestic consumption allocated to imported goods. Here, $C_{H,Ut}$ and $C_{F,Ut}$ are indices of home and foreign consumption goods consumed by domestic unconstrained households and θ is the degree of trade openness. $\eta > 0$ is the intratemporal elasticity of substitution between domestic and foreign goods. Similarly, the foreign CES consumption index is assumed as follows:

$$C_t^* \equiv \left[(1-\chi^*)^{\frac{1}{\eta}} C^{*\frac{\eta-1}{\eta}}_{F,t} + \chi^{*\frac{1}{\eta}} C^{*\frac{\eta-1}{\eta}}_{H,t} \right]^{\frac{\eta-1}{\eta}} \tag{3}$$

where $\chi^* \equiv n\theta^*$. The indices of consumption of domestic and foreign goods are given by the following CES aggregators of the consumed amounts of each type of goods:

$$C_{U,Ht} = \left[\int_0^1 C_{U,Ht}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}},\quad C_{U,Ft} = \left[\int_0^1 C_{U,Ft}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{4}$$

where ε measures the elasticity of substitution among goods within each category.

For the sake of simplicity, suppose that domestic unconstrained households can trade state-contingent bonds denominated in the home currency as in Galí and

Monacelli (2005) and De Paoli (2009). Then, the domestic unconstrained household's budget constraint can be written as

$$P_t C_{U,t} + E_t[\Delta_{t,t+1} B_{U,t+1}] + \Theta_{U,t+1} Q_{S,t} \le B_{U,t} + W_t N_{U,t}$$
$$+\Theta_{U,t}(Q_{S,t} + P_t D_{U,t}) + P_t TR_{U,t} \tag{5}$$

where P_t and W_t are the home currency price of consumer price index (CPI hereafter) and the nominal wage. $B_{U,t}$ denotes a domestic currency denominated state-contingent nominal bond in period t. $Q_{S,t}$, $\Theta_{U,t}$, and $D_{U,t}$ denote the average market value of shares in domestic goods firms, and unconstrained household's shareholdings and the corresponding real dividends at time t, respectively.

The international risk-sharing condition implies the equilibrium real exchange rate given by

$$Q_t = \kappa \left(\frac{C_t^*}{C_{U,t}} \right)^{-\sigma}, \tag{6}$$

where $\kappa = 1$ with the assumption of symmetric initial conditions. Here, the asterisk (*) denotes the foreign variable to the corresponding domestic variable. The ratio of CPI relative to domestic price index (DPI hereafter) can be expressed in terms of the terms of trade $\mathcal{S}_t = \frac{P_{F,t}}{P_{H,t}}$ as follows

$$\frac{P_t}{P_{H,t}} = [(1-\theta) + \theta \mathcal{S}_t^{1-\eta}]^{\frac{1}{1-\eta}} \equiv \mathcal{K}(\mathcal{S}_t). \tag{7}$$

2.1.2. Constrained Households

The constrained or HtM households that cannot have access to financial markets just supply labor $N_{K,t}$ and consume their income determined in each period:

$$P_t C_{K,t} = P_t N_{K,t}, \tag{8}$$

where $C_{K,t}$ is HtM household's consumption in period t.

HtM households choose their consumption and labor supply to maximize their temporal utility function ($U_{K,t}$) subject to a budget constraint (8):

$$U_{K,t} \equiv U(C_{K,t}, N_{K,t}), \tag{9}$$

where $U(C_{K,t}, N_{K,t})$ has the same form as the temporal utility of the unconstrained households.

The HtM household's optimization conditions are given by

$$N_{K,t}^{\nu} C_{K,t}^{\sigma} = w_t, \tag{10}$$

and the budget constraint (8). Here, $w_t \equiv \frac{W_t}{P_t}$ is the real wage rate at time t.

2.2. Domestic Firms

Differentiated goods and monopolistic competition are introduced following Woodford (2003) and Yun (1996). We suppose that a continuum of firms produces differentiated goods and each firm indexed by $i \in [0,1]$ produces its product with a linear technology $Y_t(i) = Z_t N_t(i)$. Here, Z_t is a technology process in home country at period t, and $Y_t(i)$ and $N_t(i)$ are output and total labor input of the i th firm, respectively. We assume that the productivity shock follows an AR (1) process as $\log Z_t = (1-\rho_Z)\log Z + \rho_Z \log Z_{t-1} + \xi_{Z,t}$, $0 < \rho_Z < 1$, where $\xi_{Z,t}$ is an i.i.d. $N(0, \sigma_Z^2)$. Given that the labor market is perfectly competitive, the firm i's demand for labor is determined by its cost minimization as follows:

$$w_t = mc_t Z_t \mathcal{K}^{-1}(\mathcal{S}_t), \tag{11}$$

where $mc_t \equiv \frac{MC_t}{P_{H,t}}$ is the domestic firm's real marginal cost and MC_t is the corresponding nominal marginal cost at time t. Hence, the labor hours of unconstrained and HtM households can be rewritten in terms of the terms of trade as follows

$$C_{s,t}^{\sigma} N_{s,t}^{\nu} = mc_t Z_t \mathcal{K}^{-1}(\mathcal{S}_t), \tag{12}$$

where $s = U, K$. Combining HtM household's expenditure constraint

$$C_{K,t} = mc_t Z_t \mathcal{K}^{-1}(\mathcal{S}_t) \tag{13}$$

and labor supply conditions $C_{s,t}^{\sigma} N_{s,t}^{\nu} = mc_t Z_t \mathcal{K}^{-1}(\mathcal{S}_t)$ leads to

$$C_{K,t} = C_{U,t}^{\sigma} N_{U,t}^{\nu}, \tag{14}$$

$$N_{K,t}^{1+\nu} = (mc_t Z_t \mathcal{K}^{-1}(\mathcal{S}_t))^{1-\sigma}. \tag{15}$$

Next, we consider a staggered-price model à la Calvo (1983) and Yun (1996). Each domestic firm resets its optimal price $\tilde{P}_{H,t}(i)$ with probability $(1-\alpha)$ in any given period, independent of the time elapsed since the last adjustment firms set the new price. Another fraction of firms, α, sets its current price at its previous price level. The firm sets, on average, its price above marginal cost.

Given that $\tilde{P}_{H,t}(i)$ is the same for the reoptimizing firms, i.e. $\tilde{P}_{H,t}(i)=\tilde{P}_{H,t}$, the optimal price-setting equation can be written as

$$E_t\left\{\sum_{k=0}^{\infty}\alpha^k\Delta_{t,t+k}\left(\frac{P_t}{P_{t+k}}\right)\left(\frac{\tilde{P}_{H,t}}{P_{H,t+k}}\right)^{-1-\varepsilon}\right.$$
$$\left.\times\left[\left(1-\tau_{t+k}\right)Y_{t,t+k}mc_{t+k}-\mathcal{M}^{-1}MC_{t+k}\frac{\tilde{P}_{H,t}}{P_{H,t+k}}Y_{t,t+k}-T_{t+k}\right]\right\}=0, \tag{16}$$

where τ_t and T_t denote a time-varying tax on sales and a lump-sum taxation/subsidy to the firm at time t. $\mathcal{M}\equiv(\varepsilon/(\varepsilon-1))$ represents the average markup in the domestic goods market.

The domestic price aggregator implies that the relative price $P_{H,t}$ satisfies the relationship:

$$1=(1-\alpha)\tilde{p}_{H,t}^{1-\varepsilon}+\alpha(1+\pi_{H,t})^{\varepsilon-1}, \tag{17}$$

where $\tilde{p}_{H,t}\equiv\frac{\tilde{P}_{H,t}}{P_{H,t}}$ and $\pi_{H,t}\equiv\frac{P_{H,t}}{P_{H,t-1}}-1$ is the DPI inflation rate at time t. Aggregation of real profits of domestic firms leads to

$$D_{U,t}=(1-\tau_t)Y_t-w_t\mathcal{K}^{-1}(\mathcal{S}_t)N_t. \tag{18}$$

The tax-adjusted markup $\mathcal{M}_t\equiv\frac{\mathcal{M}}{1-\tau_t}$ corresponds to a time-varying inefficient wedge between the marginal rate of substitution between consumption and production to the flexible price equilibrium. Following Benigno and Benigno (2006) and Woodford (2003), we assume that

$$\mu_t=(1-\rho_\mu)\mu+\rho_\mu\mu_{t-1}+\xi_{\mu,t}, \tag{19}$$

where $\mu_t\equiv\log\mathcal{M}_t$, $0<\mu<1$, and $\xi_{\mu,t}$ is an i.i.d. $N(0,\sigma_\mu^2)$.

2.3. Importing Firms

We assume that the Law of One Price holds as in Galí and Monacelli (2005) and De Paoli (2009, 2010). The price of foreign good i in domestic currency $P_{F,t}(i)$

equals its price denominated in foreign currency $P^*_{F,t}(i)$ multiplied by the nominal exchange rate, $\mathcal{E}_t$:

$$P_{F,t}(i) = \mathcal{E}_t P^*_{F,t}(i)\,. \tag{20}$$

In the rest of the world composed of unconstrained households, the foreign household faces a problem identical to that outlined above. The only difference is that a negligible weight is assigned to consumption goods produced in a small economy ($\theta^* = 1$). Therefore, $P^*_t = P^*_{F,t}$ and $C^*_t = C^*_{F,t}$ for all t.

2.4. Monetary Authority

We assume that the domestic monetary authority conducts monetary policy based on a typical Taylor interest rate rule, while the foreign monetary authority follows a strict inflation targeting rule as in Galí and Monacelli (2005) and De Paoli (2009) as follows:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(a_\pi \pi_t + a_y y_t) + \xi_{r,t}\,, \tag{21}$$
$$\pi^*_t = \pi^*\,,$$

where ξ_t is an i.i.d. $\mathrm{N}(0,\sigma_r^2)$. ρ_r, a_π, and a_y are non-negative coefficients, chosen by the monetary authority. Here, π_t and π^*_t are the domestic and foreign CPI inflation rate at time t, and $x_t \equiv \ln(\frac{X_t}{X_{ss}})$, where X_{ss} is the steady-state value of the corresponding variable X_t.

2.5. Aggregation

The aggregate level of any household-specific variable X_t is given by $X_t = \int_0^1 X_t(i)di = (1-\lambda)X_{U,t} + \lambda X_{K,t}$. Hence, aggregate consumption and aggregate hours are given by

$$C_t = (1-\lambda)C_{U,t} + \lambda C_{K,t} \tag{22}$$

and

$$N_t = (1-\lambda)N_{U,t} + \lambda N_{K,t}\,. \tag{23}$$

Aggregate dividend and bond holdings also satisfy

$$D_t = (1-\lambda)D_{U,t}, \tag{24}$$
$$B_t = (1-\lambda)B_{U,t}. \tag{25}$$

Finally, the aggregate shareholdings $Q_t = (1-\lambda)Q_{U,t}$, the equity market clearing condition implies that $Q_{U,t} = Q_{U,t+1} = (1-\lambda)^{-1}$.

2.6. Equilibrium

By aggregating individual output across firms, we find a wedge between the aggregate output Y_t and aggregate labor hours N_t

$$Y_t = \frac{Z_t N_t}{\Delta_t}, \tag{26}$$

where $\Delta_t = \int_0^1 (\frac{P_{H,t}(i)}{P_{H,t}})^{-\varepsilon} di$ is the relative domestic price dispersion in period t.[2]

Assuming a symmetric degree of home bias across countries with the negligible relative size of the home country, goods market clearing in home and foreign countries requires

$$Y_t = (1-\theta)\mathcal{K}(\mathcal{S}_t)^{\eta} + \theta \mathcal{S}_t^{\eta} C_t^*, \tag{27}$$
$$Y_t^* = C_t^*. \tag{28}$$

Notably, (26) and (27) can be simplified as

$$Z_t((1-\lambda)N_{U,t} + \lambda N_{K,t}) = (1-\theta)\mathcal{K}(\mathcal{S}_t)^{\eta} + \theta \mathcal{S}_t^{\eta} C_t^*. \tag{29}$$

The competitive equilibrium conditions consist of the efficiency conditions and the budget constraints of the households and firms, and the market-clearing conditions of each goods market, labor market, equity, money, and bond market. That is, the symmetric equilibrium is a sequential allocation of $\{C_{U,t}, N_{U,t}, C_{K,t}, N_{K,t}, Y_t\}_{t=0}^{\infty}$, a sequence of prices and costate variables for the home country $\{P_{H,t}, P_{F,t}, P_t, B_t, mc_t, R_t\}_{t=0}^{\infty}$, and a sequence of the real exchange rate $\{Q_t\}_{t=0}^{\infty}$. Here, (1) the unconstrained and constrained households' decision rules solve their optimization problems, given the states and the prices. (2) The demands for labor solve each firm's cost minimization problem and the price-setting rule solves its present value maximization problem, given the states and the prices. (3) Each goods

[2] Given that this paper is focused on the business cycles via log-linearization around the steady-state, the relative price dispersion can be neglected in the discussion of sources of business cycles in Korea.

market, labor market, equity, and bond market are cleared at the corresponding prices, given the sequence of the variables of the reset of the world $\{C_t^*, Y_t^*, P_t^*, P_{F,t}^*, B_t^*, mc_t^*, R_t^*\}_{t=0}^{\infty}$, the initial conditions for the state variables, and the exogenous domestic productivity, cost-push, and monetary shock processes $\{Z_t, \mu_t, \xi_{r,t}\}_{t=0}^{\infty}$ as well as the monetary policy rate $\{R_t\}_{t=0}^{\infty}$.

2.7. Dynamics around Steady State

We restrict our attention to the case of small fluctuations of the endogenous variables around a steady state as in King et al (1988).

Assuming that the fiscal authority implements a sales tax/subsidy to ensure the efficient steady-state, the dynamics of the economy can be simplified in terms of six endogenous variables $\{c_t, y_t, \pi_t, \pi_{H,t}, r_t, s_t\}$ and four exogenous variables $\{z_t, y_t^*, \xi_{r,t}, \mu_t\}$ as follows:

$$\sigma E_t\left[\frac{((1+\sigma\nu)-\lambda(1+\nu)\sigma)\Delta c_{t+1}-\lambda(1+\nu)(\Delta y_{t+1}-\Delta z_{t+1})}{(1-\lambda)(1+\sigma\nu)}\right]=r_t-E_t[\pi_{t+1}], \quad (30)$$

$$\pi_{H,t}=\beta E_t[\pi_{H,t+1}]+\frac{(1-\alpha)(1-\alpha\beta)}{\alpha\beta}(\sigma c_t+\nu y_t+\theta s_t-(1+\nu)z_t+\mu_t), \quad (31)$$

$$y_t=(2-\theta)\theta\eta s_t+(1-\theta)c_t+\theta y_t^*, \quad (32)$$

$$r_t=\rho_r r_{t-1}+(1-\rho_r)(a_\pi\pi_t+a_y y_t)+\xi_{r,t}, \quad (33)$$

$$(1-\theta)s_t=\sigma\left[\frac{((1+\sigma\nu)-\lambda(1+\nu)\sigma)c_t-\lambda(1+\nu)\nu(y_t-z_t)}{(1-\lambda)(1+\sigma\nu)}-y_t^*\right], \quad (34)$$

$$\pi_{H,t}=\pi_t-\theta(s_t-s_{t-1}), \quad (35)$$

$$z_t=(1-\rho_z)z+\rho_z z_{t-1}+\xi_{z,t}, \quad (36)$$

$$y_t^*=(1-\rho_{y^*})y^*+\rho_{y^*}y_{t-1}^*+\xi_{y^*,t}, \quad (37)$$

$$\mu_t=(1-\rho_\mu)\mu+\rho_\mu\mu_{t-1}+\xi_{\mu,t}. \quad (38)$$

In this system, the state vector at period t, x_t consists of (log) domestic and foreign technology shocks (z_t, y_t^*),[3] a cost-push or markup shock (μ_t), a monetary shock ($\xi_{r,t}$), and previous values of endogenous variables $\{c_{t-1}, y_{t-1}, \pi_{t-1}, \pi_{H,t-1}, r_{t-1}, s_{t-1}\}$.

[3] The foreign output is assumed to follow an AR (1) process as in Galí and Monacelli (2005).

III. Quantitative Evaluations

In this section, we will discuss the driving forces of business cycles in Korea using the small open economy TANK model in the previous section.

3.1. Estimation Methods

Given that the data do not contain enough information to estimate all parameters, a subset of the model's parameters needs to be finalized in advance. First, the inverse of the elasticity of intertemporal substitution (σ) and the inverse of Frisch labor supply elasticity (ν) are set to 2 and 1, respectively, as in Galí and Monacelli (2005) and Woodford (2003). Next, the degree of goods market openness (θ)[4] is set to 0.4. Finally, the elasticity of substitution between different goods is set equal to 6, implying a steady-state markup of 0.2 as in Galí and Monacelli (2005).

Using the relationship between the real exchange rate and the terms of trade as well as the CPI inflation rate and the DPI inflation rate, the equilibrium equations (30)–(38) can be recast in terms of five endogenous variables $\{y_t, c_t, \pi_t, q_t, r_t\}$ and four exogenous shock processes $\{z_t, y_t^*, \mu_t, \xi_{r,t}\}$. The methods of Blanchard and Khan (1980) can be applied to solve the model. Given that the empirical model of this system takes the form of a state-space econometric model, we can evaluate the likelihood function using the Kalman filtering algorithms.

Specifically, the model has 13 parameters: $\alpha, \lambda, a_\pi, a_y, \rho_z, \rho_{y^*}, \rho_\mu, \rho_r, \sigma_z, \sigma_{y^*}, \sigma_r, \sigma_\mu, \eta$. Let the vector $\boldsymbol{s}_t = [r_{t-1}, y_{t-1}, c_{t-1}, \pi_{t-1}, q_{t-1}, z_t, y_t^*, \xi_{r,t}, \mu_t]'$ and the vector $\mathbf{y}_t = [y_t, c_t, \pi_t, q_t, r_t]'$ denote the state and flow variables, respectively. Then, the log-linearized equilibrium conditions can be represented as the state-space form as follows:

$$\boldsymbol{s}_{t+1} = \boldsymbol{A}\boldsymbol{s}_t + \boldsymbol{B}\boldsymbol{\varepsilon}_{t+1}, \tag{39}$$

$$\boldsymbol{y}_t = \boldsymbol{C}\boldsymbol{s}_t, \tag{40}$$

where **A, B, C** are matrices of parameters of dimension 9×9, 9×4, and 5×9. Here, $\varepsilon_t = [\xi_{z,t}, \xi_{y_t^*}, \xi_{r,t}, \xi_{\mu,t}]'$ is assumed to be normally distributed with the zero mean and diagonal covariance matrix $\mathbf{V} = diag(\sigma_z^2, \sigma_{y^*}^2, \sigma_r^2, \sigma_\mu^2)'$. Maximum likelihood estimates of the parameters in **A**, **B**, and **C** can be obtained following Hamilton (1994).

[4] The share of importables relative to GDP is used as a proxy for the degree of goods market openness. The share of imported goods to GDP is approximately 0.35 to 0.45 during the sample periods.

3.2. Empirical Results

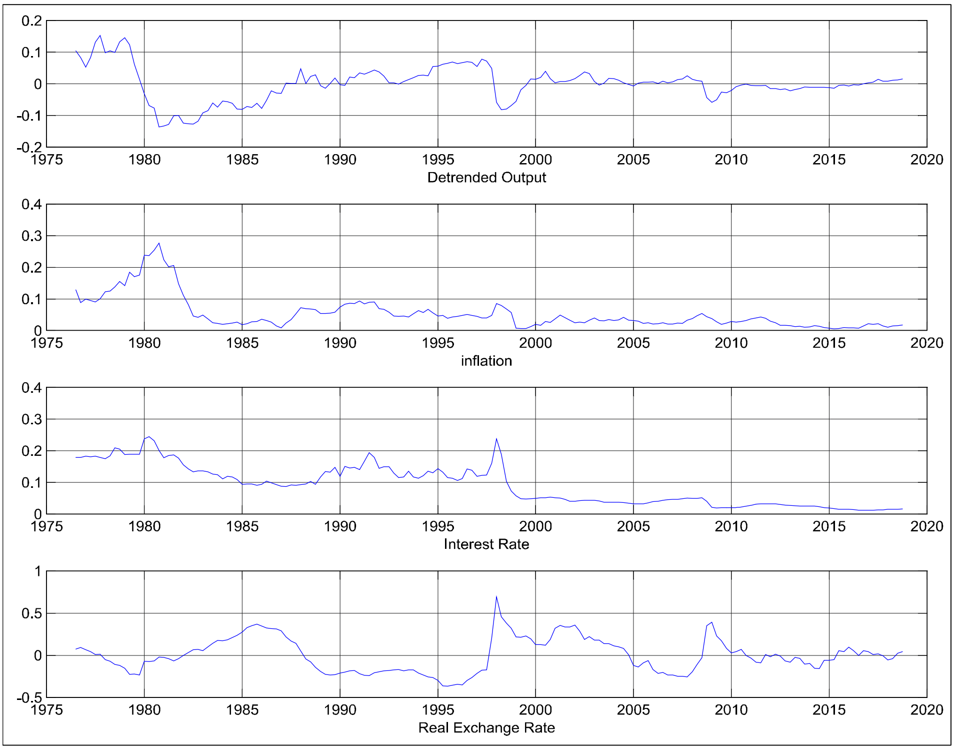
The values of π and r are taken from the steady-state inflation rate and nominal interest rate in the corresponding sample periods. The value of y is taken from the average level of log-quadratically detrended, per-capita GDP in the data. The discount factor β is determined from the condition that the steady-state nominal interest rate $1+r$ equals $(1+\pi)/\beta$. The data used in this exercise are taken from the Bank of Korea from 1976:3 to 2018:4. First, seasonally adjusted figures for real GDP, converted to log-quadratically detrended, are used to measure output. Quarterly changes in the seasonally-adjusted GDP deflator 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 USD/KRW nominal exchange rate and the US and Korea CPI are utilized to construct the real exchange rate.

By applying a Kalman filter to construct innovations in (39), we estimate the parameters α, λ, a_π, $a_y, \rho_z, \rho_{y^*}, \rho_\mu, \rho_r, \sigma_z, \sigma_{y^*}, \sigma_r, \sigma_\mu$, and η via maximum likelihood with their standard errors, as explained above. We divide the sample into three subsample periods. The first subsample period encompasses the era of rapid economic growth and managed exchange rate regime before the Asian financial crisis (1976:3–1997:2). The second one corresponds to the period with an economic slowdown and a credit crisis after the 1997 financial crisis in Korea and before the Great Recession (1997:3–2007:2). The third subsample period corresponds to the world economic turbulence of the Great Recession (2007:3–2018:4). Figure 1 shows the cyclical movements of relevant variables in Korea.

Table 1 presents maximum likelihood estimates of the key parameters in the first subsample period running from 1976:3 to 1997:2. The estimates for α and λ imply that firms have reoptimized their prices approximately every six months, and more than half of households are constrained or HtM households in the corresponding sample period. The estimate of λ, which is larger than those in previous studies such as Jung (2019), Park (2019), and Song (2020)[5], might be associated with the international market structure. Unconstrained households in the open economy can lend to or borrow from the rest of the world, while they cannot in the closed economy, in which net savings equal zero because unconstrained households cannot lend to HtM households that just spend their labor income every period. Unless unconstrained households optimally share risk with the rest of the world, they are classified as HtM households, making the estimate higher than that in the closed economy of Jung (2019). The estimates of ρ_z, ρ_{y^*}, and ρ_μ imply

[5] Jung (2019) estimates a closed economy TANK model, while Park (2019) and Song (2020) apply the Kaplan et al. (2014) methodology. They have classified cash, savings and demand deposits, and bonds, precautionary insurance as liquid assets. Then, they have defined HtM households those that have liquid net assets less than half of their monthly income as in Kaplan et al. (2014).

[Figure 1] Fluctuations of Key Macroeconomic Variables in Korea



[Table 1] Maximum Likelihood Estimates and Standard Errors (1976:3-1997:2)

Parameter	Estimate	Standard Error
α	0.5240	0.0019
λ	0.5388	0.0013
ρ_z	0.9682	0.0442
ρ_{y^*}	0.9877	0.0020
ρ_μ	0.9915	0.0008
ρ_r	0.3988	0.0055
a_π	1.0842	0.0002
a_y	0.0000	0.0001
σ_z	0.0250	0.0005
σ_{y^*}	0.0275	0.0001
σ_r	0.0101	0.0001
σ_μ	0.0856	0.0006
η	0.7698	0.0007
L^*	957.1303	

Note: L^* denotes the maximized value of the model's log-likelihood function.

that the model's exogenous shocks are highly persistent. Furthermore, the large estimates of $\sigma_z, \sigma_{y^*}, \sigma_\mu$, and σ_r imply that not only the domestic and foreign productivity shocks but also the monetary policy shock have played important roles over the business cycle in Korea before the Asian financial crisis.

Table 2 decomposes forecast variances in detrended output, inflation, the nominal interest rate, and the real exchange rate into components attributable to each of the model's four orthogonal disturbances: $\xi_{z,t}, \xi_{y^*,t}, \xi_{\mu,t}, \xi_{r,t}$. The table shows that foreign productivity and monetary shocks have dominated in explaining output variations at the short horizon. The cost-push shock has contributed to output variations by accounting for approximately 30–40 percent of output variations at the medium and longer horizons. The contribution of the domestic productivity shock to output fluctuations is moderate at all horizons in the first subsample period.

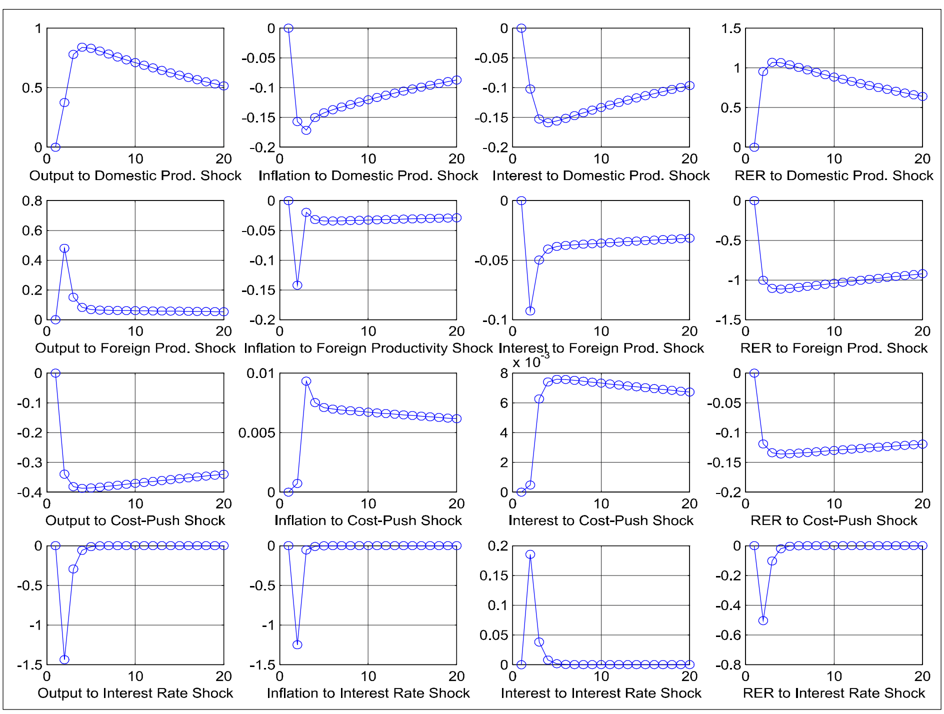
[Table 2] Forecast Error Variance Decompositions (1976:3-1997:2)

Quarters Ahead	Domestic Prod. Shock	Foreign Prod. Shock	Policy Shock	Cost-Push Shock
Output				
1	11.09	35.86	40.61	12.44
4	20.87	30.48	36.38	12.28
8	20.58	27.81	33.05	18.56
12	20.33	25.61	30.35	23.71
20	19.64	22.49	26.55	31.33
40	17.60	18.38	21.58	42.44
Inflation				
1	18.51	7.38	73.44	0.67
4	19.29	18.70	61.10	0.91
8	21.24	19.12	58.68	0.96
12	22.32	18.96	57.75	0.97
20	23.63	18.74	56.63	1.00
40	24.91	18.62	55.41	1.06
Interest Rate				
1	48.34	19.26	30.64	1.76
4	39.80	26.14	32.60	1.46
8	45.63	23.73	29.17	1.47
12	49.36	22.30	26.85	1.49
20	53.41	20.87	24.17	1.55
40	56.51	20.03	21.69	1.77
Exchange Rate				
1	29.39	61.28	7.14	2.19
4	26.89	64.32	6.57	2.22
8	25.74	67.74	4.18	2.34
12	24.56	69.88	3.12	2.44
20	22.45	72.75	2.20	2.60
40	18.74	76.88	1.48	2.90

The monetary shock dominates in explaining in movements of inflation by accounting for more than 50 percent of the unconditional variance of inflation at all horizons. The domestic and foreign productivity shocks have played a moderate role in the fluctuation of price by accounting for 10–20 percent of the unconditional variance of inflation at all horizons. The foreign productivity shock has dominated the international relative price fluctuations by accounting for more than 60 percent of the unconditional variance of the real exchange rate. The domestic productivity shock has also played a moderate role in the fluctuations of the real exchange rate. By contrast, the contribution of the monetary policy and cost-push shocks to the variations of the real exchange rate is very limited.

Figure 2 shows the impulse response functions of output, inflation, the interest rate, and the real exchange rate to one standard deviation of each shock in the first subsample period. The real exchange rate depreciates to the domestic productivity shock as output expands to the shock. The improvement of domestic productivity shock is partly accommodated by the monetary authority, which lowers its policy rate in the economy with sticky prices where actual output increases less than the efficient output. Given that output substantially falls to the unfavorable cost-push shock, the real exchange rate appreciates. The real exchange rate also appreciates to the expansion of foreign output as the price of importables falls to the shock. The persistent and strong effect of the monetary policy shock on output and inflation

[Figure 2] Impulse Response in First Subperiod: 1976:3-1997:2



reflects that the monetary authority has manipulated its policy rate to boost the economy, instead of stabilizing price during the first subsample period. During a rapid economic growth era where price stability has been subordinate to output stability, the Bank of Korea has been highly accommodative.

Table 3 presents maximum likelihood estimates of deep parameters of the model in the second subsample period, 1998:1–2007:2. In this subsample period, the Bank of Korea has adopted an inflation targeting rule and the Korean government has implemented its macroprudential tool to stabilize the housing market. The government introduced an LTV ratio in 2002 for the first time to cool down overheated housing prices. However, a credit card crisis occurred in 2003, making access to financial markets more difficult for households than before. The higher estimate of λ in the second subsample period than that in the first subsample period reflects the aggravated financial burden of households. Approximately 60 percent of households are estimated to be financially constrained during the second subsample period. This financial friction could partly explain the appearance of the so-called consumption puzzle, i.e. the fact that consumption is more volatile than output in Korea after the Asian financial crisis. Next, the larger estimate of a_π in the monetary policy rule reflects the change of the monetary policy stance, i.e. the adoption of an inflation targeting rule in Korea after the Asian financial crisis. The larger estimate for the foreign productivity shock σ_{y^*} also implies that the foreign output shock has become a more important factor over business cycles in Korea than before as the Korean economy entered an era of globalization.

[Table 3] Maximum Likelihood Estimates and Standard Errors (1998:1-2007:2)

Parameter	Estimate	Standard Error
α	0.3606	0.0281
λ	0.6450	0.0093
ρ_z	0.7596	0.0087
ρ_{y^*}	0.9599	0.0071
ρ_μ	0.9848	0.0062
ρ_r	0.1218	0.0117
a_π	1.8886	0.0104
a_y	0.0000	0.0005
σ_z	0.0205	0.0002
σ_{y^*}	0.0890	0.0068
σ_r	0.0059	0.0007
σ_μ	0.0550	0.0006
η	1.3454	0.0041
L^*	466.9791	

Note: L^* denotes the maximized value of the model's log-likelihood function.

Table 4 presents the decomposition of forecast variances in output, inflation, the nominal interest rate, and the real exchange rate into components attributable to each of the model's four orthogonal disturbances. The table shows that the cost-push shock has dominated in output variations at all horizons, and the domestic productivity shock has played a moderate role in the movements of output. The contribution of a monetary policy shock to output fluctuations has been nil during the second subsample period. Korea has moved from a managed exchange rate regime to a flexible exchange rate regime with the adoption of an inflation targeting rule after the Asian financial crisis. Under this circumstance, the Korean economy has been susceptible to the rest of the world. The foreign productivity shock has contributed heavily to variations in the inflation rate and the real exchange rate by accounting for more than 80 percent of the unconditional variance of the interest

[Table 4] Forecast Error Variance Decompositions (1998:1-2007:2)

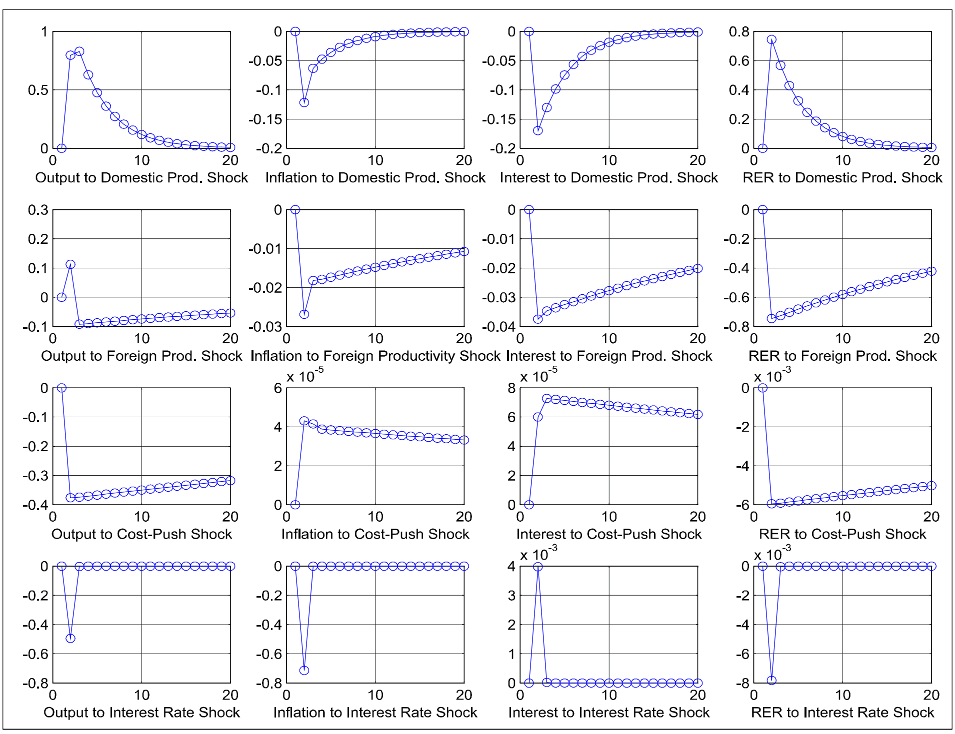
Quarters Ahead	Domestic Prod. Shock	Foreign Prod. Shock	Policy Shock	Cost-Push Shock
Output				
1	26.90	20.60	0.25	52.25
4	26.84	8.49	0.10	64.57
8	19.21	5.52	0.06	75.21
12	14.89	4.30	0.05	80.76
20	10.75	3.15	0.04	86.06
40	7.37	2.20	0.02	90.41
Inflation				
1	24.18	13.76	59.84	2.22
4	21.55	36.76	40.10	1.59
8	19.13	45.86	33.54	1.47
12	17.32	51.07	30.18	1.43
20	15.43	56.28	26.86	1.44
40	14.07	59.89	24.48	1.56
Interest Rate				
1	59.38	33.78	1.38	5.45
4	38.09	58.78	0.60	2.53
8	29.25	68.27	0.43	2.05
12	24.68	73.06	0.35	1.91
20	20.59	77.29	0.30	1.82
40	17.95	79.84	0.26	1.95
Exchange Rate				
1	2.21	95.31	0.01	2.47
4	1.33	95.99	0.00	2.68
8	0.87	96.19	0.00	2.94
12	0.68	96.13	0.00	3.19
20	0.53	95.60	0.00	3.67
40	0.44	94.87	0.00	4.69

rate and the exchange rate at all horizons. In the inflation targeting regime, the monetary authority has tried to implement predictable monetary policies to achieve its primary goal of price stability. Table 4 shows that the effect of monetary policy on the key macroeconomic variables except inflation is nil. In addition to the monetary policy shock, the foreign productivity shock has played an important role in the behavior of the inflation rate in the second subsample period of globalization.

Figure 3 presents the impulse response functions of output, inflation rate, the interest rate, and the real exchange rate to one percent standard deviation rise of each shock in the second subsample period. The effects of the domestic and foreign productivity shocks on output and the real exchange rate are much smaller in the second subsample period than those in the first subsample period because the monetary authority had not manipulated its policy rate to boost output in the inflation targeting regime.

Table 5 presents maximum likelihood estimates of these values in the third subsample period (2007:3-2018:4). The estimate for λ remains high compared with that one in the first subsample period, implying that the liquidity constraint on households has been pervasive during the Great Recession. The estimated foreign productivity and the cost-push shocks and the persistence parameters show that the negative effects of the Great Recession are huge in Korea.

[Figure 3] Impulse Response in Second Subperiod: 1998:1-2007:2



[Table 5] Maximum Likelihood Estimates and Standard Errors (2007:3-2018:4)

Parameter	Estimate	Standard Error
A	0.4585	0.0044
Λ	0.6090	0.0423
ρ_z	0.9685	0.0250
ρ_{y^*}	0.9891	0.0209
ρ_μ	0.9881	0.1845
ρ_r	0.1002	0.0218
a_π	1.3163	0.0300
a_y	0.0001	0.0046
σ_z	0.0309	0.0004
σ_{y^*}	0.0439	0.0008
σ_r	0.0033	0.0006
σ_μ	0.0797	0.0015
η	0.9418	0.1651
L^*	631.6499	

Note: L^* denotes the maximized value of the model's log-likelihood function.

Table 6 presents the decomposition of forecast variances of relevant variables into components attributable to each of the disturbances. First, the effect of a monetary policy shock on output, the interest rate, and the real exchange rate is nil, implying the ineffectiveness of a monetary policy in the economy near the zero-lower bound. The huge effect of the rest of the world economic shock on the Korean economy in the third subsample period can be read in the contribution of the cost-push shock to output variations at all horizons. The domestic productivity shock has also substantially contributed to the variations of output and inflation.

Figure 4 shows the impulse response functions of output, inflation, and the interest rate to one percent standard deviation rise of each shock in the third subsample period running from 2007:3 to 2018:4. Taking into account a small estimated value of monetary policy shock, the effect of monetary shock on output and inflation is very small in the third subsample period. This finding reflects a limited effect of monetary policy during the Great Recession period, in which the policy rate is near the zero-lower bound.

3.3. Evaluation of the Model

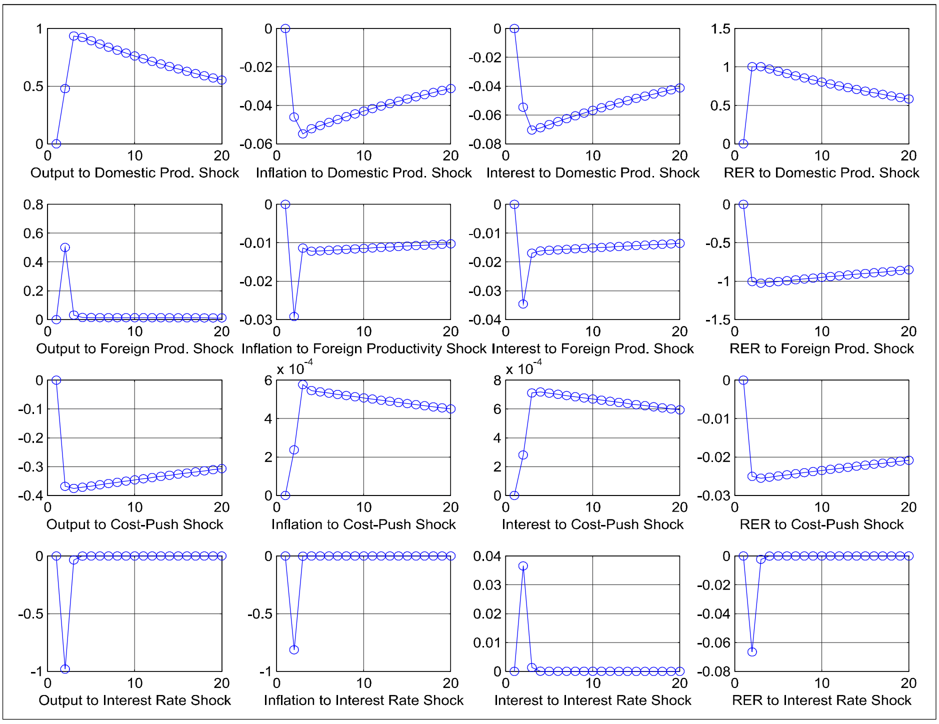
We can evaluate the success and failure of the TANK model relative to the RANK model using second moments of key macroeconomic variables and the impulse responses and variance decomposition of the selected variables.[6] The second moments and the cyclical covariability of relevant variables in the data and the corresponding moments generated from the TANK and RANK models are presented in Tables 7–9.

[Table 6] Forecast Error Variance Decompositions (2007:3-2018:4)

Quarters Ahead	Domestic Prod. Shock	Foreign Prod. Shock	Policy Shock	Cost-Push Shock
Output				
1	41.10	0.99	0.00	57.91
4	41.22	0.61	0.00	58.17
8	39.71	0.56	0.00	59.73
12	38.16	0.56	0.00	61.28
20	33.35	0.57	0.00	64.09
40	30.17	0.61	0.00	69.22
Inflation				
1	6.04	30.30	63.65	0.01
4	32.89	22.32	42.01	2.78
8	45.88	19.01	30.80	4.31
12	51.70	17.65	25.39	5.26
20	56.38	16.85	20.23	6.54
40	57.86	16.48	16.01	8.57
Interest Rate				
1	16.47	82.69	0.81	0.03
4	58.97	35.92	0.30	4.81
8	68.22	25.28	0.18	6.32
12	70.89	21.83	0.13	6.95
20	71.93	19.67	0.10	8.30
40	69.87	19.73	0.07	10.33
Exchange Rate				
1	16.33	75.24	0.00	8.43
4	15.51	76.00	0.00	8.49
8	14.54	76.90	0.00	8.56
12	13.67	77.71	0.00	8.62
20	12.21	79.08	0.00	8.71
40	9.77	81.40	0.00	8.83

[6] Some formal econometric methods such as Watson (1993)'s RMSAE need to be used to evaluate more critically the explanatory power of the theoretical model.

[Figure 4] Impulse Response in Third Subperiod: 2007:3-2018:4



[Table 7] Moments of Data and Models (1976:3-1997:4)

Variable	Std. Dev.	Cross	Corr.	x_t	with	y_{t+k}				
		k=-4	k=-3	k=-2	k=-1	k=0	k=1	k=2	k=3	k=4
	Data									
y_t	2.64	0.18	0.37	0.58	0.80	1.00	0.80	0.58	0.37	0.18
r_t	1.70	0.35	0.19	0.02	-0.08	-0.13	-0.17	-0.26	-0.38	-0.44
π_t	3.10	0.34	0.26	0.13	0.04	-0.10	-0.10	-0.19	-0.28	-0.34
q_t	9.25	-0.24	-0.33	-0.40	-0.41	-0.38	-0.27	-0.14	0.00	0.13
	TANK	Model								
y_t	3.19	-0.07	0.29	0.60	0.79	1.00	0.79	0.60	0.29	-0.07
r_t	2.06	0.03	-0.14	-0.28	-0.37	-0.47	-0.34	-0.25	-0.11	0.04
π_t	3.51	0.04	-0.25	-0.49	-0.64	-0.81	-0.56	-0.42	-0.19	0.17
q_t	3.20	-0.06	0.13	0.29	0.39	0.50	0.50	0.39	0.21	-0.02
	RANK	Model								
y_t	4.24	-0.07	0.33	0.66	0.84	1.00	0.84	0.66	0.33	-0.07
r_t	2.84	-0.02	-0.33	-0.55	-0.61	-0.52	-0.34	-0.21	-0.06	0.10
π_t	2.55	0.05	-0.31	-0.61	-0.77	-0.89	-0.74	-0.57	-028	0.07
q_t	4.54	-0.07	0.29	0.57	0.73	0.87	0.76	0.60	0.31	-0.06

[Table 8] Moments of Data and Models (1998:1-2007:2)

Variable	Std. Dev.	Cross	Corr.	x_t	with	y_{t+k}				
		k=-4	k=-3	k=-2	k=-1	k=0	k=1	k=2	k=3	k=4
	Data									
y_t	2.59	0.14	0.36	0.60	0.84	1.00	0.84	0.60	0.36	0.14
r_t	2.84	0.34	0.35	0.27	0.00	-0.42	0.00	-0.59	-0.55	-0.41
π_t	1.59	0.17	0.24	0.31	0.30	-0.03	-0.67	-0.60	-0.29	-0.24
q_t	15.27	0.05	-0.07	-0.21	-0.41	-0.68	-0.69	-0.56	-0.39	-0.22
	TANK	Model								
y_t	2.63	-0.08	0.29	0.61	0.81	1.00	0.81	0.61	0.29	-0.08
r_t	2.19	-0.06	0.00	-0.07	-0.09	-0.23	-0.37	-0.27	-0.16	-0.01
π_t	2.87	-0.01	-0.18	-0.32	-0.42	-0.47	-0.22	-0.17	-0.06	0.06
q_t	3.58	-0.07	0.13	0.30	0.40	0.53	0.58	0.43	0.22	-0.02
	RANK	Model								
y_t	3.64	-0.07	0.32	0.65	0.84	1.00	0.84	0.65	0.32	-0.07
r_t	2.00	-0.06	-0.28	-0.43	-0.46	-0.19	-0.02	0.04	0.08	0.10
π_t	1.89	0.04	-0.26	-0.50	-0.63	-0.71	-0.55	-0.42	-0.20	0.06
q_t	4.07	-0.07	0.25	0.52	0.68	0.82	0.72	0.57	0.29	-0.05

[Table 9] Moments of Data and Models (2007:3 - 2018:4)

Variable	Std. Dev.	Cross	Corr.	x_t	with	y_{t+k}				
		k=-4	k=-3	k=-2	k=-1	k=0	k=1	k=2	k=3	k=4
	Data									
y_t	1.37	-0.25	0.16	0.33	0.71	1.00	0.71	0.33	0.16	-0.25
r_t	0.69	0.37	0.55	0.69	0.77	0.60	0.20	-0.19	-0.42	-0.57
π_t	0.57	-0.13	0.16	0.27	0.18	0.30	0.30	0.08	-0.23	-0.27
q_t	11.57	0.26	0.02	-0.22	-0.54	-0.81	-0.74	-0.42	-0.09	0.16
	TANK	Model								
y_t	2.33	-0.14	0.18	0.52	0.76	1.00	0.76	0.52	0.18	-0.14
r_t	0.57	0.03	0.16	0.21	0.22	0.11	0.16	0.16	0.13	0.11
π_t	1.52	-0.02	-0.02	-0.04	-0.07	0.09	0.16	0.14	0.11	0.03
q_t	3.39	-0.10	0.17	0.43	0.60	0.83	0.69	0.50	0.22	-0.08
	RANK	Model								
y_t	3.13	-0.12	0.24	0.59	0.81	1.00	0.81	0.59	0.24	-0.12
r_t	0.80	0.03	0.01	0.01	0.03	0.22	0.32	0.30	0.22	0.05
π_t	1.33	-0.03	-0.03	-0.04	-0.06	0.06	0.14	0.14	0.10	0.03
q_t	4.00	-0.11	0.21	0.51	0.70	0.88	0.76	0.57	0.26	-0.09

First, we compare the output volatility in the data, that for the representative agent model, and that for the two-agent model. The output volatility in the TANK model is comparable to that in the data, while it is more volatile in the RANK model before the Great Recession. Although the TANK model is better than the RANK model in generating a moderate output volatility during the Great Recession, both models are not successful in producing the muted movements of output in the Great Recession.

Second, the cross-correlation between output and the real exchange generated from both models shows that they fail to generate a countercyclical real exchange rate movement in the data. The feature that the real exchange rate comoves procyclically in theoretical models echoes the consumption–real exchange rate anomaly in the international finance literature. No exceptions were found. The existing models that produce a very tight comovement between the relative consumption and the real exchange rate fail to explain the risk-sharing observed in the data. The positive comovement between output and the real exchange rate generated from the TANK model is less than that in the RANK model. Both models also cannot generate the persistent and volatile real exchange rate movements in the data. As noted by Chari et al. (2002), a very high degree of relative risk aversion is needed to explain the volatile real exchange rate movements.

The interest rate and inflation generated from the TANK and RANK models comove countercyclically as those in data in the first and second subperiods, while they move procyclically as those in the data in the third subsample period. Unlike the procyclical interest rate movements observed in advanced countries, the feature of countercyclical interest rate movements in Korea can be associated with the depressed or distorted financial markets during the government-led high economic growth era. Furthermore, the interest rate is a lagging positive indicator and a leading negative indicator in the data (i.e. $corr(y_t, r_{t-k}) < 0, corr(y_t, r_{t+k}) < 0$) for $k = 2$. However, the opposite occurs in either the TANK or RANK model in the first and second subsample periods. The interest rate in either the TANK or RANK model is a lagging negative in the first and second subsample periods. However, the interest rate is a leading positive indicator, contrary to the data. The TANK model is better than the RANK model in that the interest rate in the former is a leading indicator in the first and second subsample periods as in the data, whereas the interest rate generated from the latter is only a leading indicator in the first subsample period.

Overall, the TANK model outperforms the RANK model in generating the comovements between output and selected financial variables. To evaluate the role of HtM households over the business cycles in Korea more critically, we need a full-fledged TANK model with an idiosyncratic shock, in addition to aggregate shocks such as Bilbiie (2019), Bilbiie et al. (2020), and Cho (2020).

IV. Concluding Remarks

This paper sets up a canonical two-agent small open economy new Keynesian model and then investigates driving forces of business cycles in Korea using maximum likelihood. The paper finds that a substantial fraction of constrained households in Korea has played a key role over business cycles in Korea.

The monetary policy shock has been more important than any other shocks in explaining the behavior of the detrended output and inflation over business cycles in Korea during the high economic growth era. The cost-push and domestic productivity shocks have played pivotal roles in aggregate output fluctuations during the inflation targeting regime. The relative importance of the foreign productivity shock in the variation of output has also decreased over time. The dominance of a policy shock in the variations of inflation has decreased over time as the loose monetary policy to accommodate the high demand for liquidity during the first subsample period became proactive in controlling inflation during the second subsample period with the adoption of an inflation targeting rule at 1998. The fraction of constrained households, which has sharply increased after the Asian financial crisis, has still played an important role in business cycles in Korea in the era of the Great Recession.

Appendix

A1. Equilibrium Conditions in log-linearized forms

In this appendix, we present the log-linearized equilibrium conditions around the steady-state.

$$\sigma E_t[c_{U,t+1} - c_{U,t}] = r_t - E_t[\pi_{t+1}], \tag{A1}$$

$$y_t = (2-\theta)\theta\eta s_t + (1-\theta)c_t + \theta y_t^*, \tag{A2}$$

$$\pi_{H,t} = \beta E_t[\pi_{H,t+1}] + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha\beta}(mc_t + \mu_t), \tag{A3}$$

Labor demand and labor supply of unconstrained and constrained households are given by

$$w_t = mc_t - \theta s_t + y_t - n_t, \tag{A4}$$

$$\sigma c_{U,t} + \nu n_{U,t} = w_t, \tag{A5}$$

$$\sigma c_{K,t} + \nu n_{K,t} = w_t, \tag{A6}$$

while the budget constraint of the constrained household is given by

$$c_{K,t} = w_t + n_{K,t}. \tag{A7}$$

The risk-sharing condition in the international financial market can be expressed as

$$\sigma(c_{U,t} - y_t^*) = q_t, \tag{A8}$$

while the relationship between the real exchange rate and the terms of trade can be written as

$$q_t = (1-\theta)s_t. \tag{A9}$$

The domestic aggregate production function, total hours, and consumption are given by

$$y_t = z_t + n_t, \tag{A10}$$

$$n_t = (1-\lambda)n_{U,t} + \lambda n_{K,t}, \tag{A11}$$

$$c_t = (1-\lambda)c_{U,t} + \lambda c_{K,t}. \tag{A12}$$

The monetary policy and net export can be written as

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(a_\pi \pi_t + a_y y_t) + \xi_{r,t}, \tag{A13}$$

$$nx_t = y_t - c_t - \theta s_t. \tag{A14}$$

Finally, CPI and DPI are related as

$$\pi_t = \pi_{H,t} + \theta(s_t - s_{t-1}). \tag{A15}$$

Given exogenous variables $\{z_t, y_t^*, \xi_{r,t}, \mu_t\}$, and the foreign variables, (A1)– (A15) determine 15 variables, $\{c_{U,t}, c_{K,t}, n_{U,t}, n_{K,t}, c_t, n_t, r_t, q_t, \pi_{H,t}, \pi_t, mc_t, s_t, w_t, nx_t, y_t\}_{t=0}^{\infty}$.

A2. Steady-State and Empirical Model for Estimation

A subset of the model's parameters needs to be fixed in advance before applying the maximum likelihood procedure to estimate key parameters. The values of π and r are taken from the steady-state inflation rate and nominal interest rate in the corresponding sample periods. The time discount factor β is determined from the condition that the model's steady-state nominal interest rate r equals $(1+\pi)/\beta$.

We assume that the steady-state is efficient and equitable by assuming that government taxes or subsidizes at a constant rate τ and redistribute the proceedings in a lump-sum fashion T at the steady-state as in Bilbiie (2008) and Woodford (2003). This results in marginal cost pricing and zero profit at the steady-state. Hence, $Y = C_U = C_K = C^*$, and $Q = 1$ at the steady-state.

Next, we present an empirical model for estimation as follows. Suppose that data are available on output y_t, inflation π_t, the real exchange rate q_t, and the interest rate r_t.

$$\boldsymbol{d}_t = \begin{bmatrix} y_t \\ \pi_t \\ q_t \\ r_t \end{bmatrix}$$

Then, the empirical model can be expressed as

$$\boldsymbol{d}_t = \boldsymbol{U}\boldsymbol{s}_t,$$

where

$$\boldsymbol{U} = \begin{bmatrix} C_1 \\ C_3 \\ C_4 \\ C_5 \end{bmatrix},$$

and the vector of serially uncorrelated innovations $\boldsymbol{\varepsilon}_{t+1} = [\xi_{z,t}, \xi_{y_t^*}, \xi_{r,t}, \xi_{\mu,t}]$ is assumed to be normally distributed with zero mean and diagonal covariance matrix $\mathbf{V}$.

References

Alves, F, G. Kaplan, B. Moll and G. L. Violante (2020), "A Further Look at Propagation of Monetary Policy Shock in HANK," *Journal of Money, Credit, and Banking*, (forthcoming).

Auclert, A., M. Rognlie, and L. Straub (2018), "The Intertemporal Keynesian Cross," Mimeo.

______________________________ (2020), "Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model," Mimeo.

Benigno, G. and P. Benigno (2006), "Designing Targeting Rules for International Monetary Policy Cooperation," *Journal of Monetary Economics*, Vol. 53, No. 3, 473–506.

Bilbiie, F. O. (2008), "Limited Asset Market Participation, Monetary Policy, and Inverted Aggregate Demand Logic," *Journal of Economic Theory*, Vol. 140, No. 1, 162–196.

__________ (2019), "Monetary Policy and Heterogeneity: An Analytical Framework," Mimeo.

Bilbiie, F. O., D. R. Kanzig, and P. Surico (2020), "Capital and Income Inequality: An Aggregate Demand Complementarity," Mimeo.

Blanchard, O. J. and C. M. Kahn (1980), "The Solution of Linear Difference Models Under Rational Expectations," *Econometrica*, Vol. 48, No. 5, 1305–1311.

Calvo : Calvo, G. A. (1983), "Staggered Prices in a Utility-maximizing Framework," *Journal of Monetary Economics*, Vol. 12, No. 3, 383–398.

Campbell, J. and G. N. Mankiw (1989), "Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence," in Olivier Blanchard, Stanley Fischer (eds.), NBER Macroeconomics Annual, MIT Press, Cambridge, MA, 185–216.

Carroll, C. D., J. Slacalek, and K. Tokuoka (2014), "The Distribution of Wealth and the MPC: Implications of New European Data," *American Economic Review*, Vol. 104, No. 5, 107–111.

Chari, V., P. Kehoe, and E. McGrattan (2002), "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?" *Review of Economic Studies*, Vol. 69, No. 3, 533–563

Cho, D. (2020), "Unemployment Risk, MPC Heterogeneity, and Business Cycles," Mimeo.

Debortoli, D. and J. Galí (2018), "Monetary Policy with Heterogeneous Agents: Insights from TANK Modes."

De Paoli, B. (2009), "Monetary Policy and Welfare in a Small Open Economy," *Journal of International Economics*, Vol. 77, No. 1, 11–22.

Hamilton, J. D. (1994), Time Series Analysis, Princeton Press, NJ.

Galí, J. and T. Monacelli (2005), "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, Vol. 72, No. 3, 707–734.

Galí, J., D. López-Saildo, and J. Vallés, (2007) "Understanding the Effects of Government Spending on Consumption," *Journal of European Economic Association*, Vol. 5, No. 1, 227–270.

Ireland, P. N. (2011), "A New Keynesian Perspective on the Great Recession," *Journal of*

Money, Credit, and Banking, Vol. 43, No. 1, 31–54.

Jung, Y. (2019), "What Drives Business Cycles in Korea?" *Japan and the World Economy*, Vol. 52.

Kaplan, G., G. L. Violante, and J. Weidner (2014), The Wealthy Hand-to-Mouth, Brooking Papers on Economic Activity 2014-1, 77–153.

Kaplan G., B. Moll and G. L. Violante (2018), "Monetary Policy According to HANK," *American Economic Review*, Vol. 108, No. 4, 697–743.

King , R. G., C. Plosser, and S. T. Rebelo (1988), "Production, Growth and Business Cycles: I. The Basic Neoclassical Model," *Journal of Monetary Economics*, Vol. 21, No. 2-3, 195–232.

McKay, A., E. Nakamura and J. Steinsson (2016), "The Power of Forward Guidance Revisited," *American Economic Review*, Vol. 106, No. 10, 3133–3158.

Song, S. (2020), "Leverage, Hand-to-Mouth Households, and Heterogeneity of the Marginal Propensity to Consume: Evidence from South Korea," *Review of Economics of the Household*, Vol. 18, No. 4, 1213–1244

Park, K. Y. (2019), "The Wealthy Hand-to-Mouth Households in South Korea," *Global Economic Review*, Vol. 48, No. 1, 63–87.

Watson, M. W. (1993), "Measures of Fit for Calibrated Models," *Journal of Political Economy*, Vol. 101, No. 6, 1011–1041.

Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton, Princeton University Press, New Jersey.

Yun, T. (1996), "Monetary Policy, Nominal Price Rigidity, and Business Cycles," *Journal of Monetary Economics*, Vol. 37, No. 2, 345–370.

2 경제주체 모형을 통한 한국의 경기변동 고찰

정 용 승*

초 록 본 논문에서는 in Galí and Monacelli (2005)의 대표적 경제주체 소규모 개방경제 새 케인지언 모형에 일부 가계부문이 금융시장에 참여할 수 없다는 제약을 도입한 2 경제주체 새 케인지언 소규모개방경제모형을 이용하여 1970년대중반이후 한국의 경기변동요인을 분석하였다. 최우추정법을 이용한 분석에 따르면, 가계부문중 금융시장참여 제약을 받는 가계부문은 상당히 큰 비중을 차지하였으며 금융시장참여 제약을 받는 가계부문이 한국의 경기변동에서 매우 중요한 역할을 한 것으로 나타났다. 경기변동상의 산출물 움직임에 있어서 해외 실물충격은 그 비중이 점차 줄어든 반면, 국내 실물충격의 비중은 증대하였다. 통화정책은 경제개발시대에는 성장에 필요한 자금공급을 위해 상당히 완만히 운영되었으나 외환위기이후 물가안정목표제 채택과 함께 물가안정에 초점을 맞춤으로써 경기변동상에서 통화정책 충격의 역할은 보다 제한적으로 바뀌었다.

핵심 주제어: 경기변동, 최우추정, 소규모개방경제, 2 경제주체
경제학문헌목록 주제분류: E32

투고 일자: 2020. 10. 19. 심사 및 수정 일자: 2021. 4. 21. 게재 확정 일자: 2021. 7. 2.
* 경희대학교 경제학과 교수, e-mail: jungys@khu.ac.kr