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Implementable, Optimal Macroprudential and Monetary Policies: Implications for House Prices and Household Debt *

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Abstract

This paper addresses implementable, optimal macroprudential and monetary policies in a standard DSGE model augmented with nominal price and wage rigidities and housing sector. The paper also discusses the effect of introducing of time-varying LTV regulation in cooling down large swings of household debt. In particular, it examines macroprudential policy reacting to credit growth or housing price growth to dampen the excessive volatility of household debt. The paper shows that the time-varying macroprudential policy rules reacting to the debt to income ratio or to the credit growth are more effective in moderating the household debt swings to exogenous shocks than the time-varying macroprudential policy rule responding to the housing price growth. In particular, the time-varying macroprudential policy reacting to debt to borrower's labor income is most effective in moderating the debt fluctuations to housing demand shocks. The macroprudential policy reacting to the housing price growth is almost indifferent to the time-invariant macroprudential policy when the economy is hit by the house demand shock. The time-varying macroprudential policy is against the winds in the sense that the LTV ratio goes down when the economy expands with an increase in housing price and demand. The paper shows that there is a substantial welfare increase associated with the time-varying macroprudential policy compared to the time-invariant macroprudential policies.

Keywords Housing Price, Macroprudential Policy, Monetary Policy

JEL Classification E32,E44

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1. INTRODUCTION

The Great Recession that highlighted the linkage between macroeconomic and financial stability raised questions whether the traditional policy tools are enough to stabilize the economy. The existing policy tools, such as the monetary policy aiming at price stability and the microprudential regulations targeting at individual financial institution, showed their limitation to stabilize both real and financial markets at the same time in response to the unprecedentedly large economic shocks. The concept of macroprudential policies was suggested as a complement to the monetary policy. For the purpose of evaluate the effects of macroprudential policies, many economists started to pay attention to models with financial frictions that can yield many genuinely new insights about the conventional and unconventional policies over business cycles.

There are two strands of academic literature on macroprudential policy. The first strand of literature endorses the macroprudential policy in improving macroeconomic stability in economies with nominal rigidities. Farhi and Werning (2012) and Schmitt-Grohé and Uribe (2015) discuss the macroprudential policy with the so-called new Keynesian models, emphasizing the aggregate demand externalities. In the economy with monopolistic competition and nominal rigidities in goods and labor markets, the government needs to intervene in the market to stabilize the real sector as well as the financial sector. Farhi and Werning (2016) present examples of pecuniary externalities and aggregate demand externalities where the macroprudential policy is needed to improve the welfare. The second strand of literature endorses the macroprudential policy in improving macroeconomic stability in real business cycle economies with pecuniary externalities. Benigno et al. (2016), Bianchi (2011), and Korineck (2011) emphasize the macroprudential policy associated with pecuniary externalities. In the incomplete asset market where households are subject to collateral constraints, there is a role of macroprudential policy in promoting the financial stability.

There are vast literature that have been devoted to understanding the causes of the recent financial crisis and explaining its effects. The household and financial sectors have been the most frequently discussed area as a source of the crisis. Despite that microprudential policies were monitoring the soundness of individual financial institutions and preventing the spread of risks to the household and macroeconony, they failed to play enough roles during during the market collapse with subprime mortgage,

There are lots of macroprudential policy tools that have been discussed and introduced in both advanced and emerging economies. Some macroprudential tools have been already implemented in some advanced economies to promote the financial stability and to minimize the impacts of financial shocks to the entire economy. For example, Korea has introduced macroprudential policy tools such as regulations on loan-to-value(LTV) and debt-to-income(DTI) ratio. The Korean government has paid attention to the high level of households' leverage ratio that could be potential systemic risks to the entire financial system.

In this paper, we set up a DSGE model augmented with nominal prices, wage rigidities, and a housing sector to discuss the simple, implementable, and optimal monetary and macroprudential polices. The benchmark model is similar to Iacoviello (2005) with two-types of households: patient and impatient households. Patient households can smooth their consumption profile with their financial assets, while impatient households can do it by borrowing from the banks with collateral. Moreover, we incorporate external habit persistence into the model as in Smets and Wouters (2007). The households' tendency to catch up with other households generates unnecessary swings of debt associated with housing sector because they do not take into account the effects of their behavior on the economy. In this sense, a shock can overheat the economy in expansionary phases and cool it down excessively in contractionary phases, which calls for macroprudential policies to stabilize both the financial and the real sector.

We compare the implications of time-varying versus time-invariant macroprudential policies tools, especially LTV regulations with their interactions with the monetary policy, in the perspective of the social welfare as well as the stability of financial and real sectors. Specifically, we address how the macroprudential and monetary authorities should cooperate to stabilize the economy and improve the social welfare. For this purpose, we introduce three types of the simple and implementable macroprudential rules along with the Taylor-type interest rate rule into the model. In particular, the macroprudential authority is assumed to adjust the limits on the LTV ratios in response to the credit growth, housing price growth, or the debt to income(DTI) ratio to avoid the excessive leverage in the spirit of the Basel III regulation.

The main findings of this paper can be summarized as follows. First, the time-varying macroprudential policy responding to the DTI ratio is the most effective in stabilizing the household debt compared to the other policies considered. The optimized policy parameter values show that the macroprudential policy should aggressively respond to the DTI ratio, but with the cost of economic downturns

Second, the macroprudential policy responding to the credit growth is successful in stabilizing not only the housing market but also other sectors, but it requires longer time to stabilize the housing market than the policy responding to the DTI ratio. On the other hand, under the housing demand shock, the macroprudential policy responding to the housing price growth is indifferent from the time-invariant macroprudential policy in stabilizing the housing market.

Finally, the difference between the welfare associated with the time-varying macroprudential policy and the time-invariant macroprudential policy is substantial and the optimal macroprudential policy should be against the wind in the sense that the regulatory LTV ratio should go down when the economy expands, resulting in an increase in housing price and household debt.

The remainder of the paper is organized as follows. Section 2 presents the stylized facts in Korean households' debt and housing market, and section 3 presents a canonical DSGE model with sticky price and wage rigidities augmented with collateral constraints. Section 4 discusses the simple, optimal, implementable monetary and macroprudential policies and their properties. Then, section 5 concludes.

2. STYLIZED FACTS IN KOREAN ECONOMY

Korea is one of the few countries that are in the forefront of implementation of macroprudential policies, such as regulations on LTV and DTI ratio. Its rich experiences in the implementation of various forms of policy mix have drawn attentions to many researchers and raised interesting questions on their consequences to the housing price and financial stability.

Figure 1 presents two different measures of Korean households' financial burden. The blue line indicates the household credit to GDP ratio calculated from the flow of funds account, which is commonly used for the cross-country comparison. The red line indicates the household debt to GDP ratio from the household credit statistic collected and released by the Bank of Korea since 2002Q4.The former includes loans extended by both financial institutions and the government to household and non-profit institutions serving household, while the latter only covers loans to household from the financial institutions. Both measures show that Korean households' financial burden has steadily increased over the sample periods, except for the Asian Financial Crisis in 1997, the credit card crisis in 2003, and the Global Financial Crisis in 2008. According to the BIS(2016), the household credit to GDP ratio in Korea is very high compared to that in other countries.

One of the main reasons of such credit boom is the overheated housing market condition. In 2002 for the first time, the Korean government introduced a macroprudential tool, the limit on LTV ratio, to deal with the rapid increases in

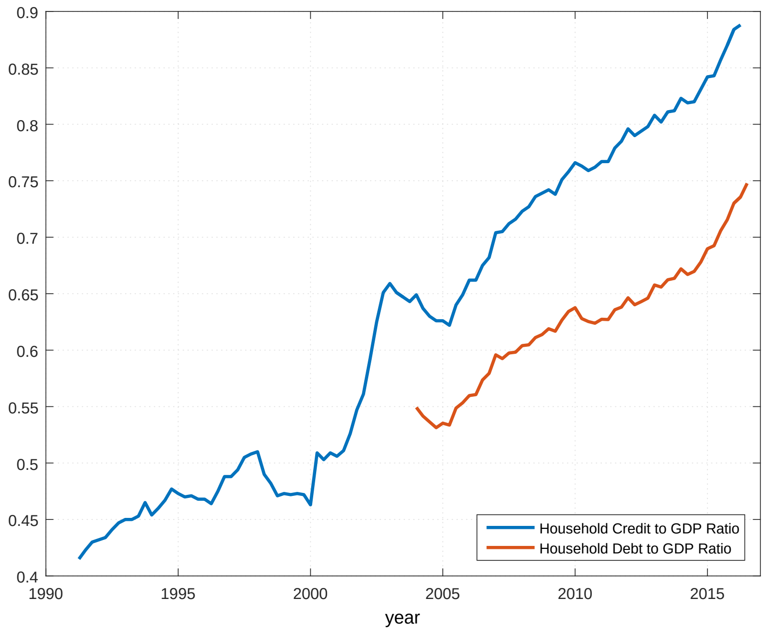

Figure 1: Household Credit and Debt to GDP Ratio

housing prices. In turn, along with tax incentives and disincentives, an additional macroprudential policy tool, the limit on DTI ratio, was introduced in 2005. Figure 2 shows the nominal and real housing prices in Korea, normalized to 100 at Dec. 2005. Despite of the government's effort to cool down the overheated housing market, the housing price has rebounded several times until the onset of the Global Financial Crisis. The recent upward trend may reflect the fact that both macroprudential and monetary policies have been relatively loosened since 2014.

Comparing the cyclical movements of both real and financial variables is a simple way to show the relationship between variables. Figure 3 shows the Hodrick-Prescott filtered cyclical movements of selected variables: the real GDP, real housing price index, household debt [1], and the call rate, since 2002Q1. Table 1 shows the standard deviation of the filtered series and cross-autocorrelation between variables. The nominal interest rate is an inverted one-year leading indicator over business cycles, and the household debt and housing price move

[1]We will use the terms "household credit" and "household debt" interchangeably.

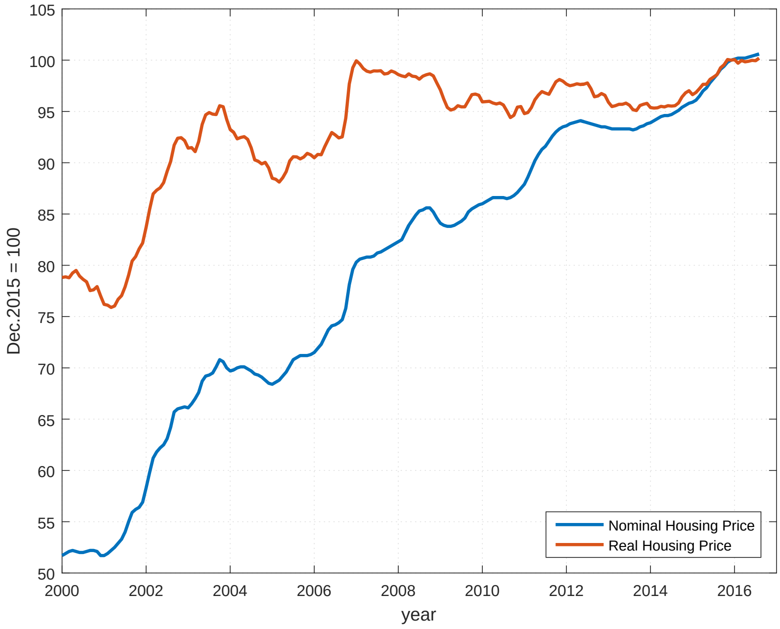

Figure 2: Nominal and Real Housing Prices

procyclically.

Variable	Stdev	Cross Autocorr. X_{t+k} with GDP Y_t (corr(X_{t+k}, Y_t))								
		-4	-3	-2	-1	0	1	2	3	4
GDP	1.12	-0.20	-0.01	0.32	0.71	1.00	0.71	0.33	-0.01	-0.20
Int. Rate	0.63	-0.36	-0.22	-0.03	0.27	0.63	0.80	0.71	0.55	0.35
HH Credit	3.19	-0.07	-0.10	0.00	0.22	0.41	0.41	0.30	0.18	0.11
Housing Price	2.94	-0.06	0.04	0.15	0.24	0.29	0.28	0.23	0.20	0.22

Table 1: Moments and Cross-autocorrelation (2002Q1 - 2016Q2)

We take a 4 variable VAR model as our empirical model to represent Korean economy with household debt and housing market. Of the four variables used in the model, two variables are monetary policy block, which contains the real GDP and the call rate. The other block represents the financial market including household debt and housing prices. We use quarterly data from 2000Q1 to 2016Q1 period, which covers the growth acceleration of both housing price and household credit that started in 2002. All variables except for the call rate are

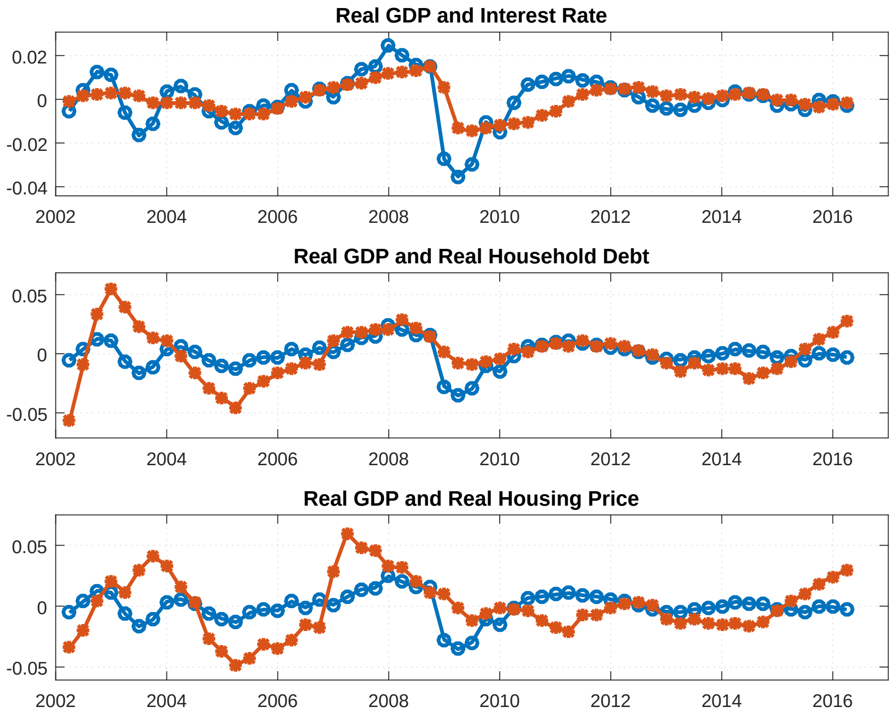

Figure 3: Business Cycle Fluctuation of Selected Macro Variables

transformed into logarithm, seasonally adjusted, and deflated by the CPI.

The model assumes that the Korean economy is represented by a structural-form equation as follows:

$$\mathbf{A}\begin{bmatrix} y_t \\ r_t \\ b_t \\ q_t \end{bmatrix} = \mathbf{B}(\mathbf{L})\begin{bmatrix} y_t \\ r_t \\ b_t \\ q_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \tag{1}$$

where A and $B(L)$ are the 4×4 and y_t is the real GDP, r_t is the call rate, b_t is the household debt, and q_t is the housing price. All shocks are assumed to be normally distributed with zero mean and mutually uncorrelated. The order of variables is determined by following assumptions: the central bank set the policy rate, approximated by the call rate, based on the contemporaneous GDP, and the call rate is short-term exogenous to the household credit, which is, in turn, short-term exogenous to the housing price. The length of lags is set to 1, chosen by Bayesian information criterion (SBIC) and the Hannan-Quinn information criterion (HQIC).

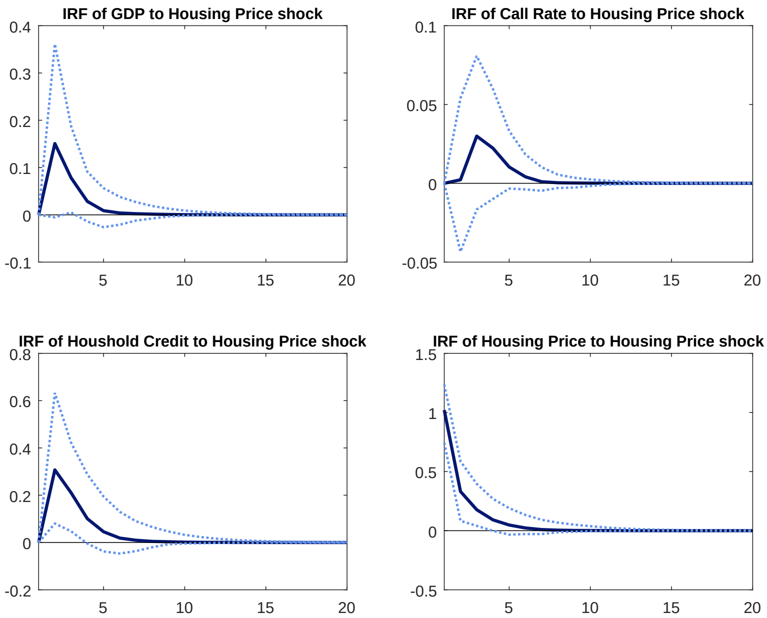

Figure 4: Impulse Responses to Housing Price Shocks

Figure 4 and Figure 5 represent the impulse responses to the Cholesky one standard deviation shock in housing prices and GDP, respectively. Figure 4 indicates that an increase in housing prices allows households to borrow more against their increased value of housing collateral. That is, the wealth effect leads households to consume more housing service and consumption goods.The increase in housing prices is transmitted to the real economic boost, generating inflation which leads to increase in interest rates. Figure 5 show that the housing price increases in the response of economic expansion, leading household's collateral value increase as well. Households, in turn, can borrow more and the level of household's debt also increases.

3. MODEL

We set up a model with a housing sector along the line of Iacoviello (2005), and Iacoviello and Neri (2010). The economy consists of patient households,

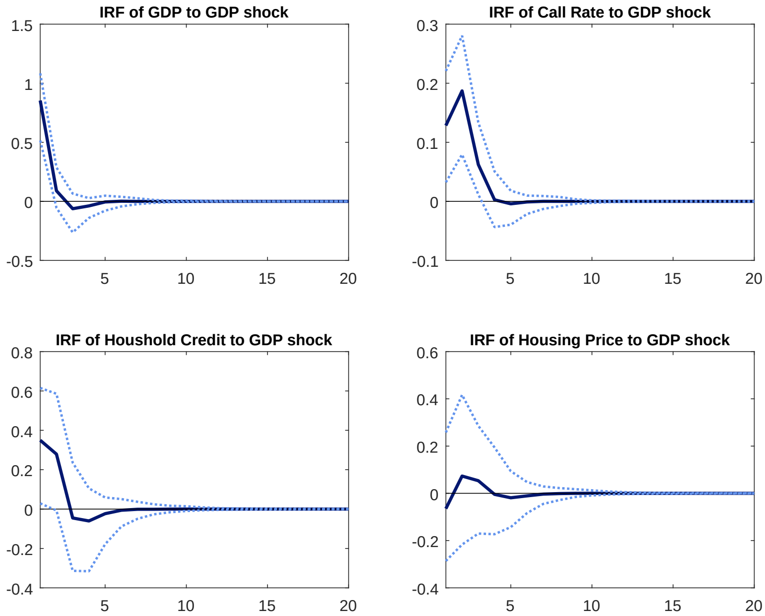

Figure 5: Impulse Responses to GDP Shocks

impatient households, firms, and a government. Each household supplies labor and consumes consumption goods as well as housing services.

3.1. PATIENT HOUSEHOLDS

Patient households, denoted by subscript A, choose consumption, housing, and working hours to maximize their life-time expected utility subject to their budget constraint. Following Abel (1990, 1999) and Smets and Wouters (2007), we assume a simple recursive preference, in which households derive utility from the level of consumption relative to a time-varying habit level as follows:

$$E_0\left[\sum_{t=0}^{\infty}\beta_A^t\left(\log(C_{A,t}-b\widetilde{C}_{A,t-1})+\mathscr{H}_t\log H_{A,t}-\frac{N_{A,t}^{1+\nu}}{1+\nu}\right)\right],\ 0<\beta_A<1, \quad (2)$$

where β_A is the patient household's discount factor, E_0 denotes the conditional expectations operator on the information available in period 0. $C_{A,t}$, $N_{A,t}$, and $H_{A,t}$ represent the patient household's consumption for composite goods, working hours, and the housing stock at time t, respectively. $\widetilde{C}_{A,t-1}$ is an external habit and $0 \leq b < 1$ measures the degree of habit persistence. In equilibrium, $\widetilde{C}_{A,t-1} = C_{A,t-1}$. It is assumed that the housing demand shock follows an AR(1) process, *i.e.* $\log(\mathscr{H}_t) = (1-\rho_D)\mathscr{H} + \rho_D \log(\mathscr{H}_{t-1}) + \varepsilon_{d_t}$, $0 < \rho_D < 1$, where $E(\varepsilon_{d_t}) = 0$ and ε_{d_t} is *i.i.d.* over time.

The patient household faces the following budget constraints

$$C_{A,t} + B_{A,t} + Q_t H_{A,t} = \frac{R_{t-1} B_{A,t-1}}{(1+\pi_t)} + Q_t H_{A,t-1} + w_{A,t} N_{A,t} + D_{A,t}, \tag{3}$$

where $B_{A,t}$ and Q_t represent the patient household's bank deposit and the housing price in units of consumption at time t, receptively. R_t, π_t, and $D_{A,t}$ denote the nominal deposit rate or policy rate, inflation rate, and profits received from firms.

The first order conditions are given by

$$\frac{1}{C_{A,t} - b\widetilde{C}_{A,t-1}} = \beta_A E_t \left[\frac{R_t}{(C_{A,t+1} - b\widetilde{C}_{A,t})(1+\pi_{t+1})} \right], \tag{4}$$

$$\frac{Q_t}{C_{A,t} - b\widetilde{C}_{A,t-1}} = \frac{\mathscr{H}_t}{H_{A,t}} + \beta_A E_t \left[\frac{Q_{t+1}}{(C_{A,t+1} - b\widetilde{C}_{A,t})} \right]. \tag{5}$$

Equation (4) states that the patient household's current and future consumption path is determined by the real interest rate. Equation (5) states that the marginal utility of consumption should be equal to the marginal benefit of housing service, composed of direct marginal benefit of housing service and the expected future benefit from the realized resale value of house.

3.2. IMPATIENT HOUSEHOLDS

Impatient households, denoted by subscript B, choose $C_{B,t}$, $N_{B,t}$, $B_{B,t}$, and $H_{B,t}$ to maximize the utility function equation (6) subject to borrowing constraints as well as budget constraints:

$$E_0 \left[\sum_{t=0}^{\infty} \beta_B^t \left(\log(C_{B,t} - b\widetilde{C}_{B,t-1}) + \mathscr{H}_t \log H_{B,t} - \frac{N_{B,t}^{1+\nu}}{1+\nu} \right) \right], \; 0 < \beta_B < \beta_A, \tag{6}$$

where β_B is the impatient household's discount factor and $C_{B,t}$, $N_{B,t}$, and $H_{B,t}$ represents the impatient household's consumption for composite goods, work hours, and the housing stock at time t, respectively. $\widetilde{C}_{B,t}$ is external habit and, in equilibrium, $\widetilde{C}_{B,t-1} = C_{B,t-1}$.

The budget constraint and borrowing constraint are given by

$$C_{B,t} + \frac{R_{t-1}B_{B,t-1}}{(1+\pi_t)} + Q_t H_{B,t} = Q_t H_{B,t-1} + B_{B,t} + w_{B,t} N_{B,t}, \tag{7}$$

$$R_t B_{B,t} \leq \psi_t E_t [Q_{t+1} H_{B,t} (1+\pi_{t+1})], \tag{8}$$

where $B_{B,t}$ represents the impatient household's bank loans and ψ_t denotes the loan-to-value ratio. ψ_t is a time-varying macroprudential policy tool, depending on the credit growth rate or housing price growth rate.

The first order conditions are given by

$$\frac{1}{C_{B,t} - b\widetilde{C}_{B,t-1}} = \beta_B E_t \left[\frac{R_t}{(C_{B,t+1} - b\widetilde{C}_{B,t})(1+\pi_{t+1})} \right] + \phi_t R_t, \tag{9}$$

$$\frac{Q_t}{C_{B,t} - b\widetilde{C}_{B,t-1}} = \frac{\mathscr{H}_t}{H_{B,t}} + \beta_B E_t \left[\frac{Q_{t+1}}{(C_{B,t+1} - b\widetilde{C}_{B,t})} \right] + \phi_t \psi_t E_t [Q_{t+1}(1+\pi_{t+1})], \tag{10}$$

where ϕ_t is the Lagrange multiplier on the borrowing constraint. Equation (9) is a modified Euler equation for consumption, reflecting the collateral constraint. If the borrowing constraint is not binding, then $\phi_t = 0$. Otherwise, $\phi_t > 0$, making the borrowing interest rate different from the deposit interest rate R_t. Equation (10) represents an intertemporal condition for choosing housing services. The marginal benefit of housing service to impatient households can be decomposed of direct marginal benefit of housing service, the expected future benefit from the realized resale value of house, and the marginal benefit accruing to the relaxation of borrowing constraint. The marginal utility of consumption should be equal to the marginal benefit of housing service per dollar.

3.3. LABOR MARKET

We incorporate nominal wage rigidities as well as nominal price rigidities to address the effects of macroprudential and monetary policy.

First, we introduce the nominal wage rigidities by assuming labor unions who sell differentiated labor types to perfectly competitive labor assemblers. The labor unions assemble differentiated labor types in a CES aggregator and sell the homogeneous labor to firms. For each labor type z, there are two labor unions k:

one for patient households and the other for impatient households. Each labor union (k, z) sets optimal nominal wages for its members by maximizing the union member's life-time utility subject to a labor demand and quadratic adjustment costs.

The maximization problem of the labor union k $(k = A, B)$ can be written as follows:

$$E_0 \sum_{t=0}^{\infty} \beta_k^t \{\Lambda_{k,t} \left[\frac{W_{k,t}(z)}{P_t} N_{k,t}(k,z) - \frac{\Theta_w}{2} (\frac{W_{k,t}(z)}{W_{k,t-1}(z)} - 1)^2 \frac{W_{k,t}}{P_t} \right] - \frac{N_{k,t}^{1+v}}{1+v} \} \tag{11}$$

subject to a labor demand $N_{k,t}(k,z) = \left(\frac{W_{k,t}(z)}{W_{k,t}} \right)^{-\varepsilon_w} N_{k,t}$. Here $\Lambda_{k,t}$ is the marginal utility of consumption for labor type k, and Θ_w denotes the degree of nominal wages rigidities. If $\Theta_w = 0$, then wages are flexible.

3.4. FIRMS

Differentiated goods and monopolistic competition are introduced into the model along the lines of Dixit and Stiglitz (1977). There is a continuum of firms producing differentiated goods using two types of labor $N_{A,t}$ and $N_{B,t}$. Each firm indexed by $i \in [0, 1]$ produces its product with labor inputs, $N_{A,t}$ and $N_{B,t}$, from patient and impatient households as follows:

$$Y_t(i) = Z_t N_{A,t}^{\theta}(i) N_{B,t}^{1-\theta}(i), \tag{12}$$

where Z_t is the productivity shock that follows an $AR(1)$ process as $\log Z_t = (1 - \rho_Z) \log Z + \rho_Z \log Z_{t-1} + \varepsilon_{Z,t}$, $0 < \rho_Z < 1$, where $E(\varepsilon_{Z,t}) = 0$ and $\varepsilon_{Z,t}$ is *i.i.d.* over time. θ measures the labor income share of patient households. Unlike Iacoviello (2005), labor efforts of patient and impatient households are not perfect substitutes in production. Firm i's demand for labor is determined by its cost minimization as follows:

$$w_{A,t} = \theta \mathscr{M}_t^{-1} \frac{Y_t(i)}{N_{A,t}(i)}, \tag{13}$$

$$w_{B,t} = (1 - \theta) \mathscr{M}_t^{-1} \frac{Y_t(i)}{N_{B,t}(i)}, \tag{14}$$

where $\mathscr{M}_t (\equiv \frac{P_t}{\mathrm{MC}_t})$ is the markup in period t and MC_t is the marginal cost.

The monopolistically competitive firm i in the goods markets set the optimal price $P_t(i)$ by maximizing the present discounted value of profits.

$$\max\ E_t[\sum_{k=0}^{\infty}\beta^k\frac{\Lambda_{A,t+k}}{P_{t+k}}((P_{t+k}(i)-\mathrm{MC}_{t+k})Y_{t+k}(i)-\frac{\Theta_p}{2}(\frac{P_{t+k}(i)}{P_{t+k-1}(i)}-1)^2P_{t+k})] \tag{15}$$

subject to

$$Y_t(i)\leq\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon_p}Y_t, \tag{16}$$

where $\Lambda_{A,t+k}$ is the impatient household's marginal utility of consumption and Y_t is the aggregate output in period t. Θ_p denotes the degree of nominal price rigidities, and ε_p is the elasticity of substitution among varieties.

Then, the newly determined price at time t is given by

$$\begin{aligned}&\frac{\Lambda_{A,t}Y_t(i)}{P_t}((1-\varepsilon)+\frac{\varepsilon}{\mathscr{M}_t})-\Theta_p\Lambda_{A,t}\left(\frac{P_t(i)}{P_{t-1}(i)}-1\right)\frac{1}{P_{t-1}(i)} \\ = \quad & -\beta\Theta_pE_t\left[\left(\frac{P_{t+1}(i)}{P_t(i)}-1\right)\frac{\Lambda_{A,t+1}P_{t+1}(i)}{P_t^2(i)}\right].\end{aligned} \tag{17}$$

Imposing a symmetric equilibrium ($P_t(i)=P_t$ for all i and t), equation (17) yields a non-linear new Keynesian Phillips curve:

$$Y_t((1-\varepsilon)+\frac{\varepsilon}{\mathscr{M}_t})-\Theta_p(\Pi_t-1)\Pi_t=-\beta\Theta_pE_t\left[\frac{\Lambda_{A,t+1}}{\Lambda_{A,t}}(\Pi_{t+1}-1)\Pi_{t+1}\right], \tag{18}$$

where $\Pi_t\equiv\frac{P_t-P_{t-1}}{P_{t-1}}$ is the inflation rate at time t.

3.5. MONETARY AUTHORITY AND GOVERNMENT

3.5.1 Monetary Policy

We assume that the monetary authority sets the policy rate according to a Taylor rule as follows

$$R_t=R_{t-1}^{\rho_r}\left((1+\pi_t)^{(1+a_\pi)}(Y_t/Y_{n,t})^{a_y}\right)^{1-\rho_r}, \tag{19}$$

where ρ_r is the parameter associated with interest rate inertia, a_π and a_y measure the response of interest rates to current inflation and output gap, respectively. $\pi_t\equiv\Pi_t-1$ and $Y_{n,t}$ is the natural level of output at time t.

3.5.2 Macroprudential Policy

We consider three types of macroprudential policies on LTV ratios. To maintain the financial market stability, the macroprudential authority adjusts the limits on LTV ratios counter-cyclically around the steady-state value in the spirit of the Basel III regulations.

First, we consider a macroprudential policy that reacts to the credit growth rate. That is, the macroprudential authority adjusts the limit on LTV ratio to moderate a credit growth as follows:

$$\psi_t = \overline{\psi}\left(\frac{B_t}{B_{t-1}}\right)^{-\eta_b}, \tag{20}$$

where $\overline{\psi}$ is the steady-state value of the loan to value ratio and η_b measures the response of the LTV ratio regulation to the credit growth to moderate credit market fluctuations. The macroprudential policy given by equation (20) stipulates that the regulatory LTV ratio is lowered in credit expansions, while it is raised in credit contractions, so that it can moderate excessive credit and housing market fluctuations.

Second, we consider an another type of macroprudential policy that reacts to the impatient household's debt to income ratio. In particular, the regulatory LTV ratio responds negatively to the ratio of debt to impatient household's real wages as follows:

$$\psi_t = \overline{\psi}\left(\frac{B_t}{w_{B,t}}\right)^{-\eta_w}, \tag{21}$$

where η_w measures the response of the LTV ratio to the DTI ratio. In the macroprudential policy given by equation (21), the LTV ratio inversely responds to DTI ratio. The government implementing the time-varying LTV ratios à la (21) lowers the LTV ratio when debt relative to disposable income increases. This policy can also moderate excessive credit expansion and housing market fluctuations.

Finally, we consider the last type of macroprudential policies that reacts to the housing price growth. That is, the regulatory LTV ratio responds negatively to the growth rate of housing prices as follows:

$$\psi_t = \overline{\psi}\left(\frac{Q_t}{Q_{t-1}}\right)^{-\eta_q}, \tag{22}$$

where η_q measures the response of the LTV ratio to the housing price growth.

3.6. EQUILIBRIUM

A symmetric equilibrium implies that all firms set the same prices, and chooses the same demand for each labor type. That is, $P_t(i) = P_t, N_{A,t}(i) = N_{A,t}, N_{B,t}(i) = N_{B,t}$, and so on for all i and t.

In a symmetric equilibrium, the NKPC is simplified as

$$\Pi_t(\Pi_t - 1) = \frac{\varepsilon Y_t}{\Theta_p}\left(\frac{1}{\mathscr{M}_t} - \frac{\varepsilon - 1}{\varepsilon}\right) + \beta E_t \left[\frac{\Lambda_{A,t+1}}{\Lambda_{A,t}} \Pi_{t+1}(\Pi_{t+1} - 1)\right] \tag{23}$$

The labor supply by a household of type k is given by

$$\Lambda_{k,t}\Pi^w_{k,t}(\Pi^w_{k,t} - 1) = \beta\Theta_w E_t[\Lambda_{x,t+1}(\Pi^w_{k,t+1} - 1)\frac{(\Pi^w_{k,t+1})^2}{\Pi_{t+1}}] + \Lambda_{k,t}(1-\varepsilon_w)N_{k,t} + \frac{\varepsilon_w N^{1+\nu}_{k,t}}{w_{k,t}}, \tag{24}$$

where $\Pi^w_{k,t}$ is the nominal wage inflation and $w_{k,t}$ is the real wage for labor type k.

Goods market and housing market clearing require that

$$Y_t = C_{A,t} + C_{B,t}. \tag{25}$$

$$H_{A,t} + H_{B,t} = \overline{H}. \tag{26}$$

4. QUANTITATIVE ANALYSIS

4.1. PARAMETER VALUES

All parameter values used in this paper are reported in Table 2. The discount factor for the patient household, β_A, is set 0.99, while that of the impatient household, β_B, is set to 0.98. The steady-state weights on housing services in the utility function $\mathscr{H}$ is set to 0.11 so that the ratio of housing wealth to GDP to be approximately 2.2 in the steady-state as in Jung et al. (2017), consistent with the Korean data.

Both the value of intertemporal elasticity of substitution and the Frisch labor supply elasticity are set to be equal to one, *i.e.* $\sigma = \nu = 1$.

The steady-state LTV ratio is set to 0.6 and the labor income share for patient households is set to 0.4. The nominal price and wage rigidity parameter values for Θ_p and Θ_w are set to comparable with the fact that firms and labor unions

Parameter	Value	Description of Parameters
r	0.016	Steady state rate of return
σ	1	Intertemporal elasticity of consumption
ν	1	Frisch elasticity of labor supply
b	0.5	Degree of external habit
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	0.007	Standard deviation of technology shock
σ_D	0.007	Standard deviation of house demand shock

Table 2: Calibrated Parameters

on average reoptimize their prices and wages per year in the Calvo type nominal price and wage rigidity model. We set the elasticity of substitution among varieties of goods and labors ε_p and ε_w to 6, implying that both the average size of price and wage markup, $\mathscr{M}$ and $\mathscr{M}_w$ are 1.2.

Finally, both the technology shock and the housing demand shock follow an AR(1) process with 0.95 persistence.

4.2. OPTIMIZED MONETARY AND MACROPRUDENTIAL RULES

Suppose that the government sets a social welfare by assigning the weight α to the patient household's welfare and $1-\alpha$ to the impatient household's welfare. Then the social welfare function can be defined as

$$\mathscr{W} \equiv \alpha \sum_{t=0}^{\infty} \beta_A^t E_0[U(C_{A,t}, H_{A,t}, N_{A,t})] + (1-\alpha) \sum_{t=0}^{\infty} \beta_B^t E_0[U(C_{B,t}, H_{B,t}, N_{B,t})]. \quad (27)$$

We will characterize the optimal, simple and implementable macroprudential and monetary policies with the values of a_π, a_y, ρ_r, and η_b or η_w, η_q. The former three values are associated with the highest value of the social welfare within the family of the interest rate feedback rules, equation (19), that respond to inflation gap as well as output gap. The latter three are related to the macroprudential rules, equation (20), equation (21), and equation (22).[2] In the optimized rules, the monetary policy parameters a_π, a_y, a_r are restricted to lie in the interval

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

$[0,3]$, while the macroprudential policy parameters η_b, η_w, and η_q are restricted to lie in the interval $[0,1]$.

The weight assigned to the patient versus impatient households is critical in evaluating the optimized rules for the interest rate and the macroprudential policy. The macroprudential policy aiming at financial stability by moderating the impatient household's credit can make the impatient household's welfare worse off, while it improves the patient household's welfare with a favorite rate of return to assets: There is a trade-off between the welfare associated with patient households and with impatient households as the regulatory LTV ratio changes.

For example, higher regulatory LTV ratio induces the impatient households to reduce their consumption of goods as well as housing services. Higher LTV ratio implies that the impatient households have to accept steeper consumption path as borrowing constraints always bind. Since higher consumption levels imply higher interest rates, increasing the impatient households' debt burden, the patient households can enjoy higher consumption with higher interest income. Considering this conflict, we set the weight α to 0.5.

In this subsection, we first compute the second-order approximation of equilibrium conditions associated with optimal monetary and macroprudential policies around the deterministic steady-state, assuming that both economies are subject to a stationary distribution of productivity and housing demand shocks. Next, we compute the first and second moments, and the implied discounted utility for artificial time series of length $T = 200$, by iterating the computation $J = 1000$ times and averaging across experiments as in Schmitt-Grohé and Uribe (2004).

4.3. TIME-INVARIANT MACROPRUDENTIAL POLICY

Consider first the time-invariant macroprudential policy in the form of $\psi = \overline{\psi}$. Table 3 and 4 present the optimized policy parameter values, the volatilities of selected variables, and the corresponding welfare associated with optimal monetary policy and time-invariant macroprudential policy. The optimal monetary policy stipulates a persistent interest rate rule that responds only to inflation rate. The interest rate moves countercyclically, while housing price and debt move procyclically. This strong countercyclical or procyclical movements reflect the fact that we have considered only the productivity shock and house demand shock, not other inefficient shock such as cost push shock, in order to focus on the optimal macroprudential policy.

Model with $\psi = \overline{\psi}$	
Variable	Values
a_y	0
a_π	1.7
ρ_r	0.9

Table 3: Optimized Policy Parameters in Model with Time-invariant LTV

Model with $\psi = \overline{\psi}$
($\mathscr{W} = -185.3541$)

Variable	Mean	Std. Dev.	Auto. Corr	$Corr(x,y)$
ψ	60	0	-	-
r	3.9655	0.2099	0.9768	-0.9990
π	-0.0207	0.0027	0.6428	-0.5241
b	0.8196	0.0241	0.8412	0.7781
q	3.1275	0.0295	0.9548	0.9771
y	1.0002	0.0201	0.9800	1

Note: r and π are expressed in percentage points and ψ, y, q and b in levels. $T = 200$, and $J = 1000$.

Table 4: Dynamic Properties of the Resource Allocations in Optimal Monetary Policy with Time-Invariant Macroprudential Policy($\psi = \overline{\psi}$)

4.4. TIME-VARYING MACROPRUDENTIAL POLICY

Table 5 and 6 present the optimized policy parameter values for each different types of time-varying macroprudential policies, and the volatilities of selected variables, and the corresponding welfare associated with optimal monetary policy and time-invariant macroprudential policies.

	Model with η_b	**Model with η_w**	**Model with η_q**
a_y	0	0	0
$1 + a_\pi$	1.7	1.8	1.7
ρ_r	0.9	0.9	0.9
$\eta_i (i = b, w, q)$	1.0	1.0	0.7

Table 5: Optimized Policy Parameters in Model with Time-varying LTV

Model with $\psi = \overline{\psi}(\frac{b_t}{b_{t-1}})^{-\eta_b}$
($\mathscr{W}$ = −185.3538)

Variable	Mean	Std. Dev.	Auto. Corr	$Corr(x,y)$
ψ_b	0.6	0.0045	0.5523	-0.0284
r	3.9918	0.2100	0.9711	-0.9989
π	-0.0048	0.0027	0.6410	-0.5241
b	0.8116	0.0204	0.9730	0.9121
q	3.1266	0.0297	0.9557	0.9768
y	0.9996	0.0203	0.9807	1

Model with $\psi = \overline{\psi}(\frac{b_t}{w_{B,t}})^{-\eta_w}$
($\mathscr{W}$ = −185.3538)

ψ_w	0.5997	0.0051	0.7428	-0.0747
r	3.9805	0.2015	0.9755	-0.9986
π	-0.0097	0.0025	0.6262	-0.5140
b	0.8189	0.0197	0.9552	0.9759
q	3.1268	0.0294	0.9527	0.9769
y	0.9999	0.0203	0.9793	1

Model with $\psi = \overline{\psi}(\frac{q_t}{q_{t-1}})^{-\eta_q}$
($\mathscr{W}$ = −185.3539)

ψ_q	0.6	0.0058	0.1438	-0.0032
r	3.9702	0.2109	0.9766	-0.9990
π	-0.0172	0.0027	0.6388	-0.5265
b	0.8197	0.0220	0.8757	0.8640
q	3.1275	0.0298	0.9564	0.9775
y	1.0001	0.0204	0.9810	1

Note: r and π are expressed in percentage points and ψ, y, q and b in levels. $T = 200$, and $J = 1000$.

Table 6: Dynamic Properties of the Resource Allocations in Optimal Monetary Policy and Macroprudential Policies with Time-varying LTV

4.4.1 Time-varying Macroprudential Policy with Credit Growth

Consider first the effects of optimal time-varying macroprudential policy responding to the credit growth in the form of equation (20). Under this policy regime, the optimized monetary policy parameter values are the same as the ones associated with the time-invariant macroprudential policy as shown in the first column of Table 5. Similar to the time-invariant case, the optimal monetary policy stipulates a persistent interest rate rule that responds only to the inflation rate. However, the optimized macroprudential policy turns out to be more aggressive to the fluctuation of the credit growth. The aggressive macroprudential policy responding to the credit growth substantially improves the social welfare compared to the one in the time-invariant macroprudential policy

4.4.2 Time-varying Macroprudential Policy with Debt to Income Ratio

Consider the effects of optimal time-varying macroprudential policy responding to the DTI ratio in the form of equation (21). Under this policy regime, the monetary authority responds more strongly to the inflation rate than under an optimal macroprudential policy responding to the credit growth as shown in the second column of Table 5. The macroprudential authority also responds aggressively to the DTI ratio, which also improves the social welfare compared to the one under the time-invariant macroprudential policy.

4.4.3 Time-varying Macroprudential Policy with housing price Growth

Finally, consider the effects of optimal time-varying macroprudential policy responding to the housing price growth in the form of equation(22). Under this policy regime, the optimized monetary policy parameter values take the same values as the ones associated with the time-invariant macroprudential policy as shown in the last column of Table 5. The aggressive macroprudential policy responding to the housing price growth improves the social welfare compared to the one in the time-invariant macroprudential policy, but it is less effective than the other time-varying macroprudential policy.

4.5. DYNAMIC EFFECTS

In this subsection, we examine and compare the dynamic effects of the economy under the different optimized policy regimes in response of various shocks.

4.5.1 The Dynamic Effects of Productivity Shocks

First, consider the effect of productivity shock on the economy. The long dashed lines in Figure 6 represent the response of the corresponding variables associated with an optimal Taylor rule and a time-invariant macroprudential policy. The circle lines represent the impulse response function to the positive productivity shock associated with an optimized interest rate rule and an optimized time-varying macroprudential policy responding to the credit growth. The long lines represent the impulse response function associated with an optimal interest rate rule and optimal time-varying macroprudential policy responding to the debt to income ratio. The long-dashed lines represent the impulse response associated with time-invariant macroprudential policy, conditional on the optimal interest rate rules.

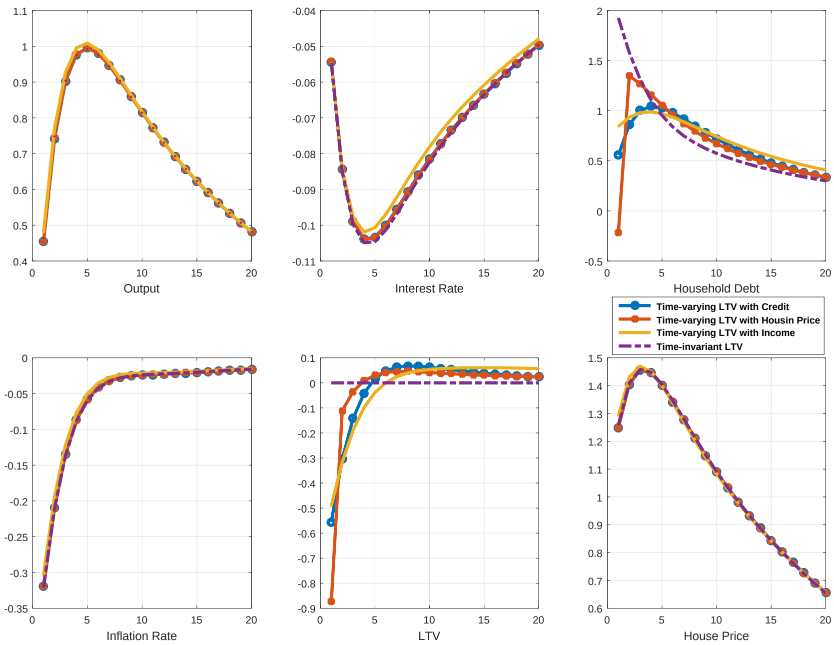

Figure 6: Impulse Responses to a Positive Productivity Shocks

A positive productivity shock expands output, while it decreases the price. With an expansion of the economy, households whose income increases demand more nondurable goods and durable goods, *i.e.* housing service. As both patient and impatient households increase their demands for house, loans increase, resulting in an increase of housing price. Figure 6 shows that the impulse response functions of all variables except household debt are similar whether the macroprudential authority implements time-varying policy or time-invariant policy. Household debt responds very differently to the productivity shock, depending on the kind of macroprudential policy tools implemented.

First, note that the household debt instantaneously increases to the shock when the macroprudential authority does not change its refulatory LTV or DTI ratio at all. The household debt initially falls and then jumps to its highest value and returns to the steady-state value when the macroprudential authority adjusts the LTV ratio to the housing price growth rate. The regulatory LTV ratio responding to the housing price growth shows the most dramatic change to the shock among the macroprudential policy rules considered. This swing reflects the fact that the output as well as the housing price show hump-shaped response to the productivity shock.

Next, consider the impulse response functions associated with macroprudential policy responding to the impatient household's debt to income ratio. The response of household debt as well as interest rate are muted compared to the ones associated with other macroprudential policy rules. The macroprudential policy responding to the debt to income ratio and the cooperative monetary policy with stronger price stability stance are successful in moderating household's debt accumulation as well as stabilizing the economy.

Finally, consider the impulse response functions associated with macroprudential policy responding to the credit growth. All relevant variables show a little bit stronger response to the shock than the ones under other macroprudential policy rules. They similar to the ones associated with macroprudential policy responding to the debt to income ratio.

4.5.2 The Dynamic Effects of House Demand Shocks

Next, consider the effect of housing demand shock in the economy. Given the increase in housing prices associated with the housing demand increase, households can borrow more with the higher collateral value. Hence, the debt amount increases. Figure 7 shows that the impact of boom in housing sector on the real sector is moderate, compared to the impact of productivity shock. Both output and inflation respond a little to the shock.

Household debt responds very differently, depending on the macroprudential policy implemented. There is no much difference between an optimal time-varying macroprudential policy responding to the housing price growth and the time-invariant macroprudential policy. Both policy rules are not successful in dampening the household debt. The macroprudential policy responding to the debt income ratio is most successful in moderating household debt. The LTV ratio which strongly responds to the boom in housing sector generates a small

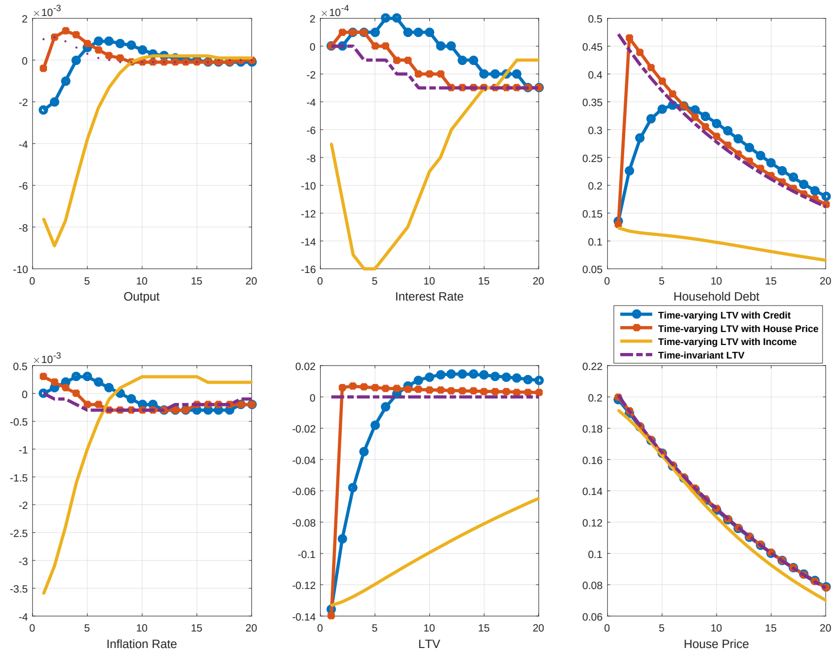

Figure 7: Impulse Responses to a Housing Demand Shocks

decline in output and inflation rate, which calls for an expansionary monetary policy to moderate the negative impact of macroprudential policy on the economy. Consider the effect of time-varying macroprudential policy responding to the credit growth. The macroprudential policy reacting to the credit growth rate entails very moderate responses of household debt, inflation rate, and output.

In sum, the macroprudential policy responding to the debt to income ratio is most successful in stabilizing the housing sector to the housing demand shock, but it accompanies cost of economic downturn. The macroprudential policy responding to the housing price growth entails a very drastic decrease in LTV ratio, but it is not so successful in stabilizing boom in housing sector. Among the time-varying macroprudential policy rules considered, the macroprudential policy associated with credit growth produces most smooth movements of relevant variables.

5. CONCLUSION

In this paper, we have set up a simple sticky price and wage model with features housing market and addressed how monetary and macroprudential authority should cooperate to improve the social welfare. The benchmark model extends Iacoviello (2005)'s two-agent model by incorporating sticky wage into the model.

We have found that the time-varying macroprudential policy responding to the impatient household's debt to income ratio is most effective in stabilizing household debt among the macroprudential policy rules considered. Though the macroprudential policy associated with the debt to income ratio is better in moderating the household debt to the house demand shock than the macroprudential policy associated with the credit growth, it costs a moderate downturn of the economy. There is no much difference between the macroprudential policy responding to the housing price growth and the time-invariant macroprudential policy in stabilizing the housing sector.

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