<論 文>

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Housing and Monetary Policy: Evidence of the Stabilization Effect in Korea derived from a DSGE Model

주택과 통화정책 : DSGE 모형에 의한 한국에서의 안정화 효과 사례

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< Abstract >

Research interest concerning macroeconomic linkages in housing has piqued since the Global Financial Crisis (GFC) of 2007-09. This paper documents evidence of such linkage in the Korean context derived from a DSGE(Dynamic Stochastic General Equilibrium) model that controls endogenous relationships between housing price and key macroeconomic variables. In particular, there are two analytical issues in our theoretical and empirical investigation: (1) the intra-temporal (or single-period) substitution between housing and non-housing consumption and (2) the stabilization effect of monetary policy from two alternative policy rules – a conventional Taylor rule that does not consider housing price vs. a modified Taylor rule that does. The results show that: (1) housing and non-housing consumption in Korea are complements, rather than substitutes, implying a positive wealth effect in that a rise in one variable causes the same direction in the other and (2) the modified Taylor rule with explicit control of housing prices is shown to be superior over the conventional rule in that both output volatility and inflation volatility are shown to be reduced under the former. These results support the Bank of Korea which considers the housing market in monetary policy.

Keyword : The elasticity of intra-temporal substitution (EIS); the inter-temporal elasticity of substitution (IES); co-integration; DSGE model; monetary policy

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I. Introduction

The housing and mortgage markets were the epicenter of the Global Financial Crisis (herein referred as “GFC”) in 2007-09, which, in turn, resulted in a contagion to the real economy and caused the Great Recession, the longest post-war recession in the U.S. Although it has long been observed that those recessions with housing as a contributing sector incurred longer, more severe, economic downturns compared to those without housing as a contributing sector (Reinhart and Rogoff, 2009), GFC caused a paradigm shift in economic research. Traditionally, while macroeconomics as a discipline in economic research treated housing as one of many durable goods, the real estate research assumed consumption and other macro factors as exogenous. In the post GFC era, having observed the severity of negative spillovers caused by the housing and mortgage crisis, the inter-sectoral studies between real estate and macro-economy are burgeoning in number.

In the public policy point of view, housing was not a subject for explicit policy consideration either. Often referred to as “benign neglect,” the rampant appreciation of housing prices did not constitute an issue for the central bank’s policy response, due to largely two reasons. First, in order for the central bank to be able to respond to house price hikes as a preemptive policy action, one should be able to discern a contagious and systemically-significant housing boom from a non-contagious one, which is generally known as a difficult analytical task. Second, there was an implicit view that an ex-post response by the central bank and other public-sector entities to stabilize the housing market is likely to be less costly than an ex-ante identification of, and a preemptive policy intervention against, a contagious price boom. After GFC, this policy premise has been turned after the huge social costs incurred after GFC.

This study aims to shed light on the endogenous linkages between housing and macro-economy by documenting evidence thereof in the Korean context. Specifically, a DSGE (Dynamic Stochastic General Equilibrium) model that controls endogenous relationships between housing price and key macroeconomic variables is used, in order to investigate theoretically and empirically two particular issues: (1) the intra-temporal (or single-period) substitution between housing and non-housing consumption and (2) the stabilization effects of monetary policy from two alternative policy intervention rules − a conventional Taylor rule that does not consider housing price vs. a modified version that does. Through simulation, we quantify effects of various regimes of monetary policy, those with and without explicit consideration of housing prices, on both inflation gap and output gap.

At the outset, it is worth noting several distinctive characteristics of housing in the Korean context. First, as any other long-term durable goods, housing offers a multi-period service and usually accounts for the largest share in household wealth. Housing and other real estate takes 75% of the total household asset in Korea, which is three times larger than financial assets[2)]. Second, thanks to financial liberalization after the Asian Financial Crisis (AFC) in the 1990s, the residential mortgage lending has been on a rise, with the mortgage debt outstanding (MDO) to GDP ratio currently being 31.5% as of 2011 (which was about 10% before AFC)[3)]. Third, housing, and the land on which it is fixed, represents the most popular class of collateral for financial institutions in Korea. Hence, fluctuations in the property value profoundly affect credit demand through a wealth effect and credit supply through a collateral effect (via maximum LT V[4)]). Fourth, housing is different from other durable goods in terms of depreciation. For example, while the depreciation rate of general durables in Korea is usually between an annualized 10-20%, housing posts a significantly low 2-4%.

With these characteristics as a backdrop, this paper investigates the aforementioned two analytical issues by using a DSGE model that controls endogenous linkages between housing and macro variables in Korea. As main findings, this study documents that: (1) housing and non-housing consumption in Korea are complements, rather than substitutes, implying a positive wealth effect in that a rise in one variable causes the same direction in the other and (2) the modified Taylor rule with an explicit controlling of housing price is shown to be superior over the conventional one in that both output gap and inflation gap are shown to be reduced under the former. This paper also discusses public policy implications out of these results to Korea and other countries, as to using monetary policy as a purview of macro-prudential regulation.

The rest of the paper consists of the following five sections: preceding literature (Section II), a DSGE model construction (Section III) to develop monetary policy frontiers (Section IV), and a summary with concluding remarks (Section V).

1) Source: KOSIS, 2012

2) Source: Bank of Korea, 2011

3) LTV means the ratio of a loan to the value of an asset (typically a house).

II. Consideration on preceding literature

Kang (2006) analyzes the relationship between property prices and economic variables and the effects of diverse economic policies targeting the real estate market stability, using the new Keynesian DSGE model, and based on the results, he investigates whether monetary policy is needed in response to changes in housing prices. He highlights that the central bank should first consider various economic conditions embracing inflation, output and real estate market while managing monetary policy and it should be through such considerations that the central bank promotes economic stability.

Kim (2009) analyzes the impact of the intra-temporal substitution elasticity (EIS) between housing and consumption on monetary policy and then argues that when the expectation for a house price rise is premised, a strong substitution between housing and consumption would lead to the increase in housing demand and decrease in consumption. He then concludes that when the two are in a strong complementary relationship, housing and consumption would rise together.

Hong (2010) emphasizes that according to the decision theory of changes in house/non-durable goods consumption ratio and asset prices, smaller EIS would better explain stock premium. In other words, he argues that to better explain equity premium puzzle using counter-cyclical changes in consumption ratio requires the assumption that the EIS between housing and consumption is smaller than that of inter-temporal elasticity substitution (IES).

According to Lee (2003), the intra-temporal substitution elasticity between housing and consumption is estimated at 0.2~0.4 based on the time-series data between 1986 and 2003, showing the two are complements.

Iacoviello (2005) plays a leading role in studying the connection of housing with macroeconomy by setting housing as a variable of macroeconomic models. He then explains the impacts of house prices on consumption and the mechanism, using a DSGE model. Meanwhile, in explaining the impacts of house prices on monetary policy, he integrates characteristics of housing and consumption into the model of log separable utility function. Iacoviello and Neri (2010) also show the significance of impacts brought by the housing market on consumption and found the impact of changes in house prices to be considerably large as time passes.

Since the GFC, several theoretical and empirical studies have been conducted to assess the impact of the housing market on macro-economy, and the effects are found to be significantly meaningful in many cases. Since Iacoviello (2005), in the setting of the macroeconomic model, both housing and consumption have been treated as variables that directly maximize the utility of households. However, in most macroeconomic models, housing and consumption are assumed to be in a mutually independent relationship and therefore treated as a log separable utility function. The model set with this assumption is not able to study an effect of complementary housing within the model.

I extend the Iacoviello(2005)[5] model with the CES (Constant Elasticity Substitution) function in a household utility, so that housing and consumption are interrelated to each other. In this regard, this study estimates the EIS within a DSGE model so as to confirm the unique characteristics of the relationship between the two. Moreover, monetary policy frontier lines are extracted from the DSGE model that reflects complementary housing. This paper also studies the effect of monetary policy responding to house prices on inflation stability and output stability.

III. DSGE Model

The model framework of this study is based upon Iacoviello(2005). The model in this study set interest rate rules that respond to house prices. The nominal interest rate is driven by monetary policy to affect households and firms. The nominal interest rate is assumed as a monetary policy tool for inflation and output stability, and interest rates were composed of interest rate rules either responding to or not responding to house prices. Inflation and output stability were tagged as the two main goals of the monetary policy, and its effectiveness was determined by whether the monetary policy goals could be achieved through the interest rate rules. The model's economic structure is set to be composed of two groups of consumers and firms, the final goods manufacturers and the central bank.

4) In the economic structure of Song (2012) model, monetary policy is assumed not to respond to house prices, and when household consumption and firm production are under the influence of interest rates, the interest rates are not under any endogenous influence by house prices.

1. Consumers as lenders

Consumers as lenders gain utility through housing services and consumption. The Constant Elasticity Substitution (CES) function[6] between housing and consumption is assumed. They receive wages by providing labor, N_t. C_t denotes consumption in the time t, and H_t represents housing service that is connected to j in the t time period. And, ε denotes the elasticity of intra-temporal substitution (EIS) between housing and consumption, while σ denotes the inter-temporal elasticity of substitution (IES). η_1 denotes a reciprocal number of labor supply. Consumer with lending capability maximizes utility function below:

$$\max\left\{b_{1,t}C_{1,t},H_{1,t},N_{1,t}\right\}_{t=0}^{\infty} E_0\sum_{t=0}^{\infty}\beta_1^t\left\{\frac{1}{1-1/\sigma}\left[\left(C_{1,t}^{\frac{\varepsilon-1}{\varepsilon}}+j_tH_{1,t}^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}\right]^{1-1/\sigma}-\frac{N_{1,t}^{\eta_2}}{\eta_1}\right\} \tag{1}$$

β_1 denotes the objective discount element. j represents the shock on house demand and is assumed to follow a stochastic process as below:

$$\ln j_t=(1-\rho_j)\ln\overline{j}+\rho_j\ln j_{t-1}+\varepsilon_{j,t}\ ,\ \ \varepsilon_{j,t}:iid\sim N(0,\sigma_j^2) \tag{2}$$

Consumer's inter-temporal budget constraint formula is as below:

$$\begin{aligned}&C_{1,t}+(H_{1,t}-H_{1,t-1})q_t+\frac{R_{t-1}}{\pi_t}b_{1,t-1}\\&=w_{1,t}N_{1,t}+b_{1,t}+f_t+fee_t,\ where\ fee_t=\phi_{h_2}q_tH_{2t}+\phi_{he}q_tH_{et}.\end{aligned} \tag{3}$$

At every t period, consumers choose consumption, housing, working hour and loan amount under the budget constraint (3). qH[7] stands for house market value. In the utility function, H,

5) Based on the co-integrated analysis of Song(2013), the utility between housing and consumption is complements for each other,

6) The subscript 1,2 and e denotes consumers as lenders, consumers as borrowers, and entrepreneurs, respectively.

in connection with *j*, is assumed to mean house prices. Then, *q* denotes the real house price, w stands for real wage, b_1 for the amount of the risk-free 1-period loan (possibly bond), and f_t for the profit of the end product supplier. fee_t represents all expenses incurred by the transaction of housing with ϕ as real estate commissions and moving expenses. It is assumed that the consumer with lending capability receives fee_t and is also engaged with real estate brokerage businesses. *R* denotes the nominal interest rate and serves as a monetary policy instrument of the central bank. At this point, the consumer receives the interest--calculated by multiplying the nominal interest rate and the loan amount from the previous period, and then pays the loan amount, b_1, in the new *t* period. At a stationary state, b_1 is displayed as a negative number, indicating the function of banks, a loan provider. The loan amount is equal to the sum of loans of borrowing consumer, b_2, and b_e. This study obtains the formula as follows: $b_1 + b_2 + b_e. = 0$

2. Consumers as borrowers

Consumers as borrowers gain the utility through the same consumption and housing service of consumers as lenders, and at the same time receives wages by providing labor to entrepreneurs. The utility between consumption and housing is connected by the CES, which is a non-separable function.

$$\max \left\{b_{2,t}, C_{2,t}, H_{2,t}, N_{2,t}\right\}_{t=0}^{\infty} E_0 \left\{ \sum_{t=0}^{\infty} \beta_2^t \frac{1}{1-\zeta} \left[\left(C_{2,t}^{\frac{\varepsilon-1}{\varepsilon}} + j_t H_{2,t}^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}} \right]^{1-\zeta} - \frac{N_{2,t}^{\eta_2}}{\eta_2} \right\} \tag{4}$$

The budget constraint formula is as below:

$$C_{2,t} + H_{2,t} - H_{2t-1} + \phi_{h2} q_t H_{2,t} + \frac{R_{t-1}}{\pi_t} b_{2,t-1} = w_{2,t} N_{2,t} + b_{2,t} \tag{5}$$

$$b_{2,t} \le m_2 q_{t+1} \pi_{t+1} H_{2,t} \quad \text{, where} \quad 0 \le m_2 \le 1 \tag{6}$$

In the Equation (6), m_2 represents the Loan to Value (LTV) ratio. It is assumed that m_2 is equal to or smaller than 1 so that the housing loan amount would not exceed the actual price of the house. The house transaction cost, ϕ_{h2}, is assumed to be in proportion to house price.

3. Entrepreneurs: Intermediate Goods Producer

Entrepreneurs producing intermediate goods gain utility only through consumption Cet. It is assumed that for the entrepreneur, housing is a corporate asset and can be modified to be capital for production without any costs. Production coefficient is assumed to follow the Cobb-Douglas production function. The optimization problem and budget constraints are as below:

$$\max\left\{C_{et}, b_{et}, I_t, K_t, H_t, N_{1,t}, N_{2,t}\right\}_{t=0}^{\infty} E_0 \sum_{t=0}^{\infty} \gamma^t \ln C_{et} \tag{7}$$

$$\frac{Y_t}{X_t} + b_{et} = C_{et} + \frac{R_{t-1}}{\pi_t} b_{et-1} + w_{1,t} N_{1,t} + w_{2,t} N_{2,t} + I_{kt} + I_{Ht} + \xi_{kt} + \xi_{Ht} \tag{8}$$

where $I_{kt} = K_t - (1-\delta) K_{t-1}$, $I_{Ht} = \left(H_{et} - (1-\delta) H_{et-1}\right) q_t$, $\xi_{Kt} = \frac{\psi_K}{2\delta}\left(\frac{I_{kt}}{K_{t-1}} - \delta\right)^2 K_{t-1}$ and $\xi_{Ht} = \phi_e q_t H_{et-1}$.

K denotes capital goods, ξ_{Kt} and ξ_{Ht} are adjustment costs of capital and housing, respectively. Y represents gross production; δ for the depreciation rate of capital goods and ϕ_e for housing transaction cost.

$$R_t b_{2,t} \le m_e q_{t+1} \pi_{t+1} H_{e,t}, \text{ where } 0 \le m_e \le 1. \tag{9}$$

Intermediary goods are produced by input factors of labor, capital and housing of consumers with lending capability and consumers with loans.

$$Y_t = Z_t \left(K_{t-1}^{\mu} H_{t-1}^{\nu}\right)\left(N_{1t-1}^{\alpha(1-\mu-\nu)} N_{2t-1}^{(1-\alpha)(1-\mu-\nu)}\right) \tag{10}$$

Z_t represents technology shock and is assumed to comply with the stochastic process as below:

$$\ln Z_t = (1-\rho_Z)\ln \overline{Z} + \rho_Z \ln Z_{t-1} + \varepsilon_{Z,t} \ , \ \varepsilon_{Z,t} : iid \sim N(0, \sigma_Z^2) \tag{11}$$

4. Final Goods Suppliers

The final goods suppliers provide profits to consumers as lenders in the monopolistic competition market. The price of consumer goods is assumed to follow Calvo(1983) type. Final goods suppliers adjust the price of consumer goods with $(1-\theta)$ probability. Also, they purchase the intermediary goods at the P^i price from entrepreneurs, and produce final products at the $P_t(g)$ price. Consumer goods, Y_t, are expressed as below:

$$Y_t = \left(\int_0^1 Y_t(g)^{(\xi-1)/\xi} dg \right)^{\frac{\xi}{\xi-1}} \tag{12}$$

The firm's price index is expressed as:

$$P_t = \left(\int_0^1 P^{i_t}(g)^{(1-\xi)/\xi} dg \right)^{\frac{1}{1-\xi}} \tag{13}$$

The price of consumer goods can be expressed as Equation (14), and X represents markup.

$$P_t^*(g) = \sum_{i=0}^{\infty} \theta^i E_t \left(\beta \frac{C_t}{C_{t+i}} \left(\frac{P_t^*(g)}{P_{t+i}^*} - \frac{X_t}{X_{t+i}} \right) Y_{t+i}(g) \right) = 0 \tag{14}$$

The final price is expressed as Equation (15).

$$P_t = \left(\theta P_{t-1}^{\xi} + (1-\theta) P_t^{*(1-\theta)} \right)^{\frac{1}{1-\xi}} \tag{15}$$

Based on Equation (15), the Phillips curve can be drawn.

$$\pi_t = \beta\pi_{t+1} - kX_t + \varepsilon_{u,t} \tag{16}$$

5. The Central Bank

The central bank has the function of controlling nominal interest rate, and is assumed to follow a conventional Taylor rule, which is expressed as below:

$$R_t = R_{t-1}^{\alpha_R}\left(\pi_{t-1}^{1+\gamma_\pi}\left(\frac{Y_{t-1}}{\overline{Y}}\right)^{\gamma_Y}\overline{R}\right)^{1-\alpha_R}\varepsilon_{R,t} \tag{17}$$

Equation (17) is log-linearized and is expressed as below:

$$R_t = \alpha_R R_{t-1} + (1-\alpha_R)\left((1+\gamma_\pi)\pi_{t-1} + \gamma_Y Y_{t-1}\right) + \varepsilon_{R,t} \tag{18}$$

Meanwhile, the optimal interest rate to draw monetary policy frontier is made to follow the Taylor rule, taking into account both conventional and modified rules.

6. Conventional Taylor Rule to Draw Monetary Policy Frontier

The conventional Taylor rule means the way that interest rate responds to output and inflation fluctuations, and is assumed to have a tendency to smooth past interest rates. This type of monetary policy is assumed to be implemented for the purpose of output and inflation stability. The purpose of the central bank is expressed by the optimization function as below:

$$J(\gamma_\pi, \gamma_Y) = \min\left\{\omega VAR(Y) + (1-\omega)VAR(\pi)\right\} \qquad (19)^{8)}$$

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7) In this paper I compute the monetary policy frontier lines based on inflation-output volatility, as in Levin et al.(1999), which is subject to the interest rate rule.

To solve the optimization problem of Equation (19), the conventional Taylor rule is used and γ_π and γ_Y are determined endogenously. In this Equation, Y means output gap and π means quarterly inflation volatility. VAR denotes unconditional variance. ω should satisfy $\omega \in [0,1]$, which means the weighted preference of monetary policy that minimizes the change in output gap against inflation fluctuation.

7. Modified Taylor Rule to Draw Monetary Policy Frontier

The modified Taylor rule means that interest rate responds to house prices as well as output and inflation fluctuations, and is assumed to have a tendency to smooth past interest rates. The modified Taylor rule is expressed as below:

$$R_t = R_{t-1}^{\alpha_R} \left(\pi_{t-1}^{1+\gamma_\pi} \left(\frac{Y_{t-1}}{\overline{Y}} \right)^{\gamma_Y} q_{t-1}^{\gamma_q} \overline{R} \right)^{1-\alpha_R} \varepsilon_{R,t} \tag{20}$$

Equation (20) is log-linearized and is expressed as below:

$$R_t = \alpha_R R_{t-1} + (1-\alpha_R)\left((1+\gamma_\pi)\pi_{t-1} + \gamma_Y Y_{t-1} + \gamma_q q_{t-1} \right) + \varepsilon_{R,t} \tag{21}$$

Equation (21), which is the instrument of the central bank, contains the house prices. And the optimization problem for modified Taylor rule is:

$$J(\gamma_\pi, \gamma_Y, \gamma_q) = \min\{\omega VAR(Y) + (1-\omega) VAR(\pi)\} \tag{22}$$

To solve the following optimization problem in Equation (22), γ_π, γ_Y and γ_q are determined. Equation (22) expresses the objective function of the Taylor rule, consisting of hypotheses of reduced output and inflation volatility. Equation (22) does not take house price volatility as an objective variable. These hypotheses are based on the attempt to additionally identify the role of interest rate rules responding to house prices. Meanwhile, γ_π, γ_Y and γ_q are the solutions to the optimization problems of Equations (20), (21), and (22). These are again used to draw the optimal monetary policy frontier to be covered in Section IV.

8. General Equilibrium Condition

Based on $H_{e,0}$, $H_{1,0}$, $H_{2,0}$, $b_{e,0}$, $b_{1,0}$ and $b_{2,0}$, DSGE is $\begin{Bmatrix} Y_t, C_{e,t}, C_{1,t}, C_{2t}, H_{e,t}, H_{1,t}, \\ H_{2t}, b_{e,t}, b_{1,t}, b_{2t}, N_{1,t}, N_{2,t} \end{Bmatrix}_{t=0}^{\infty}$ in terms of stock, and $\{w_{1t}, w_{2,t}, R_t, q_t, P_t, P_t^*, \lambda_t\}_{t=0}^{\infty}$ in terms of price combination. All economic subjects satisfy the inter-temporal budget constraint, the constraint conditions of the house mortgage loan and the first order conditions. At the stationary state, the following conditions are also satisfied.

(a) $N_1 = N_2$

(b) $H_e + H_1 + H_2 = 1$

(c) $C_e + C_1 + C_2 + I = 1$

(d) $I = I_K + I_H$

(e) $b_e + b_2 + b_1 = 0$

The wages of consumers with the lending function is $w_1 N_1 = \alpha(1-\mu-\nu)Y$, and consumers as lenders are expressed as: $w_2 N_2 = (1-\alpha)(1-\mu-\nu)Y$.

9. Estimation

To estimate parameters, the minimum distance method was used. Each parameter was estimated in order to satisfy objective functions which minimize the gap between data and model impulse responses. To that end, this analysis adopted the call rates from 1Q of 2000 to the 4Q of 2011[9], the KB Kookmin Bank's house price index, CPI-based inflation and GDP. In particular, to secure the stationary of house price and GDP, this analysis used the HP filter to extract the trend and then removed the trend through differences with original series.

8) The results are not significantly different from those with the data from 1Q of 2000 to the 4Q of 2015. The structural break in 2008 is already sufficiently reflected the data from 1Q of 2000 to the 4Q of 2011.

<Table 1> Parameter Estimation

Parameter	Value	Standard Deviation
β: Objective discount rate of consumer with lending function	0.99	0.01
β2: Objective discount rate of consumer with lending function	0.94	0.08
γ: Objective discount rate of intermediary goods producer	0.98	0.01
ε: Intra-temporal substitution elasticity	0.35	0.06
ξ: Risk aversion	2.06	1.17
α: Wage rate	0.60	0.08
v : Production elasticity of house	0.02	0.03
σu: Inflation standard deviation	1.08	0.24
σj: House impact standard deviation	4.51	3.11
σa: Technology impact standard deviation	26.25	34.62
ρ π: Inflation autoregressive rate	0.01	0.16
ρa: House demand autoregressive rate	0.96	0.04
ρz: Technology autoregressive rate	0.11	0.20

Along with this estimation, it is constructed that the Cholesky decomposition is in the order of the call rate, house prices, inflation and GDP. Since the Cholesky decomposition uses the lower triangular matrix, the array order of each variable brings significant outcomes regarding mutual connection. As a way to determine the array order, this analysis identified the degree of exogeneity through the Granger causality and examined the changes in impulse responses depending on various arrays of Cholesky decomposition. Through the appropriate time lag test, the lag of 2 was selected to be significantly meaningful. Determination of appropriate time lag was made according to the Akaike information criteria (AIC) by applying the VAR lag order selection criteria.

In this estimation, it is worth noting that the EIS is estimated to be 0.35, smaller than the statistically meaningful unit value 1, maintaining the same context of complementarity results drawn by the co-integration test as in Song (2013). A key point of this estimation is whether or not the elasticity is estimated to be smaller than 1 with statistical significance. The weakness of this estimation is that the production elasticity of housing, the standard deviation of technology shocks, the autoregressive rate of inflation and the autoregressive rate of technology are estimated to be statistically insignificant. However, the production elasticity of housing is not logically different from the calibration results by other studies and does not render the results.

The monetary policy parameters of the Taylor Rule are estimated by OLS method[10]. The role of the central bank used within the DSGE is assumed to follow the conventional Taylor rule as shown in Equation (23)

$$R_t = \alpha_R R_{t-1} + (1-\alpha_R)\big((1+\alpha_\pi)\pi_{t-1} + \alpha_Y Y_{t-1}\big) \tag{23}$$

The parameter estimation of α_R, α_π, and α_Y is in [Table 2].

<Table 2> Parameter Estimation for Monetary Policy

Parameters	Values	Standard Deviation
α_R	0.85	0.05
α_π	0.66	0.22
α_Y	0.17	0.04

10. Calibration

According to IMF (2011), the average LTV ratio is 48%, but Korea's conforming loan data shows that the average LTV is 51%. Given this consideration, Korea's average LTV is assumed as 50% as in [Table 3]. The housing shock parameter is adjusted to fit the data which is 1.4 times the house price ratio to GDP. The elasticity of labor, capital and house production is abstracted from preceding studies.

<Table 3> Calibration Results

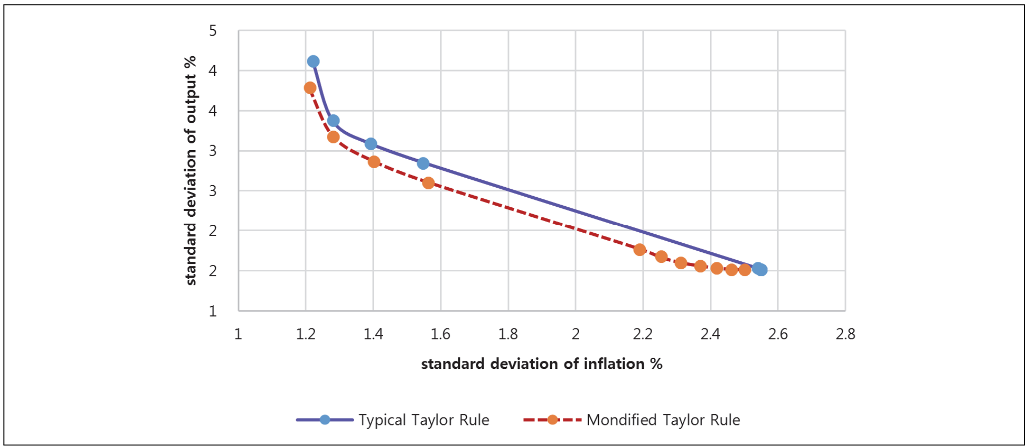
Parameters	Values	Description
m	0.5	Average mortgage ratio: LTV
j	0.39	House demand shock
μ	0.3	Elasticity against the GDP production capital
η	1.01	Labor supply reciprocal
ϕ	0.03	Housing expenses (time and costs spent on moving, tax expenses)
δ	0.03	Capital discount rate

9) Meanwhile, it is possible to estimate all coefficients of monetary policy through the minimum distance method, but this analysis applies the average value of data separated from the model to the Taylor Rule.

IV. Optimal Monetary Policy Frontier Lines

Certain functional forms of interest rate rules that comply with the Taylor rule are assumed to be Equation (17) and (20). To calculate monetary policy frontier lines in accordance with each interest rate rule requires the definition of scope of ω, the parameter in Equation (19). Here, ω embraces from 0 to 1 ($\omega \in [0,1]$). In the case of ω =1, it means monetary policy only focusing on economic (output) stability and in the case of ω =0, it means monetary policy only focusing on inflation targeting. The weighted value between inflation and economic stability is set from 0 to 1 with a 0.1 interval. For example, the case of ω =0.5 means that weighted value of the monetary policy goal is set equally by 50% on both economic stability and inflation stability. Monetary policy frontier lines are drawn by monetary goals through calculating the optimal combination of output and inflation coefficients, γ_π and γ_Y—corresponding to respective weighted values—in accordance with given interest rate rules. Here, in the Equation (20) which follows the Taylor rule, $\gamma_q = 0$ would be a conventional Taylor rule, whereas $\gamma_q \neq 0$ would be regarded as a modified Taylor rule.

[Figure 1] shows the lined dots that are the combinations of standard deviation of π (inflation) and standard deviation of Y(output) among 11 combinations of weighted values of monetary policy goals based on the modified Taylor rule. The results show that the modified interest rate rule that is responsive to house prices turns out more effective in achieving the economic and inflation stability than the conventional interest rate rule. In fact, the dotted line is placed under



<Figure 1> Monetary Policy Frontier Lines

the solid line that represents irresponsive interest rate rules, indicating that the former is more effective than the latter with the respect of low volatility (standard deviation).

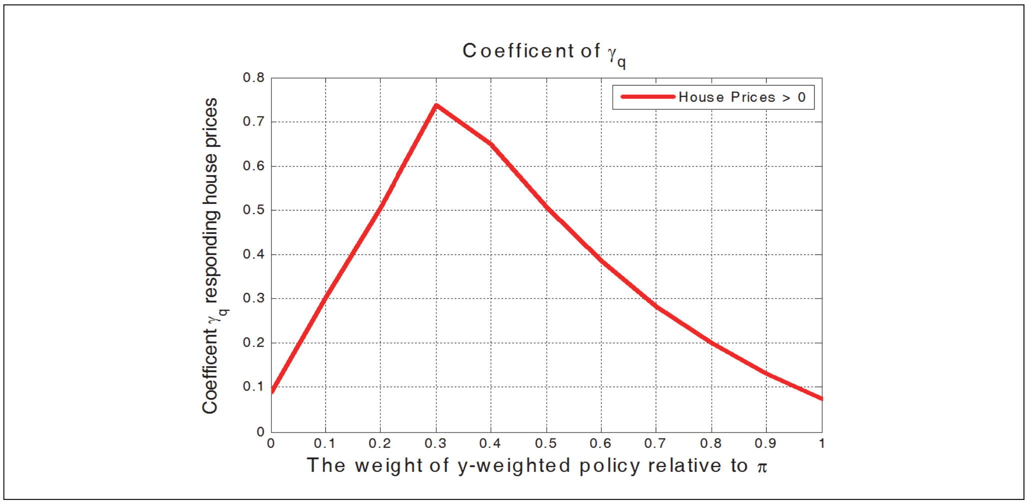
[Table 4] shows how interest rates that follow the modified Taylor rule achieve monetary policy goals better than those following the conventional Taylor rule.

<Table 4> Monetary Policy Frontier Results

	Standard Deviation π	Standard Deviation Y	Standard Deviation π	Standard Deviation Y
100% π	1.22	4.12	1.21	3.78
90% π + 10% Y	1.28	3.37	1.28	3.18
80% π + 20% Y	1.39	3.09	1.4	2.87
70% π + 30% Y	1.55	2.85	1.56	2.61
60% π + 40% Y	2.54	1.53	2.19	1.77
50% π + 50% Y	2.55	1.52	2.25	1.67
40% π + 60% Y	2.55	1.52	2.31	1.6
30% π + 70% Y	2.55	1.52	2.37	1.56
20% π + 80% Y	2.55	1.52	2.42	1.53
10% π + 90% Y	2.55	1.52	2.46	1.52
100% Y	2.55	1.52	2.5	1.51

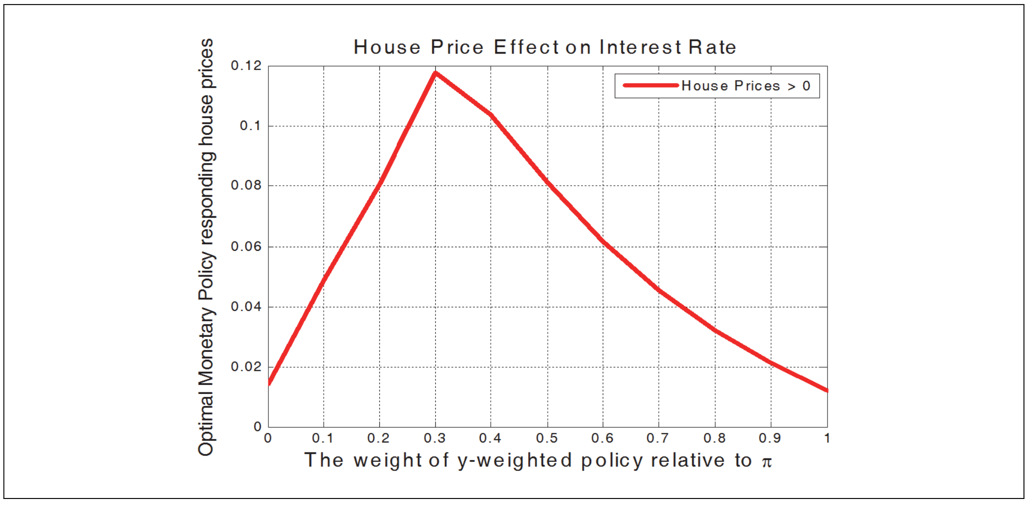
The most efficient combinations in monetary policy are observed with 70% focus on inflation stability and 30% on output stability. Considering average standard deviation across entire monetary policy, the modified interest rate rule turns out to be more advantage by both 6%p and 2%p with regard to inflation stability and output stability, respectively, compared to the conventional interest rate rule.

[Figure 2] shows the effects of house prices on interest rates among 11 combinations of monetary policy goals. The determinant coefficients, γ_{π} and γ_{q} are endogenously determined for optimization, and interest rates are optimized by these coefficients. In particular, in the case of monetary policy goals with 70%π + 30%Y, interest rates turn out to respond most significantly against house prices. Here, coefficient, γ_{q}, reaches above 0.7, strongly affecting interest rates.



<Figure 2> Response Coefficient of Interest rates against Housing Prices

[Figure 3] shows the degree of interest rate responses. According to this, when the central bank sets 30% of its focus on the goal of output stability, a 1% change in house prices would cause interest rates to respond by 0.12%. However, when the focus is only on either inflation stability or output stability, interest rates are close to zero, implying no incentives to respond to changes in house prices.



<Figure 3> Response of Interest Rates against Housing Prices

V. Conclusion and Implications

Complementary characteristics between housing and consumption are confirmed by the estimate of the EIS, 0.35. The EIS between housing and consumption is estimated at 0.35 according to the DSGE model, implying a strong complementary relationship between the two. For instance, in the case when a positive shock affects house prices to rise in the positive direction, this would set the complementary effect between housing and consumption in motion, thereby pushing both upwards. Such coordinated movement would affect the effectiveness of monetary policy, which responses against house prices under the aims at economic stability.

This study utilizes distinctive complementary characteristics existing between housing and consumption in Korea and applies them to the macroeconomic model, so that optimal monetary policy frontier lines may be drawn. In the model, the central bank's purpose of monetary policy is assumed to be stability of inflation and output. To analyze effectiveness of monetary policy responding to house prices, this study compares it with effectiveness of one that is unresponsive to house prices. The results show that the modified interest rate rule responding to house prices have a relative advantage by both 6%p in inflation stability and 2%p in economic stability compared to the conventional interest rate rule.

What needs to be noted in monetary policy frontier driven from this model is that housing and consumption are strongly co-related as complementary goods. According to monetary policy frontier, when the central bank places more emphasis on the goal of economic stability, the modified Taylor rule, responsive to house prices, turns out to contribute more to economic stabilization than those with the conventional Taylor rule, irresponsive to house prices.

In the case when an external house demand shock occurs, house prices change accordingly. Housing and consumption, as complementary goods, tend to move in a coordinated way, which is consistent with the conclusion of Kim (2009), Flavin and Nakagawa (2004), and Stokey (2009). To put it another way, when a positive shock affects house prices to rise in the positive direction, both housing and consumption rise together. Housing and consumption complement each other. Through such characteristics, the times series of the two bring larger impacts on economic fluctuations by house price changes, thereby serving as a key factor behind the economic cycle. Therefore, as the complementary relationship between the two grows stronger, monetary policy focusing on economic stability would be sensitive to economic changes driven by house price changes.

This study suggests that in the case the central bank focuses on economic stability, it may need to consider changes in house prices as a subject of monetary policy. This suggestion, however, has its own limitation in applying to actual circumstances, since it assumes that the central bank has the capability of accurately distinguishing the difference between bubble factors and fundamental factors of house prices. Also, in the model, house prices respond endogenously to fundamental factors, which increase in collateral value. In fact, it is difficult for the central bank to identify a house price bubble and therefore it is hard to ascertain that responses to house prices would definitely help stabilize the economy. As assumed earlier, assumption itself is the limitation of this study, since in the real world, house prices do not respond endogenously only to intrinsic fundamental structure, and instead are inclined to respond to sentiment and expectations.

The newly established goal in the 8th revision of the Bank of Korea Act, which stipulates "The Bank of Korea shall pay attention to financial stability in carrying out its monetary policy," highlights the growing need to monitor the movement of house prices in relation to the financial market. According to the IMF (2011) analysis, the boom and bust of the housing market is related to the instability of the financial market and depending on the significance of the relationship between financial and housing market system, each nation will experience the spread of financial instability in varied forms and degrees. One of representative functions of the housing market is the leverage effect through mortgage loan. Bernanke and Gertler (1989) highlighted the importance of the leverage through mortgage loan and net asset effect, while analyzing the role of financial accelerator. This is relevant to the pro-cyclicality that mortgage loan itself has in other countries.

Not only that, housing and consumption are complements and house prices are connected to macro-economy. Given that house prices affect consumption through the wealth effect and simultaneously cause net assets and collateral value to change, exerting influences on the stability of the financial market, the central bank's role in monitoring house prices will become more important than ever. This role could also be helpful in the central bank's challenging function.

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국문요약

주택과 통화정책:
DSGE 모형에 의한 한국에서의 안정화 효과 사례

2007년~2009년 글로벌 금융위기 이후 주택과 거시경제간의 연계성에 대한 관심이 점차 점증하였다. 본 논고는 동태적일반균형모형(DSGE Model)에 근거하여 주택과 거시경제의 연계성을 이론적 및 실증적인 방법으로 분석하였다. 동태적일반균형모형에서 주택가격과 주요 거시경제변수의 관계는 내생적으로 통제된다. 먼저 기간내대체탄력성의 추정과 이론적 분석을 통해 주택과 소비 간 특징이 보완재로서 작용하고 있음을 확인하고 동시에 한국 데이터를 모형에 적용하여 통화정책의 안정화 효과를 살펴보았다. 이때 통화정책의 효과를 분석하기위해 전통적 테일러준칙(Taylor Rule)과 수정된 테일러 준칙을 비교하였다. 수정된 테일러준칙은 주택가격이 통화정책의 메커니즘의 한 변수로 작용하는 것이고 전통적 테일러 준칙은 통화정책에서 주택가격 변수가 배제된 것이다.

결과에 따르면, 한국의 주택과 소비는 대체재가 아니라 상호 보완재로 작용하여 주택가격의 변화가 소비에 동조하는 현상이 나타나고 있음을 보여준다. 이는 주택가격이 상승할 때 소비도 상승하는 자산의 부의 효과(Wealth effect)를 지지해준다. 주택과 소비의 상호 보완적 메커니즘이 작용하는 경제구조에서 수정된 테일러준칙은 전통적 테일러준칙에 비해서 경기변동성과 물가변동성을 줄이는 측면에서 우월함을 보여준다. 이러한 결과는 최근 한국은행이 통화정책을 운영함에 있어서 주택시장을 고려하는 상황을 지지해준다.