

Macroprudential and Monetary Policies: Implications for House Prices and Household Debt

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This study examines the effect of the interaction between time-varying macroprudential policy and credit growth or house price growth on dampening the excess volatility of household debt in the standard DSGE model. The study also discusses the effect of introducing the debt-to-income ratio, aside from the loan-to-value ratio, on cooling down large household debt swings. Moreover, this study shows that the reaction of macroprudential policy to credit growth is more effective than its reaction to house price growth in moderating household debt swings to exogenous shocks.

Keywords: House price, Macroprudential policy, Monetary policy

JEL Classification: E32, E44

I. Introduction

The recent financial crisis has highlighted the interconnectedness between macroeconomic and financial stability. In particular, the housing sector is pivotal in understanding the recent financial crisis. When the house market collapsed with subprime mortgage, microprudential policies that prevent the risk faced by each company could not prevent the crisis from spreading across the financial and housing sectors in the real econ-

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omy. The traditional monetary policy is not sufficient to avoid the crisis and gain a robust recovery. Since the outbreak of the Great Recession, many economists have realized that the existing set of monetary policies aimed at price stability and the microprudential regulations targeted at the financial soundness of individual banking institutions are insufficient in stabilizing the economy from financial shocks.

The set of macroprudential policy tools are now being discussed and introduced in advanced economies. Some governments have already implemented macroprudential tools to promote the stability of the financial system and to minimize the transmission of financial shocks to the entire economy. For example, in the Korean economy, a household's relatively high leverage ratio is more vulnerable to shocks (*e.g.*, housing price collapse) than that in any other economy. The Korean government has implemented macroprudential tools, such as the loan-to-value (LTV) and debt-to-income (DTI) ratio tools to protect the system and the economy from risk.

Given that macroprudential policy inevitably interacts with monetary policy, the question of whether or not and how monetary and macroprudential policy makers should respond to financial variables warrants a close look. Some examples of macroprudential policy tools are capital-based tools (*i.e.*, countercyclical capital buffers and sectoral capital requirements) and asset-side tools (*i.e.*, LTV and DTI). LTV is regarded as one of the main macroprudential instruments of mitigating and preventing excessive credit growth.¹ Given the extensive consensus that the origin of the recent crisis is related to real estate booms and busts, we focus on the effects of macroprudential policy on the housing sector.

Abel (1990) and Campbell and Cochrane (1999) postulate that envy is one of the most important elements in human behavior, particularly in explaining preferences related to the rising household leverages in many industrial countries. In the present study, we incorporate the idea of "catching up with the Joneses" along the lines of Ljungqvist and Uhlig (2000) and Campbell and Cochrane (1999) into a canonical sticky price model. Given that the agents are determined to catch up with the Joneses without considering the effects of such behavior on aggregate demand, they unconsciously overheat the economy in expansionary phases and cool it down excessively in contractionary phases. This kind of external habit formation, which generates unnecessary fluctuations in the economy over the business cycle, calls for a more active government stabili-

¹ The LTV limits are available in 16 member states of the EU.

zation policy.

In the present study, we establish a simple sticky price model that features the housing market to discuss how monetary and macroprudential authority should react to exogenous shocks. The benchmark model is similar to that of Iacoviello (2005) with two-types of households: borrowers and savers. Impatient borrowers face the collateral constraint linked to the expected market value of their houses and labor income, whereas patient savers smoothen their consumption profile with their financial assets. We then evaluate the implications of time-varying versus time-invariant macroprudential policies, such as the LTV and DTI tools, and their interaction with the monetary policy related to financial stability and business cycles. We specifically address how the macroprudential and monetary authority react to exogenous shocks. For this purpose, we introduce into the model two kinds of simple and implementable macroprudential rules as the Taylor-type interest rate rule. The macroprudential authority responds to either the credit growth or house price growth to avoid episodes of excessive credit growth in the spirit of the Basel III regulation.

The main findings of this study can be summarized as follows: First, time-varying macroprudential policy is more effective in stabilizing household debt than time-invariant macroprudential policy, whether or not the macroprudential authority accounts for a borrower's labor income, in addition to the LTV in the macroprudential policy.

Second, macroprudential policy based on the pure LTV ratio is better in moderating household debt to house demand shock than macroprudential policy that accounts for both the borrower's labor income and market value of the house.

Finally, macroprudential policy that accounts for both the borrower's labor income and the market value of the house is better in moderating household debt to productivity shock than the macroprudential policy based on the pure LTV ratio.

The remainder of this paper is organized as follows: Section II presents an experience of the Korean economy. Section III presents a canonical sticky price model augmented with collateral constraints. Section IV discusses the simple, implementable, and optimal Taylor rule and macroprudential policy and compares the properties of monetary and macroprudential policy rules. Section V ends with a conclusion.

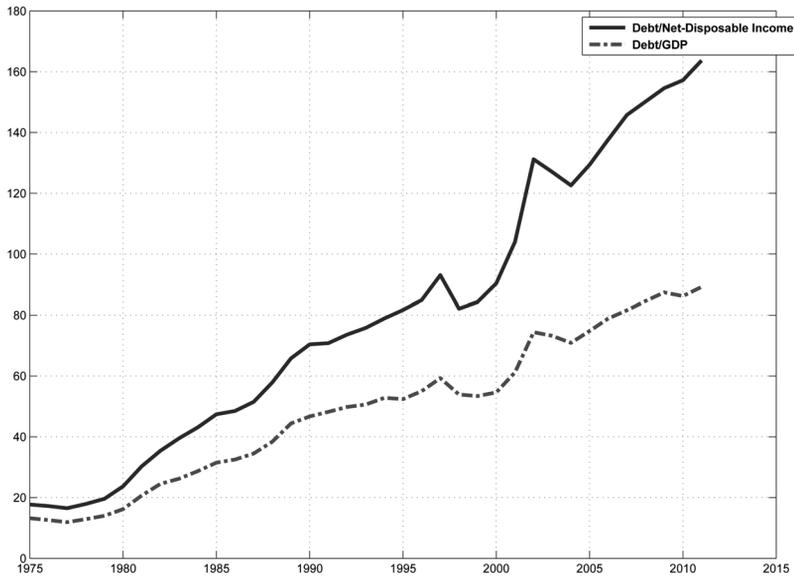


FIGURE 1
DEBT/NET-DISPOSABLE INCOME AND DEBT/GDP IN KOREA

II. An Experience of the Korean Economy

Korea is one of the few countries that are in the forefront of macroprudential policy implementation. Some of the stylized facts of the Korean economy are illustrated in this section.

Figure 1 shows the household debt to disposable income ratio in Korea. The debt to income ratio increases about 5-10% per year, except during the credit card crisis in 2003. Figure 2 shows that the household's collateralized debt increased to 20% at the beginning of 2000. The high ratio of collateralized debt indicates that households rely on banks to finance Chonse or mortgage loans.

Korea implemented its macroprudential tool in 2002 to address the rapid increase in house prices with LTVs. To moderate the house market fluctuation, the Korean government also introduced DTIL in 2005, along with tax incentives/disincentives and direct/indirect support to the construction sector. Figure 3 shows the annual growth rate of the Korean house price since 2000. Despite the Korean government's strategy of tightening the LTV across banking and non-banking financial institutions, the monetary policy has been relatively loosened. The mixed result of a

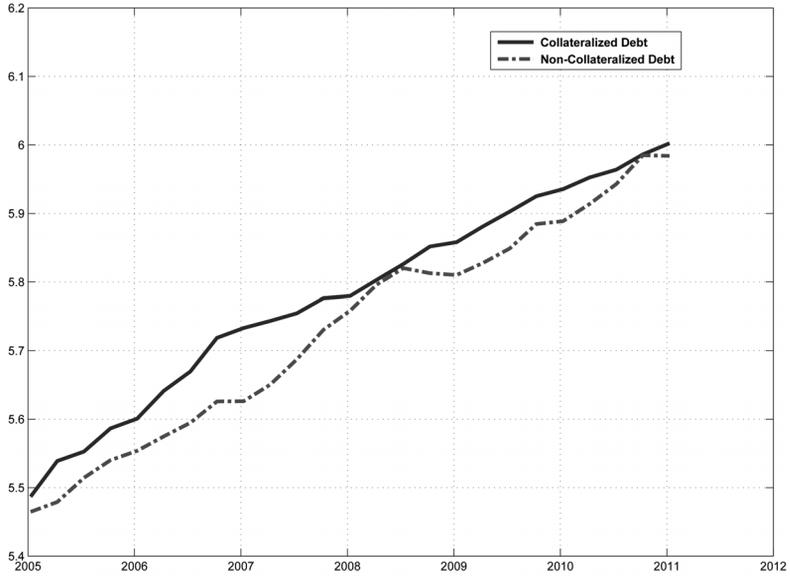


FIGURE 2
COLLATERALIZED AND NON-COLLATERALIZED DEBT IN KOREA

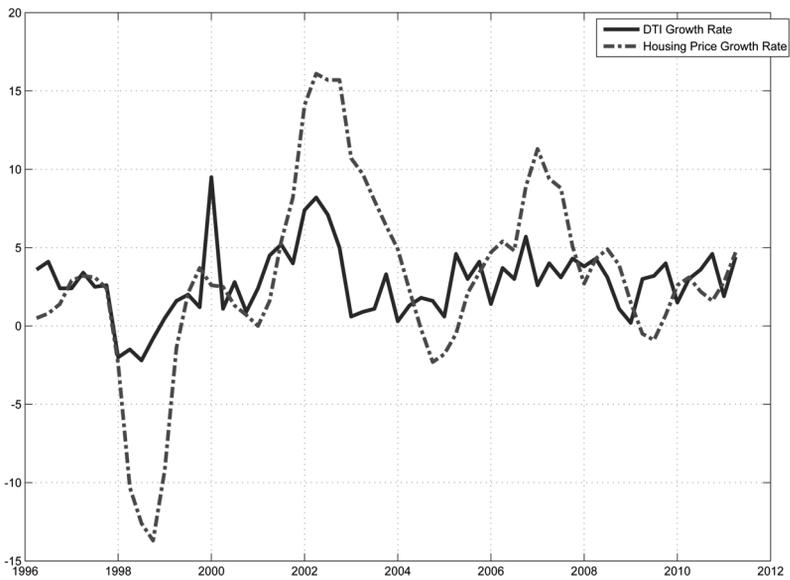


FIGURE 3
DTI GROWTH RATE AND HOUSING PRICE GROWTH RATE IN KOREA

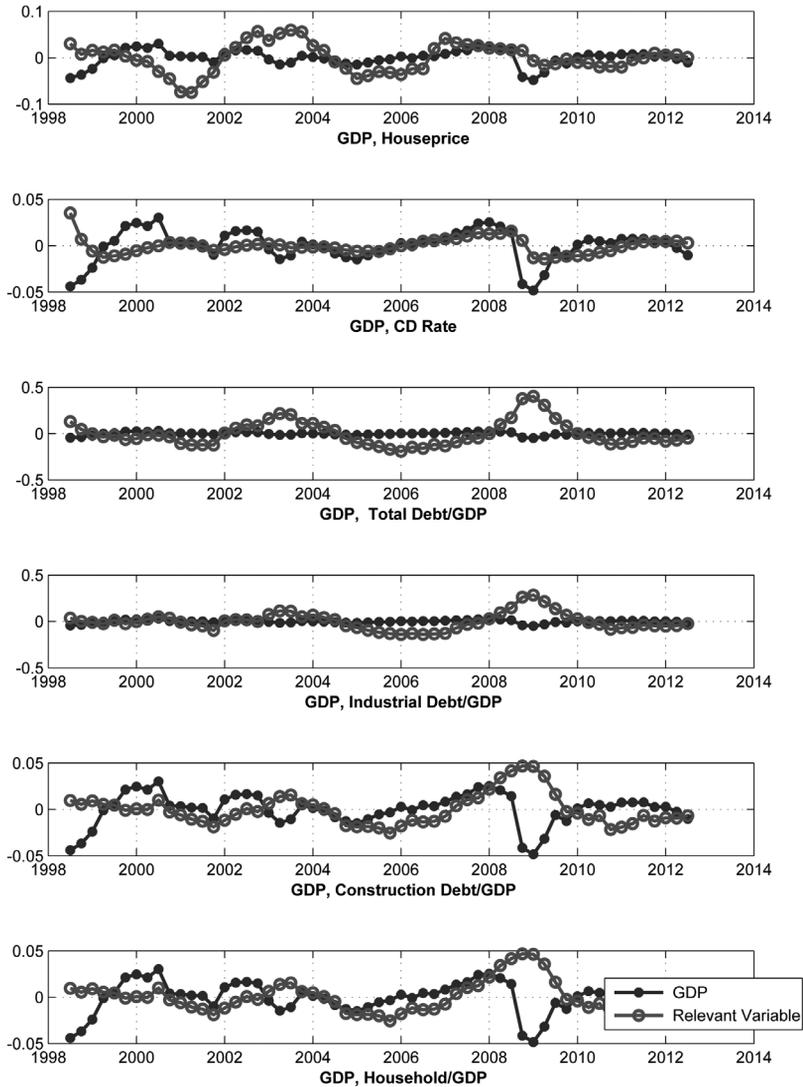


FIGURE 4
BANDPASS-FILTERED KOREAN MACROECONOMIC VARIABLES

relatively high growth rate and reduced variations in house prices may reflect this policy mix. The exploration of the consequences of lax monetary policy and tight macroprudential policy in terms of price and financial stability is interesting.

TABLE 1
MOMENTS OF DATA (1998:III-2012:III)

Variable	S.D	Cross AutoCorr.		X_t with GDP		Y_{t+k} (corr (X_t, Y_{t+k}))				
		$k=-4$	-3	-2	-1	0	1	2	3	4
y	1.56	-0.02	0.26	0.60	0.89	1.00	0.89	0.60	0.26	-0.02
q	1.26	0.18	0.25	0.31	0.36	0.36	0.30	0.19	0.05	-0.08
b/y	8.80	0.26	0.10	-0.10	-0.32	-0.50	-0.59	-0.59	-0.52	-0.41
r	1.16	-0.44	-0.46	-0.29	0.04	0.40	0.62	0.61	0.41	-0.05

Figure 4 shows the band pass filter series of selected variables, such as GDP, real housing price, and various debt ratios relative to GDP. Features of business cycles in terms of cross autocorrelations are useful in examining the features of debt variables. Table 1 shows various moments of the selected variables calculated from the estimated spectral density matrix with only the business cycle (6-32 quarter) frequencies of Korea. The nominal interest rate is an inverted leading indicator over business cycles ($\text{corr}(r_{t-3}, y_t) = -0.46$, $\text{corr}(r_{t-4}, y_t) = -0.44$). The housing price moves procyclically, whereas debt ratios move countercyclically.

III. Model

We set up a model with the housing sector based on that of Iacoviello (2005). The economy consists of savers, borrowers, final goods firms, and the government. Each household supplies labor and consumes both consumption goods and housing services.

A. Savers

Savers maximize their expected life-time utility by choosing consumption, housing, and working hours:

Abel (1990, 1999) and Smets and Wouters (2007) specify a simple recursive preference, in which a representative household derives utility from the level of consumption relative to a time-varying subsistence or habit level. We particularly assume that the utility function of a representative household takes the form

$$E_0 \sum_{t=0}^{\infty} \beta_s^t [\log(C_{st} - b\tilde{C}_{st-1}) + D_t \log H_{st} - \frac{N_{st}^{1+\nu}}{1+\nu}], \quad (1)$$

TABLE 2
CALIBRATED PARAMETERS

Parameter	Value	Description of Parameters
r	0.016	Steady state rate of return
σ	1	Intertemporal elasticity of consumption
ν	1	Inverse of Frisch elasticity of labor supply
ρ_A	0.95	First-order serial correlation of technology shock
ρ_D	0.95	First-order serial correlation of house demand shock
σ_A	0.07	Standard deviation of technology shock
σ_D	0.07	Standard deviation of house demand shock

where β_s is the saver's discount factor; E_0 denotes the conditional expectations operator on the information available in period 0; C_{st} , N_{st} , and H_{st} represent the saver's consumption for composite goods, work hours, and housing stock at time t , respectively; \tilde{C}_{st-1} is the external habit; and $0 \leq b < 1$ measures the degree of habit persistence. In equilibrium, $\tilde{C}_{st-1} = C_{st-1}$. We also assume that the housing demand shock follows an AR(1) process, that is, $\log D_t = (1 - \rho_D)\log(D) + \rho_D + \log(D_{t-1}) + \varepsilon_{dt}$, $0 < \rho_D < 1$, where $E(\varepsilon_{dt}) = 0$ and ε_{dt} is i.i.d. over time.

The saver faces the following budget constraint:

$$C_{st} + B_{st} + Q_t H_{st} = \frac{R_t B_{st-1}}{1 + \pi_t} + Q_t H_{st-1} + w_{st} N_{st} + T_{st}, \quad (2)$$

where B_{st} and Q_t represent the saver's bank deposit and the price of housing in units of consumption at time t , respectively. w_{st} , R_t , π_t , and T_{st} denote the saver's real wage, nominal deposit rate or policy rate, inflation rate, and profits received from firms, respectively.

The first-order conditions are given by

$$\frac{1}{C_{st} - b\tilde{C}_{st-1}} = \beta_s E_t \left[\frac{C_{st+1} - b\tilde{C}_{st}}{1 + \pi_{t+1}} \right] \quad (3)$$

$$W_{st} = N_{st}^\nu (C_{st} - b\tilde{C}_{st-1}) \quad (4)$$

$$\frac{D_t}{H_{st}} = \frac{Q_t}{C_{st} - b\tilde{C}_{st-t}} - \beta_s E_t \left[\frac{Q_{t+1}}{C_{st+1} - b\tilde{C}_{st}} \right] \quad (5)$$

Equation (3) is a standard Euler equation, which states that a saver's consumption depends on the real interest rate. Equations (4) and (5) are a standard condition for labor supply and an intertemporal condition for housing service, respectively.

B. Borrowers

Borrowers maximize the utility function

$$E_0 \sum_{t=0}^{\infty} \beta_b^t [\log(C_{bt} - b\tilde{C}_{bt-1}) + D_t \log H_{bt} - \frac{N_{bt}^{1+\nu}}{1+\nu}], \quad (6)$$

where β_b is the borrower's discount factor, and C_{bt} , N_{bt} , and H_{bt} represent the borrower's consumption for composite goods, work hours, and the housing stock at time t , respectively. \tilde{C}_{bt-1} is the external habit. In equilibrium, $\tilde{C}_{bt-1} = C_{bt-1}$.

The borrower faces a collateral constraint in addition to the budget constraint

$$C_{bt} + B_{bt} + Q_t H_{bt} = \frac{R_t B_{bt-1}}{1 + \pi_t} + H_{bt-1} + w_{bt} N_{bt}, \quad (7)$$

$$R_t B_{bt} \leq \chi_t E_t [Q_{t+1} H_t (1 + \pi_{t+1})], \quad (8)$$

where B_{bt} represents the borrower's bank loans, w_{bt} is the borrower's real wage, and χ_t denotes the LTV ratio which is time varying. Jappelli and Pagano (1989) explain that the share of borrowing-constrained households is larger in economies with a lower LTV.

The first-order conditions are given by

$$\frac{1}{C_{bt} - bC_{bt-1}} = \beta_s E_t \left[\frac{C_{bt+1} - bC_{bt}}{1 + \pi_{t+1}} \right] + \lambda_t R_t, \quad (9)$$

$$w_{bt} = N_{bt}^\nu (C_{bt} - b\tilde{C}_{bt-1}), \quad (10)$$

$$\frac{D_t}{H_{bt}} = \frac{Q_t}{C_{bt} - b\tilde{C}_{bt-1}} - \beta_b E_t \left[\frac{Q_{t+1}}{C_{bt+1} - b\tilde{C}_{bt}} \right] + \lambda_t \chi_t E_t [Q_{t+1} (1 + \pi_{t+1})], \quad (11)$$

where λ_t is the Lagrange multiplier on the borrowing constraint. Equation (9) is a modified form of the Euler equation for consumption. If no borrowing constraint exists, then the equation is reduced to a standard

Euler equation. Equation (10) is a standard condition for labor supply. Equation (11) is an intertemporal condition for housing service. The marginal utility of the current consumption equals the marginal benefit of a housing service, which consists of the direct utility of the housing service, the expected future consumption utility from the realized resale value of the house, and the marginal utility of relaxing the borrowing constraint.

Next, suppose that the government implements a more general macroprudential policy by combining the DTI constraints and collateral constraints, as in Gelain *et al.* (2012), the collateral constraint (8) is modified as follows:

$$R_t B_{bt} \leq \tilde{\chi}_t E_t [\eta w_{bt} N_{bt} + (1 - \eta) Q_{t+1} H_{bt} (1 + \pi_{t+1})], \quad (12)$$

where η is the weight of the borrower's wage income. The first-order conditions (10) and (11) are then replaced by

$$N_{bt}^v = \frac{w_{bt}}{(C_{bt} - b\tilde{C}_{bt-1})} + \eta \lambda_t \chi_t w_{bt}, \quad (13)$$

$$\frac{Q_t}{C_{bt} - b\tilde{C}_{bt-1}} = \frac{D_t}{H_{bt}} + \beta_b E_t \left[\frac{Q_{t+1}}{C_{bt+1} - b\tilde{C}_{bt}} \right] + \lambda_t \chi_t (1 - \eta) E_t [Q_{t+1} (1 + \pi_{t+1})], \quad (14)$$

C. Firms

Differentiated goods and monopolistic competition are introduced, as in Dixit and Stiglitz (1977). A continuum of firms that produce differentiated goods exists, and each firm that is indexed by $i \in [0, 1]$ produces its product using the linear technology

$$Y_t(i) = A_t N_{st}^\theta(i) N_{bt}^{1-\theta}(i), \quad (15)$$

where A_t is the productivity shock that follows an AR(1) process as $\log A_t = (1 - \rho_A) \log A + \rho_A \log(A_{t-1}) + \varepsilon_{At}$, $0 < \rho_A < 1$, where $E(\varepsilon_{At}) = 0$ and ε_{At} is i.i.d. over time.

Equation (15) implies that the labor efforts of the savers and borrowers are not perfect substitutes, as in Iacoviello (2005). Firm i 's demand for labor is determined by its cost minimization as follows:

$$w_{st} = \theta mc_t \frac{Y_t(i)}{N_{st}(i)}, \quad (16)$$

$$w_{bt} = (1 - \theta)mc_t \frac{Y_t(i)}{N_{bt}(i)}, \quad (17)$$

where $mc_t \equiv MC_t/P_t$ is a real marginal cost in period t .

Much research has been conducted on the price decision rules in monopolistically competitive product markets. In this subsection, a Rotemberg-type of price setting is considered. To introduce the nominal price rigidities in the model, suppose that the representative firm i faces a quadratic adjustment cost Δ_t to adjust its price, $P_t(i)$ in terms of the final goods is given by

$$\Delta_t = \frac{\Theta}{2} \left(\frac{P_t(i)}{P_t} - 1 \right)^2 P_t$$

The monopolistically competitive firms in the goods markets set their own prices by maximizing the present discounted value of profits. The firm's maximization problem is written as follows:

$$\max. E_t \left[\sum_{k=0}^{\infty} \beta_s^k \left(\frac{\Lambda_{t+k}}{P_{t+k}} \right) ((P_{t+k}(i) - MC_{t+k}) Y_{t+k}(i) - \frac{\Theta}{2} \left(\frac{P_{t+k}(i)}{P_{t+k-1}(i)} - 1 \right)^2 P_{t+k}) \right], \quad (18)$$

subject to

$$Y_t(i) \leq \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t,$$

where Λ_{t+k} is the saver's marginal utility of consumption, and Y_t is the aggregate output in period t .

The newly determined prices at time t is then given by

$$\begin{aligned} & \frac{\Lambda_t Y_t(i)}{P_t} ((1 - \varepsilon) + \varepsilon \frac{MC_t}{P_t(i)}) - \Theta \Lambda_t \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right) \left(\frac{1}{P_{t-1}(i)} \right) \\ & = -\beta \Theta E_t \left[\left(\frac{P_{t+1}(i)}{P_t(i)} - 1 \right) \frac{\Lambda_{t+1} P_{t+1}(i)}{P_t^2(i)} \right]. \end{aligned} \quad (19)$$

D. Monetary Policy

We consider a Taylor rule, which corresponds to the inflation and output gap:

$$R_t = R_{t-1}^{\rho_r} (1 + \pi_t)^{1 + \alpha_x} \left(\frac{Y_t}{Y_{nt}} \right)^{\alpha_y})^{1 - \rho_r} \quad (20)$$

where ρ_r is the parameter associated with interest rate inertia, and α_x and α_y measure the response of the interest rates to the current inflation and output gap, respectively. We do not consider a general Taylor rule, which responds to credit growth or house price growth, because little or no stabilization benefits exist for the general interest rate rule.²

E. Macroprudential Policy

We introduce macroprudential policy in terms of the regulations of LTV ratios as a way of maintaining credit market stability. We assume that a countercyclical Taylor-type macroprudential policy exists for LTV ratios; thus, it responds to the credit market status in the spirit of the Basel III regulations.

Two kinds of time-varying macroprudential policy are considered. First, the LTV ratio responds negatively to credit growth as shown by

$$\chi_t \leq \chi \left(\frac{B_t}{B_{t-1}} \right)^{-\kappa_B} \quad (21)$$

where χ is the steady-state value of the LTV ratio, and κ_B measures the response of the LTV ratio to the credit growth to avoid undesirable credit market fluctuations. In the macroprudential policy given by Equation (21), the LTV ratio inversely responds to credit growth rates. The government implementing the time-varying LTV ratios lowers the LTV ratio in booms, while it increases to avoid excessive credit and housing market fluctuations.

Second, the LTV ratio is assumed to negatively respond to the housing price growth.

² See Iacoviello (2005), who finds no stabilization effect for a generalized Taylor rule.

$$\chi_t \leq \chi \left(\frac{Q_t}{Q_{t-1}} \right)^{-\kappa_q} \quad (22)$$

where κ_q measures the response of the LTV ratio to the housing price growth. The same form of time-varying macroprudential policy is taken in the case of a generalized macroprudential policy that accounts for both DTI and LTV.

a) Equilibrium

A symmetric equilibrium implies that all firms set the same price and choose the same demand for labor: $P_t(i) = P_t$, $N_{st}(i) = N_{st}$, and $N_{bt}(i) = N_{bt}$ for all i and t .

In such equilibrium, Equation (19) is simplified into

$$\frac{\Lambda_t Y_t}{P_t} \left(mc_t - \frac{\varepsilon - 1}{\varepsilon} \right) - \Theta \Lambda_t (\pi_t - 1) \pi_t = -\beta \Theta E_t [(\pi_{t+1} - 1) \pi_{t+1}], \quad (23)$$

The clearing of the goods market requires that

$$Y_t = C_{st} + C_{bt}. \quad (24)$$

The total supply of housing is fixed and is normalized to unity:

$$H_{st} + H_{bt} = 1. \quad (25)$$

IV. Quantitative Analysis

A. Parameter Values

All the parameter values used in this study are listed in Table 1. The discount factor for savers β_s is set to 0.99, whereas that of the borrowers is set to 0.98. The steady-state weight of housing in the utility function D is set to 0.11 so that the ratio of housing wealth to GDP is approximately 2.2 in the steady state, as is consistent with the Korean data.³

The benchmark model of this study takes the value of the intertemporal elasticity of substitution and labor supply elasticity as equal to one,

³ According to the Bank of Korea (2014), the net asset to GDP ratio equals 7.7, and the housing asset to GDP ratio equals 2.2.

that is, $\sigma = \nu = 1$. The steady-state LTV ratio is set to 0.6, and the labor income share of the patient households is set to 0.4. The nominal rigidity parameter value Θ is set to a value comparable with the fact that firms reoptimize their prices per year in the Calvo-type sticky price model. The elasticity of the substitution among the varieties ε is then set to 6, implying that the average size of the markup μ is 1.2. Both the technology and weight of housing in the utility function follow an AR(1) process with 0.95 persistence and a normal distributed shock.

B. Optimized Monetary and Macprudential Rules

To characterize an optimal, simple, and implementable monetary and macroprudential policy, social welfare must be defined. Suppose that the government assigns the weight α to a saver's utility function, the social welfare function can be defined as

$$\tilde{W} \equiv \alpha \sum_{t=0}^{\infty} \beta_s^t E_0[U(C_{st}, H_{st}, N_{st})] + (1 - \alpha) \sum_{t=0}^{\infty} \beta_b^t E_0[U(C_{bt}, H_{bt}, N_{bt})] \quad (26)$$

The values α_π , α_y , ρ_r , and κ_B or κ_q are characterized such that they are associated with the highest value of social welfare within the family of the interest rate feedback rules of Form (20), which responds to the inflation gap and output gap and the macroprudential rules of Forms (21) or (22).⁴

In the optimized rules, the policy parameters α_π , α_y , ρ_r , and κ_B or κ_q are restricted to the interval $[0, 1]$.

The weight assigned to savers versus borrowers is very important in evaluating the optimized interest rate rule and macroprudential rule. Macroprudential policy improves financial stability by dampening the borrower's debt and makes the borrower's welfare better off (worse off), while it makes the saver's welfare worse off (better off) in many cases. A trade-off occurs between savers and borrowers in terms of welfare as the LTV ratio changes. For example, Campbell and Hercowitz (2009) show that a higher LTV ratio harms borrowers, whereas savers benefit from the increase. A higher LTV ratio implies that borrowers accept

⁴The rule should satisfy two requirements, the interest-rate rule and the macroprudential policy, both of which are functions of a small number of easily observable macroeconomic variables, which must deliver a unique rational expectation and induce nonnegative equilibrium dynamics for the nominal interest rate.

TABLE 3
OPTIMAL MONETARY AND MACROPRUDENTIAL POLICY PARAMETERS IN A
MODEL WITH ONLY A TIME-INVARIANT LTV ($\eta=0$)

	Model with χ_B ($b=0$)	Model with χ_B ($b=0.5$)	Model with χ_B ($b=0.5$)
\tilde{W}	-103.4204	-185.8530	-185.8530
a_y	0	0	0
a_π	1.0	0.8	0.7
ρ_r	0.9	0.8	0.8
κ_B (κ_q)	0.7	1.0	0.7
Volatilities (%)			
σ_B	2.87	3.71	3.60
σ_q	2.30	3.27	3.27
σ_y	1.80	2.39	2.38
σ_π	0.11	0.17	0.19

TABLE 4
OPTIMAL MONETARY AND MACROPRUDENTIAL POLICY PARAMETERS IN A
MODEL WITH ONLY A TIME-VARYING LTV ($\eta=0$)

	Model with χ_B ($b=0$)	Model with χ_B ($b=0.5$)	Model with χ_B ($b=0.5$)
\tilde{W}	-103.4203	-185.3524	-185.3527
a_y	0	0	0
a_π	2.0	1.8	1.7
ρ_r	0.9	0.8	0.8
κ_B (κ_q)	0.7	1.0	0.7
Volatilities (%)			
σ_B	2.64	3.20	3.36
σ_q	2.29	3.27	3.27
σ_y	1.80	2.39	2.38
σ_π	0.11	0.17	0.19

higher consumption profiles, given that borrowing constraints are always binding. However, higher consumption levels imply a higher interest rate, which increases both borrower's debt burden and saver's returns on savings. In this study, the weight α is set to 0.5.

C. Macprudential Policy with LTV Only

Consider the macroprudential policy augmented with Equation (21).

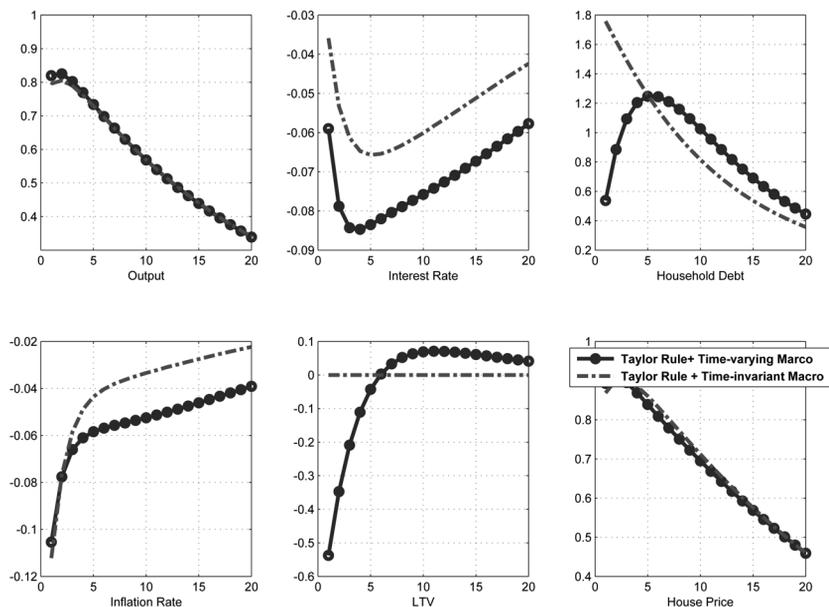


FIGURE 5
IMPULSE RESPONSE TO A POSITIVE TECHNOLOGY SHOCK

Table 3 presents the optimized parameter values, volatilities of selected variables, and the corresponding welfare when the monetary authority implements a time-invariant macroprudential policy, whereas Table 4 presents the results when the monetary authority implements a time-varying macroprudential policy.

No difference exists between a time-invariant and time-varying macroprudential policy, except for household debt volatility. The time-varying macroprudential policy successfully reduces household debt fluctuations, whether or not the authority reacts to the credit growth rate or house price growth rate.

a) Dynamic Effects of Productivity Shocks

Consider the effect of productivity shock on the economy without habit persistence in consumption. The circles in Figure 5 represent the impulse response function to the positive productivity shock when the monetary authority implements an optimized Taylor rule, and the macroprudential authority implements an optimized time-varying macroprudential policy. The long-dashed lines represent the response of the corresponding vari-

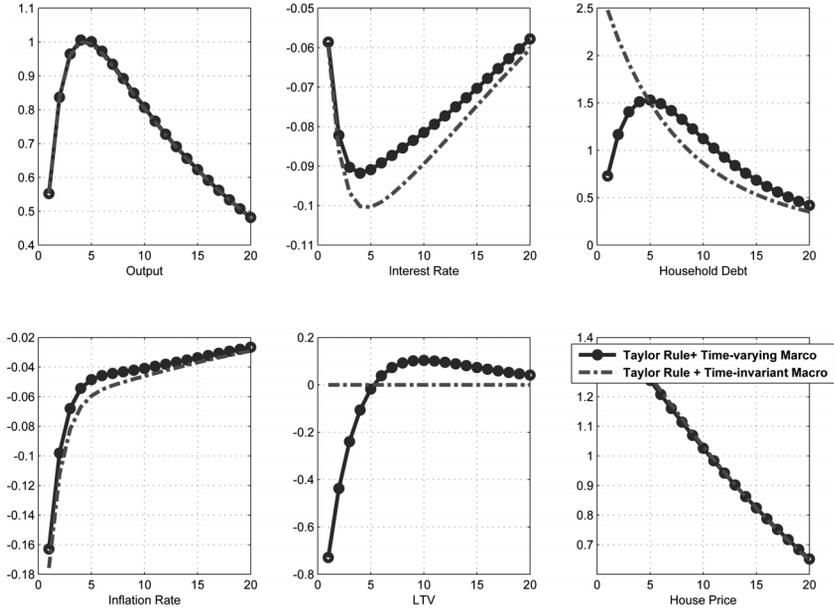


FIGURE 6

IMPULSE RESPONSE TO A POSITIVE TECHNOLOGY SHOCK

ables from the steady state when the monetary authority implements a Taylor rule, and the macroprudential authority implements a time-invariant macroprudential policy. A positive productivity shock results in an increase in output and a decrease in interest rate.

Given the expansion in the economy, the demands for house and loans increase and lead an increase of house price. Without a time-varying macroprudential policy that reacts to credit growth rate, the LTV ratio remains constant, and household debt instantaneously increases. However, household debt does not increase as much as it does in a time-invariant macroprudential policy, when a time-varying macroprudential policy is in place because the LTV ratio decreases.

Consider the effect of productivity shock on the economy with external habit persistence on consumption. As in Figure 6, the output, household debt, and house prices respond more strongly to productivity shocks in an economy with external habit than in an economy without external habit, because households with an external habit are determined to catch up with the Joneses without considering the effects of such behavior on aggregate demand. They unconsciously overheat the economy in expan-

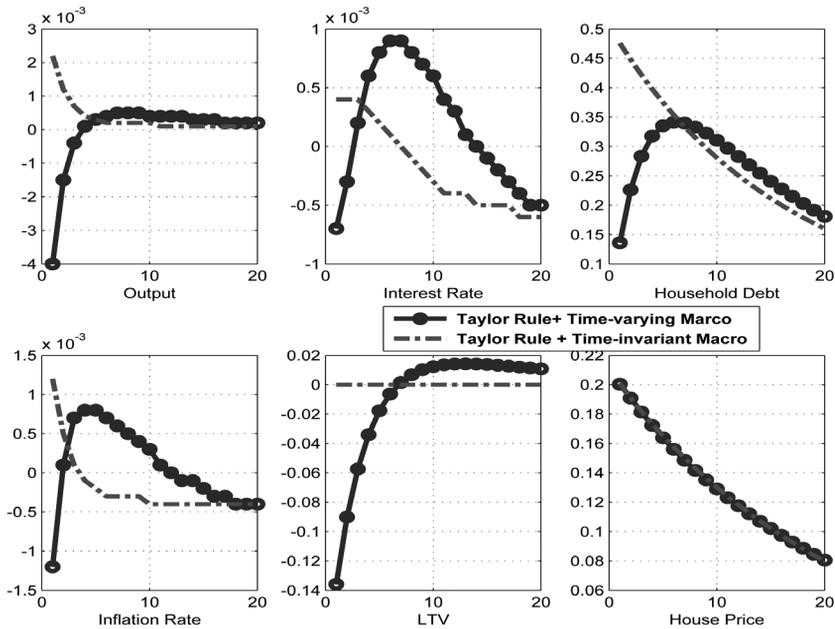


FIGURE 7

IMPULSE RESPONSE TO A POSITIVE HOUSE DEMAND SHOCK

sionary phases and cool it down excessively in contractionary phases, thereby generating unnecessary fluctuations in the economy over the business cycle. The comparison of circles and long-dashed lines in Figure 6 shows that the time-varying macroprudential policy is more effective in moderating the increase in household debt than the time-invariant macroprudential policy.

b) Dynamic Effects of House Demand Shocks

Consider the effect of housing demand shock on an economy without any habit. The circles in Figure 7 display the response of the variables when the monetary and macroprudential authorities implement an optimized Taylor rule and time-varying macroprudential rule, whereas the long-dashed lines represent the response of the corresponding variables when the said authorities implement an optimized Taylor rule and time-invariant macroprudential rule. Given the increase in house prices, the loan increases. Borrowers can borrow more from their housing collateral, which is worth more. However, when the macroprudential authority cooperates with the monetary authority with time-varying macroprudential

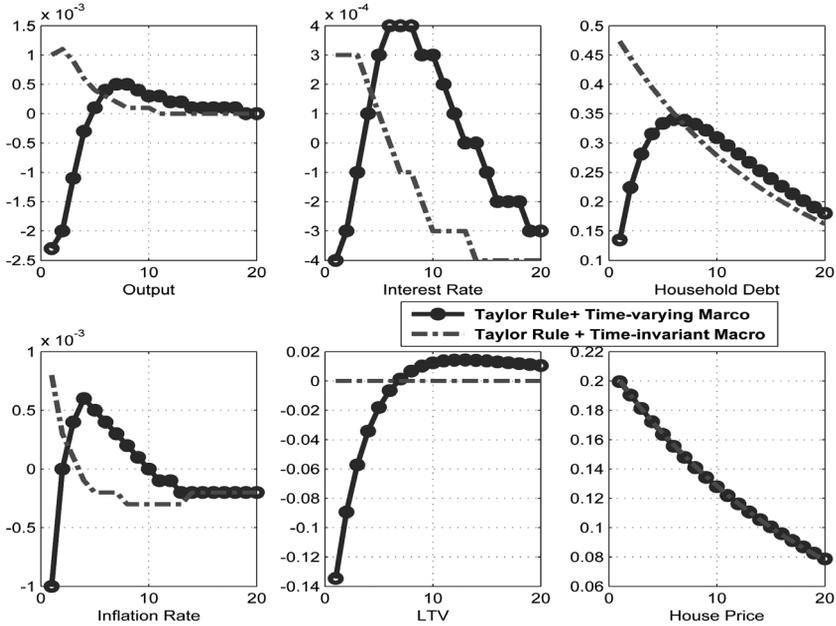


FIGURE 8
IMPULSE RESPONSE TO A POSITIVE HOUSE DEMAND SHOCK

policy to moderate the boom in housing sector, the LTV ratio decreases, and the household debt does not increase as much as that with a time-invariant macroprudential policy.

Next, consider the effect of housing demand shock on consumption, when households have an external habit. The compression of circles and long-dashed lines in Figure 8 shows that time-varying macroprudential policy is more effective in moderating the increase in household debt than the time-invariant macroprudential policy.

c) Generalized Macroprudential Policy

In this subsection, we consider the generalized macroprudential policy that incorporates DTI and LTV to enhance the financial stability given by Equation (6). Under this specification, the macroprudential authority can change the value of η to regulate the loan amount. To maintain the same steady-state LTV ratio in the numerical analysis, we need to calculate χ from the relationship

TABLE 5
OPTIMIZED MONETARY AND MACROPRUDENTIAL POLICY PARAMETERS IN A
MODEL WITH TIME-INVARIANT LTV AND DTI

	$\eta=0.5$	$\eta=0.4$	$\eta=0.3$	$\eta=0.2$	$\eta=0.1$
\tilde{W}	-183.9627	-184.4383	-184.7564	-185.1014	-185.1987
α_y	0	0	0	0	0
$1 + \alpha_\pi$	1.6	1.9	2.0	1.6	1.7
ρ_r	0.9	0.8	0.9	0.8	0.8
κ_B	1.0	1.0	1.0	1.0	1.0
Volatilities (%)					
σ_{B_0}	10.41	8.50	6.20	6.40	5.79
σ_{q_0}	3.46	3.31	3.26	3.27	3.24
σ_{y_0}	2.97	2.95	2.76	3.01	2.94
σ_{π_0}	0.38	0.26	0.27	0.27	0.25

Note: The macroprudential policy takes the form given by Equation (2).

TABLE 6
OPTIMIZED MONETARY AND MACROPRUDENTIAL POLICY PARAMETERS IN A
MODEL WITH TIME-VARYING LTV AND DTI

	$\eta=0.5$	$\eta=0.4$	$\eta=0.3$	$\eta=0.2$	$\eta=0.1$
\tilde{W}	-183.9455	-184.4125	-184.7564	-185.0058	-185.1987
α_y	0	0	0	0	0
$1 + \alpha_\pi$	1.6	1.9	2.0	1.6	1.7
ρ_r	0.9	0.8	0.9	0.8	0.8
κ_B	1.0	1.0	1.0	1.0	1.0
Relative	Volatilities				
σ_B / σ_{B_0}	0.31	0.38	0.52	0.54	0.58
σ_q / σ_{q_0}	0.87	0.93	0.97	0.96	1.00
σ_y / σ_{y_0}	0.79	0.85	0.86	0.79	0.81
$\sigma_\pi / \sigma_{\pi_0}$	0.63	1.00	0.63	0.78	0.76

$$\tilde{\chi} = \frac{\chi}{\eta(w_b N_b / QH_b) + 1 - \eta} \quad (27)$$

For example, $\tilde{\chi}=0.8802$ when $\eta=0.5$ and $\chi=0.6$ in the steady state. Moreover, the LTV ratio is endogenously time varying when the macroprudential authority considers DTI to regulate the household debt. If a borrower's labor income does not increase as much as the market value of the housing collateral, LTV decreases, thereby moderating the increase

TABLE 7
OPTIMAL MONETARY AND MACROPRUDENTIAL POLICY PARAMETERS IN A
MODEL WITH TIME-INVARIANT LTV AND DTI

	$\eta=0.5$	$\eta=0.4$	$\eta=0.3$	$\eta=0.2$	$\eta=0.1$
\tilde{W}	-183.9649	-184.4233	-184.7575	-185.0065	-185.1993
a_y	0	0	0	0	0
$1 + a_\pi$	1.5	1.6	1.8	2.0	1.6
ρ_r	0.9	0.9	0.9	0.9	0.8
κ_q	0.5	0.5	0.6	0.6	0.7
Volatilities (%)					
σ_{B_1}	3.85	3.48	3.62	3.61	3.66
σ_{q_1}	3.03	3.11	3.16	3.21	3.24
σ_{y_1}	2.28	2.31	2.34	2.36	2.37
σ_{π_1}	0.30	0.26	0.21	0.18	0.22

TABLE 8
OPTIMAL MONETARY AND MACROPRUDENTIAL POLICY PARAMETERS IN A
MODEL WITH TIME-VARYING LTV AND DTI

	$\eta=0.5$	$\eta=0.4$	$\eta=0.3$	$\eta=0.2$	$\eta=0.1$
\tilde{W}	-183.9467	-184.4232	-184.7569	-185.0061	-185.1989
a_y	0	0	0	0	0
$1 + a_\pi$	1.5	1.6	1.8	2.0	1.6
ρ_r	0.9	0.9	0.9	0.9	0.8
κ_q	0.5	0.5	0.6	0.6	0.7
Relative	Volatilities				
σ_B / σ_{B_1}	0.85	0.87	0.90	0.91	0.93
σ_q / σ_{q_1}	1.00	1.00	0.98	1.02	1.00
σ_y / σ_{y_1}	1.00	1.00	0.99	1.00	1.00
$\sigma_\pi / \sigma_{\pi_1}$	0.97	1.00	1.00	1.00	1.00

in household debt.

Tables 5-8 present the optimized parameter values, volatilities of selected variables, and the corresponding welfare.

First, household debt fluctuation increases when the macroprudential authority considers a time-invariant DTI ratio, in addition to a time-invariant LTV ratio, in collateral constraints. Although the LTV ratio in a generalized macroprudential policy as specified by Equation (12) moves endogenously to exogenous shocks, it is not enough to curb the excessive fluctuation of household debt. Tables 5 and 7 show that the time-invariant

DTI fails to moderate household debt fluctuations with a borrower's labor income fluctuation over business cycles.

Second, a time-varying macroprudential policy results in a large stabilization effect on household debt more than a time-invariant macroprudential policy as shown in Tables 6 and 8. The standard deviation of all the other relevant variables also decreases, regardless of the weight (η) to the borrower's labor income in the collateral constraints.

d) Dynamic Effects of Productivity Shocks

First, consider the effect of productivity shock on the economy. The circles in Figure 9 represent the impulse response function to the positive productivity shock when the monetary authority implements an optimized Taylor rule and the macroprudential authority implements optimized time-varying macroprudential policy. The long-dashed lines represent the response of the corresponding variables from the steady state when the monetary authority implements a Taylor rule and the macroprudential authority implements a time-invariant macroprudential policy.

Given the expansion in the economy, the demands for house and house price increase. As the increase in the borrower's labor income loosens the collateral constraints, household debt is given more room to increase even if a time-invariant macroprudential policy that reacts to credit growth or house price growth is in place. However, the increase in the household debt dampens when the macroprudential authority reacts to its generalized LTV ratio to the credit growth or house price growth. Output expansion also tends to be muted with the implementation of a time-varying macroprudential policy.

The comparison of the circles and long-dashed lines in Figure 9 shows that a time-varying macroprudential policy is more effective in moderating the increase in household debt than a time-invariant macroprudential policy.

Figure 10 shows the dynamic effects of productivity shock on the economy when the weight to the borrowers (η) varies. The increases in output, household debt, and house prices to the positive productivity shock are muted because the macroprudential authority gives more weight to the borrower's labor income in regulating the household debt.

e) Dynamic Effects of House Demand Shocks

Consider the effect of housing demand shock in the economy. The circles in Figure 11 display the response of the variables when the mon-

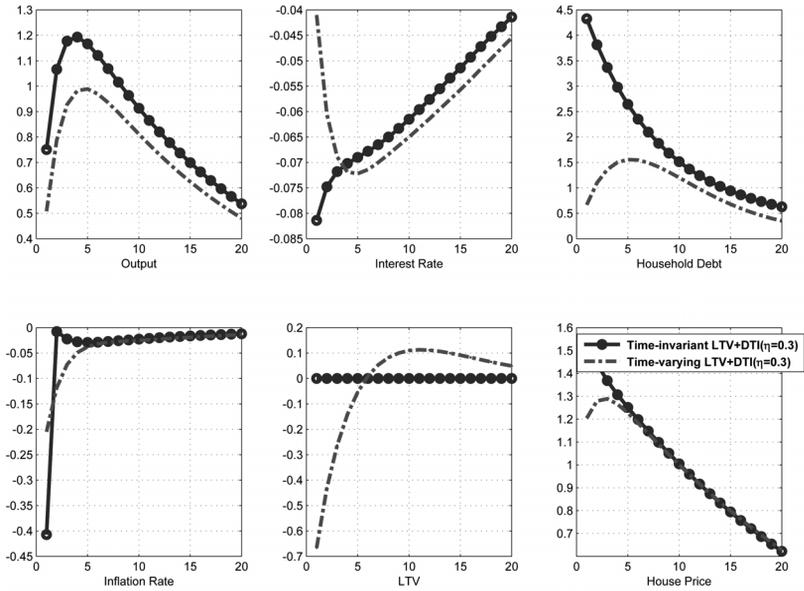


FIGURE 9
IMPULSE RESPONSE TO A POSITIVE TECHNOLOGY SHOCK

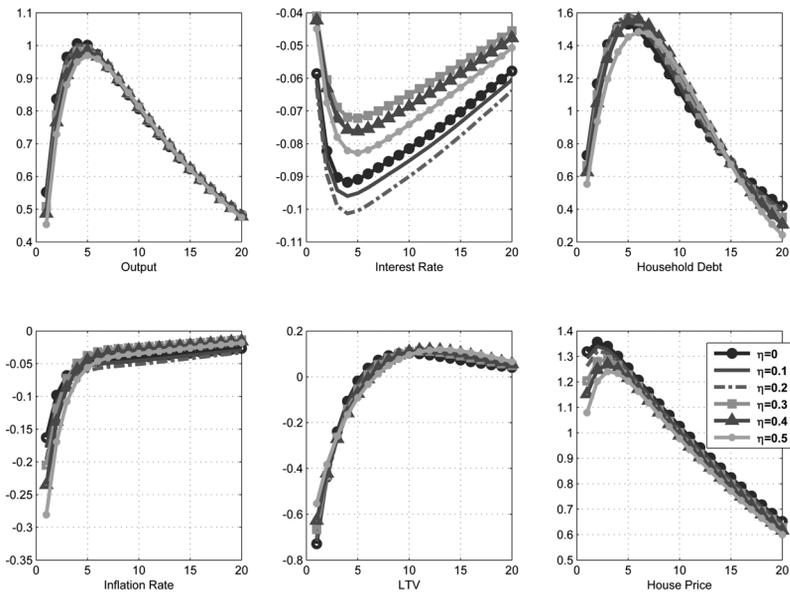


FIGURE 10
IMPULSE RESPONSE TO A POSITIVE TECHNOLOGY SHOCK

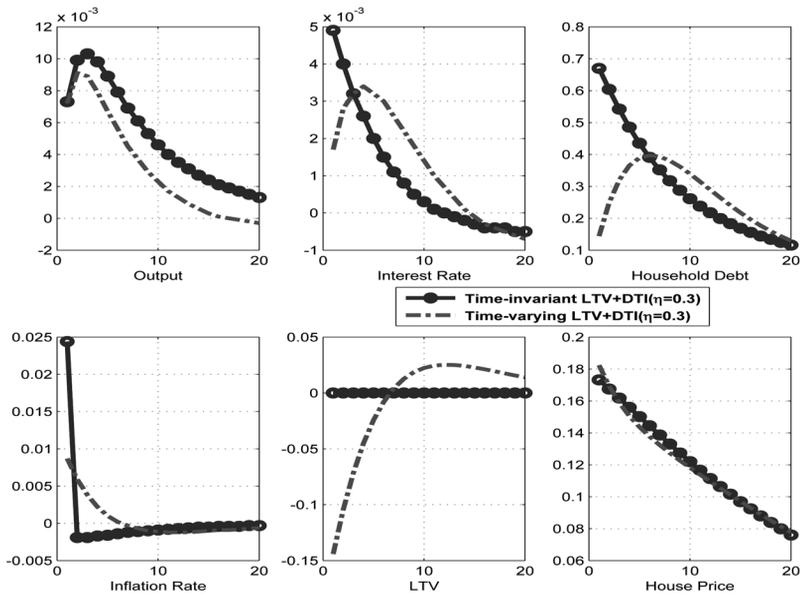


FIGURE 11

IMPULSE RESPONSE TO A POSITIVE HOUSING DEMAND SHOCK

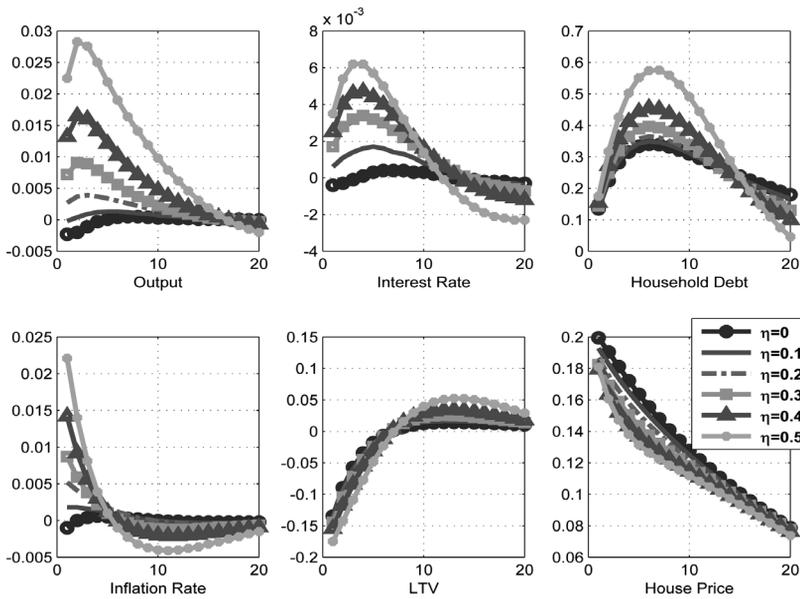


FIGURE 12

IMPULSE RESPONSE TO A POSITIVE HOUSING DEMAND SHOCK

etary and macroprudential authorities implement an optimized Taylor rule and time-varying macroprudential rule, whereas the long-dashed lines represent the response of the corresponding variables when the monetary and macroprudential authorities implement an optimized Taylor rule and time-invariant macroprudential rule. Given the increase in house prices, the loan increases. Borrowers can borrow more from their housing collateral, which is worth more. Moreover, the induced expansion of the real economy increases a borrower's labor income, giving more room for household debt to increase. However, when the macroprudential authority cooperates with the monetary authority in employing a time-varying macroprudential policy to moderate the boom in the housing sector, the LTV ratio decreases, and household debt does not increase as much as it does in a time-invariant macroprudential policy.

Figure 12 shows the dynamic effects of house price shock on the economy when the weight of the borrowers (η) varies. The increases in output, household debt, and interest rates to the positive housing demand shock are more pronounced because the macroprudential authority gives more weight to a borrower's labor income, thereby regulating the household debt.

V. Conclusion

In this study, we develop a simple sticky price model that features the housing market and discuss how monetary and macroprudential authority should react to exogenous shocks. The benchmark model is similar to that of Iacoviello (2005) with two types of households. We find that a time-varying macroprudential policy is more effective in stabilizing household debt than a time-invariant macroprudential policy, whether or not the macroprudential authority considers the borrower's labor income, in addition to the LTV ratio, in macroprudential policy. Moreover, a macroprudential policy based on the pure LTV ratio is better in moderating household debt to the house demand shock than a macroprudential policy that accounts for both the borrower's labor income and the market value of the house.

As an extension, a rigorous optimal monetary and macroprudential policy analysis is needed in a fully articulated model augmented with commercial banks.

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