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Housing Market Drivers and Dynamics in Armenia

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Abstract

This paper develops VAR model for Armenia with housing price and estimates the impact of housing price on GDP growth and inflation. Pass-through results show, that 1% increase in real housing price creates from 0.03 to 0.09% inflation and increases GDP by around 0.25% in the long run. Paper then discusses simple housing decision model and incorporates it into DSGE framework. Households are allowed to divide their disposable housing stock into private consumption and lend out to firms for commercial purposes. Having borrowing constraint in the model enables to generate both borrowing and housing cycles. Balance sheet channel allows to explain the empirically observed estimates of the effects of housing prices on the Armenian economy. According to the theoretical model's results, the long-run response of inflation to the real housing price increase as a result of housing market's specific shocks is estimated to lie in the interval of 0.045-0.118%, which is very close to empirical estimates. Moreover, model estimated commercial housing preference cycle is consistent with historical events of the Armenian economy.

JEL classification: E31, E44, E52, R21
Keywords: Commercial and personal housing, Real estate, Housing price, DSGE model, Borrowing constraint, Bayesian Estimation.

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1 Introduction

In recent years, many economists have studied the impact of changes in asset prices on economy. In this context, fluctuations of housing prices have implications for macroeconomic policy. In many developing countries stock market is not developed, in addition, the possibilities of capital markets are restrained. As a result, housing is considered as an essential asset and it is used in commercial purposes as well. Commercial real estate has played an important role in accelerating the recent upswings and downswings of asset market (Karl Case (2000)). Moreover, asset prices can have negative repercussions on economy as they collapse. So, it is important for policymakers to focus on asset price bubbles.

Movements in housing prices affect households consumption and aggregate demand through three channels: housing expenditures, households wealth effect and the balance sheet channel.

First channel is a direct effect of housing expenditures. Consider the case of monetary expansion: the decline of interest rates increases housing prices because interest rate is a cost of financing housing. As a result of increase in housing prices, expenditures on housing increases as it is more profitable to build housing. The increase in housing expenditures leads to the rise in aggregate demand (Mishkin (2001)).

Next channel is a housing wealth effect. Increase in housing prices leads to an increase in consumption spending and aggregate demand with direct wealth effect. But this effect works only for financial wealth (sum of liquid financial assets and the value of real estate minus outstanding debt) not for real wealth, as noted in Campbell and Cocco (2007). They argue, that for a homeowner who expects to live in his current house for a long time, a higher house price assumes higher rental cost of living in the house. So as mentioned in Nocera and Roma (2017), wealth effect is not an interesting channel if homeowner is not planning to sell his house. Moreover, many economists think, that this effect is related to the consumers expectations and confidence. When housing prices are high, homeowners feel wealthy and spend more, so they increase aggregate consumption and demand.

Third and the most common channel is a balance sheet channel. When house price increases, available collateral increases too, because households can use their housing as collateral when borrowing. It is associated with the increase in loans and households consumption (Bernanke and Gertler, 2000).

The aim of this paper is to find out the main drivers of housing market and to estimate the effects of housing prices on economy, as in many countries lending is collateralized with real estate. During 2000-2019, Armenia had two housing cycles. The first boom in Armenian real estate market was in 2000s. Housing construction started to increase in 2002-2003 and achieved its peak in 2008. Second boom started from 2015-2016 and continued until 2019. Housing prices show the similar pattern as housing cycle and could impact on inflation's developments. So, we attempt to find out the implications of these booms for monetary policy. For that purpose, paper empirically tests the presence of theoretical channels discussed in the literature. Then, it constructs simple VAR model and estimates the impact of housing prices on inflation and economic growth. Finally, theoretical micro-founded model is developed to explain the empirical estimates. Incorporation of balance sheet effect into DSGE model enables to explain empirical estimation results.

The remaining of the paper is organized as follows. The second section examines stylized facts related to the housing market and the economy, and empirical estimation based on vector autoregressive approach. The third section develops dynamic stochastic general equilibrium (DSGE) model and incorporates simple housing decision model into that framework. Section four estimates the theoretical model. The fifth section discusses some properties of the model. Finally, section six concludes.

2 Stylized Facts and Empirical Estimation

This section provides empirical analyses of housing prices and the key macroeconomic variables for Armenian economy. First part presents some stylized facts of the Armenian economy, and the second one builds VAR model to estimate the impact of house prices on inflation and economic growth.

Further analysis shows that fluctuations in housing prices have an important role on economic activity. For instance, Goodhart and Hofmann (2008) investigate the nexuses between house prices, credit, money and economic activity using VAR approach based on fixed-effects panel estimation. They argue, that there is a significant link between house prices, broad money, private credit and the macroeconomy. Shocks to housing prices, credit and money all have significant effects on economic activity and aggregate price. The effects of shocks to money and credit on house prices are stronger when house prices are booming.

Nocera and Roma (2017) use a structural Bayesian VAR approach to analyse the role of changes in housing prices in monetary transmission mechanism for seven euro-area countries. They use a zero and sign restrictions for identification of housing demand and monetary policy shocks. The above mentioned paper finds a positive effect of housing prices on GDP, which can be explained by housing wealth and collateral effects. They show, that wealth effect exists in some countries and 1% increase in real house prices leads to 0.15% increases in private consumption. Moreover, collateral effect is found across all countries. They indicate that on average 1% increase in real house prices increases real private credit by around 0.35%.

Iacoviello (2005) analysis the impact of housing prices on economy using simple VAR approach by including data on real GDP, inflation, real housing prices and interest rate. He finds, that there is a negative response of GDP, inflation and housing prices to positive monetary policy shock and positive comovement of GDP and housing prices in response to output and housing price shocks.

2.1 Stylized Facts

We look at the relationships between housing prices, credit, credit in GDP, and the major macroeconomic variables, such as real GDP, inflation, interest rate, private consumption, construction etc, to find out the existence of transmission channels discussed in introduction.

Real house prices started to increase in 2000-2008, but in the second quarter of 2009 they declined about 11.4% and continue to constantly decrease until the first quarter of 2017. Since 2017, real house prices started to increase. Changes in construction have the similar path as housing prices (figures 17 and 18, Appendix B). The analysis identifies significant relationship between real house prices and construction: the correlation between two variables is 0.7 and there is a two-way Granger causality significant at 5% confidence level (tables 7, 8 Appendix B).

In recent years, private credit and consumers mortgage in GDP has been increasing significantly.

There is a strong relationship between house prices and loans. House prices Granger causes mortgages at 1% confidence level and correlation between two variables is about 0.6, which is the evidence of the balance sheet channel.

The analysis shows that the relationship between house prices and real private consumption is not significant. So, wealth effect is not a very common channel for our economy.

Thus, empirically relevant channels for the Armenian economy are housing expenditures and collateral channels. The schematic representation of discussed channels are presented in the figure 1.

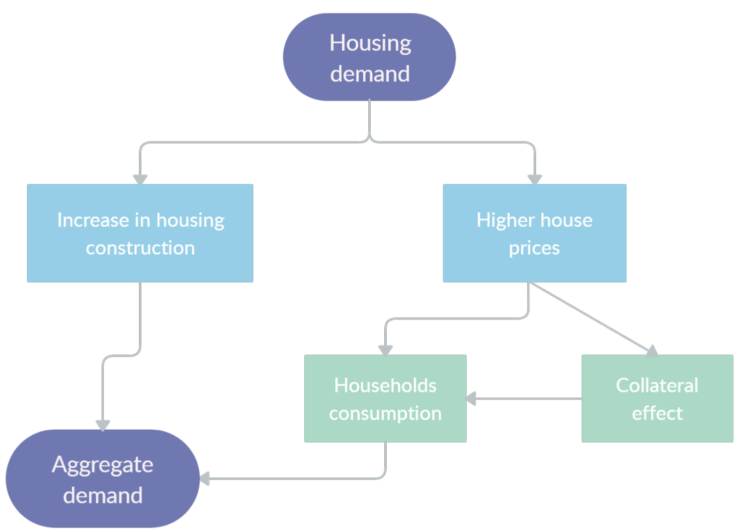

Figure 1: How do changes in housing demand affect aggregate demand

2.2 VAR Approach

As noted in Goodhart and Hofmann (2008), it is important to understand the relationship between housing prices, monetary policy and economic activity. And if there is a significant link between house prices and macroeconomy, what is the transmission mechanism, and how do fluctuations in housing prices affect economic entities' decisions.

Following Iacoveillo (2005) the paper builds simple VAR model using three classical macroeconomic variables (GDP growth, inflation and interest rate) and real housing price. The VAR model has one exogenous variable, which is remittance flowing into Armenia.

The estimation sample covers the period from the second quarter of 2002 to the fourth quarter of 2018. The lag length for the model is chosen based on Schwarz and Hannan-Quinn information criteria. Criteria suggest one lag. All time series, except interest rate are seasonally adjusted using X12 algorithm and are expressed in quarterly percentage changes. Interest rate is stationary process, which is demeaned for the inclusion in estimation process. To get real housing price, nominal housing price is deflated by CPI index. Model input variables are presented in figure 19 in Appendix C.

To analyze impulse responses, the following Choleski ordering is used: inflation, housing price, GDP growth and interest rate. The most endogenous variable is assumed to be interest rate. The less endogenous variable is inflation because of the prevailing presence of mark-up shocks in Armenian headline inflation (Appendix B, figure 13).

The impulse response functions of vector autoregressive models are represented in figures 20-23 in Appendix C.

Our results are in line with results observed in the literature (Iacoviello (2005), Nocera, Roma (2017), Goodhart, Hofmann(2008)):

- Output, house prices and inflation decrease following a positive monetary policy shock.
- The responses of output and house prices to mark-up shock are negative, however the response of interest rate is positive.
- All the model variables react positively to output and house price shocks.

Figure 2 presents the cumulative responses of model variables to housing price shock, while figure 3 represents pass-through. The latter is the ratio of cumulative values of GDP, inflation and interest rate to cumulative value of the housing price.

The cumulative response of inflation to housing price shock is 0.2, whereas the share of the housing prices in CPI is about 0.01. Therefore, there are indirect effects, which are present in the transmission channel of housing price on inflation. On the other hand, the long run response of GDP growth to housing price is 0.21.

To test the robustness of results, another VAR model is estimated using different data preparation process. As a model input data, we take the cyclical

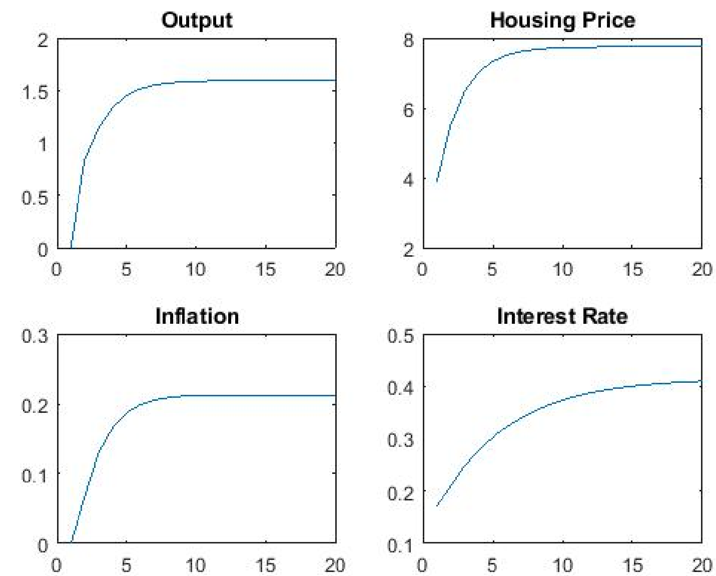

Figure 2: Cumulative responses to housing price shock

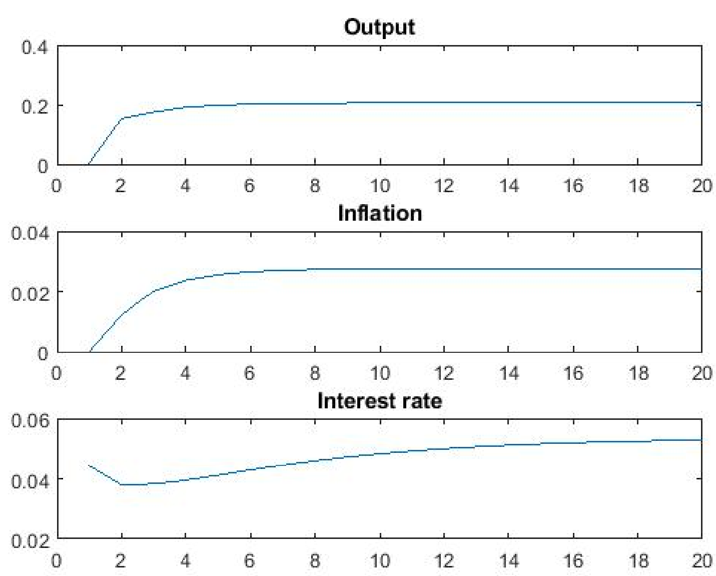

Figure 3: Housing price pass-through

component of logarithmic series using Hodrick-Prescott filter with $\lambda = 1600$. Only inflation is the same as in previous model.

Directions of impulse responses are the same compared to the previous model. Pass-through of housing prices to inflation increases to 0.09. Models results are summarized in table 1.

Table 1: Housing price pass-through

House price shock		
	VAR(demean)	VAR(HP filter)
GDP	0.21	0.3
CPI	0.03	0.09

3 The Structural Model

3.1 Model Description

To understand the structural approach based on DSGE modeling, we follow the framework of Iacoviello and Neri (2005, 2010). They develop standard DSGE models including housing both in utility and production functions. Literature separates two groups of agents. First one is the patient household or saver, which makes investment decisions and has a higher intertemporal discount factor. Second one is the impatient household or borrower, which has a lower intertemporal discount factor and borrowing constraint, so the size of the debt cannot exceed the value of the collateral (Kiyotaki and Moore, 1997).

Following the main literature housing stock is taken constant for simplicity. The overall stock is separated into housing for personal consumption and for commercial needs. The assumption of constant housing stock includes that newly created housing is divided into personal and commercial with the same proportion as existing stock.

The representative household works, consumes housing and non-housing goods, uses housing as collateral and lends out to the firms. Households solve two optimization problems. Firstly, they minimize their total expenditures and decide how much consume housing and non-housing goods. Secondly, they maximize their utility function subject to the budget and borrowing constraints. In this approach households are not separated into patient and impatient. They hold the stock of housing and at the same time, they are net borrowers.

The production side of the economy is populated by firms, which use labor and commercial housing to produce consumption goods. As mentioned in Bernanke et al. (1999), the output cannot be transformed into consumption immediately. There are also retailers operating in monopolistic competitive environment, which purchase the intermediate good and transform it into final good. As noted in Iacoviello (2005), there is a monopolistic competition in retail level, and retailers are the source of the nominal rigidities.

Model is extended following the balanced growth approach, discussed for example in Adolfson et al. (2007) and Christiano et al. (2011). To bring model to stationary form, all the real variables except prices are de-trended.

3.2 Households

The representative household consumes composite good X_t, which consists of consumption good (C_t) and personal housing (H_t^p), represented by the following equation.

$$X_t = [(1-\gamma)^{1/\eta}(C_t)^{(\eta-1)/\eta} + \gamma^{1/\eta}(H_t^p)^{(\eta-1)/\eta}]^{\eta/(\eta-1)} \tag{3.2.1}$$

where γ is the share of personal housing in consumption basket, η is the elasticity of substitution between housing and non-housing consumption.

Households minimize their total expenditures:

$$\min \{P_t^x X_t - P_t C_t - Q_t H_t^p\}$$

where P_t^x is the price of the composite good, P_t is the consumption good price and Q_t is the nominal housing price.

Optimal allocation of household's expenditures gives demand functions of consumption and personal housing:

$$C_t = (1-\gamma)\left(\frac{P_t^x}{P_t}\right)^\eta X_t \tag{3.2.2}$$

$$H_t^p = \gamma\left(\frac{P_t^x}{Q_t}\right)^\eta X_t \tag{3.2.3}$$

where $\frac{P_t^x}{P_t}$ is the relative price of composite good in terms of consumption good and $\frac{P_t^x}{Q_t}$ is the relative price level of composite good in terms of housing price.

Substituting C_t and H_t^p from (3.2.2) and (3.2.3) into (3.2.1), the aggregate price index gets the following form:

$$P_t^x = [(1-\gamma)P_t^{1-\eta} + \gamma Q_t^{1-\eta}]^{\frac{1}{1-\eta}} \tag{3.2.4}$$

The lifetime utility function of the household is given by:

$$E_t \sum_{j=0}^{\infty} \beta^j \left(d_{t+j} \ln(X_{t+j}) + j_{t+j} \ln(H_{t+j}^c) - \frac{N_{t+j}^{1+\phi}}{1+\phi} \right) \tag{3.2.5}$$

where E_t is the expectation operator conditional on information available at time t, β^j is the discount factor, d_t is the aggregate composite consumption preference shock, H_t^c is the commercial housing, which households lend to the firms, j_t is the preference of holding commercial housing, which can be associated with the change of households' expectations concerning future, N_t represents working hours, ϕ is the inverse of the Frisch elasticity. d_t and j_t follow AR(1) process.

Households maximize their utility function subject to the budget and borrowing constraints.

The budget constraint of the household is represented by the following:

$$X_t + \frac{R_{t-1}B_{t-1}}{P_t^x} = \frac{W_tN_t}{P_t^x} + \frac{Q_tH_{t-1}^c}{P_t^x} + \frac{B_t}{P_t^x} \tag{3.2.6}$$

where B_t denotes one-period nominal risk free bond, W_t is the nominal wage, R_t represents the nominal gross interest rate. So, the left hand side of the constraint represents expenditures, while the right hand side is the income of the households, consisting of the wage, the amounts of the bond and income from lending housing to the firms.

Households also have a borrowing constraint, which limits the amount of the borrowing with the value of commercial housing, its expected price and real interest rate:

$$B_t \leq \frac{mQ_{t+1}P_{t+1}H_t^c}{R_t} \tag{3.2.7}$$

where m denotes the loan-to-value (LTV) ratio.

Rearranging (3.2.6), X_t can be expressed as:

$$X_t = \frac{W_tN_t}{P_t^x} + \frac{Q_tH_{t-1}^c}{P_t^x} + \frac{B_t}{P_t^x} - \frac{R_{t-1}B_{t-1}}{P_t^x} \tag{3.2.8}$$

Inserting (3.2.8) into (3.2.5), the utility function can be expressed as follows:

$$E_t \sum_{t=j}^{\infty} \beta^j \left(d_{t+j} \ln\left(\frac{W_tN_t}{P_t^x} + \frac{Q_tH_{t-1}^c}{P_t^x} + \frac{B_t}{P_t^x} - \frac{R_{t-1}B_{t-1}}{P_t^x} \right) + j_{t+j} \ln(H_{t+j}^c) - \frac{N_{t+j}^{1+\phi}}{1+\phi} \right) \tag{3.2.9}$$

The Lagrangian function of the problem has the following form:

$$\begin{aligned} \underset{\{B_t,N_t,H_t^c\}}{\mathcal{L}} = \beta^t \Bigg(d_{t+j} ln \left(\frac{W_tN_t}{P_t^x} + \frac{Q_tH_{t-1}^c}{P_t^x} + \frac{B_t}{P_t^x} - \frac{R_{t-1}B_{t-1}}{P_t^x} \right) + j_t \ln(H_t^c) - \frac{N_t^{1+\phi}}{1+\phi} \Bigg) + \\ + \lambda_t \left(\frac{mQ_{t+1}P_{t+1}H_t^c}{R_t} - B_t \right) \end{aligned} \tag{3.2.10}$$

First order conditions of the utility maximization problem with respect to B_t, N_t and H_t^c are represented by the following equations:

$$\frac{d_t}{X_tP_t^x} = \frac{\beta d_{t+1}R_t}{X_{t+1}P_{t+1}^x} + \lambda_t \tag{3.2.11}$$

$$\frac{d_t W_t}{X_t P_t^x} = N_t^{\phi} \tag{3.2.12}$$

$$\frac{j_t}{H_t^c} = -\frac{\beta d_{t+1} Q_{t+1}}{X_{t+1} P_{t+1}^x} - \frac{\lambda_t m Q_{t+1} P_{t+1}}{R_t} \tag{3.2.13}$$

(3.2.11) is the Euler equation, which determines the intertemporal consumption allocation, where λ_t is shadow price of borrowing, which shows the additional consumption due to the change in borrowing. The equation (3.2.12) represents labor supply decision or labor-leisure decision. (3.2.13) equality is the housing-consumption decision, which is shows the supply of commercial housing by households.

Assuming, that our variables have the common stochastic trend component, the non-stationary variables can be transformed into stationary form following the balanced growth path approach. For instance, $Y_t = \tilde{Y}_t Z_t$, where $\tilde{Y}_t$ is the cyclical component and Z_t is the trend component.

First order conditions in stationary forms are represented by the set of following equations.

$$\frac{d_t \mu_{t+1}^z}{\tilde{X}_t P_t^x} = \frac{\beta d_{t+1} R_t}{\tilde{X}_{t+1} P_{t+1}^x} + \mu_{t+1}^z \tilde{\lambda}_t \tag{3.2.14}$$

$$\frac{d_t \tilde{W}_t}{\tilde{X}_t P_t^x} = N_t^{\phi} \tag{3.2.15}$$

$$\frac{\mu_{t+1}^z j_t}{\tilde{H}_t^c} = -\frac{\beta d_{t+1} Q_{t+1}}{\tilde{X}_{t+1} P_{t+1}^x} - \frac{\mu_{t+1}^z \tilde{\lambda}_t m Q_{t+1} P_{t+1}}{R_t} \tag{3.2.16}$$

where $\mu_t^z = \frac{z_t}{z_{t-1}}$ denotes the growth rate of labor augmented technology Z_t.

The rest of this section expresses household's equations block in real terms. By raising the aggregate price equation (3.2.4) into the power $1-\eta$ and dividing both sides by $P_t^{1-\eta}$, the relative price of aggregate consumption in terms of CPI gets the following form:

$$\frac{P_t^x}{P_t} = \left((1-\gamma) + \gamma q_t^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{3.2.17}$$

where q_t is the real housing price.

Additionally, multiplying and dividing (3.2.15) and (3.2.16) equations by P_t and substituting $\dfrac{P_t^x}{P_t}$ by its corresponding expression in (3.2.17), first order conditions can be expressed in real terms as follows:

$$\frac{d_t \tilde{w}_t}{\tilde{X}_t [(1-\gamma) + \gamma (q_{t+1})^{1-\eta}]^{\frac{1}{1-\eta}}} = N_t^{\phi} \tag{3.2.18}$$

$$\frac{\mu^z_{t+1} j_t}{\tilde{H}^c_t} = -\frac{\beta d_{t+1} q_{t+1}}{\tilde{X}_{t+1}[(1-\gamma)+\gamma(q_{t+1})^{1-\eta}]^{\frac{1}{1-\eta}}} - \frac{\mu^z_{t+1}\tilde{\lambda}_t m q_{t+1} P^2_{t+1}}{R_t} \tag{3.2.19}$$

3.3 Features of housing market

This section discusses the equilibrium in the housing market, which is incorporated into general equilibrium framework.

Housing stock is hold by the household, who divides it into personal and commercial consumption. The latter is the stock of the housing, that is used as asset or is lent to firms.

How does household decide to consume one additional unit of personal housing or to supply an additional amount of commercial housing? The marginal utility of commercial housing (MU_{h^c}) is the change in total utility resulting from an extra amount of housing stock devoted to commercial housing. The same applies to the marginal utility of personal housing (MU_{h^p}).
Marginal rate of substitution is represented by the ratio of marginal utilities:

$$MRS = \frac{MU_{h^c}}{MU_{h^p}},$$

which indicates the rate at which person is willing to give up some amount of personal housing for an extra unit of commercial housing.

In this set-up, housing stock is constant and the relative price of personal and commercial housing is equal to one. The opportunity cost of maintaining personal housing is the price of the commercial housing. So prices of personal and commercial housing are the same. The optimal allocation of housing stock is established in the point, where marginal utilities intersect, or in other words, the MRS = 1. At the point of intercept, household divides its housing stock into personal and commercial uses.

The marginal utilities from household's lifetime utility function in steady state have the following forms:

$$MU^c_h = \frac{j}{H^c} \tag{3.3.1}$$

$$MU_{h^p} = \frac{\gamma^{\frac{1}{\eta}}(H^p)^{-\frac{1}{\eta}}}{[(1-\gamma)^{\frac{1}{\eta}} C^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}}(H^p)^{\frac{\eta-1}{\eta}}]^{\frac{\eta-1}{\eta}}} \tag{3.3.2}$$

Therefore, the marginal utility of commercial housing depends on preference shock and the quantity of commercial housing. Moreover, marginal utility of personal housing is a function of the share of private housing in overall consumption, the stock of personal housing and the elasticity of substitution between personal housing and non-housing consumption.

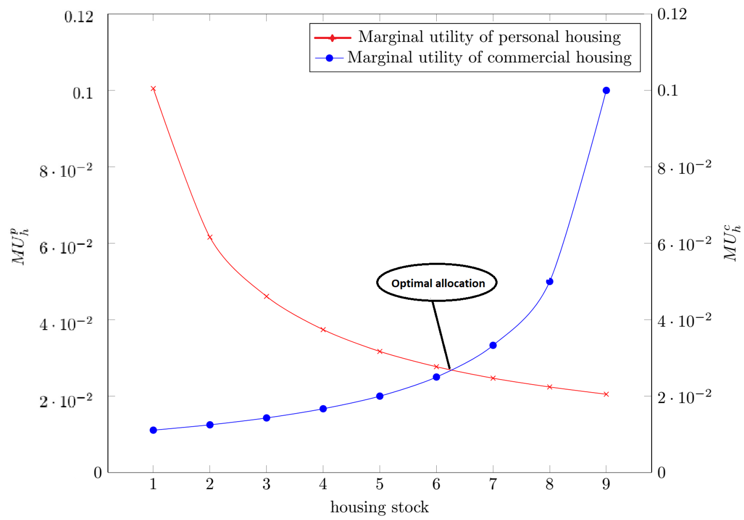

Figure 4: The optimal allocation of personal and commercial housing

Writing the first order conditions (3.2.14), (3.2.15) and (3.2.16) in steady state, and doing some transformations, we get the marginal utility of commercial housing depending on housing price:

$$MU_h^c = \frac{j}{H^c} = \frac{q(\beta R(m-1) - m\mu^z)N^\phi}{R\mu^z w} \tag{3.3.3}$$

Thus, a positive preference shock (figure 5) leads to the increase in marginal utility of commercial housing. As a result of the shock, household lends out more of its disposable housing stock and uses less for personal consumption purposes. Furthermore, the correlation between housing prices, preference parameter and marginal utility is positive.

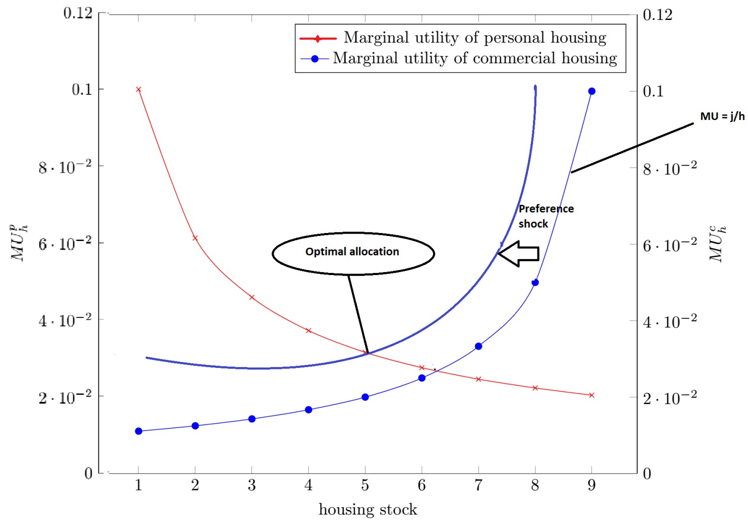

Figure 5: The impact of preference shock to households' decision

3.4 Firms

Final output is represented as an aggregate of all intermediate goods and has a form of CES production function:

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \tag{3.4.1}$$

where ϵ is the elasticity of substitution between varieties of goods.

Solving the expenditures minimization problem for final good producer, we get demand function for j^{th} intermediate good of the following form:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon} Y_t \tag{3.4.2}$$

Following Calvo (1982), paper assumes, that only $(1 - \theta)$ fraction of firms can change their prices in each period. As θ characterizes price stickiness, the aggregate price level evolves as follows:

$$P_t = (\theta P_{t-1}^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon})^{\frac{1}{1-\epsilon}} \tag{3.4.3}$$

where P_t^* is the optimal price, which firms set in period t. Raising to the power of $1-\epsilon$ and dividing both sides by $P_{t-1}^{1-\epsilon}$, the gross inflation dynamics can be represented by the following equation:

$$\Pi_t^{1-\epsilon} = \theta + (1-\theta)\left(\frac{P_t^\star}{P_{t-1}}\right)^{1-\epsilon} \tag{3.4.4}$$

There is a continuum of intermediate good producers, which produce differentiate goods, using the same constant returns to scale Cobb-Douglas production function.

$$Y_t(j) = A_t N(j)_t^\alpha Z_t^\alpha (H_{t-1}^c(j))^{1-\alpha} \tag{3.4.5}$$

where A_t is the cyclical technological process and Z_t is the labor augmenting productivity.

In the optimal allocation, all the firms use the same quantity of labor and housing services.

Intermediate good producer maximizes its profit:

$$P_t A_t N_t^\alpha Z_t^\alpha (H_{t-1}^c)^{1-\alpha} - W_t N_t - Q_t H_{t-1}^c \rightarrow max \tag{3.4.6}$$

Solution of this problem gives demand functions for labor and commercial housing of the forms:

$$\frac{W_t}{P_t} = \alpha \frac{Y_t}{N_t} \tag{3.4.7}$$

$$\frac{Q_t}{P_t} = (1-\alpha)\frac{Y_t}{H_{t-1}^c} \tag{3.4.8}$$

Substituting (3.4.7) into (3.4.8), we get the equation for optimal allocation of resources.

$$\frac{w_t}{q_t} = \frac{\alpha}{1-\alpha}\frac{H_{t-1}^c}{N_t \epsilon_t^q} \tag{3.4.9}$$

The equation shows, that the relative factor input is a negatively dependent on their relative prices. When the relative price of housing and labor rises, firms replace housing with labor.

We add ϵ_t^q shock in the optimal allocation of resources, which shows firms demand for commercial housing. The inclusion of this shock into the model enables us to separate firms demand from household's preference over housing.

In stationary representation, the optimal allocation of resources gets the following form:

$$\frac{\mu_t^z \tilde{w}_t}{q_t} = \frac{\alpha}{1-\alpha}\frac{\tilde{H}_{t-1}^c}{N_t \epsilon_t^q} \tag{3.4.10}$$

Real marginal cost is a function of factor prices used in the production process, as well as temporary productivity:

$$mc_t = \frac{\tilde{w}_t^{\alpha} q_t^{1-\alpha}}{a_t \alpha^{\alpha}(1-\alpha)^{1-\alpha}} \tag{3.4.11}$$

Intermediate good producer maximizes its profit by setting the optimal price in a way that it will stuck to that price in the future.

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t(\Lambda_{t,k} P_t^* Y_{t+k} - MC_{t+k} Y_{t+k}) \tag{3.4.12}$$

s.t.

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} Y_t \tag{3.4.13}$$

where $\Lambda_{t,k} = \beta^k (Y_{t+k}/Y_t)$ is the stochastic discount factor, MC_{t+k} is the nominal marginal cost.

After some algebra, the first order condition with respect to P_t^* gets the following form:

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{\sum_{k=0}^{\infty} \theta^k \beta^k Y_t P_{t+k}^{\epsilon} MC_{t+k}}{\sum_{k=0}^{\infty} \theta^k \beta^k Y_t P_{t+k}^{\epsilon-1}} \tag{3.4.14}$$

Log-linearizing the equation (3.4.14) around steady state and using the definition in (3.4.4), we get the standard forward-looking Phillips curve of the form.

$$\pi_t = \beta \pi_{t+1} + \lambda \hat{m} c_t + e_t^{\pi} \tag{3.4.15}$$

where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

Therefore, the inflation depends on the inflation expectations and real marginal cost.

3.5 Monetary Policy

Central bank operates through standard Taylor rule with backward-looking component of the following form.

$$R_t = \rho_R R_{t-1} + (1-\rho_R)(\phi_\pi \pi_{t+1} + \phi_y y_t) + \epsilon_t^r \tag{3.5.1}$$

where ρ_R is the persistence in interest rate, ϕ_π and ϕ_y are coefficients of responses to inflation expectations and output. ϵ_t^r is a monetary policy shock.

3.6 Market clearing conditions

The market clearing requires that output equals to consumption.

$$Y_t = C_t \tag{3.6.1}$$

The aggregate stock of the housing is constant over time and is given by the following equation. The assumption of constant housing stock is supported by the figure 11 in Appendix B, which presents the cumulative change in housing stock and GDP in Armenia. As one can see, housing stock has been increased by 45% during last two decades, which is not so much and supports the assumption of constant housing stock in the model.

$$H = H_t^p + H_t^c \tag{3.6.2}$$

Appendix A presents all the model equations in log-linear form.

4 Estimation

The model is estimated using Bayesian techniques, which is widely discussed in Canova (2007) and Fernandez-Villaverde et al. (2016). In the first step, the likelihood function is computed using a Kalman filter. Secondly, prior distributions are given to the estimated parameters. The commonly used approach to get the posterior distributions is the Metropolis-Hastings (MH) algorithm, which belongs to the group of Markov Chain Monte Carlo (MCMC) algorithms and used to generate the posterior means and distributions of parameters.

There are seven exogenous processes driving the dynamics of the model.

- Permanent productivity shock

$$\mu_t^z = \rho_{\mu^z}\mu_{t-1}^z + \epsilon_t^z$$

- Temporary productivity shock

$$a_t = \rho_a a_{t-1} + \epsilon_t^a$$

- Housing preference shock

$$j_t = \rho_j j_{t-1} + \epsilon_t^j$$

- Housing demand shock

$$e_t^q = \rho_{e^q} e_{t-1}^q + \epsilon_t^q$$

- Demand shock or preference for aggregate consumption

$$e_t^y = \rho_{e^y} e_{t-1}^y + \epsilon_t^y$$

- Price-mark-up shock

$$e_t^\pi = \rho_{e^\pi} e_{t-1}^\pi + \epsilon_t^\pi$$

- Monetary policy shock

$$R_t = \rho_r R_{t-1} + (1-\rho_r)(\phi_\pi \pi_{t+1} + \phi_y y_t) + \epsilon_t^r$$

4.1 Data

For estimating theoretical model, 6 observable variables are used. Data of Armenian GDP growth, inflation, interest rate, real wage and real housing price growth cover the period from the second quarter of 2002 to the third quarter of 2019. The interest rate is the interbank repo rate, and the housing price is the Yerevan real estate prices in real terms (dividing by CPI). As there is no aggregate data of Armenian real estate prices, we take only Yerevan prices, which are representative for our analysis. Moreover, Yerevan real estate prices are the main drivers of regional cities prices [1]. All data (except interest rate) are seasonally adjusted and are expressed in gross growth terms. Permanent productivity growth is used as an observable for the estimation, which is estimated using the model developed in Igityan and Manukyan (2020). Graphical representation of model input data is captured in figure 24 in Appendix C. As the observable variables are in gross terms and have the same permanent growth trend, data are linked to the model as follows:

- GDP growth

$$Y_t^{obs} = y_t - y_{t-1} + \mu_t^z + Y_{ss}^{obs}$$

- Inflation

$$\pi_t^{obs} = \pi_t + \pi_{ss}^{obs}$$

- Interest rate

$$r_t^{obs} = r_t + r_{ss}^{obs}$$

- Housing price

$$q_t^{obs} = q_t - q_{t-1} + q_{ss}^{obs}$$

- Wage

$$w_t^{obs} = w_t - w_{t-1} + \mu_t^z + w_{ss}^{obs}$$

- Permanent productivity growth

$$\mu_t^{z,obs} = \mu_t^z + \mu_{ss}^{z,obs}$$

Steady state values in measurement equations represent mean values of observable variables.

4.2 Calibration

As commonly used in DSGE estimation process, some parameters are calibrated to match important features observed in data. This technique leads to the more efficient estimation of non-calibrated parameters.

[1] See Appendix B, Table 6. Granger causality tests of Yerevan prices and regional cities prices.

Param.	Descrip.	Calib.
β	Discount factor	0.99
m	Loan-to-value ratio	0.7
η_b	Share of borrowing in output	0.2
α	Share of labor in prod. function	0.8
η	Elasticity of substitution between housing and non-housing goods	1.5
γ	Share of personal housing in consumption	0.2
γ_h	Share of commercial housing in total housing stock	0.25

Table 2: Calibrated Parameters

The LTV is the ratio of loans and the value of collateral, which fluctuates between 0.68 and 0.74 from 2012 to 2018. Share of borrowing in total output is the share of mortgages, which are approximately 20% in GDP. Share of capital in production function is about 0.5 (Igityan (2016)) and about a half of capital in Armenian is the commercial housing. That's why the share of labor is calibrated to 0.8. The elasticity of substitution between durable and non-durable goods in the literature is calibrated from 1 to 1.5 (Notarpietro, Siviero (2013)), which we use for the η parameter. Having no direct estimate of the share of commercial housing in total housing stock, parameter γ_h is calibrated to 0.25. The value of the parameter has no significant effect on estimation results, but having this parameter constant commercial housing cycle can be generated through preference shock. Table 2 summarizes the calibration.

4.3 Prior Distribution

Parameters lying in the interval from 0 to 1 have a beta distribution. Gamma distribution is for parameters, bounded to be positive. Standard errors of shocks follow inverse gamma distribution. The labor supply elasticity coefficient has a gamma distribution with 1.5 mean and 0.3 standard deviation. The mean of price stickiness parameter is 0.6 with standard deviation 0.1 and follows beta distribution. Persistence of interest rate has a beta distribution with 0.6 mean and 0.15 standard deviation. Reaction coefficients to inflation expectations ϕ_π and output ϕ_y follow gamma distribution with prior means 1.5 and and 0.5, respectively. Following Smets and Wouters (2007), the persistence parameters of $AR(1)$ processes follow beta distribution, with the same 0.6 mean and 0.15 standard deviation.

The mean of temporary productivity shock's standard error is set to 0.025. However, prior mean of permanent productivity shock has a value of 0.015. We give 0.35 mean for housing preference shock's standard error, 0.003 for commercial housing demand, 0.007 for aggregate consumption preference and 0.015 for monetary policy and mark-up shocks' standard errors. All the standard errors of shocks follow inverse gamma distribution with infinite standard deviation.

The calibrated priors are generally used values in DSGE literature (Gali (2015), Iacoviello (2005), Notarpietro, Siviero (2013)).

4.4 Posterior Distribution

Table 3 and 4 present mode and posterior means of the estimated structural parameters and standard deviations of shocks. They are obtained by running two parallel chains of the Metropolis-Hastings algorithm. Number of each draw is 200000, and acceptance rates are respectively 24.75% and 23.67%. Multivariate convergence diagnostics in shown in Figure 29 in Appendix C, indicating the stability of chains after 50-60 thousands draws.

		Prior Distribution			Posterior Distribution		
	Description	Distr.	Mean	S.D.	Mode	Mean	S.D.
ϕ	Labor supply elasticity	Gamma	1.5	0.3	1.96	2.069	0.252
θ	Price Stickiness	Beta	0.6	0.1	0.964	0.936	0.0085
ϕ_π	Response of interest rate to inflation expectations	Gamma	1.5	0.15	1.506	1.514	0.1509
ϕ_y	Response of interest rate to output	Gamma	0.5	0.15	0.512	0.533	0.1324
ρ_r	Persistence of policy rate	Beta	0.6	0.15	0.828	0.828	0.0392
ρ_a	Persistence of temporary prod.	Beta	0.6	0.15	0.603	0.565	0.0869
ρ_j	Persistence of commercial housing preference	Beta	0.6	0.15	0.477	0.482	0.0157
ρ_q	Persistence of commercial housing demand	Beta	0.6	0.15	0.954	0.947	0.0124
ρ_y	Persistence of aggregate consumption preference	Beta	0.6	0.15	0.521	0.58	0.022
ρ_π	Persistence of mark-up	Beta	0.6	0.15	0.316	0.309	0.0559
ρ_z	Persistence of permanent prod.	Beta	0.6	0.15	0.887	0.88	0.0364

Table 3: Priors and Posteriors of Estimated Parameters

		Prior Distribution			Posterior Distribution	
Shocks	Descrip.	Distr.	Mean	S.D.	Mean	Mode
ϵ_t^a	Temporary prod. shock	Inverse Gamma	0.025	Inf.	0.038	0.029
ϵ_t^r	Monetary policy shock	Inverse Gamma	0.015	Inf.	0.011	0.010
ϵ_t^j	Housing preference shock	Inverse Gamma	0.350	Inf.	0.901	0.907
ϵ_t^q	Demand for commercial housing shock	Inverse Gamma	0.003	Inf.	0.059	0.052
ϵ_t^z	Permanent prod. shock	Inverse Gamma	0.015	Inf.	0.005	0.005
ϵ_t^y	Aggregate consumption preference shock	Inverse Gamma	0.007	Inf.	0.002	0.053
ϵ_t^π	Mark-up shock	Inverse Gamma	0.015	Inf.	0.010	0.01

Table 4: Priors and Posteriors of Estimated Shocks

Foundation of the mode is presented in figure 25-26 in Appendix C. Posterior means of most of parameters are different from their prior counterparts, indicating the informative nature of data used in the estimation process. Posterior distributions are captured in figures 27-28 in the Appendix C. The estimated mean of labor supply elasticity is higher than its prior mean, which means that households are less sensitive to real wage changes. The posterior mean of Calvo price stickiness parameter θ is 0.936, which corresponds to the price duration of about 3.9 years. Such a high estimated value is a result of the huge variation of inflation due to mark-up shock, which makes inflation to be less sensitive with respect to marginal costs. Interest rate is more smooth compared to the prior belief. Posterior estimated parameters of interest rate reaction to inflation expectations and output are very close to their prior means. Estimation indicates, that the most persistent shock is firms' demand for commercial housing. Posterior estimated persistence of permanent productivity is 0.88. Estimated value of persistence in mark-up shock is 0.31, which is in line with its very flexible nature. The posterior estimated value of the persistence in commercial housing shock is 0.48. Estimated mean of standard deviation component is very high 0.9, which indicate, that asset prices are quite volatile.

5 Properties of the Model

5.1 Impulse Response Functions

This section analyzes impulse response functions of some important shocks driving the dynamics of the model.

Figure 6 presents the impulse response functions to the 1% positive commercial housing preference shock, which is the main driver of the commercial housing cycle. As a result, households lend out more of the existing housing stock and decline the personal consumption of housing. As shown in section 3.3, there is a positive correlation between commercial housing preference and housing price. The increase both in commercial housing and its price leads to the increase of borrowing, which accelerates the consumption of non-housing goods. On the supply side, firms hire more labor to produce additional goods and services to provide an increase demand. This puts pressures on wages and together with high housing prices increases real marginal cost. High marginal cost creates inflation. Monetary authority increases interest rate to stabilize the inflation expectations and growing economy.

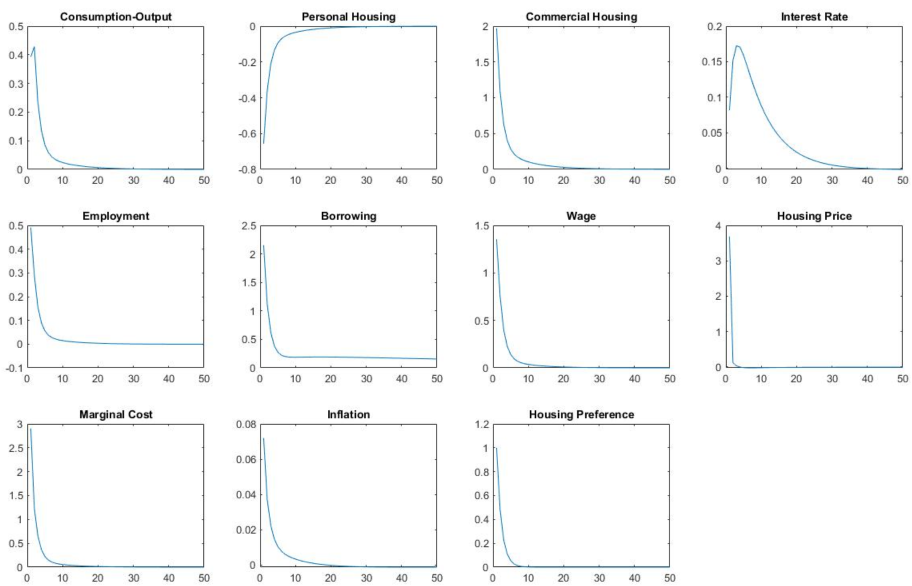

Figure 6: Impulse Responses to Commercial Housing Preference Shock

Figure 7 shows the response of the estimated model variables to the 1% of positive shock to demand for housing. The later increases housing price, forcing households to increase the lending of commercial housing. The increase of collateral results in a rise of borrowing and consumption. Similar to the previous shock's response, firms hire additional labor to produce more consumption goods. As a result of growing demand for labor, wages increase leading to the more higher marginal cost. The latter results in an increase of inflation expectations and central bank reacts by increasing the interest rate.

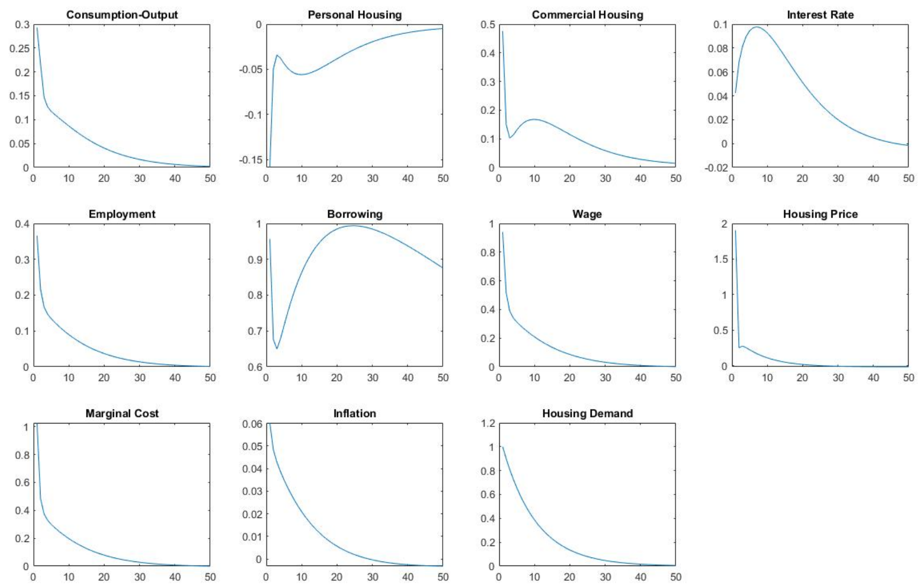

Figure 7: Impulse Responses to Commercial Housing Demand Shock

Figure 8 captures the reaction of the model economy to the positive monetary policy shock. Higher interest rate decreases aggregate demand. Firms react to tight monetary policy by decreasing demand for labor and commercial housing. Household are forced to use much of the housing stock for personal consumption. The presence of user cost of capital channel, which is the unit cost for the use of a capital asset for one period, leads to the increase of housing price at initial period of simulation (as interest rate is the opportunity cost for using housing), but it declines during next periods mostly due to domination of negative demand. But the cumulative response of housing price to contractionary monetary policy shock is negative. The impact of monetary policy to inflation is through the channel of decreased wage and housing price.

Figure 9-10 present cumulative responses of inflation and GDP change to commercial housing preference and demand shocks. Graphs capture also time-varying pass-through of these shocks. The impact of inflation increases to 0.05 and stabilizes at 0.045 in the long run in a response to preference shock. Pass-through reaches to 0.12 and stabilizes at this point after 30 periods when the commercial housing demand shock hits the economy.

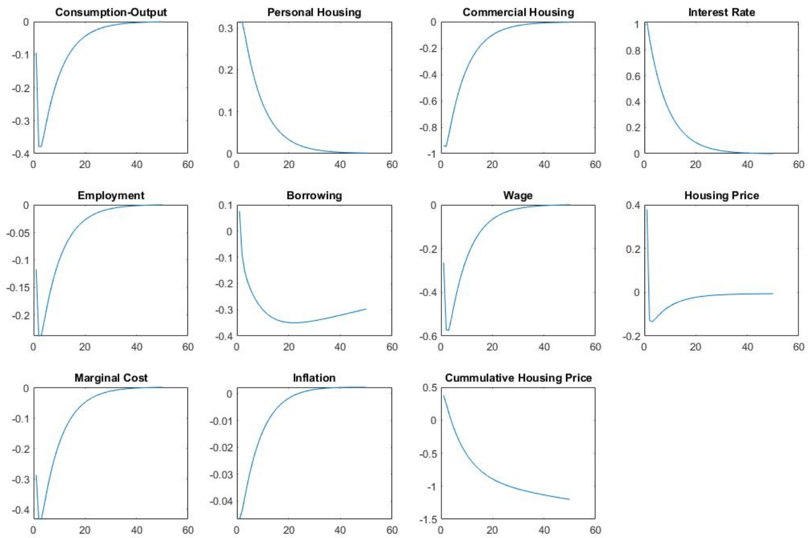

Figure 8: Impulse Responses to Monetary Policy Shock

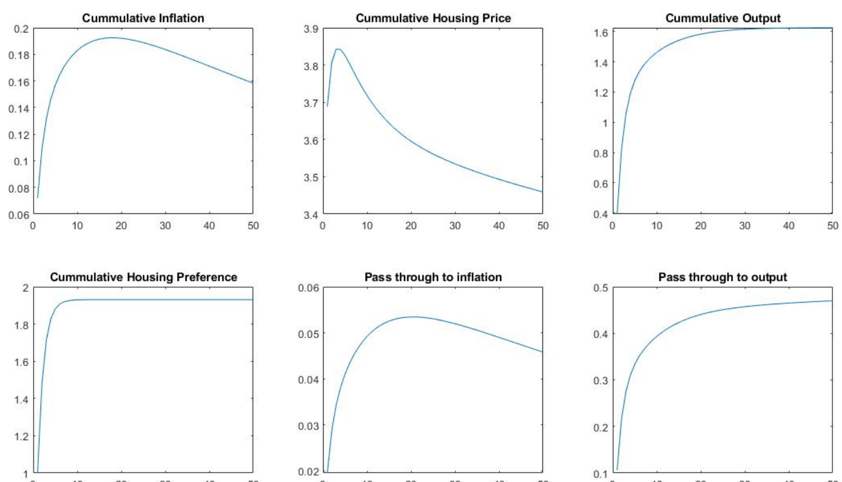

Figure 9: Cumulative Responses to Commercial Housing Preference Shock

Table 5 compares DSGE results with empirical estimates. According to the results, theoretical model is able to explain empirical results. Pass-through indicates, that 1% change in housing prices leads to 0.03 - 0.118% increase in

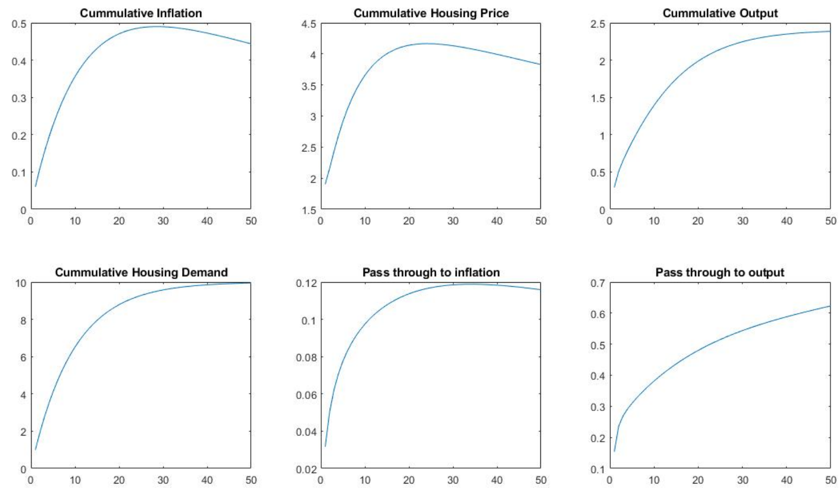

Figure 10: Cumulative Responses to Housing Demand Shock

inflation in the long-run. Moreover, the impact on GDP growth is higher and lies in the interval of 0.21 - 0.61%.

Table 5: Pass-through of estimated VAR and DSGE models

	VAR (demean)	VAR (HP)	DSGE	
	Housing price shock	Housing price shock	Housing preference shock	Housing demand shock
GDP	0.21	0.3	0.465	0.61
CPI	0.03	0.09	0.045	0.118

5.2 Estimated Historical Shocks and Smoothed Historical Variables

Figure 30 in Appendix C shows estimated historical shocks. Shock of the commercial housing preference was higher between 2002 and 2006. However, it started to decline and reached its lowest level in the first quarter of 2011. From 2012 commercial housing preference shock have increased significantly. Furthermore, due to the existence of some factors it rocketed after 2016 and hit its historical peak at the end of the estimation period. This dramatic increase in households' preferences to hold housing can be a result of the amendments of income tax law in 2015, which enables them to use income tax to cover interest payments on mortgages (Appendix B, figure 15). Armenian velvet revolution in the second quarter of the 2018 resulted in an optimistic expectations of households[2] and stimulates them to hold housing as an asset for commercial purposes, which further facilitates the increase in preference.

On the other hand, model generated demand shock of the commercial housing shows mostly the opposite signs to preference shock. The reason of this is the fact, that the main cyclical driver of the model is commercial preference shock, which also generates borrowing cycle and drives housing prices. As a result, higher prices of commercial housing leads to the decrease in demand by firms. Despite the negative demand shock in last periods, estimated historical shocks indicate the tight housing market in 2018-2019 in Armenia. Model estimates the permanent productivity shock in a way to generate the input data on permanent productivity. Positive huge monetary policy shock in the fourth quarter of 2014 and in the first quarter of 2015 is a result of strong reaction of central bank to high inflation expectations. Model estimated demand shock is highly correlated with the Armenian output gap estimated with different methods.

Model generated variables are captured in figure 31 in Appendix C. As one can see in the figure, commercial housing was high before financial crisis. It declined starting from 2006 and remained below the historical mean until 2015. Estimated personal housing behaves oppositely as there is a constant assumption of the housing stock. Model estimated debt is very similar to the actual debt observed in Armenia, indicating that the incorporation of borrowing constraint and commercial housing into a simple DSGE framework is able to generate the debt cycle. Housing demand as a variable is very smooth compared to its shock's counterpart. Demand of commercial housing can be interpreted as a housing cycle, which moves oppositely to housing preference.

5.3 Historical Decomposition

Historical shock decomposition of personal and commercial housing, as well as inflation are stored in figures 32-34 in Appendix C. Decomposition period starts at the second quarter of 2002 and ends at the third quarter of 2019. The main driver of housing is commercial preference shock. Monetary policy has some contribution in determination of housing stock. In recent years, the nature of expansionary monetary policy has been positive effect on commercial housing. Permanent productivity shock had a positive contribution to commercial housing before 2008 financial crisis. The permanent decrease in productivity after the crisis results in a negative contribution of permanent productivity on commercial housing.

During the first boom in Armenian housing market construction increased and remained high until the 2008 crisis, which was mainly due to the increase

[2] See: https://www.iri.org/sites/default/files/2018.11.23_armenia_poll.pdf

of demand for personal housing. In this period commercial housing preference declined to some extent and the motive of holding the personal housing was dominated over commercial housing preference. During the first boom Armenian mortgage market was poorly developed and the share of mortgages in GDP was low until 2008. Over the same period the share of remittances in GDP was high, which indicates, that the first boom was mainly driven by remittances (Appendix B, figure 14). Second boom, started from 2015 was driven by commercial housing. This upswing in real estate market was mainly driven by preference shock, which is reflected also in the increase of construction permits (Appendix B, figure 16) and mortgages.

Figure 34 shows the decomposition of inflation in Armenia. As one can see, inflation is mostly driven by mark-up shocks, because headline inflation is very volatile in Armenia. Model estimated net effects of housing market related shocks on inflation was almost zero from 2011 to 2015. In 2019, housing market has around 0.5% positive effect on inflation due to high positive commercial housing preference shock.

6 Conclusion

In this paper we empirically find out the importance of collateral constraint for Armenian economy, build VAR model and estimate the impact of housing prices on inflation and economic growth. Pass-through results show, that 1% increase in real housing prices leads to the increase in inflation by around 0.03-0.09% in the long run.

Then we develop simple model of housing decision and incorporates into DSGE framework. Households divide their housing stock into personal consumption and commercial use. Housing preference shock together with borrowing constraint allows to generate debt and housing cycles. The model is estimated with Bayesian technique using Armenian data. Posterior distributions of model parameters are got by running Metropolis-Hastings algorithm. Diagnostic measures of the estimation shows, that the quality of estimation is quite good.

The developed theoretical model is able to explain empirically observed results, which confirm pass-through results. Analysis estimates, that 1% real housing prices increase creates 0.03-0.12% inflation in the log run, while its contribution to GDP growth is around 0.2-0.6%. Finally, household's preference of commercial housing in its historical maximum at the last periods of the sample and there are 0.5% inflationary pressures from housing market.

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7 Appendix

7.1 Appendix A. The Log-Linearized Model

The equations of the log - linearized model are represented by the following:

$$\hat{c}_t = \gamma\eta\hat{q} + \hat{x}_t \tag{7.1.1}$$

$$\begin{aligned}\mu^{z,ss}(\hat{\mu}^z_{t+1} - \hat{x}_t - \hat{p}^x_t + \hat{e}^y_t =& \beta r^{ss}(\hat{r}_t - \hat{x}_{t+1} - \hat{p}^x_{t+1} + \hat{e}^y_{t+1}) + \\ &+ (\mu^{z,ss} - \beta r^{ss})(\hat{\lambda}_t + \mu^z_{t+1})\end{aligned} \tag{7.1.2}$$

$$\hat{w}_t - \hat{x}_t - \gamma\hat{q}_t = \phi\hat{n}_t - \hat{e}^y_t \tag{7.1.3}$$

$$\begin{aligned}&\left(\beta + \frac{(\mu^{z,ss} - \beta r^{ss})mp^{ss}}{r^{ss}}\right)(\hat{j}_t + \hat{\mu}^z_{t+1} - \hat{h}^c_t) = \beta((1-\gamma)\hat{q}_{t+1} - \hat{x}_{t+1} + \hat{e}^y_{t+1}) + \\ &+ \frac{(\mu^{z,ss} - \beta r^{ss})mp^{ss}}{r^{ss}}(\hat{\lambda}_t + \hat{q}_{t+1} + 2\hat{p}_{t+1} + \hat{\mu}^z_{t+1} - \hat{r}_t)\end{aligned} \tag{7.1.4}$$

$$\hat{p}^x_t = \hat{p}_t + \gamma\hat{q}_t \tag{7.1.5}$$

$$\hat{y}_t = \hat{a}_t + \alpha\hat{n}_t + (1-\alpha)\hat{h}^c_{t-1} - (1-\alpha)\hat{\mu}^z_t \tag{7.1.6}$$

$$\hat{mc}_t = \alpha\hat{w}_t + (1-\alpha)\hat{q}_t - \hat{a}_t \tag{7.1.7}$$

$$\hat{q}_t - \hat{w}_t = \hat{\mu}^z_t - \hat{h}^c_{t-1} + \hat{n}_t - \hat{e}^q_t \tag{7.1.8}$$

$$\hat{b}_t = \hat{q}_{t+1} + \hat{h}^c_t + \hat{p}_{t+1} + \hat{\pi}_{t+1} - \hat{r}_t \tag{7.1.9}$$

$$(1+\eta_b-\eta_b r^{ss})\hat{x}_t - \eta_b r^{ss}\hat{\mu}_z = \eta_b(\hat{b}_t - \gamma\hat{q}_t) - \eta_b r^{ss}(\hat{r}_{t-1} + \hat{b}_{t-1} - \hat{\pi}_t - \gamma\hat{q}_t) + \hat{y}_t - \gamma\hat{q}_t \tag{7.1.10}$$

$$(1-\gamma_h)\hat{h}^p_t + \gamma_h\hat{h}^c_t = 0 \tag{7.1.11}$$

$$p_t = p_{t-1} + \pi_t \tag{7.1.12}$$

$$\hat{y}_t = \hat{c}_t \tag{7.1.13}$$

$$\pi_t = \beta\pi_{t+1} + \lambda\hat{mc}_t + e^\pi_t \tag{7.1.14}$$

$$R_t = \rho_r R_{t-1} + (1-\rho_r)(\phi_\pi \pi_{t+1} + \phi_y \hat{y}_t) + \epsilon_t^r \tag{7.1.15}$$

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{7.1.16}$$

$$j_t = \rho_j j_{t-1} + \epsilon_t^j \tag{7.1.17}$$

$$e_t^q = \rho_{e^q} e_{t-1}^q + \epsilon_t^q \tag{7.1.18}$$

$$\mu_t^z = \rho_z \mu_{t-1}^z + \epsilon_t^z \tag{7.1.19}$$

$$e_t^y = \rho_{e^y} e_{t-1}^y + \epsilon_t^y \tag{7.1.20}$$

$$e_t^\pi = \rho_{e^\pi} e_{t-1}^\pi + \epsilon_t^\pi \tag{7.1.21}$$

7.2 Appendix B. Cumulative Indexes of Armenian GDP and Housing Stock

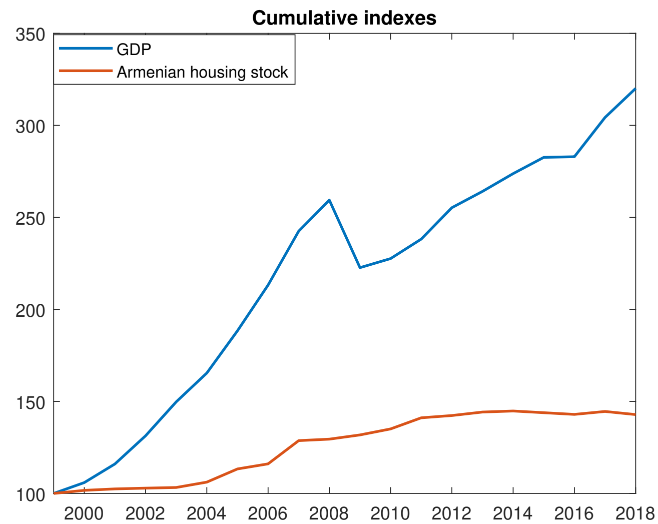

Figure 11: Cumulative Indexes of Armenian GDP and Housing Stock

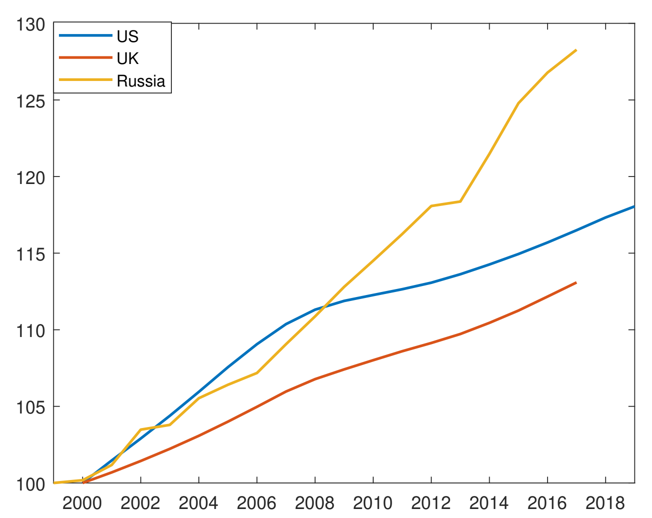

Figure 12: Cumulative Indexes of Housing Stock in different countries

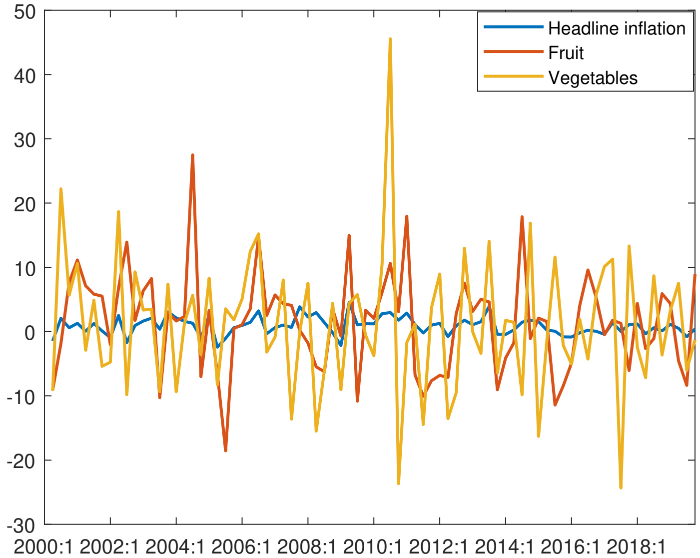

Figure 13: Seasonally adjusted Q/Q headline inflation and seasonal food inflation

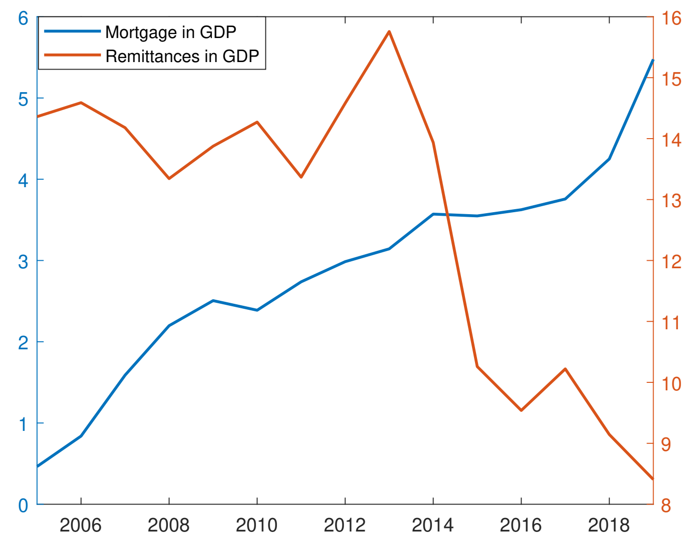

Figure 14: Mortgage in GDP combined with remittances in GDP

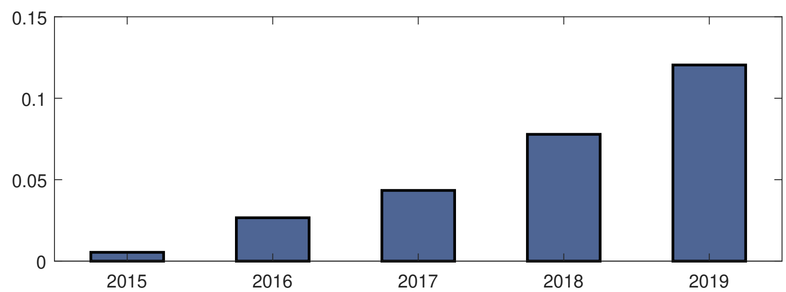

Figure 15: Repayments from government budget to households for covering interest payments on mortgages in percent of nominal GDP [3]

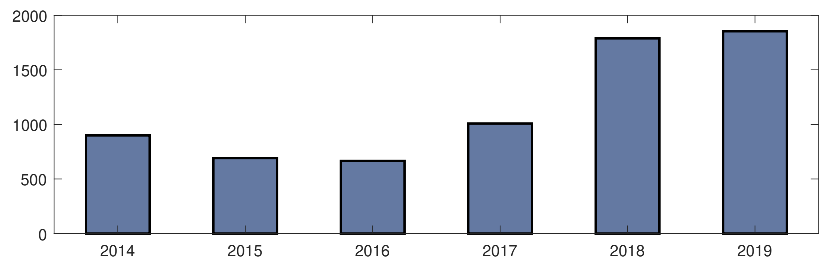

Figure 16: Construction permits [4]

[3] Source of data is the State Revenue Committee of the Republic of Armenia
[4] Department of Urban Development and Land Control of Yerevan Municipality.

Table 6: Granger causality test

Yerevan → Ashtarak	Yerevan → Aparan	Yerevan → Talin	Yerevan → Artashat
1.40370 (0.2480)	0.44899 (0.6389)	3.24097 (0.0411)	3.33381 (0.0376)
Yerevan → Masis	Yerevan → Vedi	Yerevan → Ararat	Yerevan → Vagharshapat
7.25575 (0.0009)	5.79974 (0.0035)	2.89586 (0.0575)	4.52467 (0.0119)
Yerevan → Armavir	Yerevan → Metsamor	Yerevan → Sevan	Yerevan → Gavar
9.22989 (0.0001)	0.81501 (0.4440)	3.19034 (0.0432)	5.15480 (0.0065)
Yerevan → Martuni	Yerevan → Vardenis	Yerevan → Vanadzor	Yerevan → Stepanavan
1.69197 (0.1867)	3.79332 (0.0241)	7.97299 (0.0005)	2.79224 (0.0636)
Yerevan→ Alaverdi	Yerevan → Spitak	Yerevan → Tashir	Yerevan → Abovyan
10.6675 (4.E-05)	1.53893 (0.2170)	4.83141 (0.0089)	3.21056 (0.0423)
Yerevan → Yeghvard	Yerevan → Hrazdan	Yerevan → Tsaghkadzor	Yerevan → Charencavan
5.03016 (0.0074)	15.3465 (6.E-07)	1.46164 (0.2342)	7.08977 (0.0011)
Yerevan → Gyumri	Yerevan → Artik	Yerevan → Goris	Yerevan → Kapan
9.03134 (0.0002)	6.60131 (0.0017)	1.47020 (0.2323)	9.90476 (8.E-05)
Yerevan → Sisian	Yerevan → Qajaran	Yerevan → Vayk	Yerevan → Yeghegnadzor
3.38459 (0.0358)	2.82584 (0.0616)	6.48193 (0.0019)	1.22096 (0.2971)
Yerevan → Jermuk	Yerevan → Dilijan	Yerevan → Ijevan	Yerevan → Berd
4.33231 (0.0143)	8.08540 (0.0004)	3.34549 (0.0371)	0.44451 (0.6417)

Table 7: Granger Causality tests

$\Delta Q \rightarrow \Delta GDP$	$\Delta Q \rightarrow \Delta CPI$	$\Delta Q \rightarrow \Delta Credit$	$\Delta Q \rightarrow \Delta R$
1.87	0.69	2.4	1.07
(0.13)	(0.59)	(0.06)	(0.38)
$\Delta Q \rightarrow \Delta C\_R$	$\Delta Q \rightarrow \Delta Inv$	$\Delta Q \rightarrow \Delta Cnstr$	$\Delta Q \rightarrow \Delta Mortgage$
0.76	1.57	3.26	3.35
(0.55)	(0.196)	(0.018)	(0.0272)
$\Delta GDP \rightarrow \Delta Q$	$\Delta CPI \rightarrow \Delta Q$	$\Delta Credit \rightarrow \Delta Q$	$\Delta R \rightarrow \Delta Q$
2.89	4.45	1.53	0.78
(0.03)	(0.003)	(0.2)	(0.55)
$\Delta C\_R \rightarrow \Delta Q$	$\Delta Inv \rightarrow \Delta Q$	$\Delta Cnstr \rightarrow \Delta Q$	$\Delta Mortgage \rightarrow \Delta Q$
1.157	3.15	3.157	1.049
(0.34)	(0.02)	(0.02)	(0.38)

Table 8: Correlation table of year on year growth rates

	House price	GDP	CPI	Credit	IR	C_R	INV	Cnstr
House price	1.000000	0.702290	0.065309	0.269362	-0.257583	0.493889	0.621331	0.785766
GDP	0.702290	1.000000	0.017232	0.349262	-0.075803	0.652729	0.783796	0.907686
CPI	0.065309	0.017232	1.000000	0.138820	0.271708	0.041154	0.112173	0.104595
Credit	0.269362	0.349262	0.138820	1.000000	0.341110	0.488829	0.260055	0.281402
IR	-0.257583	-0.075803	0.271708	0.341110	1.000000	-0.103081	-0.092445	-0.105933
C_R	0.493889	0.652729	0.041154	0.488829	-0.103081	1.000000	0.546827	0.597733
Cnstr	0.785766	0.907686	0.104595	0.281402	-0.105933	0.597733	0.796095	1.000000

Table 9: Correlation table of quarter on quarter growth rates

	House price	GDP	CPI	Credit	IR	C_R	Mortgage	Cnstr
House price	1.000000	0.238622	-0.161068	0.182141	-0.005652	0.110212	0.228791	0.244104
GDP	0.238622	1.000000	0.015022	0.223589	-0.034808	0.378885	0.500791	0.722093
CPI	-0.161068	0.015022	1.000000	0.100471	0.113499	-0.034577	0.146020	0.181079
Credit	0.182141	0.223589	0.100471	1.000000	0.255884	0.279511	0.172068	0.243475
IR	-0.005652	-0.034808	0.113499	0.255884	1.000000	0.024595	-0.059054	-0.066205
C_R	0.110212	0.378885	-0.034577	0.279511	0.024595	1.000000	-0.033505	0.224907
Mortgage	0.570255	0.370697	0.143844	0.867857	-0.466760	0.318971	1.000000	0.334788
Cnstr	0.244104	0.722093	0.181079	0.243475	-0.066205	0.224907	0.462683	1.000000

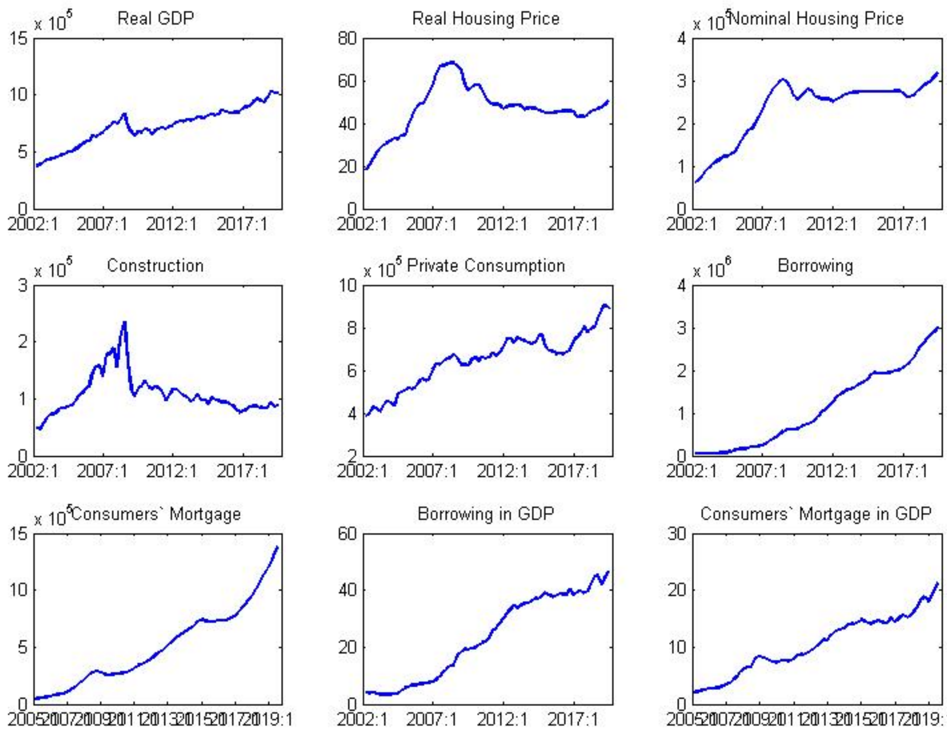

Figure 17: The dynamics of housing prices and the main macroeconomic variables

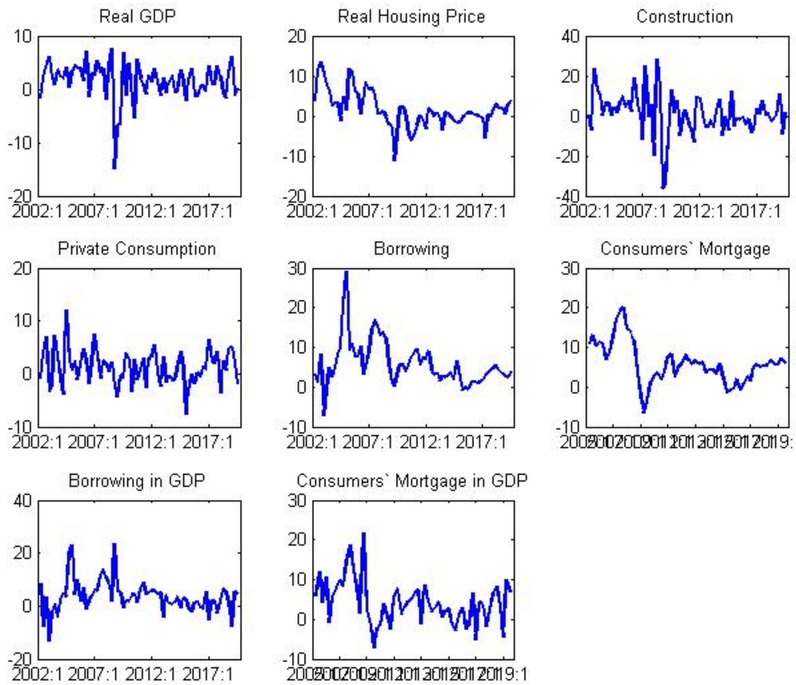

Figure 18: Growth rates of variables

7.3 Appendix C. Empirical and Theoretical Estimation Results

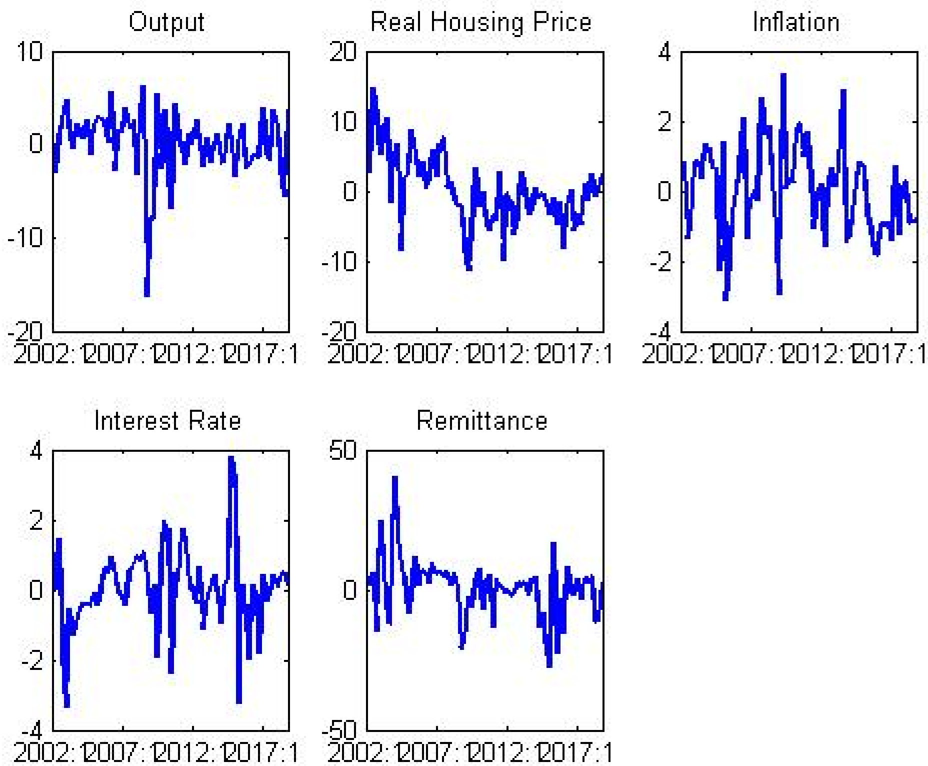

Figure 19: VAR model input data

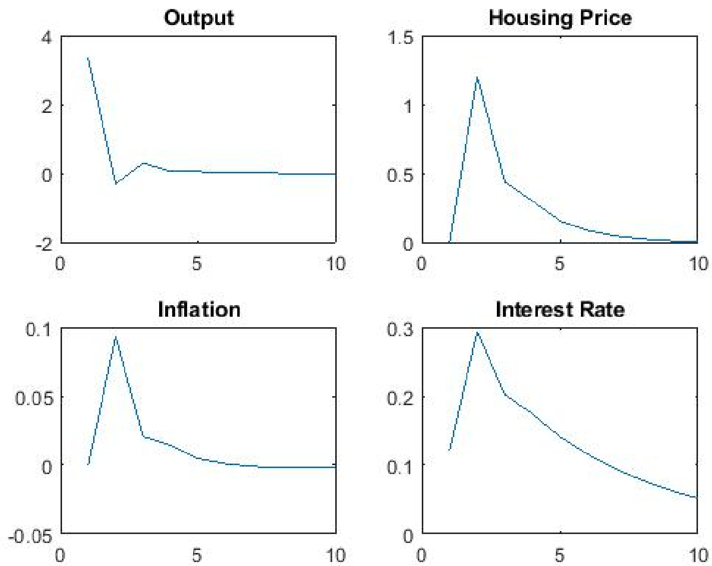

Figure 20: Responses to output shock

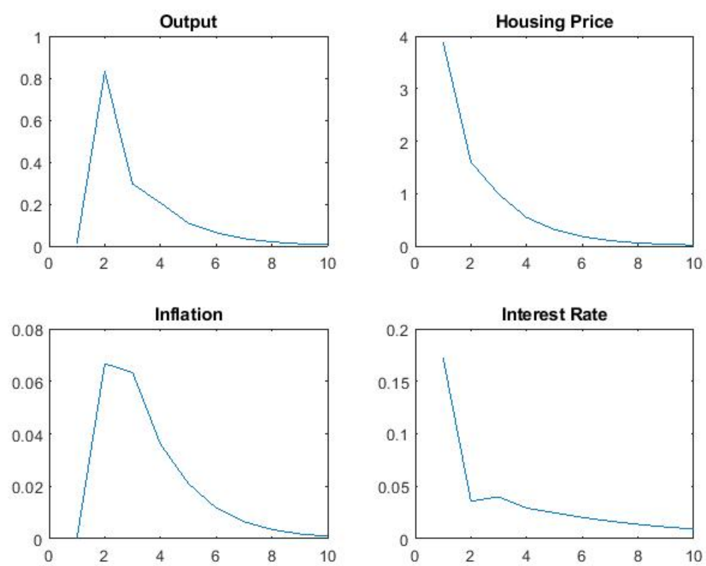

Figure 21: Responses to housing prices shock

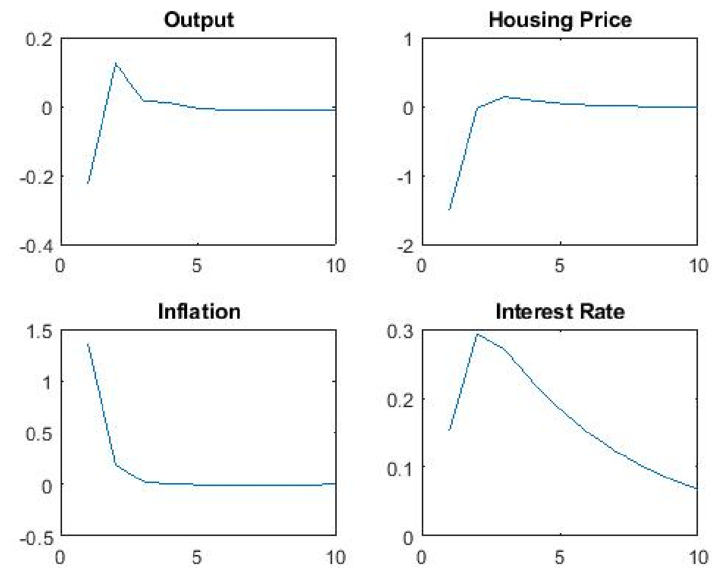

Figure 22: Responses to inflation shock

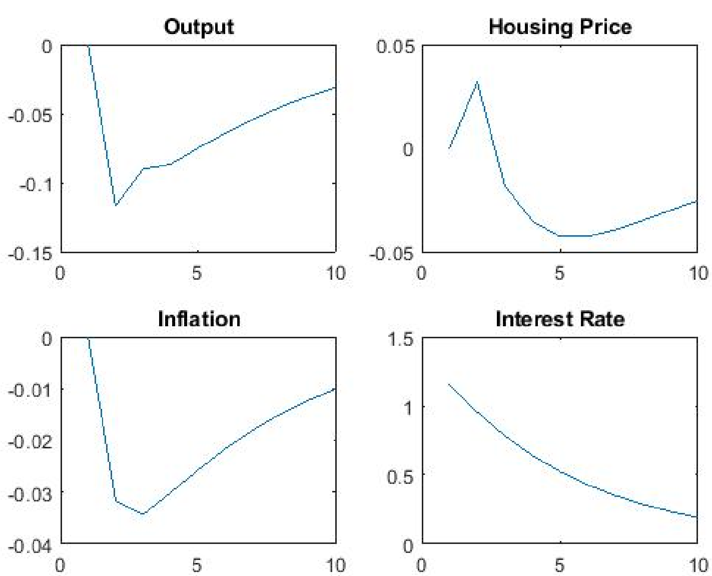

Figure 23: Responses to interest rate shock

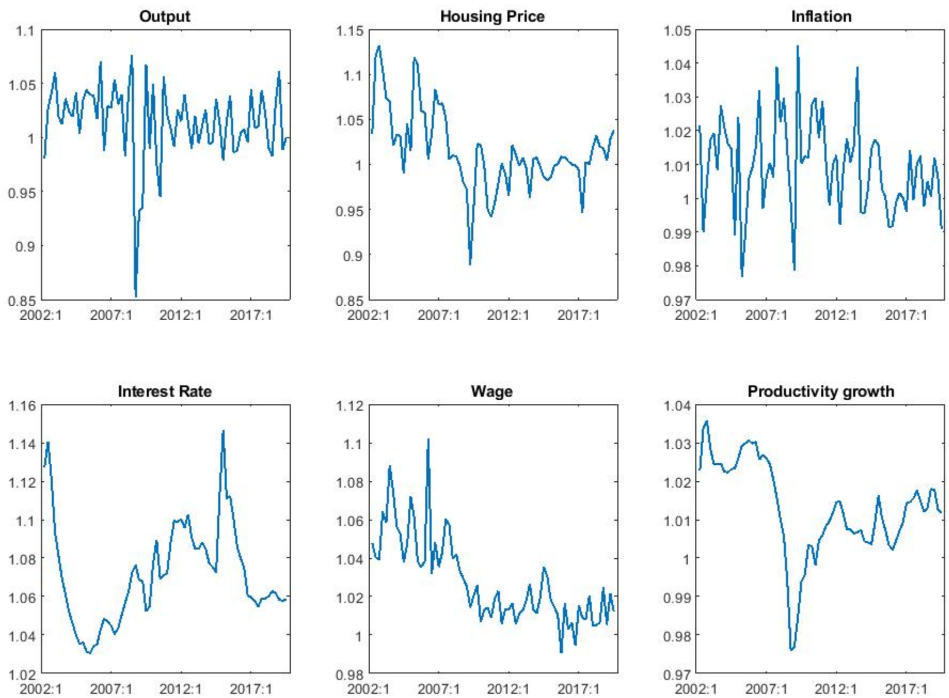

Figure 24: Graphical representation of DSGE model input data

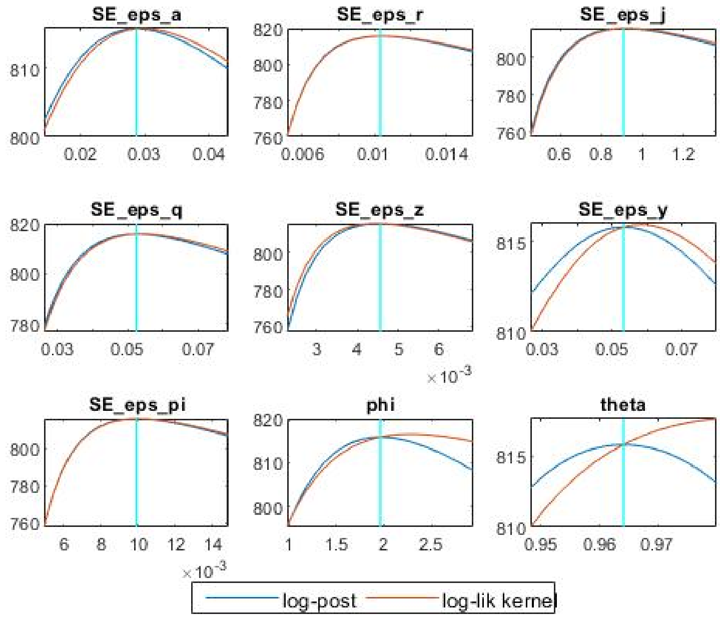

Figure 25: Mode check plots

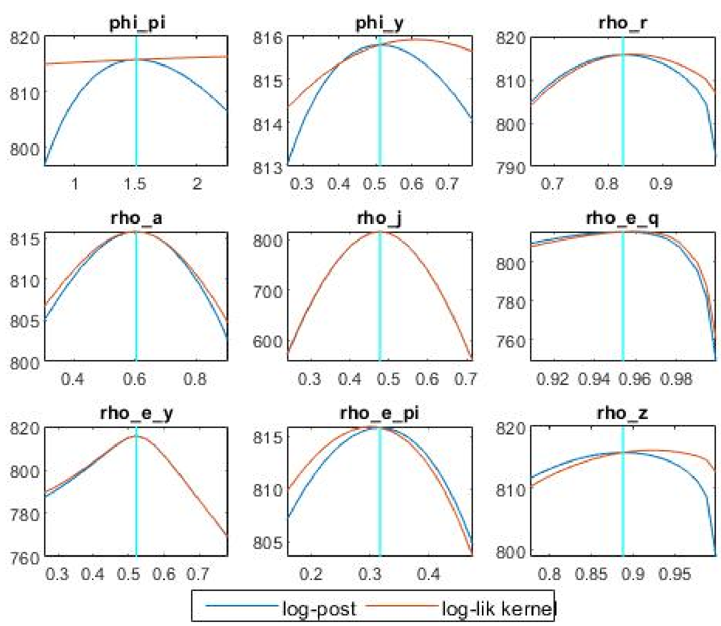

Figure 26: Mode check plots

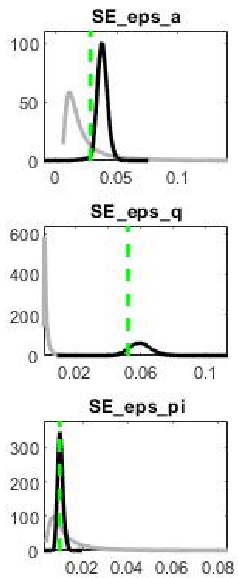

Figure 27: Prior and Posterior Distributions

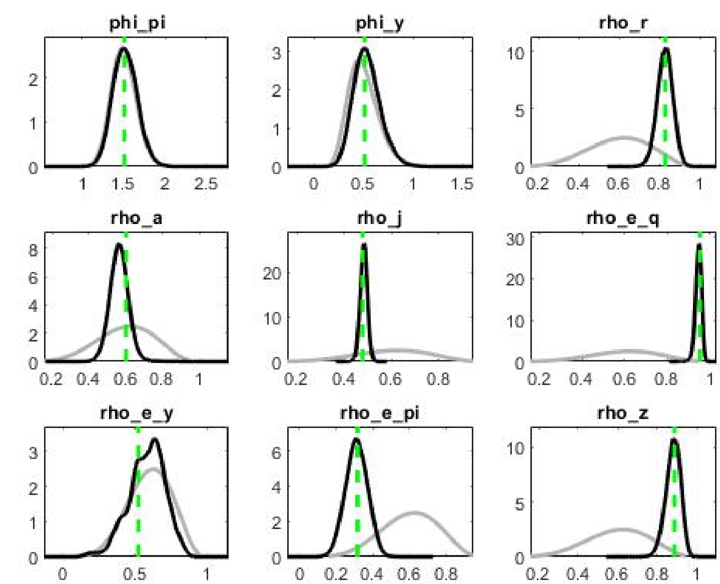

Figure 28: Prior and Posterior Distributions

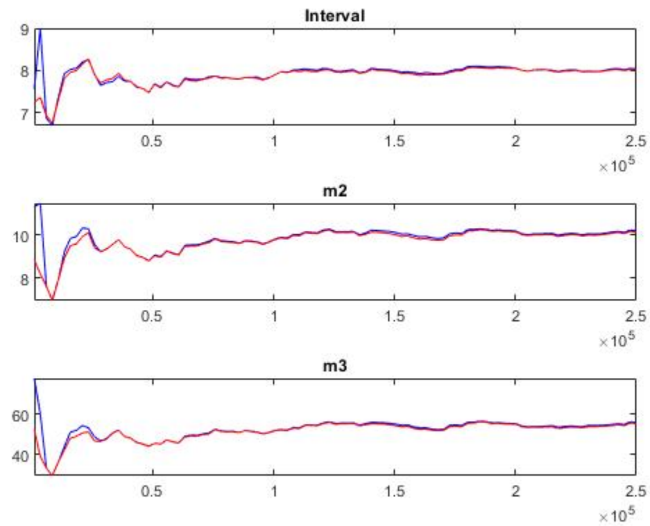

Figure 29: Multivariate convergence diagnostic

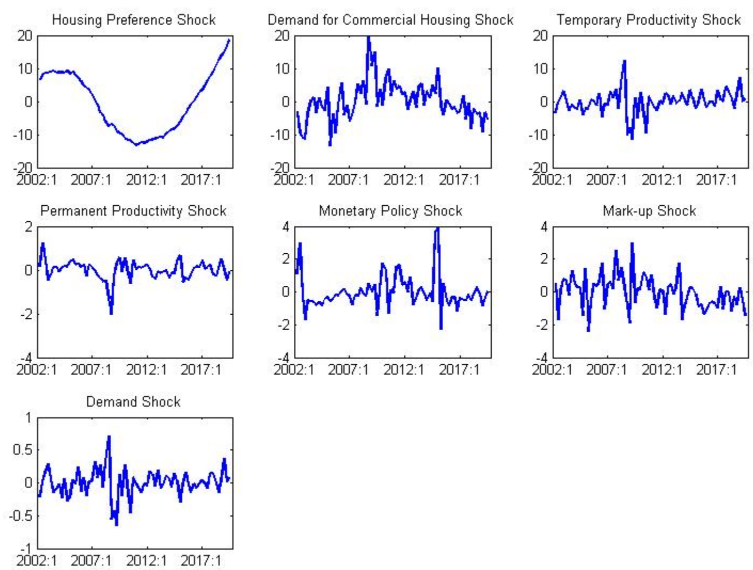

Figure 30: Estimated historical shocks

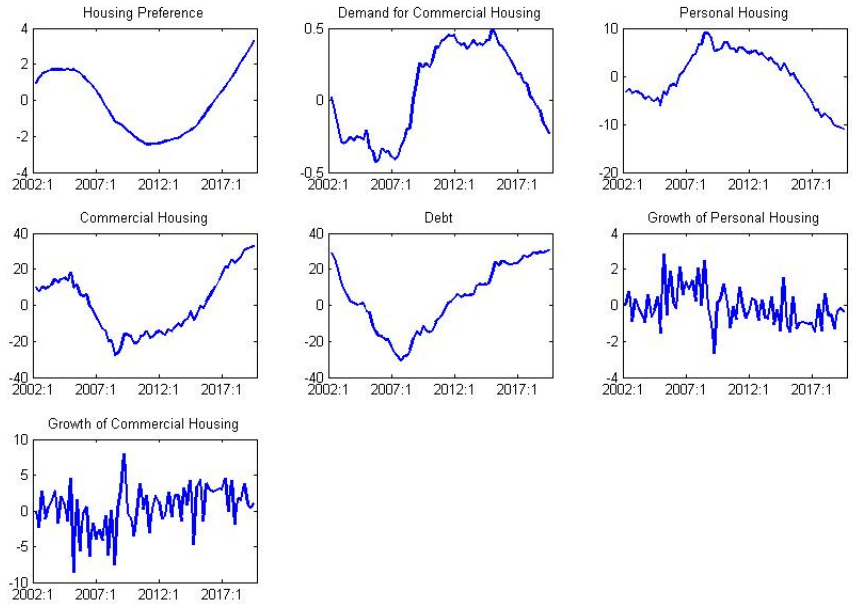

Figure 31: Smoothed historical variables

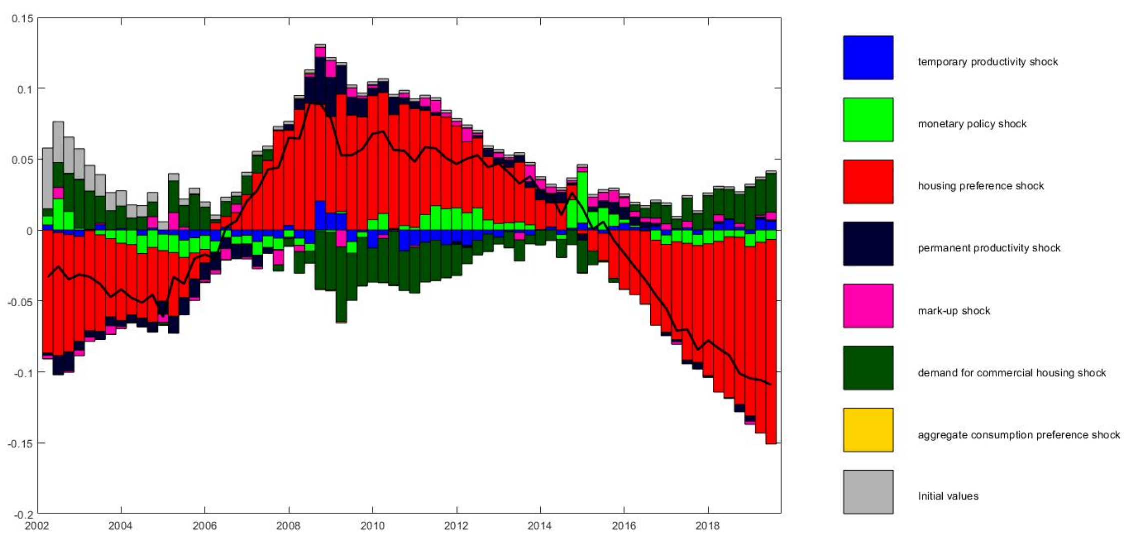

Figure 32: Historical decomposition of personal housing

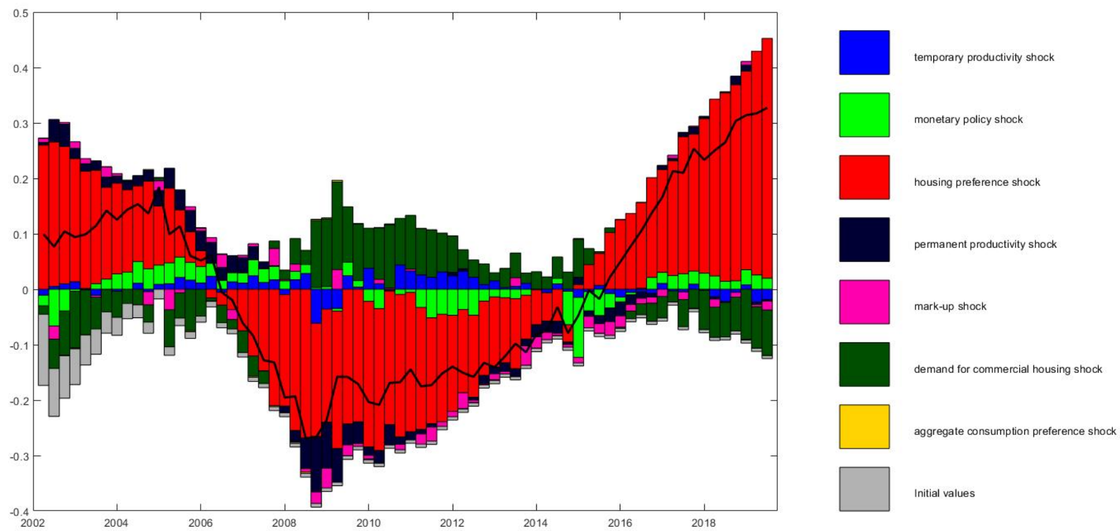

Figure 33: Historical decomposition of commercial housing

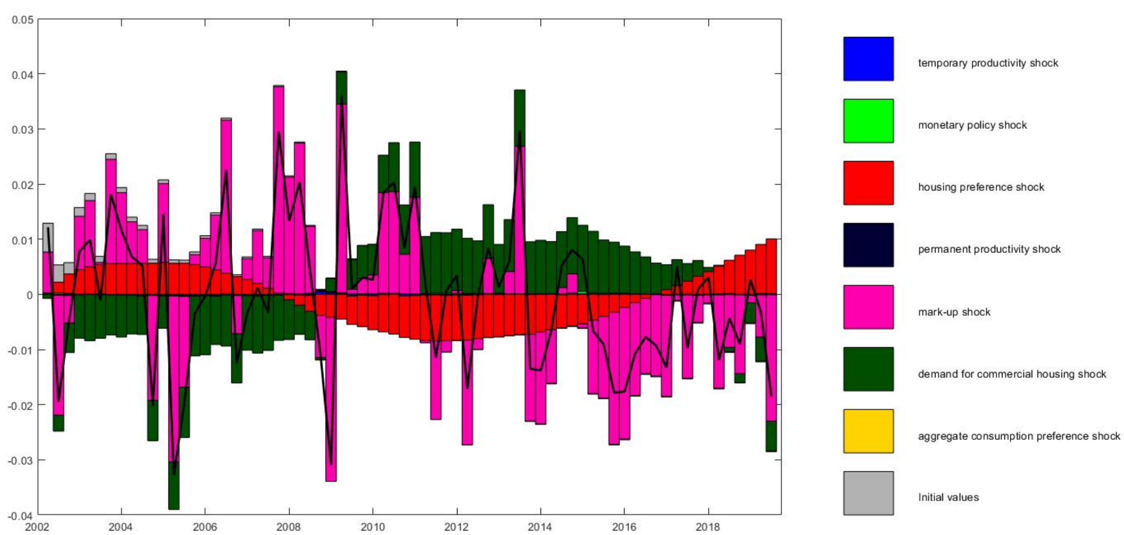

Figure 34: Historical decomposition of inflation