Journal of Money and Economy
Vol. 14, No. 3, Summer 2019
pp. 277-315

Housing in Banks' Portfolio and its Effects on Monetary Policy in Iran

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Received: 21 Jan 2020 Approved: 29 Feb 2020

The recent housing market experience has led many to concern that the developments in the housing sector are not just a passive reflection of macroeconomic activities but instead might be one of the driving forces of them. In this context, it is crucial to understand the nature of the economy by considering the housing market and build a suitable monetary policy. In this paper, using Bayesian methods, we develop and estimate a DSGE model for Iran from 1988q1 to 2017q4, which explicitly models the housing in the banks' portfolio to study the macroeconomic effects of monetary authority's reaction to the housing price inflation. Our findings indicate that this reaction amplifies all the implications of the structural shocks.

Keywords: Monetary Policy, Taylor Rule, Housing, DSGE, Bayesian Estimation.
JEL Classification*:* E52, E32, R31

1 Introduction

The role played by the housing sector in the economy has attracted remarkable attention from both academic researchers and policy-makers over the past two decades. The Central Bank of Iran's statistics shows that the housing price index has increased more than 27 times in the past twenty years. The figures also indicate that the private sector's debt to the banking system has risen nearly 13 times. These sizeable rises in property prices and household indebtedness over the recent years have augmented the attention above. It is essential to understand both the determinants of such rises and their potential implications for monetary policy and financial stability. The 2008 global financial turmoil allegedly originating from the residential property market in the US has strengthened the interests in these topics even further. In the

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This paper is part of a Ph.D. dissertation written by Diar Baheri Rad under supervision of Hossein Tavakolian and Habib Morovat.

aftermath of the crisis, a consensus emerged around a paradigm that tasks financial stability to monetary policies. Monetary policies are assigned to macroeconomic stability, often via an inflation-targeting framework (IMF, 2015). The experience of the U.S. housing market at the beginning of the 21st century (fast growth in housing prices and residential investment initially, and a decline thereafter) raise the specter that the developments in the housing sector are not just a passive reflection of macroeconomic activity but might themselves be one of the driving forces of business cycles (Iacoviello and Neri, 2010). In this context, it is interesting to know that in Iran: First, what is the nature of the economy by considering the housing market? Second, what happens if the monetary authority reacts to the housing price inflation?

In this paper, using Bayesian methods, we develop and estimate a Dynamic Stochastic General Equilibrium (DSGE) model for Iran's economy that explicitly models the housing market to address these interests. In modeling the economy, we follow two recent strands of literature. First, as in Kiyotaki and Moore (1997), we consider a dual structure on the household side, with agents belonging to two different groups according to their inter-temporal discount factor. This heterogeneity generates equilibrium debt as the result of inter-temporal borrowing between more and less impatient agents. Second, as in Iacoviello (2005) and Iacoviello and Neri (2007, 2010), we capture two main features of the housing market in our model. On the supply side, we added sectoral heterogeneity: the non-housing sector produces consumer goods and services, using labor and capital; the housing sector provides new homes using labor, capital, and land. On the demand side, housing enters households' utility, and it can be used as collateral for loans- like Iacoviello and Neri (2010) and Notarpietro (2007). Simultaneously, fluctuations in house prices affect the borrowing capacity of some of the households, on the one hand, and the relative profitability of producing new housing, on the other. These mechanisms generate feedbacks for the expenditure of households and firms.

Moreover, our DSGE model has another feature that relates to the banking system. Iranian banks have largely entered the housing market and have great exposure to mortgages. A review of the Iranian banks' balance sheets shows that their housing assets rose 122 times from about 7.1 trillion IRRs to about 887 trillion IRRs in the past two decades, while their total assets show 95 times growth. In other words, the housing has been extended in Iranian banks' portfolio. This change in assets composition increases the potential for mounting vulnerabilities in the housing market to undermine the resilience of the banking system. Given that, we assume that the banks hold housing as an asset in their balance sheets. This feature enables us to model the implications of the housing price fluctuations on the banking system.

We build a three-step track tracing mechanism to find out the implications of monetary authority's reaction to the house price inflation. We consider the deviation of housing price inflation from the targeted inflation rate in the conventional Taylor rule[1], alongside the output gap and the inflation rate deviation, and call it "Augmented Taylor Rule". To obtain a deep understanding of the ensuing implications, we increase the housing inflation's weight in the augmented Taylor rule from 0.5 to 1.5 in three steps -with 0.5 units rise in each step.

The remainder of the paper is structured as follows. Section 2 highlights the key features of the housing market in Iran. Section 3 describes the model. An overview of the statistical methodology, data series, calibrated parameters, and prior distributions is given in Section 4, and section 5 presents the empirical results. Finally, section 6 discusses the findings and concludes.

2 Housing Market in Iran

Housing has a significant role in the quality of life and welfare of societies as one of the indispensable needs of humankind. The provision of a proper place for a living has been one of the main objectives of the households over time, and there has always been a great deal of effort to reach it (Qolizadeh and Fooladgar, 2016). Housing has enshrined in the Universal Declaration of Human Rights as part of the standard of living, alongside food, clothing, and health, as it directly affects the welfare (Doling et al., 2013).

Statistical analysis of the household budget survey in Iran shows in the past 13 years every Iranian household has spent more than 30% of its expenditure on housing. The housing sector, based on the share of investment, employment, and GDP, is a prominent economic sector, dedicating 6.6% of GDP, 43.9% of total investment, and 13.5% of employment. The following table shows the share of the housing sector in household expenditure, total investment, GDP and employment since 2005.

[1] Taylor rule or Taylor principle, introduced by the economist John B. Taylor, is a proposed guideline for how central banks should alter interest rates in response to changes in inflation, output, or other economic conditions.

Table 1
Remarked housing features in the economy of Iran

YEAR	SHARE OF HOUSEHOLD EXPENDITURE	SHARE OF TOTAL INVESTMENT	SHARE OF GDP	SHARE OF EMPLOYMENT
2005	25.9	37.9	6.7	10.4
2006	28.4	35.9	6.1	11.4
2007	30.0	43.1	7.2	12.3
2008	32.8	44.3	8.1	14.1
2009	31.4	43.6	7.7	13.1
2010	32.1	43.9	7.4	13.7
2011	30.5	42.1	7.6	15.3
2012	32.0	52.6	8.0	15.4
2013	32.2	52.7	7.3	15.5
2014	32.3	48.5	7.0	15.0
2015	32.6	48.3	5.9	13.9
2016	33.0	40.8	4.5	13.1
2017	34.2	40.8	4.4	13.1
2018	34.8	40.2	4.4	12.6

Reference: Central Bank of Iran's National Accounts, and Statistical Centre of Iran's Labor Force Survey.

As shown in Table 1, every Iranian household spends about one-third of its annual expenditure in housing, including the cost of renting a home for tenants and imputed rental of owner-occupied dwellings. Besides, a survey of the private sector's investment costs indicates the significant share of the housing sector in total investments made by households in recent years, reaching more 50% in some years. The construction sector's value-added is about 6.6% of the total value-added of the economy, which constitutes a significant part of Iran's oil-based economy. Finally, by analyzing the results of the "Statistical Centre of Iran's Labor Force Survey", the employment share of the housing sector is about 13% of the total economy. Accordingly, an average of about three million people works directly in this sector.

As an economic commodity, housing has some distinctive characteristics that complicate its market analysis (Nasrollahi and Azad, 2013). The first is the bi-directionality of the housing, which is both consumed and treated as an asset as well, as a result of its durability and the very low depreciation. Jin and Zeng (2004) estimated the depreciation rate of buildings to be 0.015, while the depreciation rate of other capital goods was estimated at 0.065. Other features of the housing are the timeliness of completion of investment projects, the low elasticity of housing supply, and the more extended housing supply response to a positive demand shock than the negative demand shock (Salmani and Sadeghi, 2015).

According to the 2001 Input-Output table form, Iran housing has a remarkable backward linkage index, making it a key sector for demand development. Thus, stimulating housing demand can lead to significant changes in the whole economy (Mehregan, 2014). Analyzing the house price changes certifies that although there has been an upward trend along with the prices in the economy as a whole, the fluctuations of housing prices have been higher than the consumer's price index (Rhamani and Isfahani, 2016).

As shown in the following figures, based on the average price of one square meter of dwelling in Tehran, the prices have increased more than 11 times from 2004 to 2018. A survey of the central bank of Iran's CPI data shows a nine times increase for the same period.

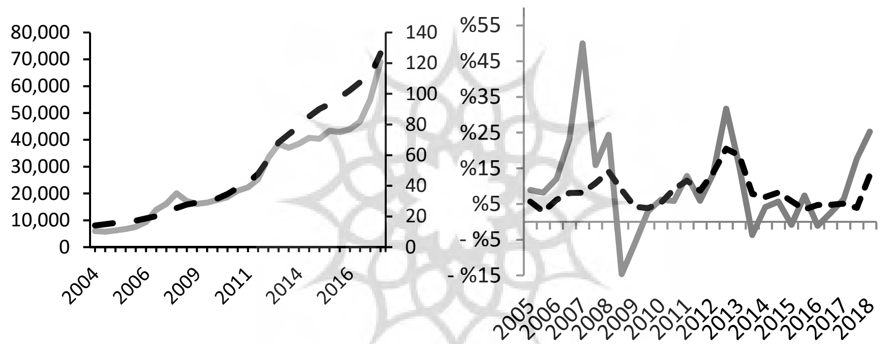


Figure 1. The Price of One Square Meter of Dwelling in Tehran and Its Growth Rate (solid line), CPI 2016=100 and its growth rate (dashed line)
Reference: Central Bank of Iran's CPI index, Statistical Centre of Iran's House Price Survey.

The financial crisis of 2008 indicated that there is a strong linkage between housing, housing finance, and other economic sectors. In the United States, over-lending to low-credit applicants and converting these credits into complex financial instruments plunged the economy into a deep crisis. That is why policymakers must consider the housing price as well. Holding housing as an asset by the households, the private sector's investment in this sector, and its strong backward and forward linkage with other economic sectors, indicate the importance of considering this market when macroeconomic policies are implementing -primarily monetary policies.

A level number of empirical papers have pointed out the existing relationship between housing and business cycles. For instance, Leamer

(2007) compares the US housing market cycle and the US business cycle as defined by the Dating Committee of the NBER, from 1947 to 2006. By using the contributions to GDP growth during the 8 phases of recession covering the whole period, Leamer points out that the business cycle is a consumer cycle mainly driven by residential investment. Consequently, the author argues that residential investment can be seen as an accurate early warning of an upcoming recession. Ahearne et al. (2005) find that real house prices are pro-cyclical, which is co-moving with real GDP, consumption, investment, CPI, budget and current account balances and output gaps. They note also that house price booms are typically preceded by a period of easing monetary policy, but then diminishing slack and rising inflation leads monetary authorities to begin tightening policy before house price peak. We also refer to Iacovello (2005), for a theoretical monetary business cycle model that formalizes the interaction between house prices and the business cycle or to Goodhart and Hofmann (2008) for empirical evidence of a significant multidirectional link between house prices, broad money, private credit, and the macroeconomy. Ferrara and Koopman (2009) implemented several multivariate unobserved component models to assess commonalities in the housing and business cycles of the four main euro area countries including Germany, France, Italy, and Spain, and to detect cyclical relationships between the macroeconomy and the housing sector. They show synchronization among the business cycles of the four countries, leading thus to the existence of common cycles in the euro area. They find out that among the four countries, Spain presents the strongest relationships between business and housing cycles for both short-term and long-term cycles, pointing out the contribution of the housing sector to the Spanish economic growth.

There are also several papers on housing in Iran. Pakniyat et al. (2018) use a DSGE approach to investigate the effects of banks' investment on housing in Iran and confirmed the Dutch disease with an oil shock hitting the economy. They point out that the freezing of banks' assets increases their exposure to plunging in severe crisis. Mahmoodi et al. (2019) based on Iacovello and Neri (2010) estimate from 2005 to 2017 using the Bayesian approach and find out that the collateral effect is a prominent channel for the housing sector to affect the macro-economy in Iran. Abolhasani et al. (2016) study the impact of oil shocks and monetary shocks on production and inflation in the housing sector of the Iranian economy and show that higher money growth rate temporary increases output and inflation in both housing and non-housing sectors and due to the higher elasticity of supply in the non-housing sector, and the effects of monetary shock on production in this sector are more than the housing sector.

The below figure shows the GDP growth rates for Iran, covering 25 years and plots it against the private sector's housing investment. During the period, the private sector's investment in housing is cyclical with economic growth rates. In periods of expansion, the housing investment by the private sector shows a leaping movement.

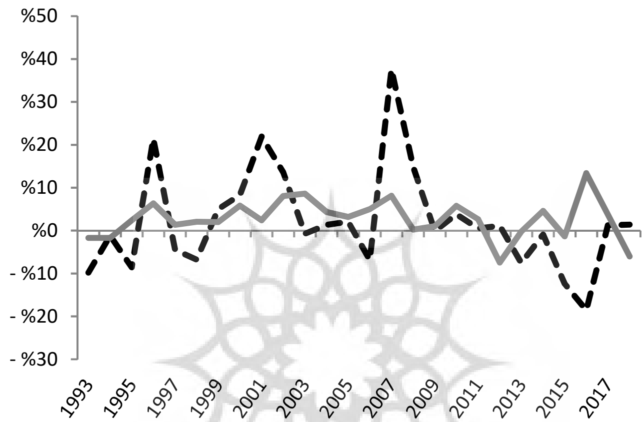


Figure 2. GDP Growth Rates (solid line) and Private Housing Investment (dashed line)
Reference: Central Bank of Iran's National Accounts.

Both commercial banks and households have increased their investment in real estate in recent years in response to the high price volatility in the housing sector. Due to the abrupt rise in the prices, households are aiming to finance the procurement of their housing by taking loans from banks. Therefore, monetary policymakers in Iran need to pay more attention to both the effects of their policies on this sector and the effects of house price changes on their decisions. The policy-makers must take into consideration the interactions between the housing sector and monetary policy, in addition to traditional monetary policy goals and instruments.

Housing prices can influence other macroeconomic variables through two primary channels. The first channel is the "Asset Price Channel" or the "Wealth Channel". According to the theory of wealth effect, the homeowners' wealth increases as the housing prices increase, and this leads to an increase in their consumption based on the "Life Cycle Theory of Consumption" by Ando and Modigliani. This increase in consumption will lead to an increase in aggregate demand, leading to an increase in output and economic growth. The second channel is the "Credit Channel" or the "Balance Sheet Channel". According to Bernanke and Gretler (1995), an increase in housing prices raise the asset side of the firms' balance sheet and lead to lower credit costs. As the value of the firms' durable assets flourishes due to increased housing prices, the credit risk of the firm reduces and leads to an increase in the investment through the balance sheet channel. Consequently, output and employment will increase.

3 The Model

To model the economy, we use a DSGE model with five decision-making agents: Households, firms, banking systems, central banks as a monetary authority, and government. For simplicity, we assume that the economy is closed. The economy is populated by two infinitely lived types of households: patient and impatient. Households consume, work, and accumulate housing. These agents have different degrees of patience reflected in different discount factors for their future utility. The heterogeneity in agents' discount factors provides a simple way to generate financial flows in equilibrium: patient households (savers) purchase a positive amount of saving assets (deposits) and do not borrow, while impatient households (borrowers) borrow from the banking system. When taking a bank loan, borrower households face a borrowing constraint i.e. they can only borrow up to a fraction of their collateral. The firms are comprised of two subdivisions of goods and services producers and house producers. Goods and services producers use labor and capital to produce non-housing goods, and the housing sector produces new homes combining labor, capital, and land. Financial flows are channeled through the banking sector. Banks take deposits and supply loans to the agents and set interest rates on both deposits and loans to maximize profits. We assume that banks also enter the housing market and hold housing as an asset in their balance sheet. We describe the key features of the model in this section.

3.1 Households

There are two groups of households in the economy: Patient (P) and Impatient (I). The only difference between these groups is that patient household's discount factor (β^P) is higher than impatient household's (β^I).

3.1.1 Patient Households

The representative patient household maximizes the expected utility:

$$\mathbb{E}_t \sum_{t=0}^{\infty} {\beta^{P}}^{t} \left\{ \varepsilon_t^c (1-\alpha) \log(c_t^P(i) - \alpha c_{t-1}^P) + \log h_t^P(i) - \frac{[n_t^P(i)]^{1+\eta}}{1+\eta} + \frac{[m_t^P(i)]^{1-\phi^m}}{1-\phi^m} \right\} \quad (1)$$

which is a function of current individual consumption $c_t^P(i)$, lagged aggregate consumption c_{t-1}^P, housing services $h_t^P(i)$, hours worked $n_t^P(i)$, and stock of real money $m_t^P(i)$. Parameter α measures the degree of habit formation in consumption: each household in the economy derives a positive utility from consumption in period $t \geq 0$ only if it can consume more than a fraction α of the economy-wide per capita consumption at $t-1$. ε_t^c captures exogenous inter-temporal shock to preferences and has an AR(1) representation with *i.i.d.* normal innovations: $\ln \varepsilon_t^c = (1-\rho^c) \ln \bar{\varepsilon}^c + \rho^c \ln \varepsilon_{t-1}^c + u_t^c,\ u_t^c \sim N(0, {\sigma^c}^2)$. The inverse of the elasticity of work effort with respect to the real wage and the inverse of the elasticity of money stock demand are denoted by η and ϕ^m, respectively.

Household optimizes the inter-temporal utility function subject to the following budget constraint expressed in real terms:

$$c_t^P(i) + i_t^P(i) + d_t(i) + m_t^P(i) + p_t^h \Delta h_t^P(i) + tax_t^P(i) = w_t^P n_t^P(i) + p_t^k k_t^P(i) + \left(1 + r_{t-1}^d\right) \frac{d_{t-1}(i)}{\pi_t} + \frac{m_{t-1}^P(i)}{\pi_t} + div_t^P \quad (2)$$

The flow of expenses includes current consumption $c_t^P(i)$, investment ($i_t^P = k_t^P - (1-\delta^k) k_{t-1}^P$), accumulative of housing services ($\Delta h_t^P = \mathrm{h}_\mathrm{t}^\mathrm{P} - (1-\delta^\mathrm{h})\mathrm{h}_{\mathrm{t}-1}^\mathrm{P}$), deposits at banking system (d_t), and lump-sum tax $tax_t^P(i)$. Resources are composed of wage earnings $w_t^P n_t^P(i)$, investment earnings $p_t^k k_t^P(i)$, gross interest income on last period deposit $\frac{(1+r_{t-1}^d) d_{t-1}(i)}{\pi_t}$, where $\pi_t = P_t / P_{t-1}$ denotes gross inflation rate, money stock of last period $\frac{m_{t-1}^P(i)}{\pi_t}$, and dividend from firms and banking system div_t^P.

The Lagrangian equation is as follows:

$$max\ \mathbb{E}_0 \sum_{t=0}^{\infty} {\beta^{P}}^{t} \ell_t \left(c_t^P(i), h_t^P(i), m_t^P(i), n_t^P(i), k_{t-1}^P(i), d_t(i)\right)$$

where:

$$\ell_t(c_t^P(i), h_t^P(i), m_t^P(i), n_t^P(i), k_{t-1}^P(i), d_t(i)) = \varepsilon_t^c(1-\alpha)\, log(c_t^P(i) - \alpha c_{t-1}^P) + log\, h_t^P(i) - \frac{[n_t^P(i)]^{1+\eta}}{1+\eta} + \frac{[m_t^P(i)]^{1-\phi^m}}{1-\phi^m} + \lambda_t^P \Big[w_t^P n_t^P(i) + p_t^k k_{t-1}^P(i) + (1+r_{t-1}^d)\frac{d_{t-1}(i)}{\pi_t} + \frac{m_{t-1}^P(i)}{\pi_t} + div_t^P(i) - c_t^P(i) - i_t^P(i) - d_t(i) - m_t^P(i) - p_t^h \Delta h_t^P(i) - tax_t^P(i) \Big] \quad (3)$$

The sequence of first-order conditions is given by:

$$(\partial c_t^P) \quad \lambda_t^P = \frac{\varepsilon_t^c(1-\alpha)}{c_t^P - \alpha c_{t-1}^P} - \alpha(1-\alpha)\beta^P E_t \frac{\varepsilon_{t+1}^c}{c_{t+1}^P - \alpha c_t^P} \quad (4)$$

$$(\partial d_t) \quad \lambda_t^P = (1+r_t^d)\beta^P E_t \frac{\lambda_{t+1}^P}{\pi_{t+1}} \quad (5)$$

$$(\partial m_t^P) \quad (m_t^P)^{-\phi^m} = \left(\frac{r_t^d}{1+r_t^d}\right)\lambda_t^P \quad (6)$$

$$(\partial h_t^P) \quad \frac{1}{h_t^P} = \lambda_t^P p_t^h - \beta^P(1-\delta^h)E_t p_{t+1}^h \lambda_{t+1}^P \quad (7)$$

$$(\partial k_t^P) \quad \lambda_t^P = \beta^P E_t[(1-\delta^k) + p_{t+1}^k]\lambda_{t+1}^P \quad (8)$$

$$(\partial n_t^P) \quad w_t^P = \frac{(n_t^P)^\eta}{\lambda_t^P} \quad (9)$$

3.1.2 Impatient Households

Impatient households do not hold deposits. The impatient representative household maximizes the expected utility:

$$\mathbb{E}_t \sum_{t=0}^{\infty} {\beta^I}^t \left\{ \varepsilon_t^c(1-\alpha)\, log(c_t^I(i) - \alpha c_{t-1}^I) + log\, h_t^I(i) - \frac{[n_t^I(i)]^{1+\eta}}{1+\eta} + \frac{[m_t^I(i)]^{1-\phi^m}}{1-\phi^m} \right\} \quad (10)$$

which depends on current consumption $c_t^I(i)$, lagged aggregate consumption c_{t-1}^I, housing services $h_t^I(i)$, and hours worked $n_t^I(i)$, and real money stock $m_t^I(i)$. Similarly, $ln\, \varepsilon_t^c = (1-\rho^c)\, ln\, \bar{\varepsilon}^c + \rho^c\, ln\, \varepsilon_{t-1}^c + u_t^c$, $u_t^c \sim N(0, {\sigma^c}^2)$ is the exogenous inter-temporal preferences shock.

The maximization of the inter-temporal utility function is constrained. Firstly, household maximizes subject to the following (real term) budget constraints:

$$c_t^I(i) + m_t^I(i) + p_t^h \Delta h_t^I(i) + \left(1 + r_{t-1}^b\right) \frac{b_{t-1}^I(i)}{\pi_t} + tax_t^I(i) = w_t^I n_t^I(i) + b_t^I(i) + \frac{m_{t-1}^P(i)}{\pi_t} + div_t^I(i) \quad (11)$$

Secondly, impatient households face a borrowing constraint; they can only borrow up to a certain fraction (ω^I) of the value of their collateralizable new housing investment at period $t \geq 0$:

$$b_t^I = \omega^I [h_t^I - \left(1 - \delta^h\right) h_{t-1}^I] \quad (12)$$

The Lagrangian equation is as follows:

$$max\ \mathbb{E}_0 \sum_{t=0}^{\infty} {\beta^I}^t \ell_t \left(c_t^I(i), h_t^I(i), m_t^I(i), n_t^I(i), b_t^I(i)\right)$$

where:

$$\ell_t(c_t^I(i), h_t^I(i), m_t^I(i), n_t^I(i), b_t^I(i)) = \varepsilon_t^c (1 - \alpha) \log(c_t^I(i) - \alpha c_{t-1}^I) + \log h_t^I(i) - \frac{\left(n_t^I(i)\right)^{1+\eta}}{1+\eta} + \frac{\left(m_t^I(i)\right)^{1-\phi^m}}{1-\phi^m} + \lambda_t^P \left[w_t^I n_t^I(i) + b_t^I(i) + \frac{m_{t-1}^P(i)}{\pi_t} + div_t^I(i) - c_t^I(i) - m_t^I(i) - p_t^h \Delta h_t^I(i) - \left(1 + r_{t-1}^b\right) \frac{b_{t-1}^I(i)}{\pi_t} - tax_t^I(i)) \right] + \varphi_t^I \left[\omega^I \left(h_t^I - \left(1 - \delta^h\right) h_{t-1}^I\right) - b_t^I \right] \quad (13)$$

The first-order conditions are given by:

$$(\partial c_t^I) \quad \lambda_t^I = \frac{\varepsilon_t^c (1-\alpha)}{c_t^I - \alpha c_{t-1}^I} - \alpha(1 - \alpha)\beta^I E_t \frac{\varepsilon_{t+1}^c}{c_{t+1}^I - \alpha c_t^I} \quad (14)$$

$$(\partial b_t^I) \quad \lambda_t^I = \left(1 + r_t^b\right) \beta^I E_t \frac{\lambda_{t+1}^I}{\pi_{t+1}} + \varphi_t^I \quad (15)$$

$$(\partial m_t^I) \quad (m_t^I)^{-\phi^m} = \left(\frac{r_t^b}{1+r_t^b}\right) \lambda_t^I \quad (16)$$

$$(\partial h_t^I) \quad \frac{1}{h_t^I} = \lambda_t^I p_t^h - \beta^I \left(1 - \delta^h\right) E_t p_{t+1}^h \lambda_{t+1}^P - p_t^h \omega^I \varphi_t^I + \beta^I \left(1 - \delta^h\right) \omega^I E_t p_{t+1}^h \varphi_{t+1}^I \quad (17)$$

$$(\partial n_t^I) \quad w_t^I = \frac{\left(n_t^I\right)^\eta}{\lambda_t^I} \quad (18)$$

3.2 Firms

Firms are comprised of goods and services producers and house producers enjoying a monopolistic competitive market. They hire labor and capital from households, paying the salary, and capital return. Each firm sells its differentiated product to final good producers, which operate in a competitive market. Final good producers, as an aggregator, combine the intermediate goods with zero cost to produce the final goods.

3.2.1 Goods and Services Producers

3.2.1.1 Final Goods and Services Producers

Final goods and services producers buy differentiated intermediate good and service $y_t^c(j)$ at price $P_t^c(j)$ (indexed by $j \in [0,1]$) and produce final goods and services using the following aggregation Dixit-Stiglitz technology:

$$y_t^c = \left[\int_0^1 y_t^c(j)^{\frac{1}{1+\theta_t^c}} dj\right]^{1+\theta_t^c}$$

Where $\ln \theta_t^c = (1-\rho^{\theta c}) \ln \bar{\theta}^c + \rho^{\theta c} \ln \theta_{t-1}^c + u_t^{\theta c},\ u_t^{\theta c} \sim N(0, {\sigma^{\theta c}}^2)$ is a stationary price mark-up shock. θ_t^c is interpreted as a cost-push shock in the inflation equation. The profit maximization condition can be obtained by solving the following problem:

$$max \ \ P_t^c(j) y_t^c(j) \quad s.t. \ \left[\int_0^1 y_t^c(j)^{\frac{1}{1+\theta_t^c}} dj\right]^{1+\theta_t^c} \geq y_t^c(j) \tag{19}$$

which leads to the following condition:

$$y_t^c(j) = \left[\frac{P_t^c(j)}{P_t^c}\right]^{-\frac{1+\theta_t^c}{\theta_t^c}} y_t^c, \ \ \forall j \in [0,1] \tag{20}$$

where P_t^c is the price of the intermediate good j and P_t^c is a price index, which can be written as:

$$P_t^c = \left[\int_0^1 \left(P_t^c(j)\right)^{-\frac{1}{\theta_t^c}} dj\right]^{-\theta_t^c} \tag{21}$$

3.2.1.2 Intermediate Goods and Services Producers

Each intermediate firm, indexed by $j \in [0,1]$, produces $y_t^c(j)$ units of differentiated goods and services in a monopolistic competitive market using the following Cobb-Douglas production technology:

$$y_t^c(j) = A_t^c[(n_t^{Pc}(j))^a(n_t^{Ic}(j))^{1-a}]^{1-\mu^c}[k_{t-1}^{Pc}(j)]^{\mu^c} \tag{22}$$

Where $n_t^{Pc}(j)$ and $n_t^{Ic}(j)$ are the labor hired from Patient and Impatient households respectively, $k_{t-1}^{Pc}(j)$ is the capital stock used in the goods and services production sector, and $\ln A_t^c = \rho^{Ac}\ln A_{t-1}^c + (1-\rho^{Ac})\ln \bar{A}^c + u_t^{Ac}$, $u_t^{Ac} \sim N(0, {\sigma^{Ac}}^2)$ is a stationary technology shock.

Firm j finance a fraction (ω^c) of its working capital by borrowing from banking system:

$$b_t^c(j) = \omega^c[w_t^P n_t^{Pc}(j) + w_t^I n_t^{Ic}(j)] \tag{23}$$

Firms minimize costs subject to the technology constraint:

$$\begin{aligned} &min \quad w_t^P n_t^{Pc}(j) + w_t^I n_t^{Ic}(j) + p_t^k k_{t-1}^{Pc}(j) + r_t^b b_t^c(j) \\ &s.t. \quad y_t^c = A_t^c[(n_t^{Pc})^a(n_t^{Ic})^{1-a}]^{1-\mu^c}[k_{t-1}^{Pc}]^{\mu^c} \end{aligned}$$

The associated Lagrangian can be written by:

$$min \quad w_t^P n_t^{Pc}(j) + w_t^I n_t^{Ic}(j) + p_t^k k_{t-1}^{Pc}(j) + r_t^b b_t^c(j) + \phi_t^c\{y_t^c(j) - A_t^c[(n_t^{Pc})^a(n_t^{Ic})^{1-a}]^{1-\mu^c}[k_{t-1}^{Pc}]^{\mu^c}\} \tag{24}$$

from where the first-order conditions are:

$$(\partial n_t^{Pc}) \quad w_t^P\left(1+\omega^c r_t^b\right) = \phi_t^c a(1-\mu^c)\frac{y_t^c}{n_t^{Pc}} \tag{25}$$

$$(\partial n_t^{Ic}) \quad w_t^I(1+\omega^c r_t^b) = \phi_t^c(1-a)(1-\mu^c)\frac{y_t^c}{n_t^{Ic}} \tag{26}$$

$$(\partial k_{t-1}^{Pc}) \quad k_{t-1}^{Pc} = \phi_t^c\mu^c\frac{y_t^c}{p_t^k} \tag{27}$$

where the Lagrange multiplier ϕ_t^c represents the real marginal cost. Solving (25) and (26) for the Lagrangian multiplier gives:

$$w_t^P = \frac{a(1-\mu^c)}{\mu^c}\frac{p_t^k k_{t-1}^{Pc}}{n_t^{Pc}}\frac{1}{1+\omega^c r_t^b} \tag{28}$$

$$w_t^I = \frac{(1-a)(1-\mu^c)}{\mu^c}\frac{p_t^k k_{t-1}^{Pc}}{n_t^{Ic}}\frac{1}{1+\omega^c r_t^b} \tag{29}$$

which shows the labor demand from Patient and Impatient households, respectively. Substituting (25) to (27) in the production technology, an expression for the real marginal cost obtains:

$$\phi_t^c = \frac{1}{A_t^c}\left\{\left[\frac{w_t^P(1+\omega^c r_t^b)}{a(1-\mu^c)}\right]^a \left[\frac{w_t^I(1+\omega^c r_t^b)}{(1-a)(1-\mu^c)}\right]^{1-a}\right\}^{1-\mu^c} \left\{\frac{p_t^k}{\mu^c}\right\}^{\mu^c} \quad (30)$$

Taking into account the monopolistic competitive market assumption and for the sake of entering rigidity into the model, we assume that, each period, only a fraction $(1-\omega)$ of intermediate goods and services producers, randomly chosen, can optimally re-adjust their prices (see Calvo, 1983). For those that cannot re-adjust (ω), prices are indexed to past inflation as follows:

$$P_t^c(j) = (\pi_{t-1})^\tau P_{t-1}^c(j)$$

Where τ is the parameter curbing the degree of price indexation. In each period $t \geq 0$, intermediate good producers maximize the stream of expected discounted profits:

$$max\ \mathbb{E}_t \sum_{k=0}^{\infty} (\omega\beta^P)^k \frac{\theta_{t+k}^c}{\theta_t^c}\left[\prod_{s=1}^{k}(\pi_{t+s-1})^\tau \frac{P_t^c(j)}{P_{t+k}^c} - \phi_{t+k}^c\right] y_{t+k}^c(j)$$

subject to the sequence of intermediate goods and services demand functions by the final goods and services producers; see (21):

$$y_{t+k}^c(j) = \left[\prod_{s=1}^{k}(\pi_{t+s-1})^\tau \frac{P_t^c(j)}{P_t^c}\right]^{-\frac{1+\theta_t^c}{\theta_t^c}} y_{t+k}^c\ ,\ \forall k \geq 0$$

The first-order condition for the optimal price leads to an equation describing the dynamics of the inflation rate. It is given by the hybrid New Keynesian Phillips Curve:

$$\pi_t = \frac{\tau}{1+\beta^P\tau}\pi_{t-1} + \frac{\beta^P}{1+\beta^P\tau}E_t\pi_{t+1} + \frac{1}{1+\beta^P\tau}\frac{(1-\beta^P\omega)(1-\omega)}{\omega}\phi_t^c + \theta_t^c \quad (31)$$

3.2.2 Housing Producers

3.2.2.1 Final Housing Producers

Similarly, final housing producers buy differentiated intermediate housing $y_t^h(j)$ at price $P_t^h(j)$ (indexed by $j \in [0,1]$) and produce final housing using an aggregation Dixit-Stiglitz technology as follows:

$$y_t^h = \left[\int_0^1 y_t^h(j)^{\frac{1}{1+\theta_t^h}} dj\right]^{1+\theta_t^h}$$

Where again $\ln\theta_t^h = (1-\rho^{\theta h})\ln\bar{\theta}^h + \rho^{\theta h}\ln\theta_{t-1}^h + u_t^{\theta h}$, $u_t^{\theta h} \sim N(0, {\sigma^{\theta h}}^2)$ is a stationary price mark-up shock. The profit maximization problem is:

$$max \;\; P_t^h(j) y_t^h(j) \quad s.t. \; \left[\int_0^1 y_t^h(j)^{\frac{1}{1+\theta_t^h}} dj\right]^{1+\theta_t^h} \geq y_t^h(j) \tag{32}$$

which leads to the following condition:

$$y_t^h(j) = \left[\frac{P_t^h(j)}{P_t^h}\right]^{-\frac{1+\theta_t^h}{\theta_t^h}} y_t^h, \;\; \forall j \in [0,1] \tag{33}$$

which can be written as:

$$P_t^h = \left[\int_0^1 \left(P_t^h(j)\right)^{-\frac{1}{\theta_t^h}} dj\right]^{-\theta_t^h} \tag{34}$$

3.2.2.2 Intermediate Housing Producers

Intermediate house producer operates in a monopolistic competitive market. They produce $y_t^h(j)$ units of differentiated housing with a Cobb-Douglas production technology as following:

$$y_t^h(j) = A_t^h[(n_t^{Ph}(j))^{a}(n_t^{Ih}(j))^{1-a}]^{1-\mu^h-\mu^l}[k_{t-1}^{Ph}(j)]^{\mu^h}[l_t(j)]^{\mu^l} \tag{35}$$

$n_t^{Pc}(j)$ and $n_t^{Ic}(j)$ are the labor hired from Patient and Impatient households respectively, $k_{t-1}^{Ph}(j)$ is the capital stock used in the housing sector, $l_t(j)$ is the land used, and $\ln A_t^h = \rho^{Ah}\ln A_{t-1}^h + \left(1-\rho^{Ah}\right)\ln\bar{A}^h + u_t^{Ah}$, $u_t^{Ah} \sim N(0, {\sigma^{Ah}}^2)$ is the stationary technology shock.

Similarly, firm j finance a fraction (ω^h) of its working capital by taking loans from banking system:

$$b_t^h(j) = \omega^h[w_t^P n_t^{Ph}(j) + w_t^I n_t^{Ih}(j)] \tag{36}$$

As a result of this, the firm's costs minimization problem follows as:

$$min \quad w_t^P n_t^{Ph}(j) + w_t^I n_t^{Ih}(j) + p_t^k k_{t-1}^{Ph}(j) + r_t^b b_t^h$$
$$s.t. \quad y_t^h(j) = A_t^h[(n_t^{Ph}(j))^a (n_t^{Ih}(j))^{1-a}]^{1-\mu^h-\mu^l}[k_{t-1}^{Ph}(j)]^{\mu^h}[l_t(j)]^{\mu^l}$$

The associated Lagrangian can be written by:

$$min \quad w_t^P n_t^{Ph}(j) + w_t^I n_t^{Ih}(j) + p_t^k k_{t-1}^{Ph}(j) + r_t^b b_t^h + \phi_t^h \Big\{ y_t^h(j) - A_t^h[(n_t^{Ph}(j))^a (n_t^{Ih}(j))^{1-a}]^{1-\mu^h-\mu^l}[k_{t-1}^{Ph}(j)]^{\mu^h}[l_t(j)]^{\mu^l} \Big\} \quad (37)$$

The firs-order conditions are:

$$(\partial n_t^{Ph}) \quad w_t^P = \phi_t^h a(1-\mu^h-\mu^l)\frac{y_t^h}{n_t^{Ph}}\frac{1}{1+\omega^h r_t^b} \quad (38)$$

$$(\partial n_t^{Ih}) \quad w_t^I = \phi_t^h (1-a)(1-\mu^h-\mu^l)\frac{y_t^h}{n_t^{Ih}}\frac{1}{1+\omega^h r_t^b} \quad (39)$$

$$(\partial k_{t-1}^{Ph}) \quad k_{t-1}^{Ph} = \phi_t^h \mu^h \frac{y_t^h}{p_t^k} \quad (40)$$

$$(\partial l_t) \quad l_t = \phi_t^h \mu^l \frac{y_t^h}{p_t^l} \quad (41)$$

where the Lagrange multiplier ϕ_t^h represents the real marginal cost. Solving (38), (39), and (41) for the Lagrangian multiplier gives:

$$w_t^P = \frac{a(1-\mu^h-\mu^l)}{\mu^h}\frac{p_t^k k_{t-1}^{Ph}}{n_t^{Ph}}\frac{1}{1+\omega^h r_t^b} \quad (42)$$

$$w_t^I = \frac{(1-a)(1-\mu^h-\mu^l)}{\mu^h}\frac{p_t^k k_{t-1}^{Ph}}{n_t^{Ih}}\frac{1}{1+\omega^h r_t^b} \quad (43)$$

$$l_t = \frac{\mu^l}{\mu^h}\frac{p_t^k k_{t-1}^{Ph}}{p_t^l} \quad (44)$$

Substituting (38) to (41) in the production technology, the real marginal cost can be obtained:

$$\phi_t^h = \frac{1}{A_t^h}\left\{\left[\frac{w_t^P(1+\omega^h r_t^b)}{a(1-\mu^h-\mu^l)}\right]^a \left[\frac{w_t^I(1+\omega^h r_t^b)}{(1-a)(1-\mu^h-\mu^l)}\right]^{1-a}\right\}^{1-\mu^h-\mu^l} \left\{\frac{p_t^k}{\mu^h}\right\}^{\mu^h} \left\{\frac{p_t^l}{\mu^l}\right\}^{\mu^l} \quad (45)$$

As for goods and services producers, we assume that each period, only a fraction $(1-\omega)$ of intermediate housing producers, can optimally re-adjust their prices and for the rest prices are indexed to past inflation as follows:

$P_t^h(j) = (\pi_{t-1})^\tau P_{t-1}^h(j)$

In each period $t \geq 0$, intermediate house producers maximize the stream of expected discounted profits:

$$max\ \mathbb{E}_t \sum_{k=0}^{\infty} (\omega\beta^P)^k \frac{\theta_{t+k}^h}{\theta_t^h} \left[\prod_{s=1}^{k} (\pi_{t+s-1})^\tau \frac{P_t^h(j)}{P_{t+k}^h} - \phi_{t+k}^h\right] y_{t+k}^h(j)$$

Subject to the sequence of intermediate housing demand functions by the final housing producers; see (34):

$$y_{t+k}^h(j) = \left[\prod_{s=1}^{k} (\pi_{t+s-1})^\tau \frac{P_t^h(j)}{P_t^h}\right]^{-\frac{1+\theta_t^h}{\theta_t^h}} y_{t+k}^h\ ,\ \forall k \geq 0$$

The hybrid New Keynesian Phillips Curve can be obtained as:

$$\pi_t^h = \frac{\tau}{1+\beta^P\tau}\pi_{t-1}^h + \frac{\beta^P}{1+\beta^P\tau}E_t\pi_{t+1}^h + \frac{1}{1+\beta^P\tau}\frac{(1-\beta^P\omega)(1-\omega)}{\omega}\phi_t^h + \theta_t^h \tag{46}$$

3.3 Banks

The banks intermediate funds between savers and borrowers.

The key feature of the banks is that they have to obey a balance sheet identity: The banks combine bank capital (equity) and deposits on the liability side and issue loans and acquire housing on the asset side:

$$b_t + p_t^h h_t^b = k_t^b + d_t \tag{47}$$

where $b_t = b_t^I + b_t^c + b_t^h$ is total loans issued by banks. Moreover, there is an exogenous risk-weighted capital-assets ratio for banks. As deposits and capital are perfect substitutes, this bank capital requirement provides a way to pin down the choices by the bank. It implies that banks are subject to a quadratic cost whenever the risk-weighted capital to assets ratio deviates from a target:

$$\left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b} - \vartheta^b\right)^2$$

where ϖ^b and ϖ^h are the risk weights assigned to the bank's assets (loans and housing), respectively. The parameter ϑ^b captures the optimal capital to assets ratio exogenously set by the monetary authority.

Each bank $j \in [0,1]$ capital is accumulated each period out of retained earnings according to:

$$k_t^b(j) = \left(1-\delta^b\right)k_{t-1}^b(j) + \theta^b \Pi_{t-1}^b(j) \tag{48}$$

where $\Pi_t^b(j)$ is the profits made by the bank j, θ^b summarizes the dividend policy of the bank, and δ^b measures resources used in managing bank capital and organizing the overall banking intermediation functions.

We assume that there is a required reserve obligation based on the deposits taken by the bank:

$$RR_t = \lambda_t^{RR} d_{t-1} \tag{49}$$

where $\ln \lambda_t^{RR} = \rho^{\lambda^{RR}} \ln \lambda_{t-1}^{RR} + \left(1-\rho^{\lambda^{RR}}\right) \ln \bar{\lambda}^{RR} + u_t^{RR},\ u_t^{RR} \sim N(0, {\sigma^{RR}}^2)$ measures the required reserve ratio.

The overall profit of the bank can be obtained as:

$$\Pi_t^b = \left(1+r_t^b\right)b_t - \left(1+r_t^d\right)d_t - k_t^b + p_t^h\left[h_t^b - \left(1-\delta^h\right)h_{t-1}^b\right] - RR_t - \frac{\kappa^k}{2}\left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b} - \vartheta^b\right)^2 k_t^b$$

Using the balance sheet identity and substituting out k_t^b gives:

$$\Pi_t^b = r_t^b b_t - r_t^d d_t - RR_t - p_t^h h_{t-1}^b\left(1-\delta^h\right) - \frac{\kappa^k}{2}\left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b} - \vartheta^b\right)^2 k_t^b \tag{50}$$

The problem for wholesale bank is to choose loans, deposits, and housing to maximize profits, subject to a balance sheet constraint:

$$\begin{aligned} &min \quad \mathbb{E}_t \sum_{t=0}^{\infty} {\beta^P}^t \Pi_t^b \\ &s.t. \quad b_t + p_t^h h_t^b = K_t^b + d_t \end{aligned}$$

The firs-order conditions are:

$$(\partial d_t) \quad \lambda_t^b = r_t^d \tag{51}$$

$$(\partial b_t) \quad \lambda_t^b = r_t^b - \kappa^k \varpi^b \left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b}\right)^2 \left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b} - \vartheta^b\right) \tag{52}$$

$$\left(\partial h_t^b\right) \quad \lambda_t^b = \left(1-\delta^h\right)\beta^P E_t \frac{p_{t+1}^h}{p_t^h} + \frac{\kappa^k \varpi^h}{p_t^h}\left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b}\right)^2 \left(\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b} - \vartheta^b\right) - 1 \tag{53}$$

The equations (51) and (52) yield a condition linking the spread between rates on loans and deposits:

$$r_t^d = r_t^b - \kappa^k \varpi^b (\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b})^2 (\frac{k_t^b}{\varpi^b b_t + \varpi^h h_t^b} - \vartheta^b) \quad (54)$$

We assume that in the steady-state banks violate the optimal capital to assets ratio by 0.02, hence, the value for the parameter κ^k in the steady-state can be obtained.

3.4 Monetary Authority

Central bank as the monetary authority governs and regulates the money market. We capture both sides of its balance sheet to model the central bank. On the assets side, we assume there is no debt issued by the banking system. Hence, the monetary base resources follow as:

$$mb_t = gd_t + fr_t \quad (55)$$

where gd_t and fr_t denote the net government debt and net foreign reserves, respectively. The foreign reserves of the bank accumulate through the time:

$$fr_t = \frac{fr_{t-1}}{\pi_t} + O_t \quad (56)$$

by an exogenous endowment oil sell, which follows an AR(1) representation:

$$\ln O_t = \rho^O \ln O_{t-1} + (1 - \rho^O) \ln \bar{O} + u_t^O, \;\; u_t^O \sim N(0, {\sigma^O}^2) \quad (57)$$

On the liabilities side, vis-à-vis, there are money and the required reserves of the banking system. That is:

$$mb_t = m_t + RR_t \quad (58)$$

where $m_t = m_t^P + m_t^I$ is denoting the total money that is assumed to be held only by the households.

3.5 Government

The government expenditure assumed to be financed by lump-sum taxes paid by the households ($tax_t = tax_t^P + tax_t^I$) and issuing debt from the central bank, so the balanced budget condition implies that:

$$g_t = tax_t + \frac{gd_t + fr_t - (gd_{t-1} + fr_{t-1})}{P_t}$$

where gd_t and fr_t denote government debt and foreign reserves, hence, $\frac{gd_t + fr_t - (gd_{t-1} + fr_{t-1})}{P_t}$ is the money created by the government debt to the central bank.

The Fiscal policy is exogenous and assumed to behave as follows:

$$g_t = \rho^g \ln g_{t-1} + (1 - \rho^g) \ln \bar{g} + u_t^g, \;\; u_t^g \sim N(0, {\sigma^g}^2) \tag{59}$$

3.6 Monetary Policy

The monetary authority follows a Taylor rule of the type:

$$r_t^d = \left(r_{t-1}^d\right)^{\varphi^r} \left(\frac{\pi_t}{\pi^*}\right)^{(1-\varphi^r)\varphi^\pi} \left(\frac{y_t}{\tilde{y}}\right)^{(1-\varphi^r)\varphi^y} u_t^r \tag{60}$$

where φ^π and φ^y are weights assigned to inflation and output stabilization, respectively, and $u_t^r \sim N(0, {\sigma^r}^2)$ is an exogenous shock to monetary policy.

The spread between the deposit rate and loan rate follows as:

$$r_t^b = r_t^d + \zeta_t \tag{60}$$

where $\zeta_t = \rho^\zeta \ln \zeta_{t-1} + \left(1 - \rho^\zeta\right) \ln \bar{\zeta} + u_t^\zeta, \;\; u_t^\zeta \sim N(0, {\sigma^\zeta}^2)$.

3.7 Aggregation and Market Clearing

Two equations clearing the labor markets are:

$$n_t^P = n_t^{Pc} + n_t^{Ph} \tag{61}$$

And

$$n_t^I = n_t^{Ic} + n_t^{Ih} \tag{62}$$

The aggregate output constraint is:

$$y_t^c = c_t + i_t^P + g_t \tag{63}$$

where $c_t = c_t^P + c_t^I$ denotes aggregate consumption.

The equilibrium in the housing market is given by:

$$y_t^h = H_t - (1 - \delta^h)H_{t-1} \quad (64)$$

where $H_t = h_t^P + h_t^l + h_t^b$ denotes aggregate housing stock of the economy. Total land is fixed and normalized to one, $l_t = 1$.

To close the model, the total output is:

$$y_t = y_t^c + y_t^h \quad (65)$$

4 Estimation

4.1 Data and Calibration

Our estimation follows by a Bayesian approach: we choose prior distributions for the parameters, and we estimate their posterior distribution using the Metropolis-Hastings algorithm[1]. The posterior distributions of the model parameters and all other associated empirical results have been obtained using Dynare (ver. 4.5.7.) toolbox for MATLAB. As our model is expressed in the form of log-deviations from the steady-state (the model is not designed to explain long-run trends and seasonal fluctuations in the observed variables), data should be transformed into a form suitable for computing the likelihood function. We use ten observable variables for estimation: gross domestic non-housing production, gross housing sector production, consumption, government expenditure, oil production, real inflation rate, house price inflation rate, nominal interest rates, nominal deposit rates, and required reserve.

As mentioned above, the data transformed into a log-form and using the Hodrick-Prescott (HP) filter all the seasonal features of the series are removed. We estimate the model from 1988q1 to 2017q4, giving 120 observations per data series. All observables are sourced from the Central Bank of Iran's quarterly national accounts and economic time series database. It is notable that nominal interest and deposit rates are obtained from balance sheets of banks, rather than using the approved ones. The table (2) shows descriptive Statistics of these observables variables. All the variable means are approximately indicating that they properly satisfy the model features and needs.

[1] See An and Schorfheide (2007) for a description of the methodology.

Table 2
Descriptive Statistics of Observable Variables

variable	mean	st.dev	median	max	min
non-Housing GDP	0.0010	0.0235	0.0004	0.0702	-0.0585
Housing Production	0.0001	0.0787	0.0072	0.2284	-0.1711
Consumption	0.0020	0.0339	0.0007	0.1187	-0.1437
Government Expenditure	0.0000	0.0883	-0.0089	0.2549	-0.2265
Oil production	0.0021	0.1278	0.0028	0.3335	-0.4684
Real Inflation Rate	0.0000	0.0562	0.0091	0.1958	-0.1190
House Price Inflation	0.0000	0.1498	0.0052	0.3553	-0.4016
Nominal Interest Rate	0.0000	0.0549	0.0009	0.1069	-0.1071
Nominal Deposit Rate	0.0000	0.0653	0.0049	0.1083	-0.1170
Required Reserve	-0.0003	0.0704	0.0028	0.1520	-0.1927

Model parameters are derived through a combination of calibration and estimation. The parameters determining the steady-state are calibrated in order to obtain reasonable values for some key steady-state values. Among the calibrated parameters, the steady-state shares are set to match with the corresponding sample averages. Table 3 reports the values of these parameters. According to the national accounts time series of Central Bank of Iran (CBI), consumption, government expenditure, and private investment have 50.4%, 18.8%, and 30.8% shares of total GDP (excluding the housing sector), respectively. The housing sector has a 6.8% share of total GDP, leaves the remaining 93.2% to the non-housing goods and services.

Table 3
Steady-state Shares and ratios

Parameter	Description	Value
$\bar{c}/\overline{y^c}$	consumption to non-housing GDP share	0.504
$\bar{g}/\overline{y^c}$	government Expenditure to non-housing GDP share	0.188
$\overline{\iota^P}/\overline{y^c}$	private investment to non-housing GDP share	0.308
$\overline{y^c}/\bar{y}$	non-housing sector output to total GDP share	0.932
$\overline{y^h}/\bar{y}$	housing sector output to total GDP share	0.068
$\overline{b^I}/\bar{b}$	housing loans taken by Impatient households to total loans	0.05
$\overline{b^c}/\bar{b}$	loans taken by non-housing sector to total loans	0.88
$\overline{b^h}/\bar{b}$	loans taken by housing sector to total loans	0.07

The discount factor of Patient households is set to 0.85. We set the impatient household discount factor to 0.8095, implying the annual interest rate of %20. The depreciation rate for capital and housing assumed to be 0.03 and 0.02, respectively.

We set the capital share in the goods and services production function to 0.75, and for the house production function, the share of capital and land are set to 0.75 and 0.2, respectively.

Based on the banking system reports of CBI, housing loans taken by households from the banking system has an average of 5% share of total loans, in the past 5 years. Respectively, loans taken by housing and non-housing sectors are 7% and 88%. According to the capital adequacy obligations made by the CBI, capital to risk-adjusted assets ratio is set to 0.08, assigning 0.7 and 1 weight to the loans and housing, respectively. The capital management cost ratio is set to 0.01 and parameter κ^k is set to 428.5, implying the 0.06 spread between deposit and loan interest rate (we assume that there is a 0.02 deviation from the optimal capital to risk-adjusted assets in the steady-state). Table 4 reports the values of the calibrated parameters.

Table 4
Calibrated Parameters

Parameter	Description	Value
β^P	Patient households discount factor	0.85
β^I	Impatient households discount factor	0.8095
μ^c	capital share in the non-housing production function	0.75
μ^h	capital share in the housing production function	0.75
μ^l	land share in the housing production function	0.2
δ^k	the depreciation rate of capital	0.03
δ^h	the depreciation rate of housing	0.02
ϑ^b	bank's capital to risk-adjusted assets ratio	0.08
δ^b	bank's capital management cost ratio	0.01
ϖ^b	risk weight assigned to loans	0.7
ϖ^h	risk weight assigned to housing	1
κ^k	capital adequacy deviation cost parameter	428.5

4.2 Prior Distributions

Our priors are in Tables 5. We used inverse gamma priors for the standard errors of the shocks. For the persistence parameters of technologies and preference shock, we choose a beta-distribution with a prior mean of 0.9. The persistence parameter of government expenditure and oil are set to 0.7 and 0.85, respectively. We set the prior mean of the habit parameter in consumption at 0.2. We choose a gamma prior for the parameter describing the inverse elasticity of substitution of working with a mean of 2.8. The prior of the inverse of the elasticity of money stock demand is assumed to be gamma, with a mean of 4.2.

For the monetary policy rule, we base our priors on a Taylor rule responding gradually to inflation, so that the prior means of φ^r, φ^π and φ^y are, respectively, 0.85, 0.1 and 0.01. We select the prior mean of the Calvo price at 0.5. The prior for the indexation parameter is loosely centered on 0.5.

4.3 Posterior Distributions

Table 5 reports the posterior means, standard deviation, and 90% probability intervals for the structural parameters, together with the prior distributions and means. Besides, Figure 4 reports the prior and posterior marginal densities of the parameters in the model. Draws from the posterior distribution of the parameters are obtained using the random walk version of the Metropolis-Hastings algorithm.

The estimated model suggests a lower rate of technological progress in both housing and non-housing sector. It can also be seen that the estimated persistence parameters of price mark-up shocks in both sectors are lower than our prior means.

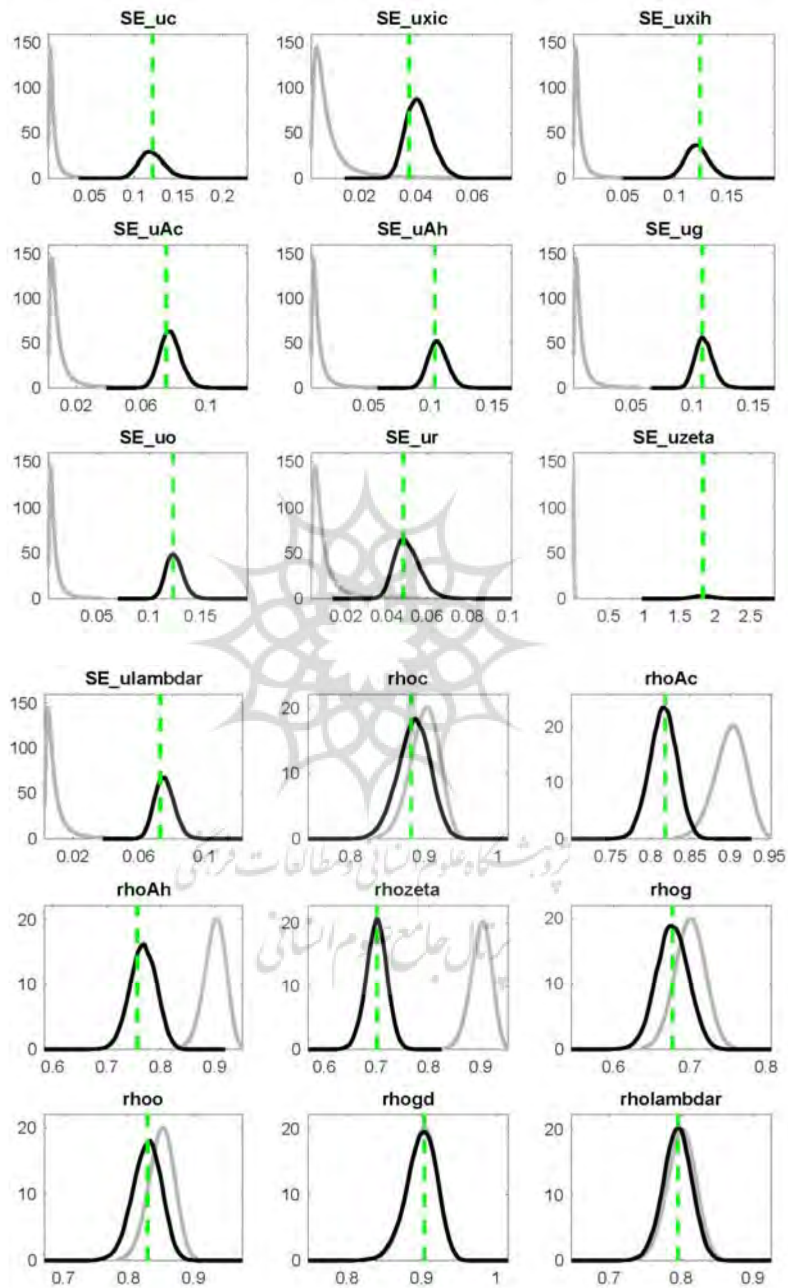
The posterior mean of ω -the parameter that governs the degree of price stickiness faced by the intermediate producers- implies that prices persist on average for about 1.6 periods. It is somewhat lower than our expectations. It might be due to the high inflation rates in recent years. The higher inflation rate means more upward fluctuations in prices that force more producers to optimally re-adjust their prices. However, given the positive indexation coefficient (0.81), prices change every period, although not in response to changes in marginal costs.

Turning to the monetary policy rule, our estimates suggest more responsiveness of monetary policy to the inflation rate. In other words, a higher estimated φ^π means that the monetary authority has to be more concerned about the deviation of the inflation rate from its targeted value. The estimated output stabilization parameter shows the same as our prior mean, suggesting that the model had no information about the output gap.

Table 5
The prior and posterior distributions of the parameters

parameter	prior distribution	prior mean	posterior mode	posterior st.dev	90% HPD interval	
ρ^{c}	Beta	0.9	0.8821	0.02	0.8498	0.9213
ρ^{Ac}	Beta	0.9	0.8184	0.02	0.7875	0.8427
ρ^{Ah}	Beta	0.9	0.7561	0.02	0.7285	0.8075
ρ^{ζ}	Beta	0.9	0.7008	0.02	0.6673	0.7325
ρ^{g}	Beta	0.7	0.6770	0.02	0.6431	0.7106
ρ^{O}	Beta	0.85	0.8292	0.02	0.7929	0.8639
$\rho^{\lambda^{RR}}$	Beta	0.8	0.7953	0.02	0.7631	0.8276
$\rho^{\theta c}$	Beta	0.8	0.6494	0.02	0.6425	0.7768
$\rho^{\theta h}$	Beta	0.8	0.6823	0.02	0.6425	0.7768
ϕ^{m}	Gamma	4.2	4.1994	0.05	4.1184	4.2801
η	Gamma	2.8	2.7931	0.05	2.7128	2.8754
τ	Beta	0.85	0.8132	0.01	0.7939	0.8325
a	Beta	0.3	0.3018	0.01	0.2857	0.3189
α	Beta	0.2	0.2065	0.01	0.1915	0.2242
μ^{c}	Beta	0.75	0.7184	0.01	0.7027	0.7382
μ^{h}	Beta	0.75	0.7724	0.01	0.756	0.7865
μ^{l}	Beta	0.2	0.3769	0.01	0.3591	0.3938
φ^{r}	Beta	0.85	0.8527	0.02	0.8191	0.884
φ^{π}	Normal	0.1	0.6856	0.005	0.0915	0.1078
φ^{y}	Normal	0.01	0.01	0.0005	0.0092	0.0108
ω	Beta	0.5	0.3826	0.01	0.3712	0.3987
u_t^{c}	Inv. Gamma	0.01	0.1210	∞	0.0978	0.1427
$u_t^{\theta c}$	Inv. Gamma	0.01	0.0374	∞	0.0336	0.1427
$u_t^{\theta h}$	Inv. Gamma	0.01	0.1239	∞	0.1025	0.1386
u_t^{Ac}	Inv. Gamma	0.01	0.0752	∞	0.0672	0.0880
u_t^{Ah}	Inv. Gamma	0.01	0.1030	∞	0.0929	0.1181
u_t^{g}	Inv. Gamma	0.01	0.1079	∞	0.0974	0.1207
u_t^{O}	Inv. Gamma	0.01	0.1232	∞	0.1109	0.1372
u_t^{r}	Inv. Gamma	0.01	0.0481	∞	0.0402	0.0602
u_t^{ζ}	Inv. Gamma	0.01	1.8250	∞	1.6063	2.0484
u_t^{RR}	Inv. Gamma	0.01	0.0729	∞	0.0657	0.0849

Prior and posterior density graphs of all estimated parameters are shown in Figure 3.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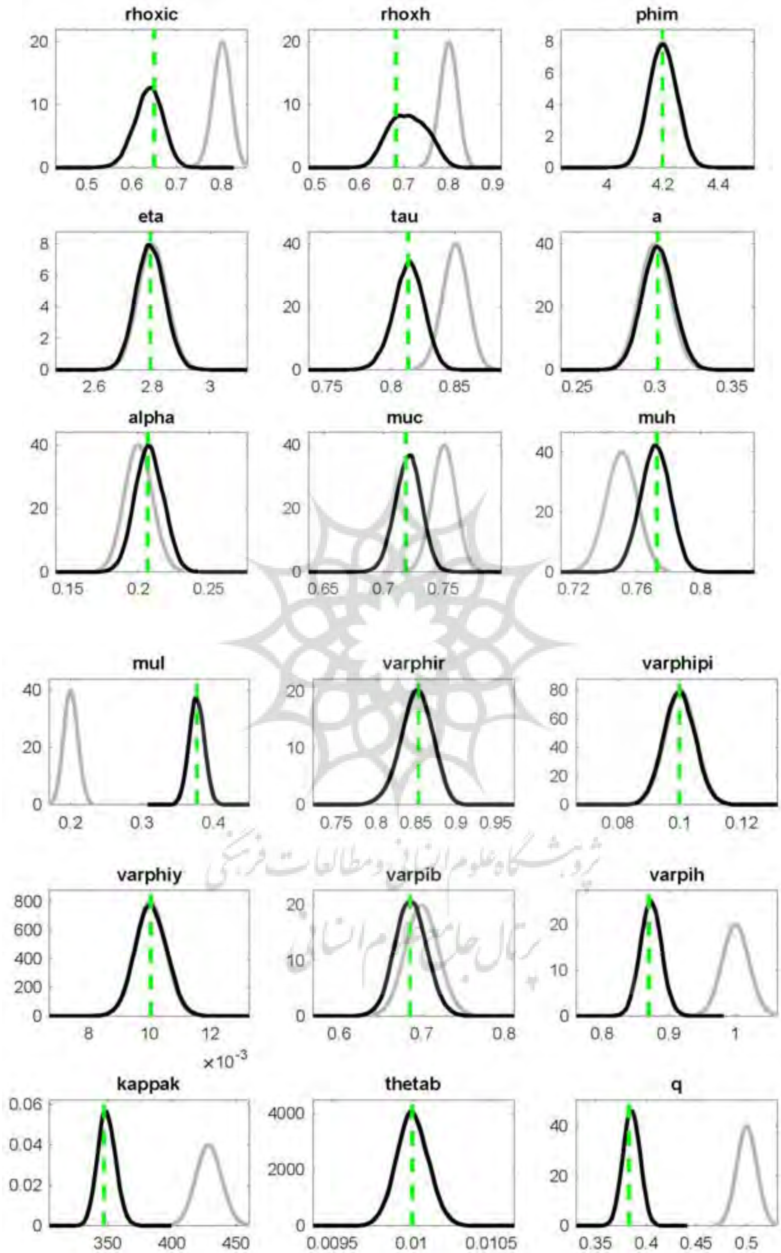

Figure 3. Prior Distribution and Estimated Posterior Distribution of the Parameters

The linear Kalman filter forecasts evaluated at the posterior modes are plotted against all observables throughout the full sample period. As shown in Figure 4, all observables data indicate a good fit with the corresponding filtered forecasts, except, it produces less satisfactory fit to the inflation rate of non-housing products series. Note that the inflation series is the most volatile one in our sample, which can partly explain the lack of an adequate fit. Nevertheless, it follows that the empirical fit of our DSGE model is good for the observables, and can informally be considered sufficient for the macroeconomic variables of Iran.

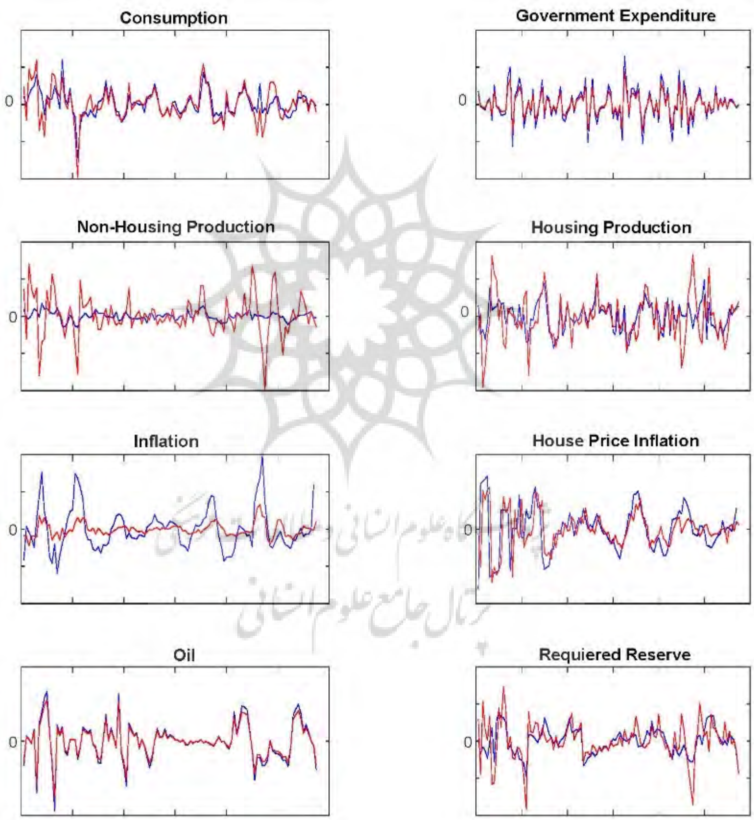

Figure 4. Actual Data (blue line) and Corresponding Kalman Filter Forecasts (red line)

5 Empirical Results

According to our goal in this paper, we step up a new consideration in the monetary rule: we assume that the monetary authority reacts to the housing price inflation, alongside the non-housing inflation and output gap. Hence, we update the Taylor rule in equation (60) as a new one:

$$r_t^d = \left(r_{t-1}^d\right)^{\varphi^r} \left(\frac{\pi_t}{\pi^*}\right)^{(1-\varphi^r)\varphi^\pi} \left(\frac{y_t}{\tilde{y}}\right)^{(1-\varphi^r)\varphi^y} \left(\frac{\pi_t^h}{\pi^{h^*}}\right)^{(1-\varphi^r)\varphi^{\pi^h}} u_t^r \qquad (66)$$

and call it "Augmented Taylor Rule". To obtain a thorough insight into what happens if the monetary authority considers housing inflation in its monetary rule, we trace a three-step track. Initially, we set the weight of deviation in the housing inflation rate from the targeted rate to 0.5, and in the next steps, we raised it with 0.5 units at each step. It, alongside the previous basic simple Taylor rule that implies no consideration on housing inflation, i.e. $\varphi^{\pi^h} = 0$, gives four tracks to trace.

The reaction of the endogenous model variables to structural shocks can be examined using Bayesian impulse response functions (IRF). To illustrate the main properties of the model, we plotted a combination of those four pre-mentioned IRFs, focusing on the impact of preference shock, technological shocks, housing price mark-up shock, and a monetary policy shocks.

Figure 5 plots IRFs to the preference shock. We also call it a demand shock, since it causes the total consumption to rise. A positive demand shock generates a boom-bust response of the non-housing output. The initial jump in production can be due to an increased optimism of the households that shift from capital accumulation to consumption. However, the ensuing drop in investment seems remarkable; it quickly generates a bust in the overall level of the non-housing sector's output. The interactions in the house production are vice-versa; the house production drops at first, and then rises.

As shown in the below figures, adding the monetary authority's reaction to the housing price inflation does not much affect the IRFs. A plausible cause might be that this shock, in essence, hits the non-housing sector and has not much to do with the housing sector. As one can see, the more monetary authority takes the housing inflation into account, the less will go the total loans that banking system issues in the economy, and it will take more periods to get back to its steady-state level. Another important implication is that a preference shock leads to a greater boom in the non-housing output (and similarly, a higher initial burst in the housing output), as a result of monetary authority's reaction to the housing inflation.

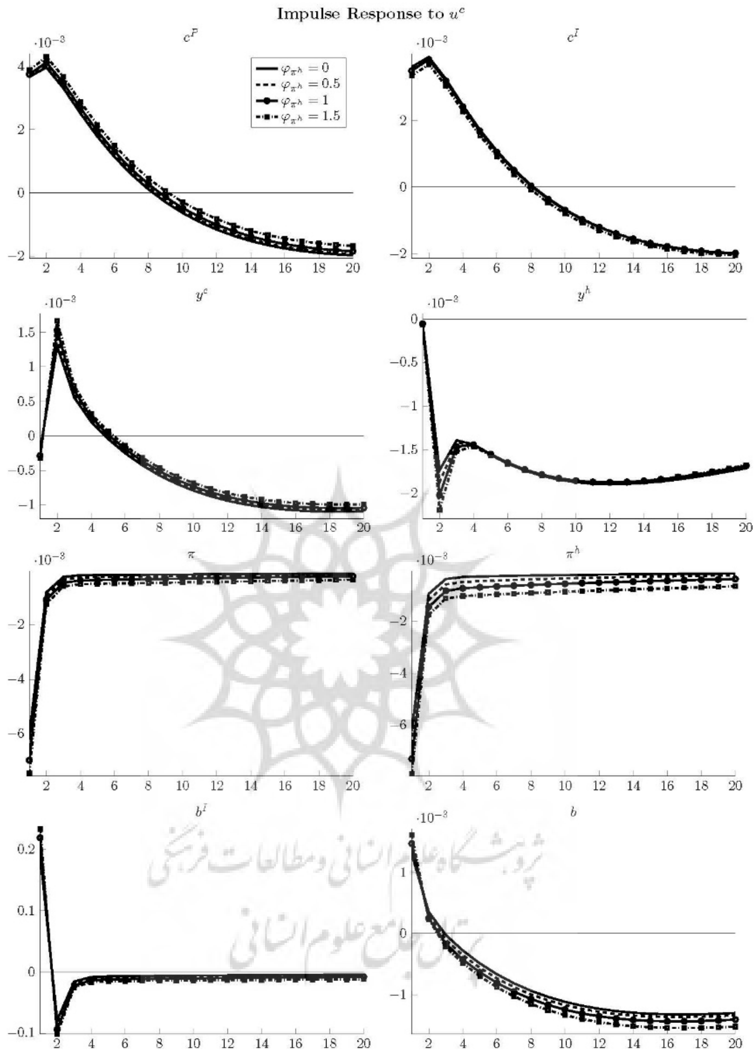

Figure 5. IRFs to a Preference Shock

Figure 6 depicts the model's response to a one standard deviation unexpected innovation to the non-housing technology. This shock hits the goods and services production side of the economy: productivity of labor and capital rises uniformly for all intermediate goods and services producers, and this leads to a decrease in marginal cost. A gradual process of producer price reduction ensues, and inflation falls. The rise in productivity in the non-housing sector motivates patient households to move their investments from the housing sector to the non-housing sector, leading to an overall upturn in the non-housing output. It implies a decline in housing production. With an ensuing decrease in the non-housing output, the housing production rises and waves back to its steady-state level.

An important implication of considering monetary authority's reaction to the housing inflation is that, following an unexpected innovation to the non-housing sector, the consumption of patient households rises less than the situation that there is no consideration of the housing inflation in the monetary policy. For impatient households, it is vice-versa. The reason why this happens relates to the different degrees of patience between these households. As patient households are the only ones who invest in the economy, they are more willing to reduce their consumption and accumulate more capital and deposit in favor of rising future incomes. For the impatient households, the consumption will be higher so that the total consumption remains fixed. As shown in the below figures, since the impatient households collateralize their housing to get loans from the banking system, the more monetary authority reacts to the housing inflation, the higher would be the loans taken by the impatient households.

The response to a one standard deviation unexpected innovation to the housing technology is shown in figure 7. In contrast with the non-housing technology shock, this shock makes the house production more productive; hence, capitals shift from the non-housing sector to the housing sector. Due to the increased housing investment, and thanks to a fall in construction costs, housing prices drop. In other words, positive technology shock in the housing sector leads the house production to rise and the goods and services output to decline. As productivity increases for all intermediate producers, the marginal cost decrease, and this leads to a downturn in the inflation rate. It implies that households have much tendency to accumulate houses, i.e., a fall in consumption.

Turning to the monetary policy, one can see, as the monetary authority considers the housing inflation, the downturn in the consumption for the patient households diminishes. For impatient households, it is vice-versa. One rational reason might relate to the collateral effect. As impatient households collateralize their housing to get bank loans, they still have a strong will to substitute out their consumption to accumulate more housing; hence, their consumption's downturn worsens.

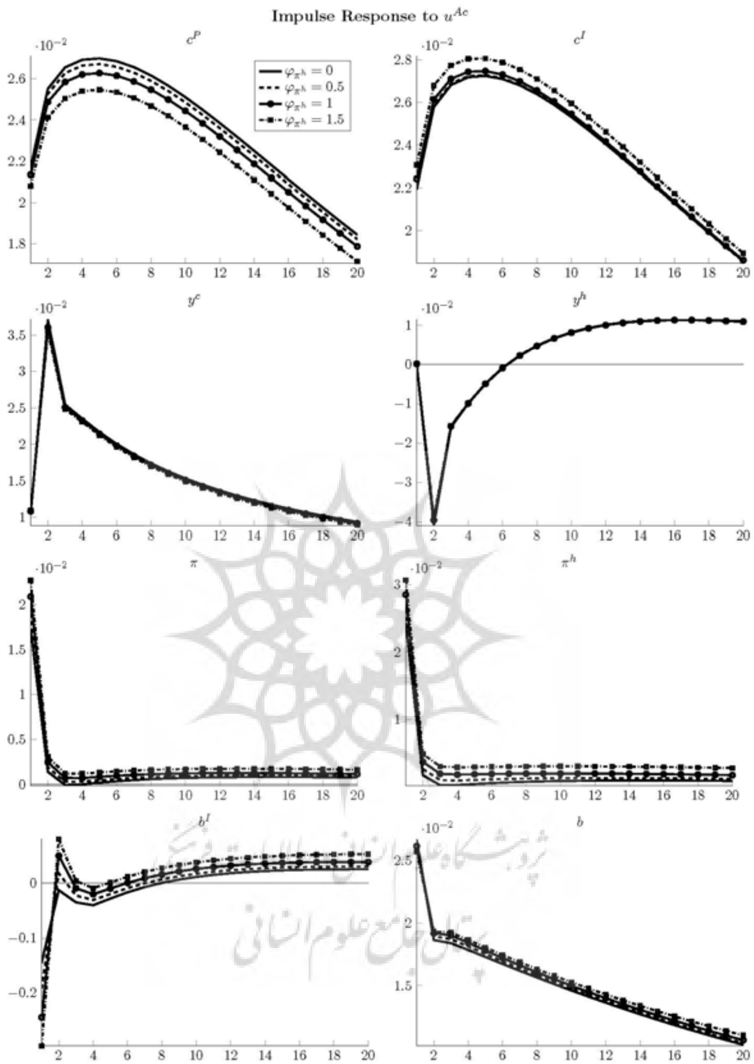

Figure 6. IRFs to a Non-Housing Technology Shock

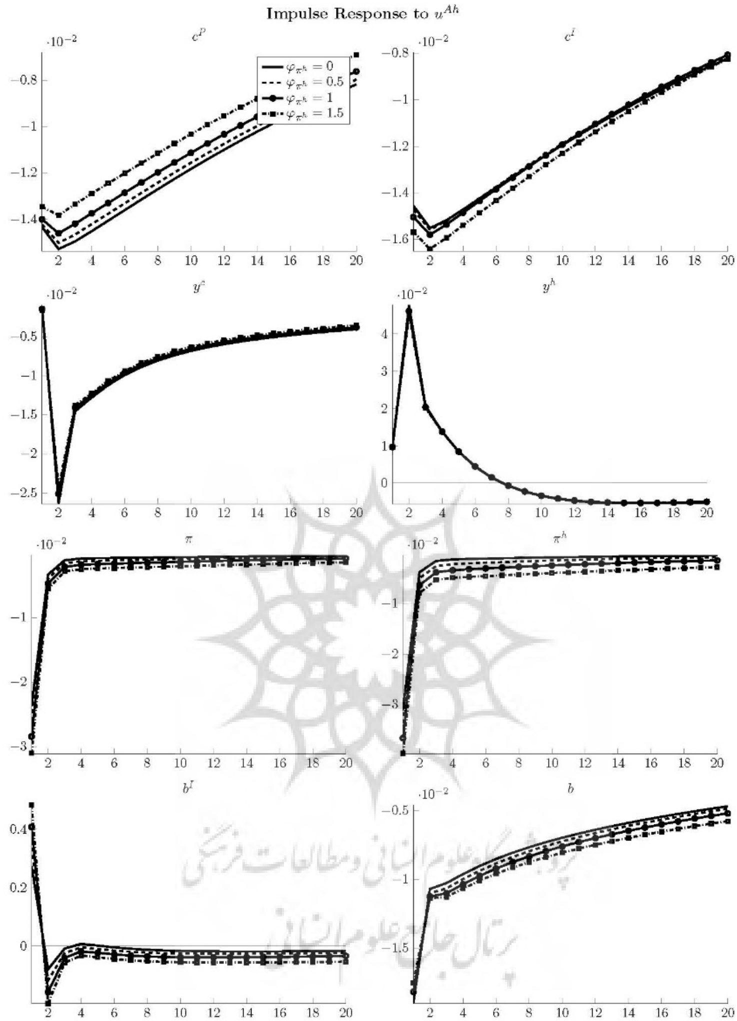

Figure 7. IRFs to a Non-Housing Technology Shock

The model's response to one standard deviation shock to a house price mark-up is shown in figure 8. A positive shock extends the substitutability of houses produced by intermediate housing and drives up the mark-ups charged by them. As a result, house price inflation jumps up, and leads to an increase in both households' consumption, as they will tend to substitute housing with consumption. It is clear that this increase in consumption leads to an increase in goods and services production, and the reduced housing demand leads to a decrease in house production.

It is interesting to study the effects of a positive house price mark-up shock on the loan market. (1) On the supply side, through the balance sheet channel, inflation in house prices strengthen the asset side of the bank's balance sheet; hence, they are capable of issuing more loans in the economy. (2) On the demand side, in the aftermath of the shock, as mentioned above, the impatient households reduce their housing demand, causing an immediate fall in loans taken by them. But through the collateral effect, the increase in house prices makes them capable of taking more loans. It can be seen with a rapid rise in the impatient household's loan.

All the effects of the shock described above get amplified as a result of the monetary authority's reaction to the housing price inflation.

Finally, figure 9 plots a monetary policy shock. A positive monetary policy shock raises the inflation rates in both the non-housing and housing sectors. The effects of a monetary policy shock on private consumption are somewhat tricky. For the impatient household's consumption, it is an upturn, while it is a downturn for patient ones. Again this is because of the different degrees of patience. As the patient households are those who deposit a fraction of their wealth in the banking system, an increase in the deposit rates (that comes straight after the policy shock) motivates them to reduce consumption in favor of gaining more income in the future. For impatient households, the interactions are vice-versa. As the loan rate rise, the cost of borrowing from the banking system increases; hence, they are reluctant to get loans. Thanks to the decline in their costs, the patient households are now capable of more consumption.

Comparing the IRFs produced by different levels of response to the housing inflation suggests that caring more about the housing inflation rate amplifies the result. A critical implication of the monetary authority's reaction to the housing inflation relates to the aggregate loans issued by the banking system. Taking housing inflation into account leads to an increase in the bank's profitability. The assumption that banks hold housing as an asset in our model extends this implication through the balance sheet effect. It is evident that the more policy rule reacts to the housing inflation, the more would be the increase in the aggregate loans issued by the banking system.

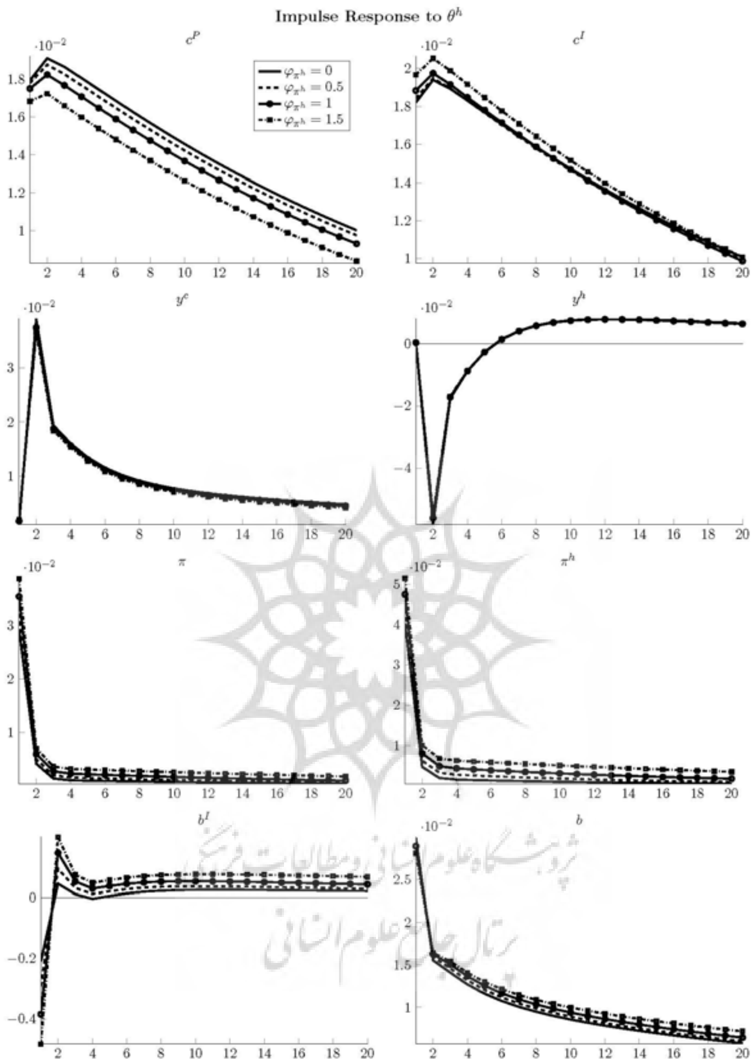

Figure 8. IRFs to a Housing Price Mark-Up Shock

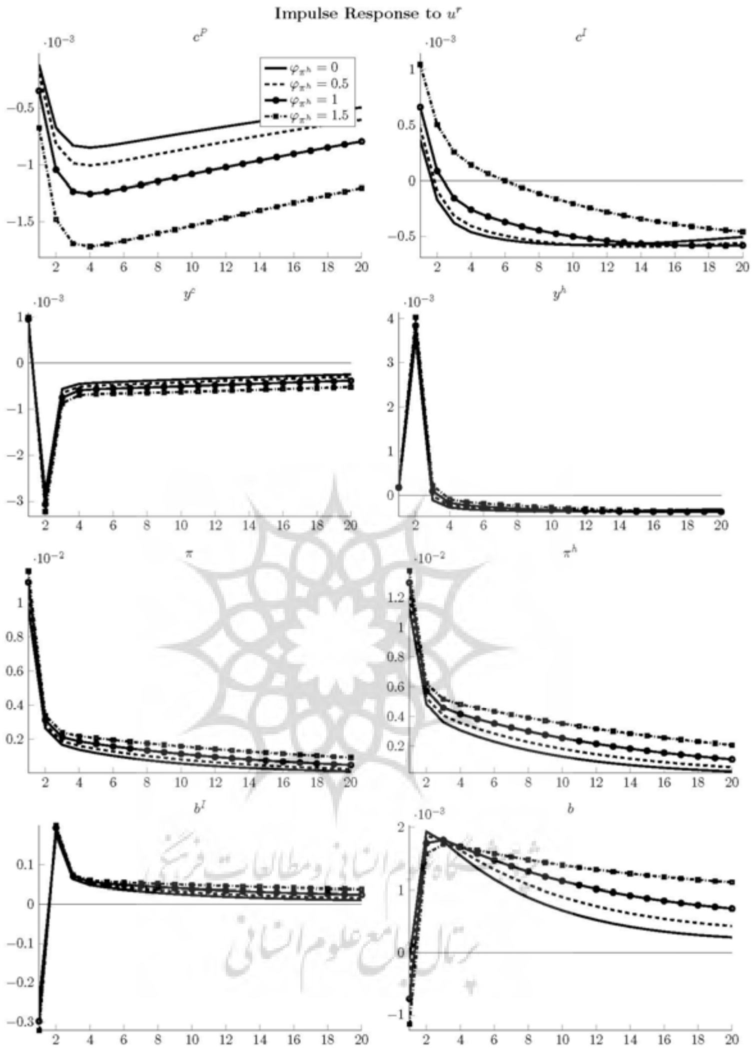

Figure 9. IRFs to a Monetary Policy Shock

6 Conclusion

The fast growth in prices and residential investment in the housing market of Iran has led many studies to concern the developments in the housing sector. In this paper, we developed a Dynamic Stochastic General Equilibrium (DSGE) model -with 5 main sectors- for Iran's economy that explicitly models the housing in the banks' portfolio. There are two types of households and two types of firms. Using different discount factors, households separated into patient and impatient ones to provide savings and borrowing flows in the equilibrium. The firms divided into non-housing and housing producers. All the financial flows channeled through a banking system that holds housing as an asset.

Using Bayesian methods, we estimated the model, covering the 1988q1 to 2017q4 period. The corresponding filtered forecasts showed that the empirical fit of our DSGE model is good for the observables, and can informally be considered adequate for the macroeconomic variables of Iran. Following up on our goal in this paper, we update the Taylor rule to a new "Augmented Taylor Rule", which considers the monetary authority's reaction to the house price inflation, alongside the non-housing inflation and output gap. To obtain a thorough insight, we built a three-step track to trace. Initially, we set the weight of deviation in the housing inflation rate from the targeted rate to 0.5, and in the next steps, we increased it with 0.5 units at each step, which gives us a total of four IRFs to analyze the structural shock's effects.

The IRFs of structural shocks indicate that when a house price mark-up shock hits the economy, the decline in the housing demand leads to an increase in consumption. On the demand side of the loan market, the initial decrease in impatient household's loan inverts, as a result of the collateral effect. On the supply side, through the balance sheet effect, the aggregate loans rise. The monetary authority's reaction to the house price inflation amplifies these effects.

For a positive monetary policy shock, the results are heterogeneous; it increases the consumption of the impatient households, in contrast with decreasing the patient household's consumption. These implications are straight due to the heterogeneity assumption between household agents. The difference between their discount factors separates households into borrowers and lenders in equilibrium. That is why the patient households reduce their consumption in favor of more future income, as the impatient households raise their consumption with a waiver of borrowing. Again tracing our three-step track indicates that the reaction of the monetary authority to the housing inflation amplifies the implication.

We suggest that the future developments of the model incorporate the optimal monetary policy regarding the house price inflation alongside the conventional inflation-targeting policy to study the optimal monetary policy implications.

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