Heterogeneous rental markets in a DSGE model of the euro area

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Abstract

The euro area economies are bound together by monetary policy while still inhibiting many heterogeneities. Amongst them the share of home owners. This paper presents a medium scale New Keynesian DSGE model of the euro area with an extensive housing market which explicitly models endogenous tenure choice. Results from the calibrated model indicate that there are various parameters determining the ownership rate. Dependent on the drivers of the heterogeneity shocks have substantial effects on real variables when homeownership rates differ across countries.

Keywords: DSGE, ownership-rates, housing, heterogeneities, monetary union

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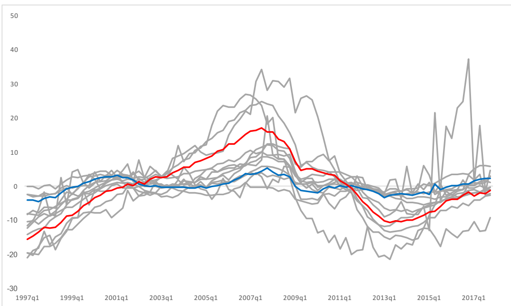
1 Introduction

1.1 Motivation

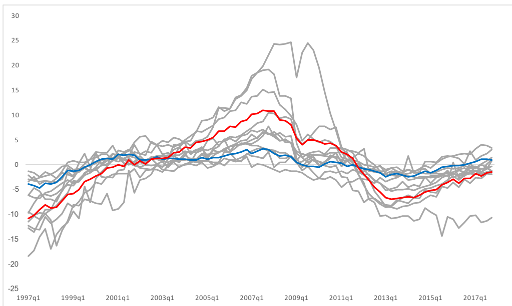
This paper seeks to explore the effects of the duality in housing markets. Rental markets have often been neglected in general equilibrium. Yet, in many countries half of the population lives in a rented home. This can impose significant real effects if wrongly modeled. Questions that relate to this are: Is the rental market a friction yet a source of stability? What role do rental markets play for the real economy? How are shocks propagated? How large are the spillovers from the real estate and housing market to the real economy if a rental market is included. Does the high share of renters smooth consumption over the business cycle? The development of prices in the real estate and rental markets is important both from a political and monetary policy point of view. Tracing the development and identifying the channels that link these is an important issue in the literature.

While it is a well established fact that the surge in house prices in the periphery was due to the fall in interest rates after the euro introduction. Yet, it has not been analyzed which role the structure of the housing market in the countries had. Figure 1 gives an intuition of the EMUs heterogeneities with respect to the ownership rates. While peripheral countries with higher ownership rates seem to be experiencing boom and busts, the core countries with lower ownership rates seem to be more stable.

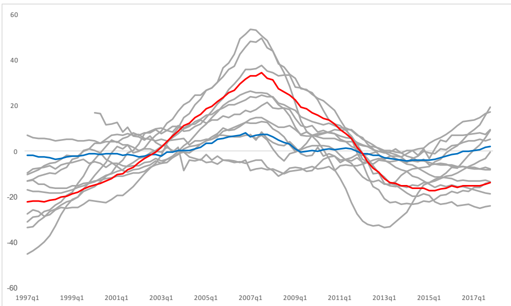
Figure 1: Stylized Time Series of EMU



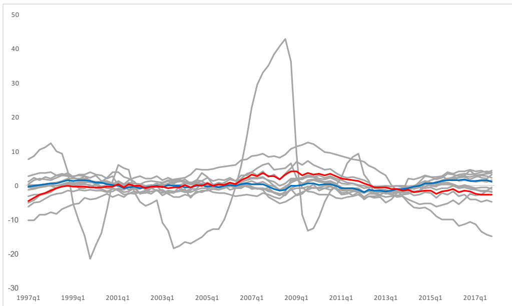
(a) GDP



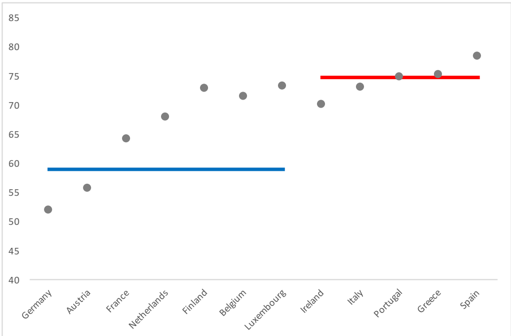
(b) private consumption



(c) real house prices



(d) real rents



(e) ownership rates

1.2 Related literature

Various economic papers have focused on the real estate sector and housing markets. Since Leeper's: "housing is the cycle" and the subsequent financial crisis the research on housing markets has become crucial and inherent in many business cycle models. It has been shown that developments in the financial and housing markets can have effects on the real economy. E.g. various studies established the fact that there is a positive relation between rising house prices and consumption through both, collateral and wealth effects (e.g. Aladangady (2017)). Another is the seminal paper by Iacoviello and Neri (2010), where they estimate a medium scale DSGE model with US data. Others have picked up the string of research and extended it to specificities of a monetary union (e.g. Aspachs-Bracons and Rabanal (2011), Quint and Rabanal (2014), Rubio (2014), Brzoza-Brzezina et al. (2015), Gareis and Mayer (2017) and Rubio and Comunale (2018)).

Others in the DSGE literature have tried to extend the approach and include the long forgotten part of the housing market. A rental market can basically be included in two ways. Either one adds an additional household, the "renters", that live in a fashion of a hand-to-mouth consumer, as seen in Alpanda and Zubairy (2016) and Ghiaie and Rouillard (2018). Yet, d'Albis and Iliopulos (2013) shows that housing wealth in form of the stock is needed in the utility function. With a rental market included in the model, impatient households otherwise fully substitute owner-occupied housing with rental services. The other way is that the model opens up the tenure choice of the representative consumer as in Mora-Sanguinetti and Rubio (2014), Rubio (2015) or Sun and Tsang (2017). Representative agents are in a position to choose whether to live in an owned house or to rent. The research shows that a larger rental share leads to a more pronounced stabilizing effect of monetary policy (Rubio, 2015).
The paper that comes closest to this project is the model by Mora-Sanguinetti and Rubio (2014). Instead of choosing a two-country setup, that form a monetary union, the authors model the external sector as being exogenous. This is a valid assumption for small open economies (SOEs) and their research target Spain being such one. However, for other EMU countries this assumption is not feasible. This model accordingly divides the EMU into two regions the core countries and the peripheral economies.

In a recent publication Corsetti et al. (2018) find that monetary policy transmission to the real economy is influenced by the share of home owners. The strength of the housing channel is significantly correlated with the structure of the housing markets. In countries with less developed rental markets the author find a stronger consumption effect in response.

1.3 Contribution

The paper contributes to the literature in the following way. First, to the best of my knowledge it represents the most extensive approach including a rental market in a DSGE model of a monetary union. An aspect that should not be neglected given the importance of rental markets in economies such as Germany. Second, this paper seeks to analyze effects of heterogeneities in the housing market (especially the rental market) in a monetary union. Third, using EMU data the model can be estimated to shed light on some of the unobserved parameters' values.

The remainder is organized as follows: Section 2 gives an outline of the model. Section 3 describes the calibration and results thereof. Section 4 considers the estimation approach. Section 5 concludes the paper.

2 The model

The modelling framework in its international dimension follows loosely Aspachs-Bracons and Rabanal (2011). The two structurally symmetric countries (Home and Foreign) are of sizes n and $(1-n)$, respectively. Each country is inhibited by various agents, two continuous households, namely savers and borrowers, as well as by entrepreneurs and relies on the model by Sun and Tsang (2017)[1] that builds on the work of Iacoviello and Neri (2010). The firms in each country produce two differentiated products. One being a consumption good and the other being houses as a durable good. Further, the entrepreneurs act as landlords and offer rental services to both types of households.[2] In contrast to Iacoviello and Neri (2010)

[1] A previous setup of the model extended this model to the two country case. However, the assumption of the model that entrepreneurs would be able to borrow up to the rental housing stocks value imposed unrealistic features that came apparent when analyzing countries with heterogeneous home-ownership rates.

[2] See Appendix for a graphical representation of the model.

and Sun and Tsang (2017) we simplify the model at some points (e.g. treatment of land in the model or heterogeneity between households through parameters) and add parts that seem relevant with respect to the research question (e.g. imperfect supply of rental housing).

Notation

$$C^{B*}_{C,t}(H)$$

In the case of this example, C is the variable (consumption), B denotes the borrower household and further differentiates between savers or entrepreneurs. The (H) defines that the variable specifically describes the consumption home-produced goods. Only the equations for the Home country are presented as the equations are symmetric across regions. An asterisk symbols a foreign variable. Variables without a time subscript refer to their steady state values.

2.1 Agents

The economy is populated by three types of infinitely-lived agents, savers (indicated by the superscript S), borrowers (B) and entrepreneurs (E). The size of each group of households is proxied by α the share of savers in the production function.[3] The wage share determines the economic sizes of the two households. Apart from their discount rate, structural parameters (such as weights in the utility function etc.) do not differ between households.

Savers

The Savers or unconstrained households lifetime utility function is separable in consumption C^S_t, housing H^S_t and hours worked L^S_t, and given by

$$U^S_t = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \xi^{TP}_t \left(\Theta^S \ln(C^S_t - hC^S_{t-1}) + \xi^{HP}_t \frac{\ln(H^S_t)}{1-\sigma_H} - \xi^{LS}_t \frac{(L^S_t)^{1+\eta}}{1+\eta} \right) \tag{1}$$

where β is the discount factor, h defines the degree that the actors underlie internal habit persistence in consumption.[4] This means that in the optimization process previous levels of the households consumption are taken into account. $\Theta = (1-h^S)/(1-\beta h^S)$ is a scaling factor and an elegant way for normalization in a way that the marginal consumption ends up being $1/C$. η is the inverse Frisch labor elasticity and determines the households reaction in labor supply on wage changes. ξ^{TP}_t is a time preference shock, ξ^{HP}_t is a housing preference shock that also weights housing utility and ξ^{LS}_t is a labor supply shock.
The households consume the aggregated consumption good that is formed by the Dixit-Stiglitz aggregator from the home-produced good $C^S_t(H)$ and the foreign-produced good $C^S_t(F)$[5] with a constant elasticity of substitution σ_C. ω_C is a weighting factor determining the home-bias in consumption.

$$C^S_t = \left[\omega_C^{\frac{1}{\sigma_C}} \left(C^S_t(H)\right)^{\frac{\sigma_C-1}{\sigma_C}} + (1-\omega_C)^{\frac{1}{\sigma_C}} \left(C^S_t(F)\right)^{\frac{\sigma_C-1}{\sigma_C}} \right]^{\frac{\sigma_C}{\sigma_C-1}} \tag{2}$$

This results in the corresponding consumption price index

$$P_t = \left[\omega_C P_t(H)^{1-\omega_C} + (1-\omega_C) P_t(F)^{1-\omega_C} \right]^{\frac{1}{1-\omega_C}} \tag{3}$$

where $P_t(H)$ and $P_t(H)$ denote prices of consumption goods in the two countries.
Further, the households decide between living in an owner-occupied home $H^S_{O,t}$ or relying on rental services Z^S_t.

$$H^S_t = \left[\omega_H (H^S_{O,t})^{1-\sigma_H} + (1-\omega_H)(Z^S_t)^{1-\sigma_H} \right] \tag{4}$$

[3] Quint and Rabanal (2014) normalize the total population to one and assign weights λ and $(1-\lambda)$ to savers and borrowers, respectively.

[4] In this case habit depends on the lagged consumption (as in Iacoviello and Neri (2010)) while other models suggest that the variable of interest is lagged aggregate consumption, implying "keeping up with the Joneses" motivation (see e.g. Smets and Wouters (2003) or Quint and Rabanal (2014)). The latter approach treats the external consumption as exogenous which simplifies the optimization problem.

[5] Note that only consumption goods are tradeable.

where ω_H is a weight factor that measures the bias for owner-occupation. σ_H defines the substitute-ability between the two forms of housing (perfect substitutes if $\sigma_H \to 0$).
The households supply competitive labor $L^S_{j,t}$ to both sectors $j = C,H$ (consumption good and housing production). The aggregate labor index reads as

$$L^S_t = \left[\omega_L^{-\sigma_L}(L^S_{C,t})^{1+\sigma_L} + (1-\omega_L)^{-\sigma_L}(L^S_{H,t})^{1+\sigma_L}\right]^{\frac{1}{1+\sigma_L}} \tag{5}$$

where ω_L weights the size of each sector. σ_L induces imperfect labor mobility between the two sectors. If $\sigma_L \to 0$ the households view labor in the two sectors as perfect substitutes and changing from one to the other comes at no costs.
The optimization is carried out with respect to the budget constraint, where spending equals income in each period. In nominal terms it is given by

$$\begin{aligned} P_t C^S_t + Q_{H,t}[H^S_{O,t} - (1-\delta_O)H^S_{O,t-1}] + Q_{Z,t}Z^S_t + R^B_{t-1}B^{SB}_{t-1} + R^E_{t-1}B^{SE}_{t-1} + R_{t-1}D_{t-1} + \frac{\Psi_d}{2}B^{SE^2}_t + \frac{\Psi_d}{2}D^2_t \\ = \frac{W^S_{C,t}L^S_{C,t}}{X_{C,t}} + \frac{W^S_{H,t}L^S_{H,t}}{X_{H,t}} + \Pi^S_t + B^{SB}_t + B^{SE}_t + D_t \end{aligned} \tag{6}$$

divided by the consumption price index P_t and therefore measured in terms of the consumption good, the budget constraint in real terms is[6]

$$\begin{aligned} C^S_t + q_{H,t}[H^S_{O,t} - (1-\delta_O)H^S_{O,t-1}] + q_{Z,t}Z^S_t + \frac{R^B_{t-1}b^{SB}_{t-1}}{\pi_t} + \frac{R^E_{t-1}b^{SE}_{t-1}}{\pi_t} + \frac{R_{t-1}d_{t-1}}{\pi_t} + \frac{\Psi_d}{2}b^{SE^2}_t + \frac{\Psi_d}{2}d^2_t \\ = \frac{w^S_{C,t}L^S_{C,t}}{X_{wC,t}} + \frac{w^S_{H,t}L^S_{H,t}}{X_{wH,t}} + \frac{\Pi^S_t}{P_t} + b^{SB}_t + b^{SE}_t + d_t \end{aligned} \tag{7}$$

The real house price is captured by $q_{H,t}$ and owner-occupied houses depreciate at rate δ_O. The one period rent is $q_{Z,t}$. Savers real domestic bond holdings (that go exclusively to borrowers) are represented by b^{SB}_t, while R^B_{t-1} is the associated nominal interest rate payed on credit from the previous period. b^{SE}_t and R^E_{t-1} describes bond holdings and the interest rate with entrepreneurs. International bonds are represented by d_t with the respective nominal interest rate R_t. The borrowing costs parameter Ψ_d applies when deviating from the steady state. This ensures stationarity of both bond holdings with entrepreneurs and foreign debt. On the income side, $w^S_{C,t}$ and $w^S_{H,t}$ are real wages in the two sectors. Dividends Π^S_t are lump-sum transfers that are remitted by entrepreneurs and labor unions that are ultimately held by the households.
For the other equations we forgo the nominal representation and only quote the variables in real terms.

$$\Pi^S_t = \frac{X_t - 1}{X_t}y_t + \frac{X_{Z,t}-1}{X_{Z,t}}q_{Z,t}Z,t + \frac{X_{wC,t}-1}{X_{wC,t}}w^S_{C,t}L^S_{C,t} + \frac{X_{wH,t}-1}{X_{wH,t}}w^S_{H,t}L^S_{H,t} \tag{8}$$

$X_{C,t}$, $X_{Z,t}$, $X_{wC,t}$ and $X_{wH,t}$ are markups charged by retailers, entrepreneurs and labor unions respectively. As retailers are owned by the saver households their income is fully reimbursed to them.

Borrowers

The Borrowers face a similar decision problem as the savers with three distinctions. First, they are due to their lower discount factor β^B more impatient than the savers. This leads to the situation where both agents fulfill their destinies according to their names. However, borrowers can only borrow up to a certain limit, that is determined by the value of their housing stock. Second, borrowers are restricted to domestic bond markets. Third, their dividend payments differ. Borrowers only receive transfer payments from the labor unions and not from the firms.
The borrowers or constrained households utility function is also separable in consumption C^B_t, housing H^B_t and hours worked L^B_t, and given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} (\beta^B)^t \xi^{TP}_t \left(\Theta^B \ln(C^B_t - hC^B_{t-1}) + \xi^{HP}_t \frac{\ln(H^B_t)}{1-\sigma_H} - \xi^{LS}_t \frac{(L^B_t)^{1+\eta}}{1+\eta} \right) \tag{9}$$

[6] Variables in capital letters depict nominal values, variables in small letters depict real values. The CPI inflation rate is given by $\pi_t = \frac{P_t}{P_{t-1}}$.

the budget constraint

$$
\begin{aligned}
C_t^B + q_{H,t}[H_{O,t}^B - (1-\delta_O)H_{O,t-1}^B] + q_{Z,t}Z_t^B + \frac{R_{t-1}^B b_{t-1}^{BS}}{\pi_t} \\
= \frac{w_{C,t}^B L_{C,t}^B}{X_{C,t}} + \frac{w_{H,t}^B L_{H,t}^B}{X_{H,t}} + \frac{\Pi_t^B}{P_t} + b_t^{BS}
\end{aligned} \tag{10}
$$

where dividend payments exclusively come from labor unions.

$$
\Pi_t^S = \frac{X_{wC,t}-1}{X_{wC,t}} w_{C,t}^S L_{C,t}^S + \frac{X_{wH,t}-1}{X_{wH,t}} w_{H,t}^S L_{H,t}^S \tag{11}
$$

The borrowers borrowing constraint is given by

$$
b_t^{BS} \leq \xi_t^{LTV} \mathbb{E}_t \frac{q_{H,t+1} H_{O,t}^B (1-\delta_O)\pi_t}{R_t^B} \tag{12}
$$

where ξ_t^{LTV} is a LTV shock that also determines the LTV ratio in steady state. Accordingly, the borrowing of the household cannot exceed the If it holds that $\beta^B < \beta$ the collateral constraint holds with equality and is assumed to be always binding in the model.

Entrepreneurs

The third type of agents optimize a simpler form of utility, which is given by

$$
\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \xi_t^{TP} \left(\Theta \ln(C_t^E - h^E C_{t-1}^E)\right) \tag{13}
$$

Entrepreneurs share the discount factor β of the savers households. The composite consumption index looks the same as for the other agents. Their budget constraint reads as

$$
\begin{aligned}
\frac{y_t}{X_{C,t}} + \frac{q_{Z,t}Z_t}{X_{Z,t}} + q_{H,t}\left[IH_t - (H_{Z,t} - (1-\delta_Z)H_{Z,t-1})\right] + b_t^{ES} = \\
C_t^E + \frac{R_{t-1}^E b_{t-1}^{ES}}{\pi_t} + \frac{inv_{C,t}}{\xi_t^{KC}} + inv_{H,t} + k_{y,t} + \sum_{i=C,H} w_{i,t}^S L_{i,t}^S + \sum_{i=C,H} w_{i,t}^B L_{i,t}^B + \Psi_{k,t} + \Psi_{H,t}
\end{aligned} \tag{14}
$$

$X_{C,t}$ is the markup on consumption goods charged by retailers. $H_{Z,t}$ is the stock of rental housing owned by entrepreneurs. The rental market efficiency parameter Γ determines the amount of rental homes ($\Gamma H_{Z,t} = Z_t^B + Z_t^S$). Investment is subject to the investment specific shock $\xi_{KC,t}$. $k_{y,t}$ being the intermediate inputs.
The law of motion of investment for the production of the consumption good $inv_{C,t}$ and housing investment $inv_{H,t}$ are

$$
inv_{C,t} = k_{C,t} - (1-\delta_{kC})k_{C,t-1} \tag{15}
$$

$$
inv_{H,t} = k_{H,t} - (1-\delta_{kH})k_{H,t-1} \tag{16}
$$

and the capital adjustment cost (à la Rotemberg)

$$
\Psi_{k,t} = \frac{\Psi_{kC}}{2}\left(\frac{k_{C,t}}{k_{C,t-1}} - 1\right)^2 k_{C,t-1} + \frac{\Psi_{kH}}{2}\left(\frac{k_{H,t}}{K_{H,t-1}} - 1\right)^2 k_{H,t-1} \tag{17}
$$

$k_{C,t}$ and $k_{H,t}$ determine the capital employed in the two sectors.
The adjustment cost for changes in supply of rental houses are analogously designed and prevent households from switching between owner-occupation and rental tenure too quickly.

$$
\Psi_{H,t} = \frac{\Psi_H}{2}\left(\frac{H_{Z,t}}{H_{Z,t-1}} - 1\right)^2 H_{Z,t-1} \tag{18}
$$

where the parameters Ψ_{kC} and Ψ_{kH} relate to the costs in the two sectors and Ψ_H to costs associated with changing the rental housing stock.
The consumption good is produced with labor and capital. In contrast to Iacoviello and Neri (2010) and Sun and Tsang (2017) this model drops the use of land. The production function is

$$
y_t = (\xi_t^C (L_t^S)^{\alpha} (L_t^B)^{1-\alpha})^{1-\mu_C} (k_{C,t-1})^{\mu_C} \tag{19}
$$

Housing production additionally uses intermediate inputs from the consumption sector denoted by $k_{Y,t}$

$$IH_t = (\xi_t^H (L_t^S)^\alpha (L_t^B)^{1-\alpha})^{1-\mu_H-\mu_l} (k_{H,t-1})^{\mu_H} (k_{y,t})^{\mu_y} \tag{20}$$

ξ_t^C and ξ_t^H denote sector specific technology shocks. The share of savers households is given by α. μ_C, μ_H and μ_y are the parameters standard to a Cobb-Douglas production function.

2.2 Nominal Rigidities

Mora-Sanguinetti and Rubio (2014) does only include nominal rigidities in rental markets and prices at the retail level. Yet, wage stickiness in both sectors plays an important role with respect to the persistence of shocks and should therefore be included (Aspachs-Bracons and Rabanal, 2011).
(Allowing for differences in wages accross sectors and households, the setup implies that each type of household governs its labor union which negotiate the wages in accordance to their intertemporal consumption needs.) Nominal frictions are amongst others covered by rigidities in prices and wages which are partial indexed to the respective past inflation rate

$$\ln \pi_t - \phi_\pi \ln \pi_{t-1} = \beta^S (\mathbb{E}_t \ln \pi_{t+1} - \phi_\pi \ln \pi_t) - \frac{(1-\theta_\pi)(1-\beta^S\theta_\pi)}{\theta_\pi} \ln\left(\frac{X_{C,t}}{X_C}\right) + \xi_t^P \tag{21}$$

Firms are able to reset their prices with a probability θ_π. The Phillips Curves inhibits partial indexation ϕ_π to the previous periods inflation rate. ξ_t^P describes an external cost-push shock.
The log linearized version of the rental Phillips Curve

$$\begin{aligned} \ln\left(\frac{\pi_t q_{Z,t}}{q_{Z,t-1}}\right) - \phi_Z \ln\left(\frac{\pi_{t-1} q_{Z,t-1}}{q_{Z,t-2}}\right) = \\ \beta^S\left(\mathbb{E}_t \ln\left(\frac{\pi_{t+1} q_{Z,t+1}}{q_{Z,t}}\right) - \phi_Z \ln\left(\frac{\pi_t q_{Z,t}}{q_{Z,t-1}}\right)\right) - \frac{(1-\theta_Z)(1-\beta^S\theta_Z)}{\theta_Z} \ln\left(\frac{X_{Z,t}}{X_Z}\right) \end{aligned} \tag{22}$$

The first term in parenthesis relates to the real inflation in period t which is indexed by parameter θ_Z to prior rent inflation. $\phi_w C$ determines the probabilities of rent readjustment.
Wage stickiness is modeled the same way. The following equations represent the savers Calvo-wages. Borrowers wages are modeled similarly.

$$\begin{aligned} \ln\left(\frac{\pi_t w_{C,t}^S}{w_{C,t-1}^S}\right) - \phi_{wC} \ln\left(\frac{\pi_{t-1} w_{C,t-1}^S}{w_{C,t-2}^S}\right) = \\ \beta^S\left(\mathbb{E}_t \ln\left(\frac{\pi_{t+1} w_{C,t+1}^S}{w_{C,t}^S}\right) - \phi_{wC} \ln\left(\frac{\pi_t w_{C,t}^S}{w_{C,t-1}^S}\right)\right) - \frac{(1-\theta_{wC})(1-\beta^S\theta_{wC})}{\theta_{wC}} \ln\left(\frac{X_{wC,t}}{X_{wC}}\right) \end{aligned} \tag{23}$$

$$\begin{aligned} \ln\left(\frac{\pi_t w_{H,t}^S}{w_{H,t-1}^S}\right) - \phi_{wH} \ln\left(\frac{\pi_{t-1} w_{H,t-1}^S}{w_{H,t-2}^S}\right) = \\ \beta^S\left(\mathbb{E}_t \ln\left(\frac{\pi_{t+1} w_{H,t+1}^S}{w_{H,t}^S}\right) - \phi_{wH} \ln\left(\frac{\pi_t w_{H,t}^S}{w_{H,t-1}^S}\right)\right) - \frac{(1-\theta_{wH})(1-\beta^S\theta_{wH})}{\theta_{wH}} \ln\left(\frac{X_{wH,t}}{X_{wH}}\right) \end{aligned} \tag{24}$$

Again ϕ_{wC} and ϕ_{wH} describe the partial indexation to previous periods and the Calvo-wage parameters θ_{wC} and θ_{wH} cover the wage stickiness in the two sectors. This setup implies that only a fraction of θ_{wC} contracts can be readjusted to optimal values in each period inducing a friction in the labor market.

2.3 Monetary Policy

The monetary autonomy (ECB) performs monetary policy following a Taylor rule that targets CPI inflation weighted by country size

$$\ln R_t = \rho^R \ln(R_{t-1}) + (1-\rho^R)\gamma_\pi n \ \ln(\pi_t) + 1 - \rho^R \gamma_\pi (1-n) \ln(\pi_t^*) + (1-\rho^R)R + \varepsilon_t^R \tag{25}$$

where ρ^R is an AR(1) weight parameter that smooths the interest rate and γ_π is the inflation sensitivity parameter.

2.4 Market Clearing

Following Walras' law, we observe the market clearing conditions. The home country production equals domestic investment and both countries consumption demand. The parameter n accounts for the economic sizes of the two economies.[7]

$$\begin{aligned} n^{aux}\left(k_{y,t}+inv_{H,t}+\frac{inv_{C,t}}{\xi_{kC,t}}+\frac{P_t(H)C_t(H)}{P_t}\right)+(1-n^{aux})\left(\frac{P_t(F)^*C_t(F)^*}{P_t}\right) \\ =n^{aux}\left(y_t-\Psi_{k,t}-\Psi_{H,t}-\frac{\Psi_d}{2}{b_t^{ES}}^2-\frac{\Psi_d}{2}{b_t^{SE}}^2-\frac{\Psi_d}{2}{d_t}^2\right) \end{aligned} \tag{26}$$

where

$$C_t(H)=C_t^S(H)+C_t^B(H)+C_t^E(H) \tag{27}$$

$$C_t(F)=C_t^S(F)+C_t^B(F)+C_t^E(F) \tag{28}$$

and illustratively the savers demand for the home produced consumption good[8] is

$$C_t^S(H)=\omega_C\left(\frac{P_t(H)}{P_t}\right)^{-\sigma_C}C_t^S \tag{29}$$

The quantity of newly built houses must equal its demand

$$IH_t=(H_{O,t}^S+H_{O,t}^B)-(1-\delta_O)(H_{O,t-1}^S+H_{O,t-1}^B)+(H_{Z,t}^S+H_{Z,t}^B)-(1-\delta_Z)(H_{Z,t-1}^S+H_{Z,t-1}^B) \tag{30}$$

and the rental market clears according to

$$\Gamma H_{Z,t}=Z_t^S+Z_t^B. \tag{31}$$

Domestic bond markets

$$b_t^{SB}+b_t^{BS}=0 \tag{32}$$

$$b_t^{SE}+b_t^{ES}=0 \tag{33}$$

$$\tag{34}$$

and international bond markets

$$\begin{aligned} nD_t+(1-n)D_t^*&=0\\ \Leftrightarrow nP_t\frac{D_t}{P_t}+(1-n)P_t^*\frac{D_t^*}{P_t^*}&=0\\ \Leftrightarrow nd_t+(1-n)\left(\frac{P_t^*}{P_t}\right)d_t^*&=0 \end{aligned} \tag{35}$$

where d_t^* is foreign held bonds in real terms. As the model abstracts from any price distortions it holds that

$$P_t(H)=P_t^*(F) \tag{36}$$

$$P_t(F)=P_t^*(H) \tag{37}$$

The law of motion of the net foreign assets postition is given by

$$\begin{aligned} nD_t&=n\frac{R_{t-1}D_{t-1}}{(1-\Psi D_t)}+(1-n)P_t(H)C_t(H)^*-nP_t(F)C_t(F)\\ n\frac{D_t}{P_t}&=n\frac{R_{t-1}D_{t-1}}{(1-\Psi D_t)P_t}\frac{P_{t-1}}{P_{t-1}}+(1-n)\frac{P_t(H)}{P_t}C_t(H)^*-n\frac{P_t(F)}{P_t}C_t(F)\\ d_t&=\frac{R_{t-1}}{(1-\Psi D_t)\pi_t}d_{t-1}+\frac{(1-n)}{n}\left(\frac{P_t(H)}{P_t}\right)C_t(H)^*-\left(\frac{P_t(F)}{P_t}\right)C_t(F) \end{aligned} \tag{38}$$

where the adjustment cost parameter Ψ_d ensures stationarity of the process.

[7] For computational and model-building reasons we use an auxiliary variable n^{aux} as a workaround to account for the real sizes of the economies. See the Appendix for further reference.

[8] See Appendix for derivation.

2.5 Shocks

The model includes the i.i.d. shocks ε_t^R referring to a monetary policy (interest) rate shock and the costs push shock ε_t^P materializing in the consumption good philips curve. Besides these, the model features a rich menu of AR(1) shocks (e.g. ξ_t^{TP},...) which are depicted below.

Household shocks

$$\text{time preference shock: } \ln \xi_t^{TP} = \rho^{TP} \ln \xi_{t-1}^{TP} + \varepsilon_t^{TP} \tag{39}$$

$$\text{housing preference shock: } \ln \xi_t^{HP} = (1-\rho)^{HP} \ln \xi^{HP} + \rho^{HP} \ln \xi_{t-1}^{HP} + \varepsilon_t^{HP} \tag{40}$$

$$\text{labor supply shock: } \ln \xi_t^{LS} = \rho^{LS} \ln \xi_{t-1}^{LS} + \varepsilon_t^{LS} \tag{41}$$

Other shocks

$$\text{investment shock: } \ln \xi_t^{KC} = \rho^{KC} \ln \xi_{t-1}^{KC} + \varepsilon_t^{KC} \tag{42}$$

$$\text{consumption sector productivity shock: } \ln \xi_t^{C} = \rho^{C} \ln \xi_{t-1}^{C} + \varepsilon_t^{C} \tag{43}$$

$$\text{housing sector productivity shock: } \ln \xi_t^{H} = \rho^{H} \ln \xi_{t-1}^{H} + \varepsilon_t^{H} \tag{44}$$

$$\text{LTV shock: } \ln \xi_t^{LTV} = (1-\rho^{LTV}) \ln \xi^{LTV} + \rho^{LTV} \ln \xi_{t-1}^{LTV} + \varepsilon_t^{LTV} \tag{45}$$

Note that both the housing preference shock's and the LTV shock's steady state are different from zero.

3 Calibration

The calibration exercise is executed as follows. For the benchmark model, we divide the euro area – which consists of the twelve original members – in two parts. Austria, Belgium, Finland, France, Germany, Luxembourg and Netherlands comprise the core of size n, whereas Greece, Ireland, Italy, Portugal and Spain belong to the periphery of size $(1-n)$. In the benchmark calibration these differ in size and with respect to their ownership ratio. The core having a lower share of homeowners as the periphery.
The determination of the parameter values follows a multiple approach. First, parameters are calibrated in a way to match steady state targets that are observed in the data series (see Table 1). Second, parameters that do not affect the steady state ratios of interest are taken from related models in the literature. Finally, all other parameters and shocks are estimated to fit the data series used for estimation (see Table 2 and 3). Before that these parameters are calibrated to their prior means.
Savers and borrowers do only vary with respect to their discount factors. Accordingly, both agents have the same parameters with respect to consumption, housing and labor supply.

Table 1: Selected calibrated Parameters

Parameter	Value	Describtion	Source
Households			
β	0.995	Savers' and Entrepreneurs' discount factor	$R^{obs} = 2.1\%$
β^B	0.95	Borrowers' discount factor	Sun and Tsang (2017)
ω_C	0.8	Home bias in consumption	Eurostat
ω_C^*	0.8	Home bias in consumption (foreign)	$1-\left(\frac{n^{aux}}{(1-n^{aux})}\frac{C}{C^*}(1-\omega^C)\right)$
Other			
δ_O	0.008	Owner-occupied housing depreciation rate	Sun and Tsang (2017)
δ_Z	0.016	Rental housing depreciation rate	Sun and Tsang (2017)
δ_{KC}	0.025	Capital depreciation rate of consumption sector	Sun and Tsang (2017)
δ_{KH}	0.03	Capital depreciation rate of housing sector	Sun and Tsang (2017)
X_C, X_Z, X_{WC}, X_{WH}	1.15	Markups in the steady state	Sun and Tsang (2017)
μ_C	0.35	Capital input share in consumption sector	Sun and Tsang (2017)
μ_H	0.1	Capital input share in housing sector	Sun and Tsang (2017)
μ_y	0.1	Intermediate good input share in housing sector	Sun and Tsang (2017)
ξ_{HP}	0.12	Housing weight in utility function	Sun and Tsang (2017)
ξ_{LTV}	0.8	Borrowers' LTV ratio	Calza et al. (2013)
Ψ_d	0.001	Cost parameter of debt	
ρ^R	0.77	AR(1) coefficient Taylor rule	Aspachs-Bracons and Rabanal (2011)
γ_π	1.25	Inflation sensitivity Taylor rule	Aspachs-Bracons and Rabanal (2011)
n	0.64	Economic size of EMU core	Eurostat

Note: The table mainly reports calibrated parameters for the home country. If not stated otherwise, parameters of the foreign country coincide with the home calibration. Additionally some parameters relate to the EMU in general.

The model implies that the inflation rate is zero in steady state. The discount factor β is calibrated to match the average interest rate in the given time period and is close to the standard value of 0.99 proposed by Kydland and Prescott (1982). The stronger discounting borrower (β^B) provokes that households are endogenously split into groups of two agents with the borrowing constraint binding in steady state. As standard in two country models, the consumers opt to consume more domestic products. n^{aux} is an auxiliary variable weighting the countries as the model is calculated in levels. Housing depreciation rates δ_i differ in size. A fact based on experience which is known as the bad tenant risk in the literature. Capital depreciation rates and input shares of the production functions are at standard values. The steady state LTV ratio is set to 0.8 slightly above average in the EMU (Calza et al., 2013). A marginal cost Ψ_d secures that borrowing returns to the steady state.

Ownershipratio

An essential ratio that has to be matched is the homeownership rate in both blocks. As the ratio is endogenously determined in the model, this poses a tricky task.[9] Amongst the parameters that primarily move the ratio are the share of savers α, the preference/weight parameter for owner-occupied housing in the utility function ω_H, the households rate of substitution σ_H and the rental market efficiency parameter Γ, which also drives the price-rent ratio to a significant part. The rental mark-up X_Z and the LTV_B ratio complete this set of parameters. Figures 2 and 3 show the owner-occupation rates for a pair of parameters while holding all the others fixed at calibrated (respective prior mean) values.
As can be seen from the figures, most of the considered parameters move the ownershipratio in the expected direction. It is increasing in ω_H as the households value it more. The ratio is also increasing in α as savers seem to be willing and rather qualified to afford to live in an owner-occupied home. By construction, an increase in the rental efficiency parameter Γ leads to a decrease in owner-occupation. Naturally, the higher the LTV ratio, the more households live in their own home. Yet, the housing substitution elasticity imposes some higher-order movements for $\sigma_H \to 0$.[10]

[9] E.g. d'Albis and Iliopulos (2013) and Alpanda and Zubairy (2016) directly calibrate the share of owners and renters in the model as they form an individual type of households.
[10] Note that these pairwise combinations are arbitrarily chosen by the author for illustrative purposes.

Figure 2: Ownership calibration exercise (ω_H and second parameter; keeping the others fixed at baseline calibration)

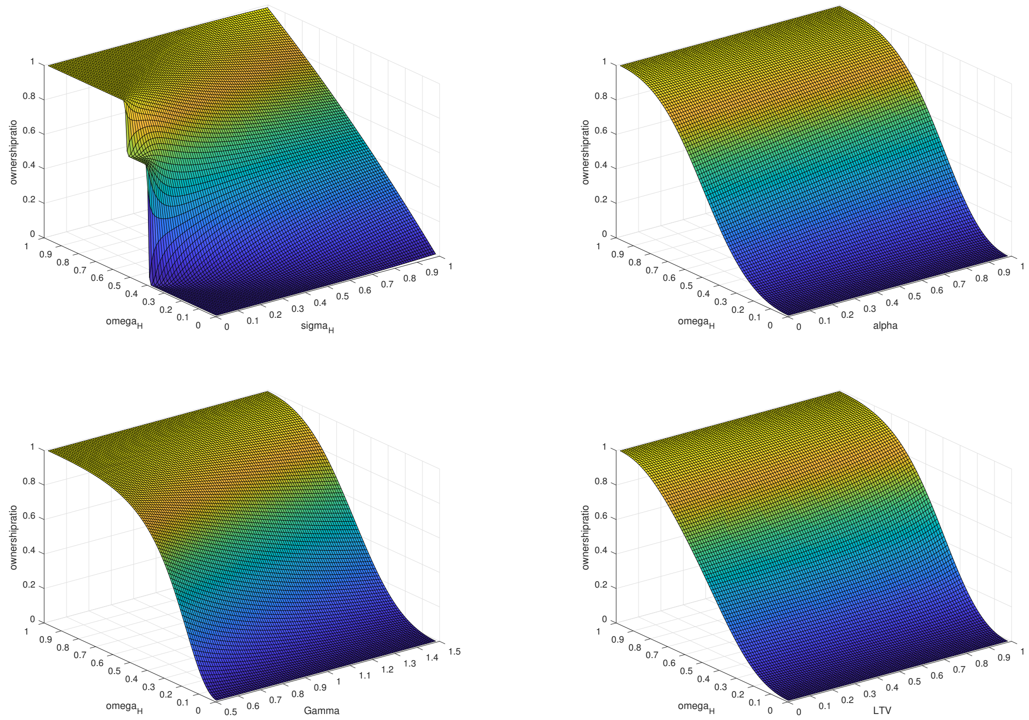
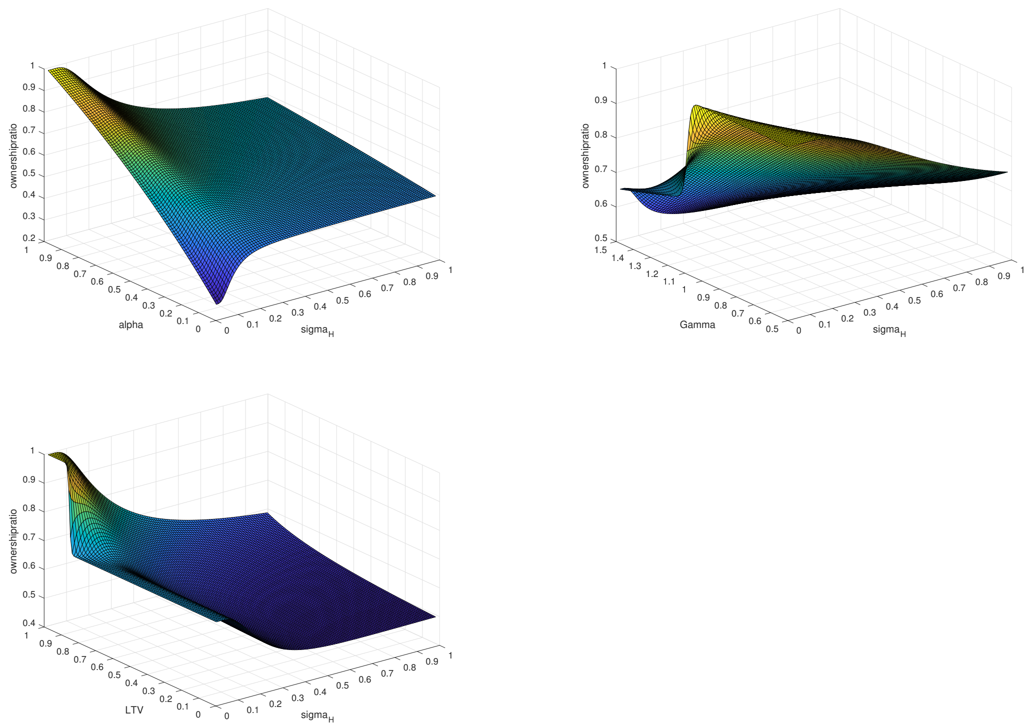


Figure 3: Ownership calibration exercise (σ_H and second parameter; keeping the others fixed at baseline calibration)



Apart from the LTV ratio, there is no micro evidence for the parameters of interest that would help to calibrate the model to meet the ownership ratio. Arguably information on the share of savers α can be taken from other estimations (e.g. Quint and Rabanal (2014)). Yet, this makes it an appropriate subject of research for Bayesian estimation. However, the model is also calibrated to meet the target ratio. Results of such approaches, where each of the "housing related" parameters is individually used to calibrate the ratio keeping the others constant at their prior means can be found in Section 5.

4 Estimation

The estimation of parameters of the model using Bayesian methods should shed light on the determinants of the heterogeneous ownership rates. Real data (see Appendix) is used to estimate the model using Bayesian methods. In a second step it can be evaluated how well the model matches the cyclical properties of the data.
Table 2 and 3 provide information on the estimation. The prior means are additionally the values of the calibrated baseline model.

Table 2: Prior and Posterior Distribution of Estimated Parameters (Home)

		Prior Distribution			Posterior Distribution			
Parameter	Describtion	Distr.	Mean	St. Dev.	Mean	Median	5%	95%
Parameters with housing focus								
α	Savers' labor share in production	beta	0.5	0.1	x	x	x	x
ω_H	Weight of OO housing	beta	0.5	0.1	x	x	x	x
σ_H	Housing elasticity of substitution	beta	0.5	0.1	x	x	x	x
Ψ_H	Adj. cost parameter landlords	gamma	5	1	x	x	x	x
Γ	Rental market efficiency	normal	1.3	0.1	x	x	x	x
ϕ_Z	Indexation of rents	beta	0.5	0.1	x	x	x	x
θ_Z	Calvo parameter rents	beta	0.667	0.1	x	x	x	x
Other								
h	Habit in consumption	beta	0.5	0.1	x	x	x	x
σ_C	Int. good consumption elasticity	normal	2	0.1	x	x	x	x
ω_L	Labor weight	beta	0.5	0.1	x	x	x	x
σ_L	Labor reallocation parameter	normal	1	0.1	x	x	x	x
η	Labor supply elasticity and disutility	gamma	0.5	0.1	x	x	x	x
Ψ_{kC}	Adj. cost parameter capital consumption	gamma	10	1	x	x	x	x
Ψ_{kH}	Adj. cost parameter capital housing	gamma	10	1	x	x	x	x
ϕ_π	Indexation of goods prices	beta	0.5	0.1	x	x	x	x
θ_π	Calvo parameter goods prices	beta	0.667	0.1	x	x	x	x
ϕ_{wC}	Indexation of wages cons. sector	beta	0.5	0.1	x	x	x	x
θ_{wC}	Calvo parameter wages cons. sector	beta	0.667	0.1	x	x	x	x
ϕ_{wH}	Indexation of wages housing sector	beta	0.5	0.1	x	x	x	x
θ_{wH}	Calvo parameter wages housing sector	beta	0.667	0.1	x	x	x	x

Table 3: Prior and Posterior Distribution of Shocks (Home)

		Prior Distribution			Posterior Distribution			
Parameter	Describtion	Distr.	Mean	St. Dev.	Mean	Median	5%	95%
ρ^{TP}	AR(1) coeff. time preference	beta	0.8	0.1	x	x	x	x
ε^{TP}	St. Dev. time preference	inv. gamma	0.001	0.01	x	x	x	x
ρ^{HP}	AR(1) coeff. housing preference	beta	0.8	0.1	x	x	x	x
ε^{HP}	St. Dev. housing preference	inv. gamma	0.001	0.01	x	x	x	x
ρ^{LS}	AR(1) coeff. labor supply	beta	0.8	0.1	x	x	x	x
ε^{LS}	St. Dev. labor supply	inv. gamma	0.001	0.01	x	x	x	x
ρ^{kC}	AR(1) coeff. consumption investment	beta	0.8	0.1	x	x	x	x
ε^{kC}	St. Dev. consumption investment	inv. gamma	0.001	0.01	x	x	x	x
ρ^{C}	AR(1) coeff. consumption technology	beta	0.8	0.1	x	x	x	x
ε^{C}	St. Dev. consumption technology	inv. gamma	0.001	0.01	x	x	x	x
ρ^{H}	AR(1) coeff. housing technology	beta	0.8	0.1	x	x	x	x
ε^{H}	St. Dev. housing technology	inv. gamma	0.001	0.01	x	x	x	x
ρ^{LTV}	AR(1) coeff. LTV	beta	0.8	0.1	x	x	x	x
ε^{LTV}	St. Dev. LTV	inv. gamma	0.001	0.01	x	x	x	x
ε^{P}	St. Dev. cost push	inv. gamma	0.001	0.01	x	x	x	x
ε^{R}	St. Dev. interest rate	inv. gamma	0.001	0.01	x	x	x	x

5 Findings

This section presents findings of the calibrated model. It presents impulse response functions (IRF) to selected shocks in the core (Home) and periphery (Foreign) of the EMU. As mentioned above, the calibration exercise was to meet the owner-occupation rates in both regions using one parameter at a time (these being $\alpha, \omega_H, \sigma_H, \xi^{LTV}$ and Γ). The corresponding ownership ratios are 0.59 and 0.76.

Results of the IRFs indicate that depending on which parameter drives the ownership ratio, effects of the shocks can be substantial.[11] The most apparent effects are observed if the LTV ratio or the share of savers is heterogeneous across countries. This is in line with findings by Gareis and Mayer (2017) and Rubio (2014).

[11] This section only contains IRFs following an interest rate shock. Further figures can be found in the Appendix.

Figure 4: Monetary Policy Shock (α being the utilized parameter)

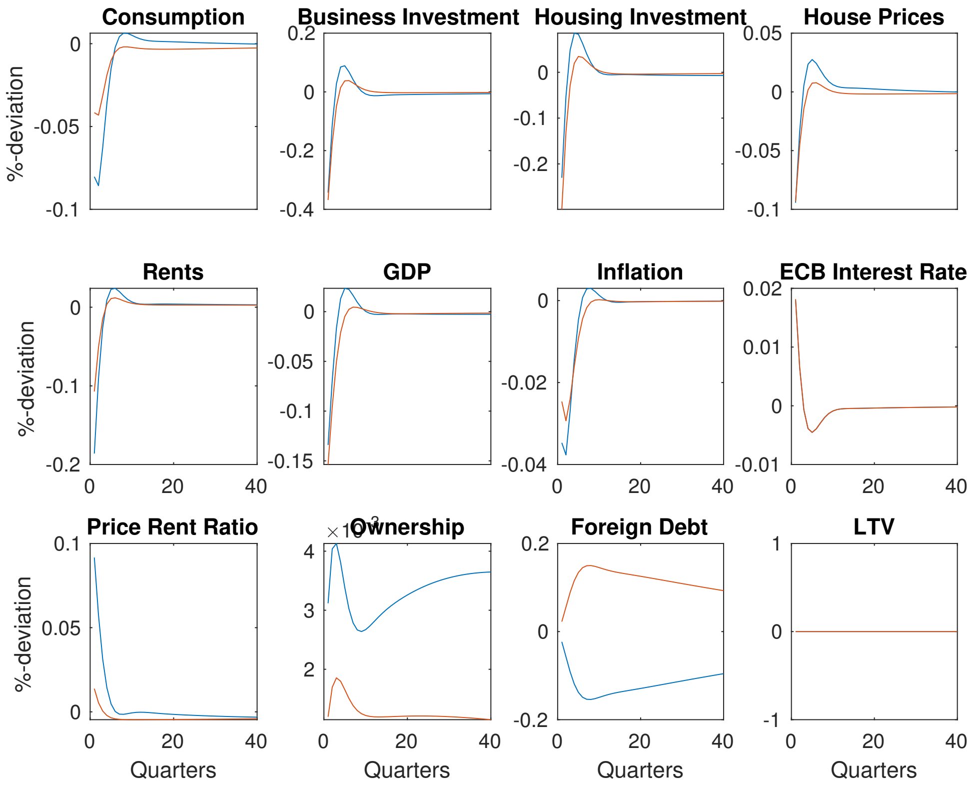


Figure 5: Monetary Policy Shock (ω_H being the utilized parameter)

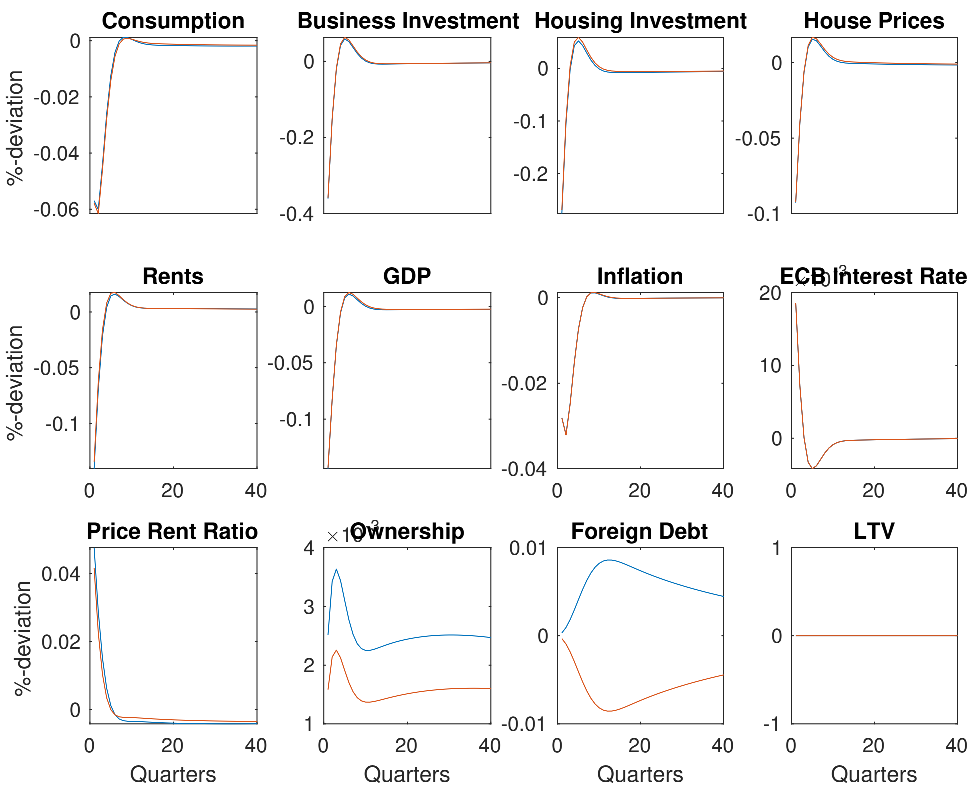


Figure 6: Monetary Policy Shock (σ_H being the utilized parameter)

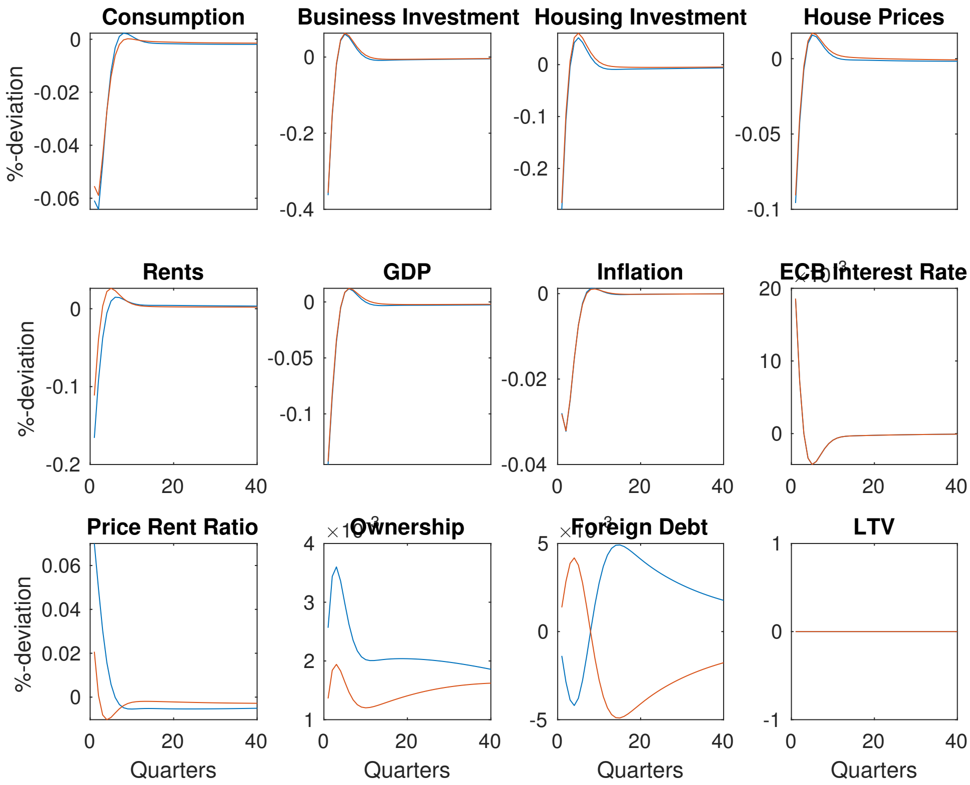


Figure 7: Monetary Policy Shock (ξ^{LTV} being the utilized parameter)

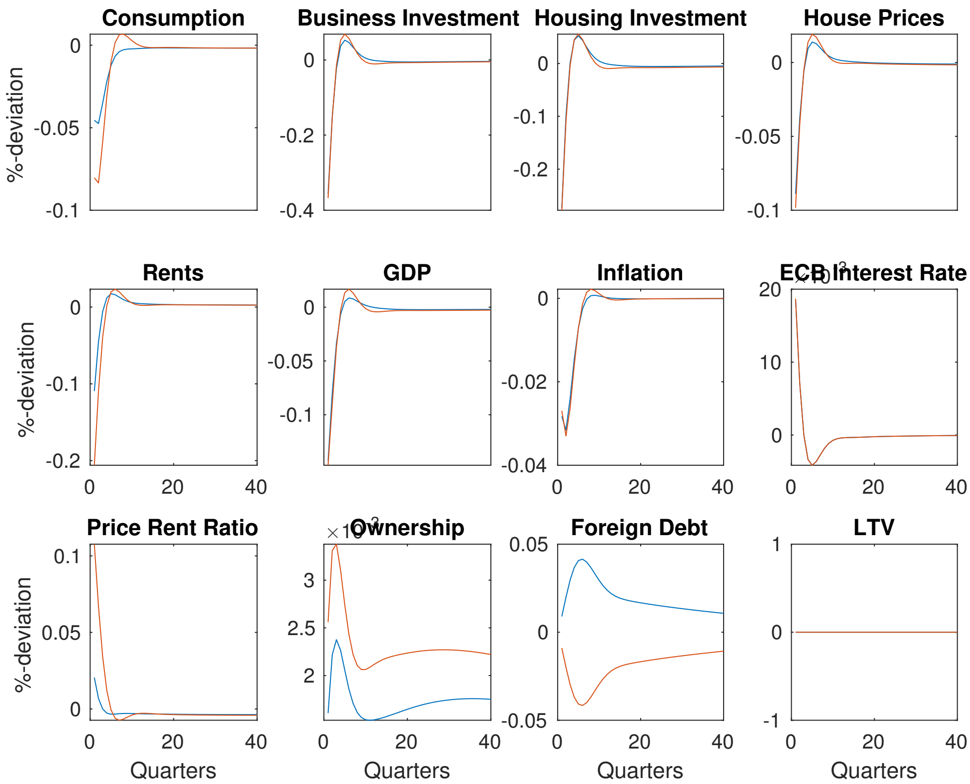
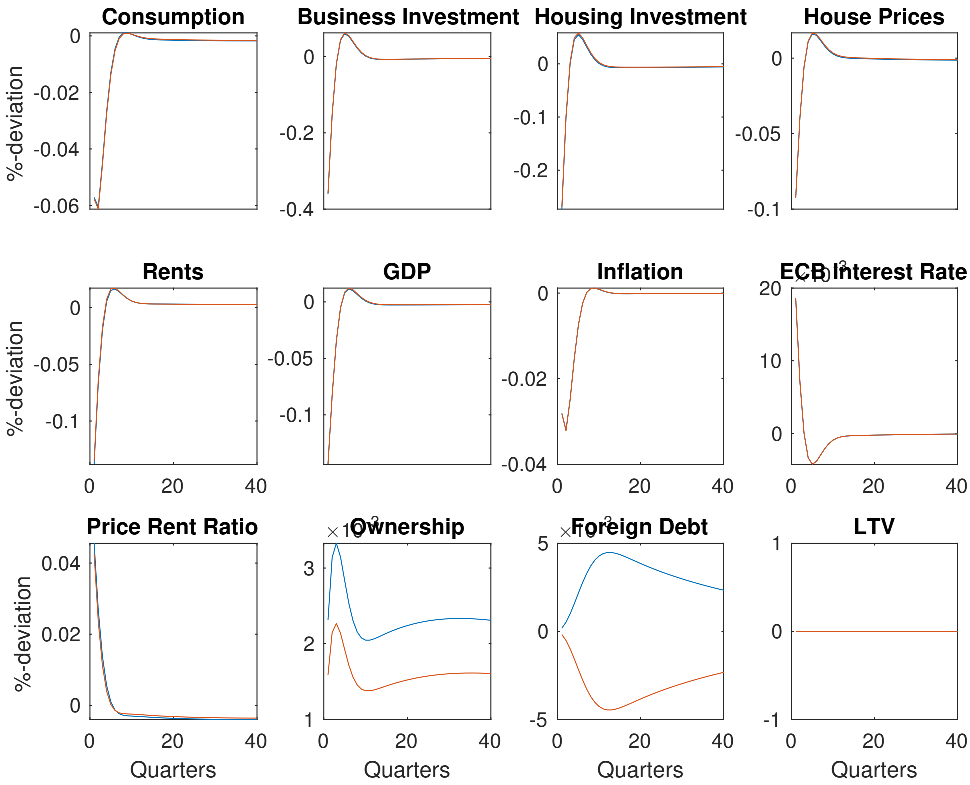


Figure 8: Monetary Policy Shock (Γ being the utilized parameter)



6 Conclusion

This paper presents a two region New Keynesian DSGE model with an extensive housing market including endogenous tenure choice for a monetary union. The calibrated model indicates that the effects of stochastic shocks are heterogeneous across countries with different rental market characteristics. The effect depends significantly on the driver of the ownership rate. A Bayesian estimation of the model can shed light on the true deep parameters determining heterogeneities in the rental markets across countries.

A Model

First order conditions

The Optimization exercise can be performed using both nominal and real representation of the variables and equations. For the households we use the nominal form, which is more intuitive to follow.
The savers' Lagrangian is given by[12]

$$\mathscr{L}_1^S = \mathbb{E}_0 \sum_{t=0}^{\infty} (\beta)^t \xi_t^{TP} \left(\Theta^S \ln(C_t^S - \vartheta C_{t-1}^S) + \xi_t^{HP} \frac{\ln(H_t^S)}{1-\sigma_H} - \xi_t^{LS} \frac{(L_t^S)^{1+\eta}}{1+\eta} \right)$$
$$-\lambda_1^S \Bigg(P_t C_t^S + Q_{H,t}(H_{O,t}^S - (1-\delta_O) H_{O,t-1}^S) + Q_{Z,t} Z_t^S + R_{t-1}^B B_{t-1}^{SB} + R_{t-1}^E B_{t-1}^{SE} + R_{t-1} D_{t-1} \tag{46}$$
$$+ \frac{\Psi_d}{2} B_t^{SE^2} + \frac{\Psi_d}{2} D_t^2 - \frac{W_{C,t}^S L_{C,t}^S}{X_{C,t}} - \frac{W_{H,t}^S L_{H,t}^S}{X_{H,t}} - \Pi_t^S - B_t^{SB} - B_t^{SE} - D_t \Bigg)$$

The consumption optimization can be formulated as a two stage decision following Aspachs-Bracons and Rabanal (2011). First, households decide how much of the aggregate good they would like to consume and in a second step they face the decision on how much spending on home and foreign produced goods. The first order condition (FOC) with respect to consumption is

$$\frac{\partial \mathscr{L}_1^S}{\partial C_t^S} = U_{C,t}^S - \lambda_{1,t}^S P_t = 0 \Leftrightarrow \lambda_{1,t}^S = \frac{U_{C,t}^S}{P_t}$$

where

$$\frac{\partial U_t^S}{\partial C_t^S} = \Theta^S \left(\frac{\xi_t^{TP}}{C_t^S - \vartheta C_{t-1}^S} - \frac{\beta^S \vartheta \xi_{t+1}^{TP}}{C_{t+1}^S - \vartheta C_t^S} \right) =: U_{C,t}^S \tag{47}$$

Due to the presence of international trade within the Monetary Union, in a second step the actors minimize their spending under the restriction that aggregated consumption must equal their spending decision from the FOCs

$$\min \mathscr{L}_2^S = P_t(H) C_t^S(H) + P_t(F) C_t^S(F) - \lambda_{2,t}^S \left(\left[\omega_C^{\frac{1}{\sigma_C}} (C_t^S(H))^{\frac{\sigma_C - 1}{\sigma_C}} + (1-\omega_C)^{\frac{1}{\sigma_C}} (C_t^S(F))^{\frac{\sigma_C-1}{\sigma_C}} \right]^{\frac{\sigma_C}{\sigma_C - 1}} - C_t^S \right)$$

$$\frac{\partial \mathscr{L}_2^S}{\partial C_t^S(H)} = P_t(H) - \lambda_{2,t}^S \omega_C^{\frac{1}{\sigma_C}} C_t^S(H)^{\frac{\sigma_C - 1 - \sigma_C}{\sigma_C}} \left[\omega_C^{\frac{1}{\sigma_C}} (C_t^S(H))^{\frac{\sigma_C-1}{\sigma_C}} + (1-\omega_C)^{\frac{1}{\sigma_C}} (C_t^S(F))^{\frac{\sigma_C-1}{\sigma_C}} \right]^{\frac{\sigma_C}{\sigma_C-1}-1} = 0$$

$$\Rightarrow P_t(H) = \lambda_{2,t}^S \omega_C^{\frac{1}{\sigma_C}} C_t^S(H)^{-\frac{1}{\sigma_C}} \left[\omega_C^{\frac{1}{\sigma_C}} (C_t^S(H))^{\frac{\sigma_C-1}{\sigma_C}} + (1-\omega_C)^{\frac{1}{\sigma_C}} (C_t^S(F))^{\frac{\sigma_C-1}{\sigma_C}} \right]^{\frac{1}{\sigma_C-1}}$$

$$\Leftrightarrow C_t^S(H) = \omega_C \left(\frac{P_t(H)}{P_t} \right)^{-\sigma_C} \left[\omega_C^{\frac{1}{\sigma_C}} (C_t^S(H))^{\frac{\sigma_C-1}{\sigma_C}} + (1-\omega_C)^{\frac{1}{\sigma_C}} (C_t^S(F))^{\frac{\sigma_C-1}{\sigma_C}} \right]^{\frac{\sigma_C}{\sigma_C-1}}$$

$$\Leftrightarrow C_t^S(H) = \omega_C \left(\frac{P_t(H)}{P_t} \right)^{-\sigma_C} C_t^S \tag{48}$$

Where we used the fact that $\lambda_{2,t}^S$ equals the price of an extra unit of the aggregate consumption good and we substitute $\lambda_{2,t}^S = P_t$. Analogously the demand for the foreign-produced consumption good

$$C_t^S(F) = (1-\omega_C) \left(\frac{P_t(F)}{P_t} \right)^{-\sigma_C} C_t^S \tag{49}$$

The relevant price index P_t for the aggregate consumption good, also known as the CPI, is given by the aggregate price level that considers imports.

$$P_t = \left[\omega_C P_t(H)^{1-\sigma_C} + (1-\omega_C) P_t(F)^{1-\sigma_C} \right]^{\frac{1}{1-\sigma_C}} \tag{50}$$

[12]We follow Iacoviello and Neri (2010) and treat the dividends as a lump-sum transfer which do not play a role in the agents optimization problem.

The FOC with respect to the bond holdings with the borrower households is

$$\begin{aligned}\frac{\partial \mathcal{L}_1^S}{\partial B_t^{SB}} &= \lambda_{1,t}^S - \mathbb{E}_t\beta\left[\lambda_{t+1}^S R_t^{SB}\right] = 0\\ \Leftrightarrow \frac{U_{C,t}^S}{P_t} &= \mathbb{E}_t\beta\left[\frac{U_{C,t+1}^S R_t^{SB}}{U_{C,t}^S \pi_{t+1}}\right].\end{aligned} \tag{51}$$

The FOC with respect to the bond holdings with the entrepreneurs is

$$\vdots$$

Figure 9: Representation of the model structure

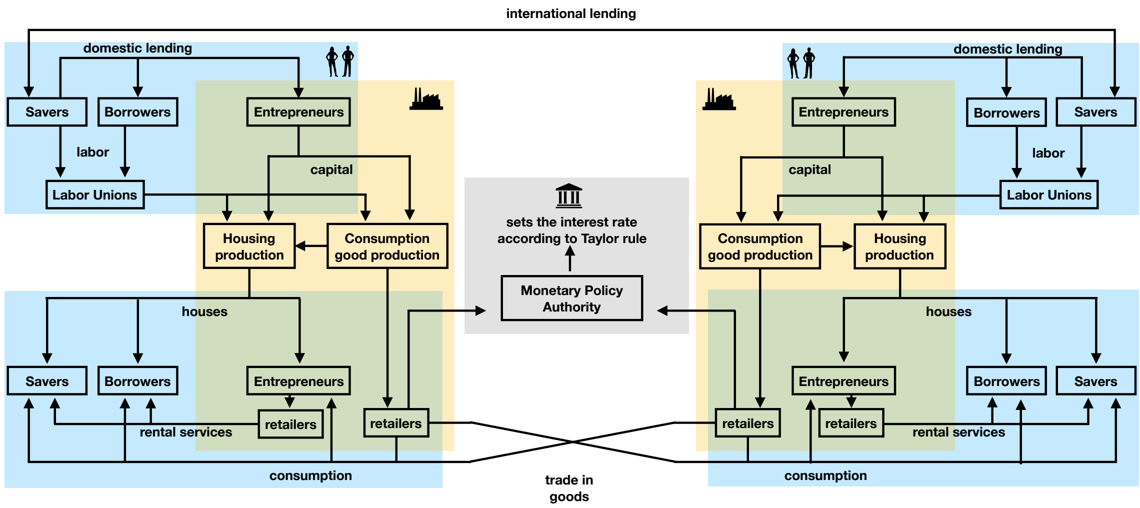
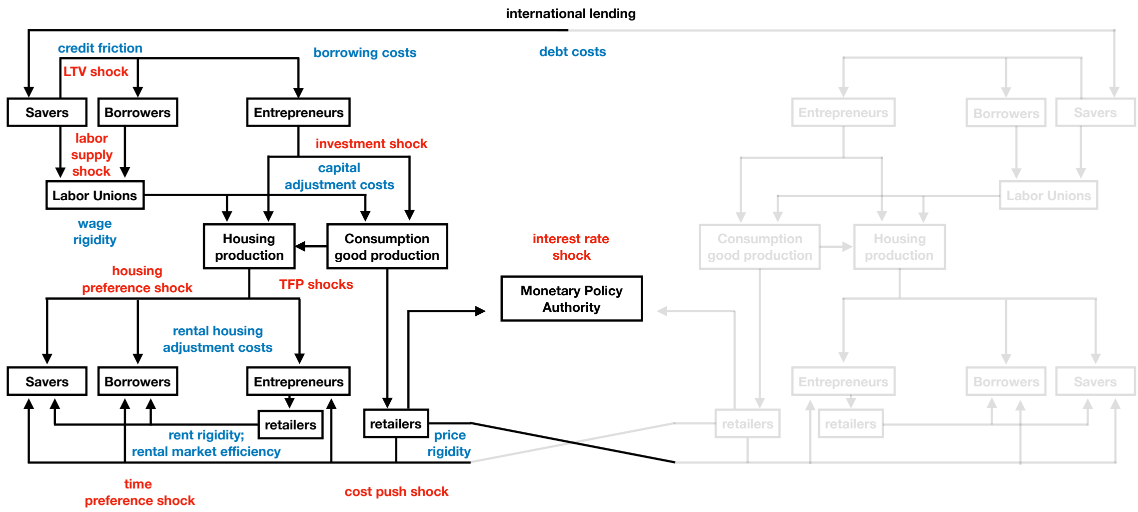


Figure 10: Representation of the model structure including shocks and frictions



B Data

Real consumption: Consumption of households, seasonally and working day adjusted, deflated with the the harmonized index of consumer prices. Source: Eurostat.
Real business investment: Gross fixed capital formation excluding housing investment, seasonally and working day adjusted, Source: Eurostat.
Real housing investment: Gross fixed capital formation in dwellings, seasonally and working day adjusted. Source: Eurostat.
Real house prices: Nominal house price index deflated with the harmonized index of consumer prices. Source: OECD
Real rental prices: Nominal rental price index deflated with the harmonized index of consumer prices. Source: OECD.
Ownership rate: Tenure status: owner. Yearly data for a limited period. Missing data is calculated by linear interpolation. Source: Eurostat.
Inflation: Overall harmonized index of consumer prices (excluding food and energy prices?? and housing?), seasonally and working day adjusted. Source: Eurostat.
Nominal interest rate: Three month Euribor. Source: ECB.

C IRFs

The figures in this section show responses to a Housing Preference and a Time Preference shock in the respective region an are therefore comparable.

Figure 11: Housing Preference (α being the utilized parameter)

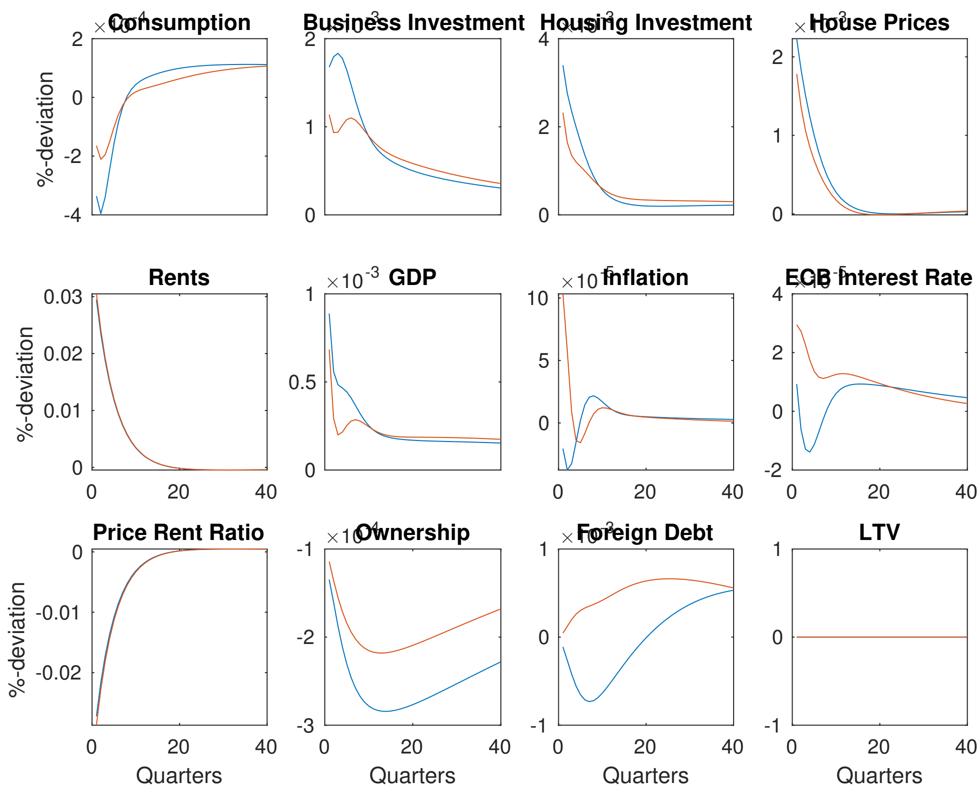


Figure 12: Housing Preference (ω_H being the utilized parameter)

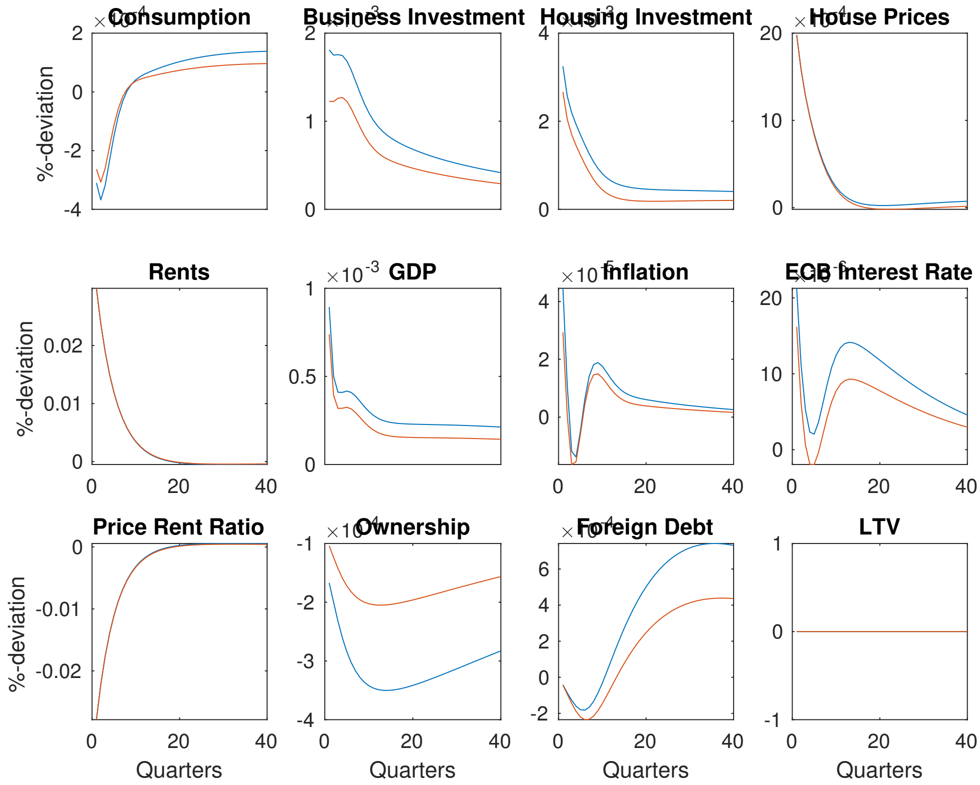


Figure 13: Housing Preference (σ_H being the utilized parameter)

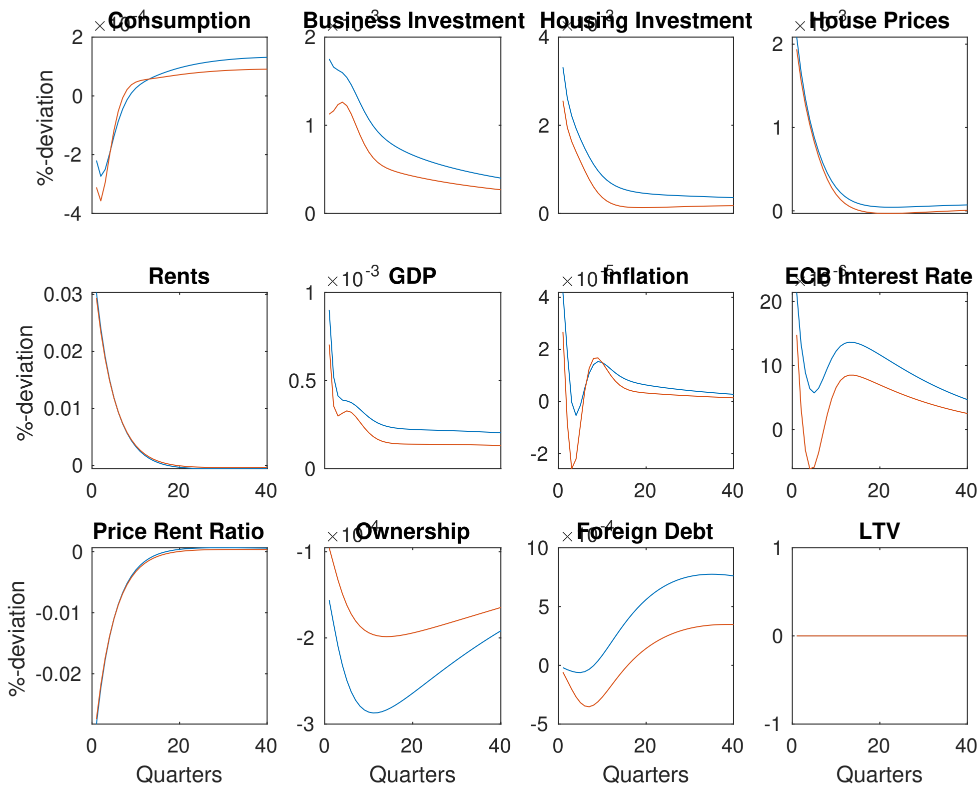


Figure 14: Housing Preference (ξ^{LTV} being the utilized parameter)

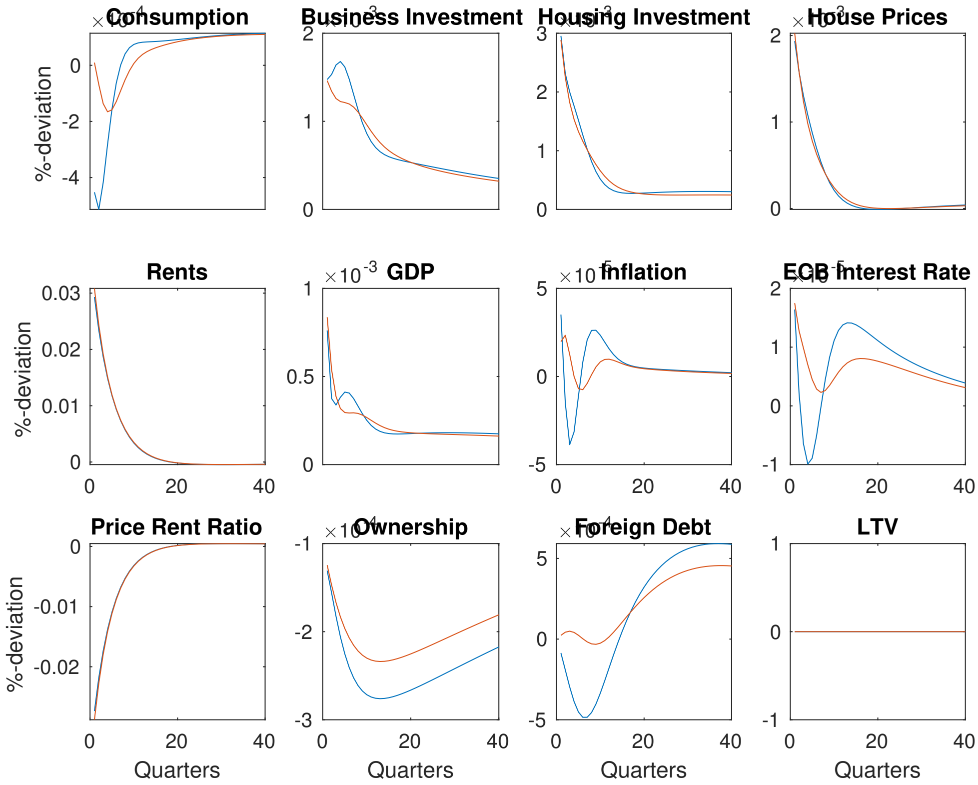


Figure 15: Housing Preference (Γ being the utilized parameter)

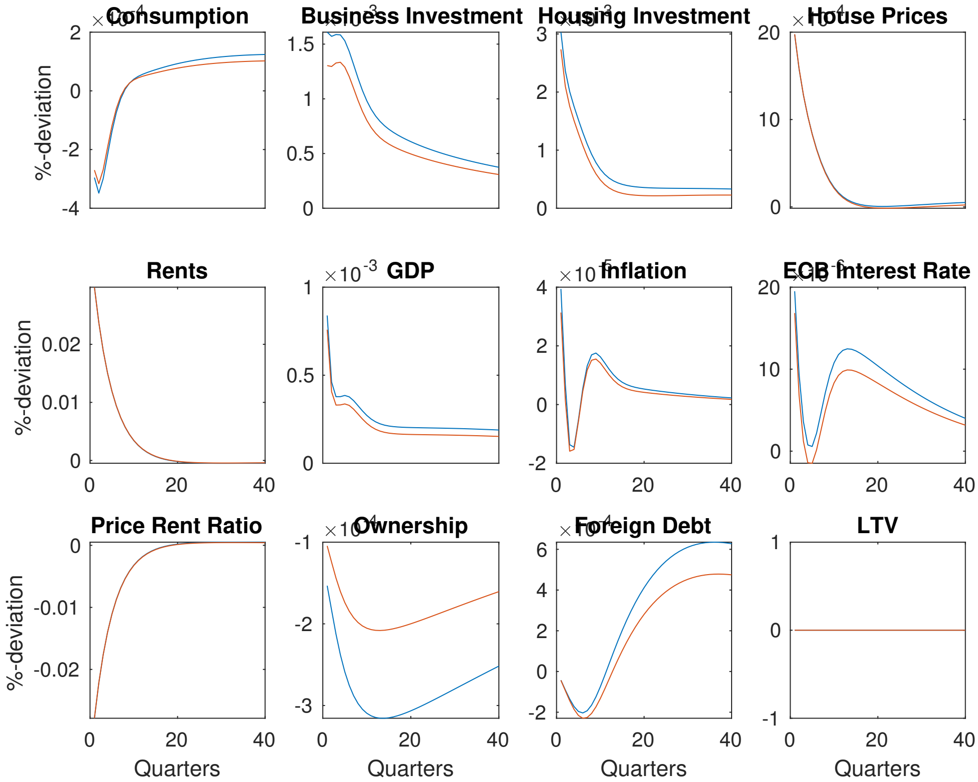


Figure 16: Time Preference (α being the utilized parameter)

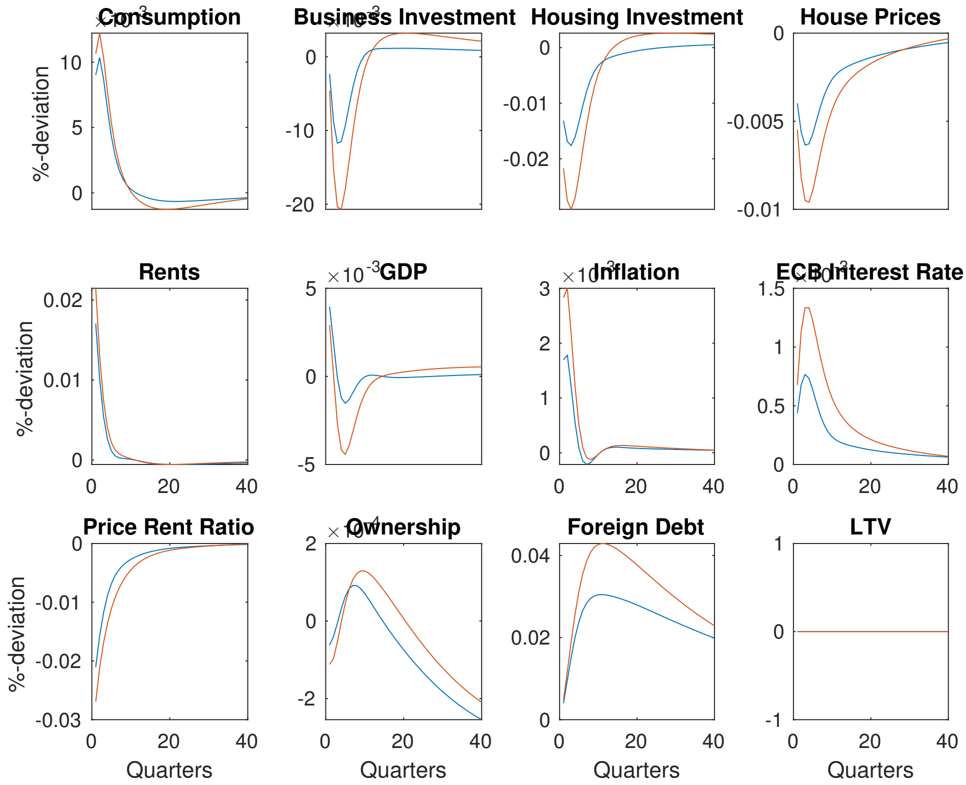


Figure 17: Time Preference (ω_H being the utilized parameter)

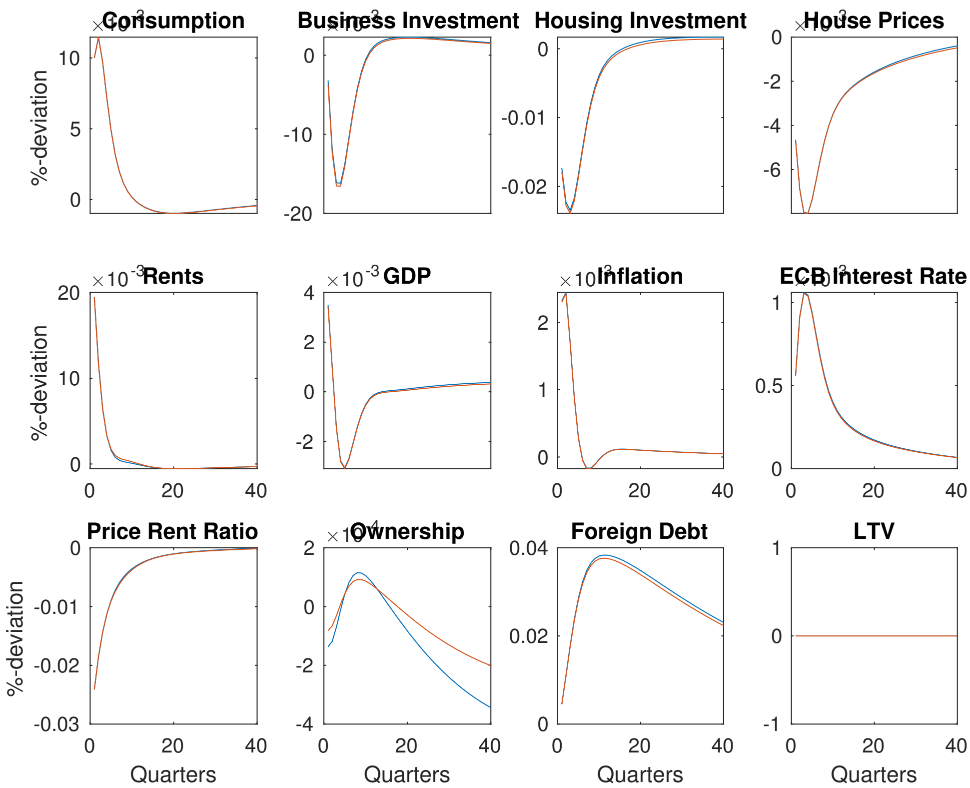


Figure 18: Time Preference (σ_H being the utilized parameter)

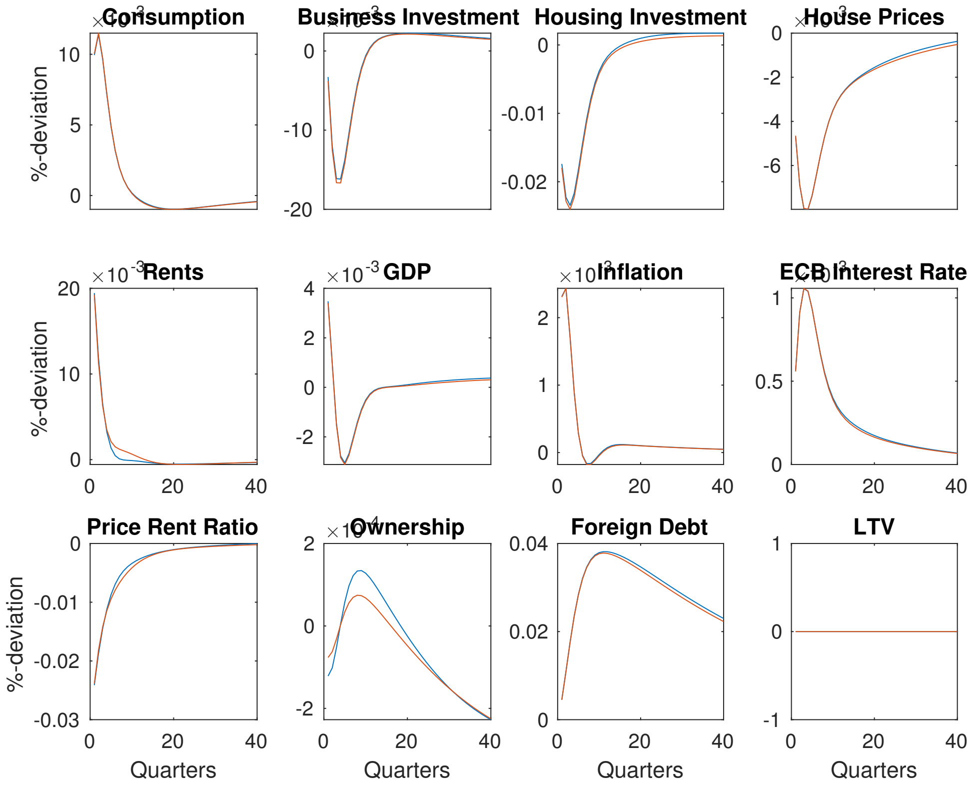


Figure 19: Time Preference (ξ^{LTV} being the utilized parameter)

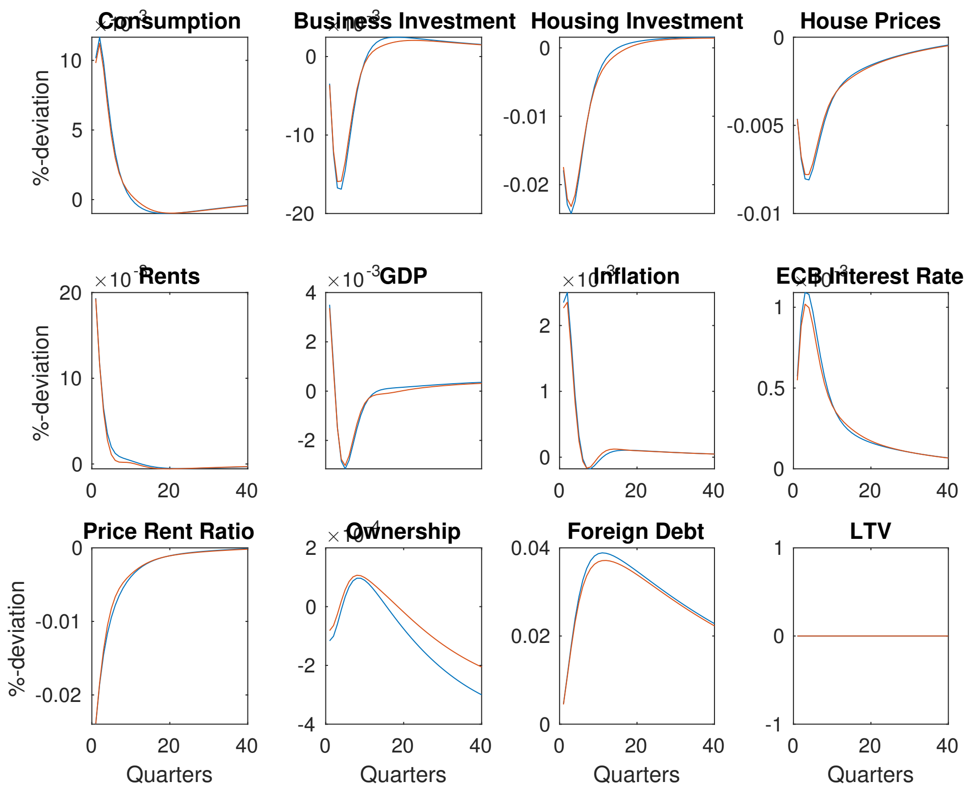
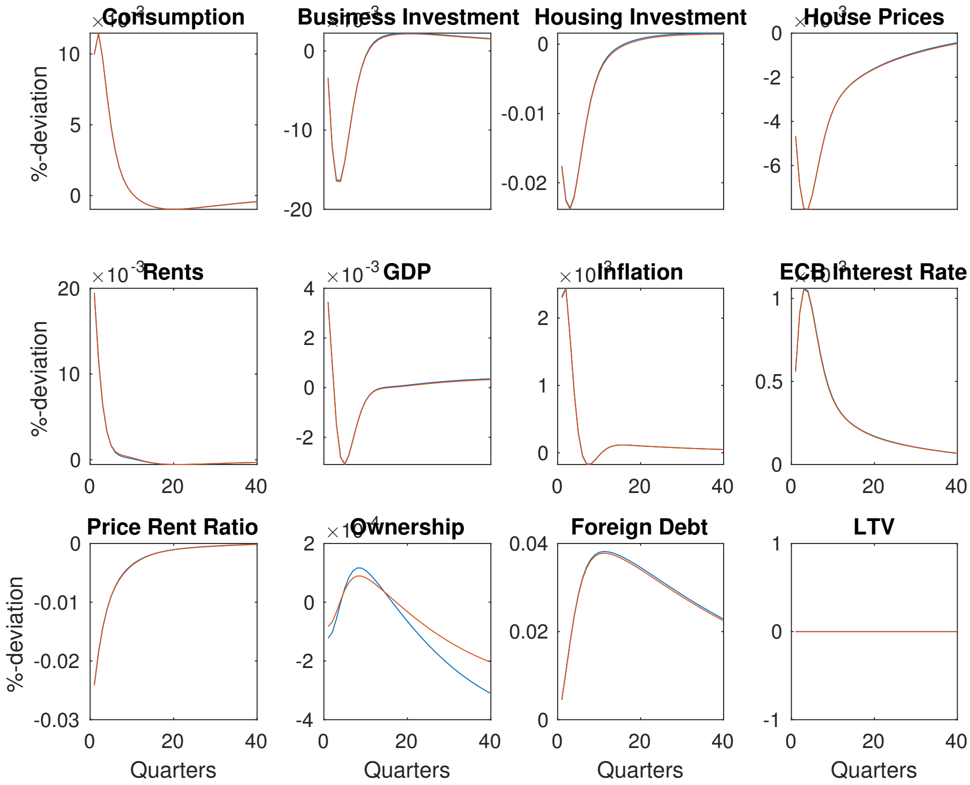


Figure 20: Time Preference (Γ being the utilized parameter)



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