REMS1: Adding Financial Frictions and a Housing Market to REMS

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Abstract

We introduce an update of REMS, the model used by the Spanish Ministries of Economy and Finance for ex-ante policy evaluation. We include two new features in the model: credit-constrained consumers, which are added to the existing optimizing consumers and liquidity-constrained (RoTs) consumers; and a market for housing. Credit-constrained consumers can borrow up to a limit defined by the expected value of their houses. Part of the real estate accumulated by patient households is offered to impatient and liquidity-contrained households as house to rent. Impatient households can decide between purchasing houses to occupy themselves or renting houses from patient households. Completely liquidity-constrained households only have access to rented houses. We illustrate how this housing market reacts to different shocks and we simulate the expected effects of Spain's 2014 fiscal reform.

Key words: REMS, credit constraints, mortgages, housing

1 Introduction

In the last eight years, the REMS model has become one of the reference tools used by different institutions for ex-ante macro evaluation of the effects of a number of policies and shocks affecting the Spanish economy. A non-exhaustive list of events that have merited the use of REMS for evaluation includes the following: increased transport infrastructure related to high-speed railways (2007), the rise in the risk premium (2007 and 2013); the Disability Law (2008); the 400 euros check (2008); oil price shocks (2008 and 2014); the implementation of the Lisbon Strategy (2009); the downturn in residential investment (2010); the labour market reform (2012); and the 2014 tax reform (2014). After all these years and simulations we believe REMS has fulfilled its purpose. However, the time has come for a change in its architecture in order to adapt the model to the new economic environment and in response to the latest developments in macro modelling. This task centres on the reinforcement of financial frictions and the estimation of part of the parameters using data that include the financial crisis period. Thus, two new estimated versions of the model (EREMS1 and EREMS2) will replace the old REMS, differing from one another with respect to the detail in which the labour market and the banking sector will be introduced.

In this paper, we present a modest update of REMS following the first steps of the roadmap to EREMS1. To this end, we include two new features in the model: credit-constrained consumers, which are added to the existing optimizing consumers and liquidity-constrained (RoTs) consumers, and a housing market. Credit-constrained consumers can borrow up to a limit defined by the expected value of their houses. Part of the real estate accumulated by patient households is offered to impatient and liquidity-constrained households as houses to rent. Impatient households can decide between purchasing houses to occupy themselves or renting houses from patient households. Completely liquidity-constrained households only have access to rented houses.

This paper builds on the basic reference of Boscá et al. (2010). The following section highlights only the main differences with respect to the existing REMS as explained in Boscá et al. (2010). Section 3 illustrates the reaction of macroeconomic variables and the housing market to various shocks, and provides an evaluation of the 2014 fiscal reform using the updated model. Section 4 presents the conclusions.

2 Borrowing constraints and the housing market

As in Kiyotaki and Moore (1997) and Iacoviello (2005), there are two types of consumers that have access to financial markets. N_t^o of them are patient and N_t^b are impatient. Patient households are characterized by discounting the future less heavily than impatient ones. This ensures that in the steady-state, and under fairly general conditions, patient households are net lenders while impatient households become net borrowers. Borrowers face a binding constraint in the amount of credit they can take that is given by the expected real value of their real estate holdings. Houses are assumed to be their only collateralizable asset. In addition, there is another group of the population N_t^r which is liquidity-constrained. This group of households cannot trade with financial or physical assets and thus in each period they consume out of their disposable income. The size of the working-age population is given by $N_t = N_t^o + N_t^b + N_t^r$. Let $1 - \lambda^b - \lambda^r$, $\lambda^b$and λ^r denote the proportions of lenders, borrowers and liquidity-constrained households, respectively, in the working-age population. These shares are assumed to be constant over time, unless otherwise stated. In our notation, variables and parameters indexed by o, b and r respectively denote patient (lenders), impatient (borrowers) and liquidity-constrained households. Non-indexed variables apply indistinctly to all types of households.

2.1 Patient households (lenders)

Patient households discount the future less heavily than impatient ones. They face the following maximization program:

$$\max_{\substack{c_t^o, j_t^o, k_t^o, \\ b_t^o, b_t^p, b_t^{o,w} m_t^o, x_t^o, \widetilde{x}_t^o}} E_t \sum_{t=0}^{\infty} \beta^{ot} \begin{bmatrix} \ln\left(c_t^o - hc_{t-1}^o\right) + \phi_x \ln\left(x_t^o\right) + \\ n_{t-1}^o \phi_1 \frac{(T-l_{1t})^{1-\eta}}{1-\eta} + (1-n_{t-1}^o)\phi_2 \frac{(T-l_{2t})^{1-\eta}}{1-\eta} + \chi_m \ln\left(m_t^o\right) \end{bmatrix}$$

subject to

$$\begin{gathered} \left(r_t(1-\tau_t^k) + \tau_t^k \delta\right) k_{t-1}^o + w_t \left(1-\tau_t^l\right) \left(n_{t-1}^o l_{1t} + rr_t s \left(1-n_{t-1}^o\right) l_{2t}\right) \\ + \left(\left(1-\tau_t^l\right) g_{st} - trh_t^o\right) + \frac{m_{t-1}^o}{1+\pi_t^c} + \left(1+r_{t-1}^n\right)\left(\frac{b_{t-1}^o}{1+\pi_t^c} + \frac{b_{t-1}^p}{1+\pi_t^c}\right) \\ +(1+r_{t-1}^{emu}) \frac{b_{t-1}^{o,w}}{1+\pi_t^c} + \frac{P_t^a}{P_t}\left(1-\tau_t^r\right) A_t^a \widetilde{x}_{t-1}^o - \zeta_t^o = \\ \frac{P_t^h}{P_t}\left(\left(1+\tau_t^h\right)\left(\gamma_A \gamma_N x_t^o - x_{t-1}^o\right) + \left(1+\tau_t^s\right)\left(\gamma_A \gamma_N \widetilde{x}_t^o - \widetilde{x}_{t-1}^o\right)\right) \\ (1+\tau_t^c) c_t^o \frac{P_t^c}{P_t} + \frac{P_t^i}{P_t} j_t^o \left(1 + \frac{\phi}{2}\left(\frac{j_t^o}{k_{t-1}^o}\right)\right) + \gamma_A \gamma_N \left(m_t^o + b_t^o + b_t^p + \frac{b_t^{o,emu}}{\phi_{bt}}\right) \end{gathered} \tag{1}$$

$$\gamma_A \gamma_N k_{t+1}^o = j_t^o + (1-\delta) k_t^o \tag{2}$$

$$\gamma_N n_{t+1}^o = (1-\sigma) n_t^o + \rho_t^w s (1-n_t^o) \tag{3}$$

$$k_0^o, b_0^o, b_0^p, b_0^{ow}, m_0^o \tag{4}$$

c_t^o, x_t^o, n_t^o and $s(1-n_t^o)$ represent, respectively, consumption, housing holdings, the employment rate and the unemployment rate of patient optimizing households; s is the (exogenous) share of the non-employed workers actively searching for jobs; T, l_{1t} and l_{2t} are total endowment of time, hours worked per employee and hours devoted to job search by unemployed workers. l_{1t} is determined jointly by the firm and the worker as part of the same Nash bargaining that is used to determine wages (see section 2.5). l_{2t} is assumed to be a function of the overall economic activity, so that individual households take it as given.

There are a number of preference parameters defining the utility function of optimizing households. Future utility is discounted at a rate parameter of $\beta^o \in (0,1)$, which is higher than the equivalent for impatient and liquidity-constrained households $\beta^o > \beta^b$. The parameter η defines the Frisch elasticity of labour supply. Also, $h^o > 0$ indicates that consumption is subject to habits. The subjective value that workers assign to leisure may vary across employment statuses, and thus $\phi_1 \neq \phi_2$ in general.

For simplicity, we adopt the money-in-the-utility function approach to incorporate money into the model. The timing implicit in this specification assumes that this variable is the household's real money holdings at the end of period, after having purchased consumption goods, which yields utility.

The budget constraint (1) describes the various sources and uses of income. The term $w_t \left(1-\tau^l\right) n_t^o l_{1t}$ captures net labour income earned by the fraction of employed workers, where w_t stands for hourly real wages. The product $\overline{rr} w_t \left(1-\tau^l\right) s\left(1-n_t^o\right) l_{2t}$ measures unemployment benefits accruing to the unemployed, where $\overline{rr}$ denotes the replacement rate of unemployment benefits relative to the market wage.

Impatient households hold different assets, namely private physical capital (k_t^o), domestic private (b_t^o) and public (b_t^p) bonds, euro-zone bonds (b_t^{oemu}) and money balances (M_t^o). Barring money, the rest of these assets yield some remuneration. The remaining two sources of revenues are lump-sum transfers, trh_t, and other government transfers, g_{st}.

There is a fixed amount of real estate in the economy [1], although investment in housing can be made by both patient and impatient households. Regarding the housing market, we closely follow Ortega *et al.* (2011); lenders own and occupy a stock of houses x_t^o although they can also own houses that they do not occupy and that can be rented to other households. The term

$$\frac{P_t^h}{P_t}\left(\left(1+\tau^h\right)\left(\gamma_A\gamma_N x_t^o - x_{t-1}^o\right) + \left(1+\tau^s\right)\left(\gamma_A\gamma_N \widetilde{x}_t^o - \widetilde{x}_{t-1}^o\right)\right)$$

denotes total housing investment by patient households, of which $\left(\gamma_A\gamma_N x_t^o - x_{t-1}^o\right)$ contributes to increasing the stock of owner-occupied houses and $\left(\gamma_A\gamma_N \widetilde{x}_t^o - \widetilde{x}_{t-1}^o\right)$ is the part of investment in houses that are not intended for owner occupancy. The ratio $\frac{P_t^h}{P_t}$ represents the real housing price, τ^h is a (typically negative) tax on owner-occupied houses acquisitions, and τ^s is a tax charged on the purchases of houses for uses other than owner-occupation. Each individual lender (denoted by l) investing in houses faces an adjustment cost ζ_{tl}^o that we model as a quadratic function of his individual investment, proportional to the total value of the housing stock (which is taken as given from the point of view of an individual investor). Specifically:

$$\zeta_{tl}^o = \frac{\phi_h}{2}\left[\left(\gamma_A\gamma_N \frac{x_{tl}^o}{x_{t-1l}^o} - 1\right)^2 \frac{P_t^h}{P_t} x_t^o + \left(\gamma_A\gamma_N \frac{\widetilde{x}_{tl}^o}{\widetilde{x}_{t-1l}^o} - 1\right)^2 \frac{P_t^h}{P_t} \widetilde{x}_t^o\right] \tag{5}$$

We assume that owner-occupied houses are transformed into housing services in the proportion of one to one. However, this is not the case for the rest of

[1] According to Iacoviello (2005), the assumption of an aggregate fixed housing stock is not crucial to the propagation mechanism of shocks in the economy.

the houses owned by lenders, which can be transformed into rental services in a proportion depending on a parameter A^a. Thus, at the beginning of period t, a part $\widetilde{x}^o_{t-1}$ of the impatient households' housing stock is used to produce rental services according to the production function

$$Rent^o_t = A^a \widetilde{x}^o_{t-1} \tag{6}$$

These rental services are sold to both borrowers and completely liquidity-constrained households at a relative price $\frac{P^a_t}{P_t}$ and the generated income can be subject to a tax τ^r_t.Note that the presence in the model of the relative prices P^c_t/P_t, P^i_t/P_t, $\frac{P^h_t}{P_t}$, $\frac{P^a_t}{P_t}$ implies that a distinction is made between the deflators of consumption, investment, housing, rental services and aggregate output.

The remaining constraints faced by Ricardian households concern the laws of motion for capital and employment.

Given the recursive structure of the above problem, it may be equivalently rewritten in terms of a dynamic program. Thus, the value function $W(\Omega^o_t)$ satisfies the following Bellman equation:

$$W(\Omega^o_t) = \max_{\substack{c^o_t, j^o_t, k^o_t, \\ b^o_t, b^p_t, b^{o,w}_t, m^o_t, x^o_t, \widetilde{x}^o_t}} \left\{ \begin{array}{c} \ln\left(c^o_t - hc^o_{t-1}\right) + \phi_x \ln(x^o_t) + n^o_{t-1}\phi_1 \frac{(T-l_{1t})^{1-\eta}}{1-\eta} \\ +(1-n^o_{t-1})\phi_2 \frac{(T-l_2)^{1-\eta}}{1-\eta} + \chi_m \ln(m^o_t) + \beta^o E_t W(\Omega^o_{t+1}) \end{array} \right\} \tag{7}$$

where the maximization is subject to constraints (1) to (3).

The solution to the optimization program above generates the following first order conditions:

$$\lambda^o_{1t} = \frac{1}{(P^c_t/P_t)(1+\tau^c_t)} \left(\frac{1}{c^o_t - h^o c^o_{t-1}} - \beta^o \frac{h^o}{c^o_{t+1} - h^o c^o_t} \right) \tag{8}$$

$$\gamma_A \gamma_N \frac{\lambda^o_{2t}}{\lambda^o_{1t}} = \tag{9}$$

$$\beta E_t \frac{\lambda^o_{1t+1}}{\lambda^o_{1t}} \left\{ \left[r_{t+1}(1-\tau^k_{t+1}) + \tau^k_{t+1}\delta \right] + \frac{\phi}{2} \frac{P^i_{t+1}}{P_{t+1}} \frac{j^{o2}_{t+1}}{k^{o2}_{t+1}} + \frac{\lambda^o_{2t+1}}{\lambda^o_{1t+1}}(1-\delta) \right\}$$

$$\lambda^o_{2t} = \lambda^o_{1t} \frac{P^i_t}{P_t} \left[1 + \phi\left(\frac{j^o_t}{k^o_t} \right) \right] \tag{10}$$

$$\gamma_A \gamma_N E_t \frac{\lambda^o_{1t}}{\lambda^o_{1t+1}} = \beta E_t \frac{1+r^n_t}{1+\pi^c_{t+1}} \tag{11}$$

$$\gamma_A \gamma_N \lambda^o_{1t} \frac{1}{\phi_{bt}} = \beta E_t \frac{\lambda^o_{1t+1}(1+r^{emu}_t)}{1+\pi^c_{t+1}} \tag{12}$$

$$\frac{\chi_m}{m_t^o} = \gamma_A \gamma_N \lambda_{1t}^o \frac{r_t^n}{1 + r_t^n} \tag{13}$$

$$\gamma_A \gamma_N \frac{P_t^h}{P_t} \lambda_{1t}^o \left[\left(1 + \tau^h\right) + \phi_h \left(\gamma_A \gamma_N \frac{x_t^o}{x_{t-1}^o} - 1 \right) \frac{x_t^o}{x_{t-1}^o} \right] = \frac{\phi_x}{x_t^o}$$
$$+\beta^o E_t \lambda_{1t+1}^o \frac{P_{t+1}^h}{P_{t+1}} \left[\left(1 + \tau^h\right) + \gamma_A \gamma_N \phi_h \left(\gamma_A \gamma_N \frac{x_{t+1}^o}{x_t^o} - 1 \right) \left(\frac{x_{t+1}^o}{x_t^o} \right)^2 \right] \tag{14}$$

$$\gamma_A \gamma_N \frac{P_t^h}{P_t} \lambda_{1t}^o \left[(1 + \tau^s) + \phi_h \left(\gamma_A \gamma_N \frac{\widetilde{x}_t^o}{\widetilde{x}_{t-1}^o} - 1 \right) \frac{\widetilde{x}_t^o}{\widetilde{x}_{t-1}^o} \right] = \beta^o E_t \lambda_{1t+1}^o \frac{P_{t+1}^a}{P_{t+1}} (1 - \tau^r) A^a$$
$$+\beta^o E_t \lambda_{1t+1}^o \frac{P_{t+1}^h}{P_{t+1}} \left[(1 + \tau^s) + \gamma_A \gamma_N \phi_h \left(\gamma_A \gamma_N \frac{\widetilde{x}_{t+1}^o}{\widetilde{x}_t^o} - 1 \right) \left(\frac{\widetilde{x}_{t+1}^o}{\widetilde{x}_t^o} \right)^2 \right] \tag{15}$$

as well as the three households' restrictions (1), (2) and (3).

Expression (14) is the first order condition that makes it possible to obtain optimal housing demand by patient households for their own occupation, whereas (15) is the first order condition for the demand for houses that will be used to produce rental services.

2.2 Impatient Households (borrowers)

Impatient households discount the future more heavily than patient ones, so their discount rate satisfies $\beta^b < \beta^o$. We also assume that these households do not hold physical capital, so they face the following maximization program:

$$\max_{c_t^b, b_t^b, x_t^b, Rent_t^b} E_t \sum_{t=0}^{\infty} (\beta^b)^t \left[\begin{array}{c} \ln\left(c_t^b - h c_{t-1}^b\right) + \phi_x \ln\left(\widehat{x}_t^b\right) + n_{t-1}^b \phi_1 \frac{(1-l_{1t})^{1-\eta}}{1-\eta} \\ +(1 - n_{t-1}^b)\phi_2 \frac{(1-l_2)^{1-\eta}}{1-\eta} \end{array} \right] \tag{16}$$

where $\widetilde{x}_t^b$ is a composite made up of owner-occupied and rented houses:

$$\widehat{x}_t^b = \left[\omega_h^{\frac{1}{\epsilon_h}} \left(x_t^b\right)^{\frac{(\epsilon_h - 1)}{\epsilon_h}} + (1 - \omega_h)^{\frac{1}{\epsilon_h}} \left(Rent_t^b\right)^{\frac{(\epsilon_h - 1)}{\epsilon_h}} \right]^{\epsilon_h/(\epsilon_h - 1)} \tag{17}$$

The above problem is subject to the specific liquidity constraint, a borrowing limit and the law of motion of employment, as reflected in:

$$\begin{aligned} & w_t\left(1-\tau_t^l\right)\left(n_{t-1}^b l_{1t}+rr_t s\left(1-n_{t-1}^b\right) l_{2t}\right)+\left(\left(1-\tau_t^l\right) g_{st}-trh_t^b\right) \\ & +\left(1+r_{t-1}^n\right)\frac{b_{t-1}^b}{1+\pi_t^c}-\zeta_t^b-\frac{P_t^h}{P_t}\left(1+\tau^h\right)\left(\gamma_A\gamma_N x_t^b-x_{t-1}^b\right) \\ & -\frac{P_t^a}{P_t}\left(1+\tau^a\right) Rent_t^b-\left(1+\tau_t^c\right)\frac{P_t^c}{P_t}c_t^b-\gamma_A\gamma_N b_t^b=0 \end{aligned} \tag{18}$$

$$b_t^b \leq -m^b E_t\left(\frac{\frac{P_{t+1}^h}{P_{t+1}}\left(1+\pi_{t+1}\right) x_t^b}{1+r_t^n}\right) \tag{19}$$

$$\gamma_N n_t^b=(1-\sigma) n_{t-1}^b+\rho_t^w s(1-n_{t-1}^b) \tag{20}$$

where τ^a stands for a (typically negative) tax on rental payments and $\zeta_t^b = \frac{\phi_h}{2}\left(\gamma_A\gamma_N\frac{x_{tl}^b}{x_{t-1l}^b}-1\right)^2\frac{P_t^h}{P_t}x_t^b$ denotes the housing adjustment cost. We assume that parameter ϕ_x accounting for housing weight in life-time utility, is the same as for patient households. Later we will allow for random shocks to this parameter that affect housing demand and house prices.

The restriction(18) displays some differences with respect to that for patient individuals. First, because they are more impatient than lenders they borrow from lenders (b_t^b is negative). Second, they do not accumulate physical capital. Third, they do not purchase houses in excess of owner-occupied houses (x_t^b), but instead rent houses from lenders ($Rent_t^b$). Renting houses can be subject to a deduction, so that τ^a is typically negative. With respect to the borrowing constraint (19), parameter m^b is the loan-to-value ratio.Thus, the total amount lent is limited to a fraction of the value of the asset given by m^b.

In the case of impatient households, the value function $W(\Omega_t^b)$ satisfies the following Bellman equation:

$$W(\Omega_t^b)=\max_{c_t^b, b_t^b, x_t^b, Rent_t^b}\left\{\begin{array}{c}\ln\left(c_t^b-hc_{t-1}^b\right)+\phi_x\ln\left(\widehat{x}_t^b\right)+n_{t-1}^b\phi_1\frac{(T-l_{1t})^{1-\eta}}{1-\eta} \\ +(1-n_{t-1}^b)\phi_2\frac{(T-l_2)^{1-\eta}}{1-\eta}+\beta^b E_t W(\Omega_{t+1}^b)\end{array}\right\} \tag{21}$$

where maximization is subject to constraints (18), (19) and (20).

The solution to the optimization program is characterized by the following first-order conditions:

$$\lambda_{1t}^b=\frac{1}{(P_t^c/P_t)(1+\tau_t^c)}\left(\frac{1}{c_t^b-h^b c_{t-1}^b}-\beta^b\frac{h^b}{c_{t+1}^b-h^b c_t^b}\right) \tag{22}$$

$$\gamma_A\gamma_N\lambda_{1t}^b=\beta^b E_t\lambda_{1t+1}^b\left(\frac{1+r_t^n}{1+\pi_{t+1}^c}\right)+\mu_t^b\left(1+r_t^n\right) \tag{23}$$

$$\gamma_A\gamma_N\frac{P_t^h}{P_t}\lambda_{1t}^b\left[\left(1+\tau^h\right)+\phi_h\left(\gamma_A\gamma_N\frac{x_t^b}{x_{t-1}^b}-1\right)\frac{x_t^b}{x_{t-1}^b}\right]=$$

$$\frac{\phi_x}{\widehat{x}_t^b}\left(\frac{\omega_h\widehat{x}_t^b}{x_t^b}\right)^{\frac{1}{\epsilon_h}}+\mu_t^b m^b\frac{P_{t+1}^h}{P_{t+1}}\left(1+\pi_{t+1}\right)$$

$$+\beta^b E_t\lambda_{1t+1}^b\frac{P_{t+1}^h}{P_{t+1}}\left[\left(1+\tau^h\right)+\gamma_A\gamma_N\phi_h\left(\gamma_A\gamma_N\frac{x_{t+1}^b}{x_t^b}-1\right)\left(\frac{x_{t+1}^b}{x_t^b}\right)^2\right] \quad (24)$$

$$\frac{\phi_x}{\widehat{x}_t^b}\left(\frac{(1-\omega_h)\,\widehat{x}_t^b}{Rent_t^b}\right)^{\frac{1}{\epsilon_h}}=\lambda_{1t}^b\frac{P_t^a}{P_t}\left(1+\tau^a\right) \quad (25)$$

where μ_t^b is the Lagrange multiplier of the borrowing constraint.

2.3 Liquidity-constrained households (RoTs)

RoT households do not have access to capital markets, so they face the following maximization program:

$$\max_{c_t^r, Rent_t^r} E_t\sum_{t=0}^{\infty}\beta^{bt}\left[\begin{array}{c}\ln\left(c_t^r-h^r c_{t-1}^r\right)+\phi_r\ln\left(Rent_t^r\right)+\\ n_t^r\phi_1\frac{(T-l_{1t})^{1-\eta}}{1-\eta}+(1-n_t^r)\phi_2\frac{(T-l_{2t})^{1-\eta}}{1-\eta}\end{array}\right]$$

subject to the law of motion of employment (27) and the specific liquidity constraint whereby consumption expenditure in each period must be equal to current labour income and government transfers, as reflected in:

$$w_t\left(1-\tau_t^l\right)\left(n_t^r l_{1t}+\overline{rr}s\left(1-n_t^r\right)l_{2t}\right)+g_{st}\left(1-\tau_t^l\right)$$
$$-\frac{P_t^a}{P_t}\left(1+\tau^a\right)Rent_t^r-trh_t-(1+\tau_t^c)c_t^r\frac{P_t^c}{P_t}=0 \quad (26)$$

$$\gamma_N n_{t+1}^r=(1-\sigma)n_t^r+\rho_t^w s(1-n_t^r) \quad (27)$$

$$n_0^r \quad (28)$$

where n_0^r represents the initial aggregate employment rate, which is the sole stock variable in the above program. Note that *RoT* consumers do not save, thus they do not hold any assets.

In this case, the value function $W(\Omega_t^r)$ satisfies the following Bellman equation:

$$W(\Omega_t^r)=\max_{c_t^r, Rent_t^r}\left\{\begin{array}{c}\ln\left(c_t^r-hc_{t-1}^r\right)+\phi_r\ln\left(Rent_t^r\right)\\ +n_{t-1}^r\phi_1\frac{(1-l_{1t})^{1-\eta}}{1-\eta}+(1-n_{t-1}^r)\phi_2\frac{(1-l_{2t})^{1-\eta}}{1-\eta}+\beta^b E_t W(\Omega_{t+1}^r)\end{array}\right\} \quad (29)$$

where the maximization is subject to constraints (26) and (27).

The solution to the optimization program is characterized by the following first order conditions:

$$\lambda_{1t}^{r}=\frac{1}{(P_t^c/P_t)c_t^r(1+\tau_t^c)}\left(\frac{1}{c_t^r-h^r c_{t-1}^r}-\beta^b\frac{h^r}{c_{t+1}^r-h^r c_t^r}\right) \tag{30}$$

$$\frac{\phi_r}{Rent_t^r}=\lambda_{1t}^r\frac{P_t^a}{P_t}\left(1+\tau^a\right) \tag{31}$$

2.4 Aggregation

For the variables that exclusively concern patient households, aggregation is performed as follows:

$$k_t=\left(1-\lambda^r-\lambda^b\right)k_t^o \tag{32}$$

$$j_t=\left(1-\lambda^r-\lambda^b\right)j_t^o \tag{33}$$

$$b_t=\left(1-\lambda^r-\lambda^b\right)b_t^p \tag{34}$$

$$b_t^w=\left(1-\lambda^r-\lambda^b\right)b_t^{o,w} \tag{35}$$

$$m_t=\left(1-\lambda^r-\lambda^b\right)m_t^o \tag{36}$$

Aggregate consumption and employment can be defined as a weighted average of the corresponding variables for each household type:

$$c_t=\left(1-\lambda^r-\lambda^b\right)c_t^o+\lambda^r c_t^r+\lambda^b c_t^b \tag{37}$$

$$n_t=\left(1-\lambda^r-\lambda^b\right)n_t^o+\lambda^r n_t^r+\lambda^b n_t^b \tag{38}$$

$$\lambda^b b_t^b+\left(1-\lambda^r-\lambda^b\right)b_t^o=0 \tag{39}$$

Lump-sum transfers are aggregated in the usual way as

$$trh_t=\lambda^b trh_t^b+\lambda^r trh_t^r+\left(1-\lambda^r-\lambda^b\right)trh_t^l \tag{40}$$

where additionally we assume that transfers are distributed according to the population size in each group so that $trh_t^o=trh_t^b=trh_t^r=trh_t$.

We consider a trade union that groups the surpluses from employment, in terms of consumption, of the three different types of households and uses this aggregate in the negotiation of hours and wages (see below):

$$\lambda_{ht}=\left(1-\lambda^b-\lambda^r\right)\frac{\lambda_{ht}^o}{\lambda_{1t}^o}+\lambda^b\frac{\lambda_{ht}^b}{\lambda_{1t}^b}+\lambda^r\frac{\lambda_{ht}^r}{\lambda_{1t}^b} \tag{41}$$

where $\lambda^o_{ht}/\lambda^o_{1t}$, $\lambda^b_{ht}/\lambda^b_{1t}$ and $\lambda^r_{ht}/\lambda^r_{1t}$ respectively denote the earning premium (in terms of consumption) of employment over unemployment for a patient, an impatient and a *RoT* worker.

The housing market is characterized by the following aggregated variables:

- Total stock of real state in the economy

$$X = \lambda^b x^b_t + \left(1 - \lambda^r - \lambda^b\right) x^o_t + \left(1 - \lambda^r - \lambda^b\right) \widetilde{x}^o_t \tag{42}$$

- Total rental services

$$\left(1 - \lambda^r - \lambda^b\right) Rent^o_t = \left(1 - \lambda^r - \lambda^b\right) A^a \widetilde{x}^o_{t-1} = \lambda^b Rent^b + \lambda^r Rent^r \tag{43}$$

- Total owner-occupied houses

$$\lambda^b x^b_t + \left(1 - \lambda^r - \lambda^b\right) x^o_t$$

- Total houses for renting

$$\left(1 - \lambda^r - \lambda^b\right) \widetilde{x}^o_t$$

- Total houses with no mortgage outstanding

$$\left(1 - \lambda^r - \lambda^b\right) x^o_t + \left(1 - \lambda^r - \lambda^b\right) \widetilde{x}^o_t$$

- Total houses with a mortgage

$$\lambda^b x^b_t$$

2.5 Trade in the labour market: the labour contract

Once a representative job-seeking worker and vacancy-offering firm match, they negotiate a labour contract in hours and wages. There is risk sharing at the household level but not among household types. Although lenders, borrowers and RoT households have a different reservation wage they pool together in the labour market and bargain with firms to distribute employment according to their shares in the working-age population. The implication of this assumption is that all workers receive the same wages, work the same number of hours, and are subject to the same unemployment rates.

Following standard practice, the Nash bargain process maximizes the weighted product of the parties' surpluses from employment.

$$\max_{w_t,\, l_{1t}} \left[\lambda^r \frac{\lambda^r_{ht}}{\lambda^r_{1t}} + \lambda^b \frac{\lambda^b_{ht}}{\lambda^b_{1t}} + \left(1 - \lambda^r - \lambda^b\right) \frac{\lambda^o_{ht}}{\lambda^o_{1t}} \right]^{\lambda^w} (\lambda_{ft})^{(1-\lambda^w)} = \max_{w_t, l_{1t}} (\lambda_{ht})^{\lambda^w} (\lambda_{ft})^{1-\lambda^w} \tag{44}$$

where $\lambda^w \in [0,1]$ reflects the workers' bargaining power. The first term in brackets represents the worker surplus (as a weighted average of RoT, borrowers and Ricardian workers' surpluses) while the second is the firm surplus. More specifically, $\lambda^o_{ht}/\lambda^o_{1t}$, $\lambda^b_{ht}/\lambda^b_{1t}$ and $\lambda^r_{ht}/\lambda^r_{1t}$ respectively denote the earning premium (in terms of consumption) of employment over unemployment for a patient, an impatient and a RoT worker.

The solution of the Nash maximization problem gives the optimal real wage and hours worked

$$\begin{aligned} w_t \left(1 - \tau^l\right) l_{1t} &= \lambda^w \left[\frac{\left(1 - \tau^l\right)}{(1 + \tau^{sc})} \alpha m c_t \frac{y_t}{n_{t-1}} + \frac{\left(1 - \tau^l\right)}{(1 + \tau^{sc})} \frac{\kappa_v v_t}{(1 - n_{t-1})} \right] \\ &+(1 - \lambda^w) \left[\left(\frac{1 - \lambda^r - \lambda^b}{\lambda^o_{1t}} + \frac{\lambda^r}{\lambda^r_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right) \left(\phi_2 \frac{(1 - l_2)^{1-\eta}}{1 - \eta} - \phi_1 \frac{(1 - l_{1t})^{1-\eta}}{1 - \eta} \right) + \left(1 - \tau^l\right) g_{ut} \right] \\ &+(1 - \lambda^w)(1 - \sigma - \rho^w_t)\lambda^b E_t \frac{\lambda^b_{ht+1}}{\lambda^b_{1t+1}} \left(\beta^o \frac{\lambda^o_{1t+1}}{\lambda^o_{1t}} - \beta^b \frac{\lambda^b_{1t+1}}{\lambda^b_{1t}} \right) \\ &+(1 - \lambda^w)(1 - \sigma - \rho^w_t)\lambda^r E_t \frac{\lambda^r_{ht+1}}{\lambda^r_{1t+1}} \left(\beta^o \frac{\lambda^o_{1t+1}}{\lambda^o_{1t}} - \beta^b \frac{\lambda^r_{1t+1}}{\lambda^r_{1t}} \right) \end{aligned} \tag{45}$$

$$\frac{\left(1 - \tau^l\right)}{(1 + \tau^{sc})} \alpha m c_t \frac{y_t}{n_{t-1} l_{1t}} = \phi_1 (T - l_{1t})^{-\eta} \left[\frac{1 - \lambda^r - \lambda^b}{\lambda^o_{1t}} + \frac{\lambda^r}{\lambda^r_{1t}} + \frac{\lambda^b}{\lambda^b_{1t}} \right] \tag{46}$$

2.6 Calibration

We initially set the preferences discount rate for lenders $\beta^o = 0.99$, and for borrowers and hand-to-mouth consumers $\beta^b = \beta^r = 0.95$. We initially assume no housing adjustment costs $\phi_h = 0$, no habits in consumption $h^b = h^r = 0$, and no taxes or subsidies distorting the housing market, $\tau^h = \tau^s = \tau^r = \tau^a = 0$. The utility parameter for housing ϕ_x is set to obtain a real house price $\frac{P^h_t}{P_t} = 1$. The real value of the aggregate stock of houses X is calibrated to match the sample average of total stock of houses over yearly GDP for the period (1986-2006) which is equal to 160%. The efficiency parameter in the rental market for housing services A^a is set to obtain a ratio of the house price over the rental rate $\frac{P^h_t}{P^a_t} = 65.5$ from expression (15). The assumption regarding the steady state value of the relative price $\frac{P_t^h}{P_t^a}$ is founded on the idea that in an efficient housing market equilibrium we would expect $P_t^a \simeq r^n P_t^h$. The resulting value impies that the average house price is roughly equivalent to 16 years of rental payments. The elasticity of substitution parameter ϵ_h in the CES function is set to 2, following Ortega *et al.* (2011). The loan-to-value parameter m^b, the share of borrowers, λ^b, and the weight of mortgaged houses in the CES utility function, ω_h, are jointly calibrated to obtain a share of mortgaged houses in total houses, $\frac{\lambda^b x_t^b}{X}$, close to 30%. The share of hand-to-mouth consumers, λ^r, and their marginal utility parameter for housing services, ϕ_r, are jointly set to reproduce the weight of rented houses in the total stock of houses, $\frac{(1-\lambda^r-\lambda^b)\widetilde{x}_t^o}{X}$, a value about 12%. The following table displays the corresponding values for the key parameters regarding the housing market.

Parameter	Value
ϕ_x	0.17
X	3.7
A^a	0.99
m^b	0.88
λ^b	0.45
ω_h	0.9
ϵ_h	2
λ^r	0.15
ϕ_r	0.09

Table 1: Calibrated parameters

3 Results

3.1 Response to macroeconomic shocks

Next we study the performance of the model by looking at the response of some variables following different perturbations in the economy, starting with a technological shock (Figure 1). After a technological shock there is an increase

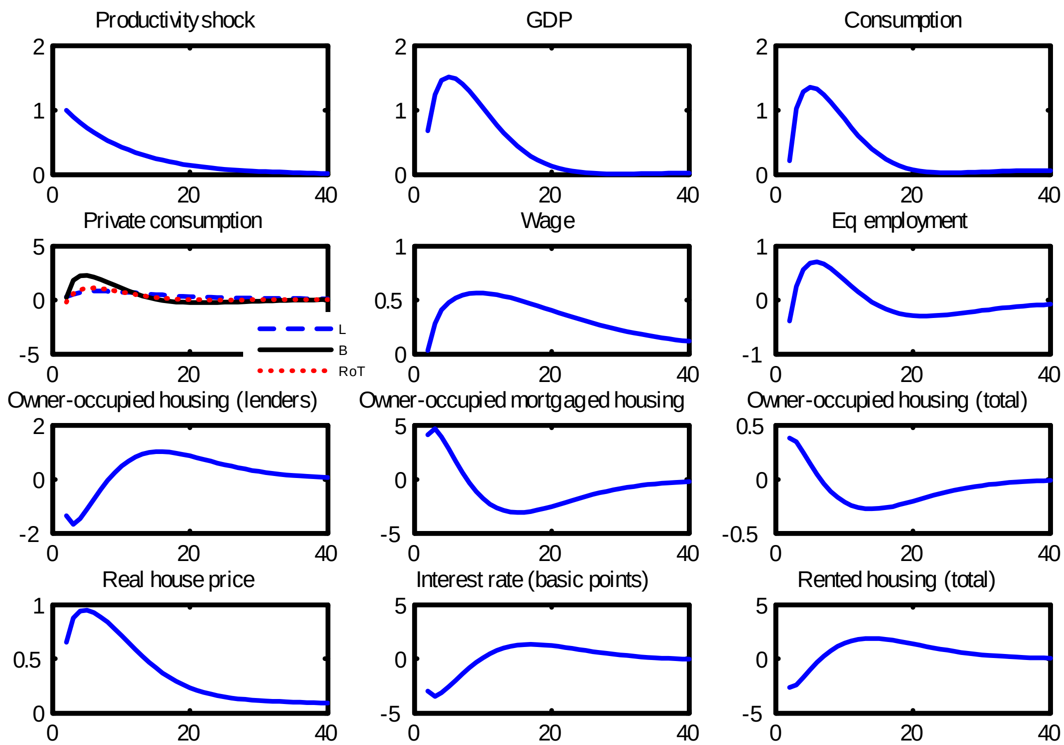

Fig. 1. Response to a 1 percent increase in the TFP

in GDP, consumption and investment. The boost in productivity makes labour income rise in the short run, despite the initial drop in working hours. Also, the effect on private spending positively affects the real house price, which eases credit-constrained consumers access to borrowing. As a result, the volume of mortgaged housing that can be collateralised goes up and substitutes for rented houses in the short run. According to our results, the rise in aggregate consumption is mainly driven by borrowers' behaviour as they take advantage of the improvements in both labour income and the value of their assets.

Figure 2 displays the effects of a government spending shock. Despite the positive response of hand-to-mouth households, driven by the increase in labour income, the model features an aggregate crowding out effect that is due to the standard reaction of optimizing Ricardian individuals, as well as to a sizable fall in credit-constrained household consumption during the first periods. The real house price falls following the rise in the interest rate and the expected value of owner occupied houses is reduced. Hence, borrowers are initially forced to reduce the amount of debt they can take on to finance consumption. In addition, the weakness of the owner-occupied housing market favours the rented housing market, the volume of which increases by 2 percent on impact.

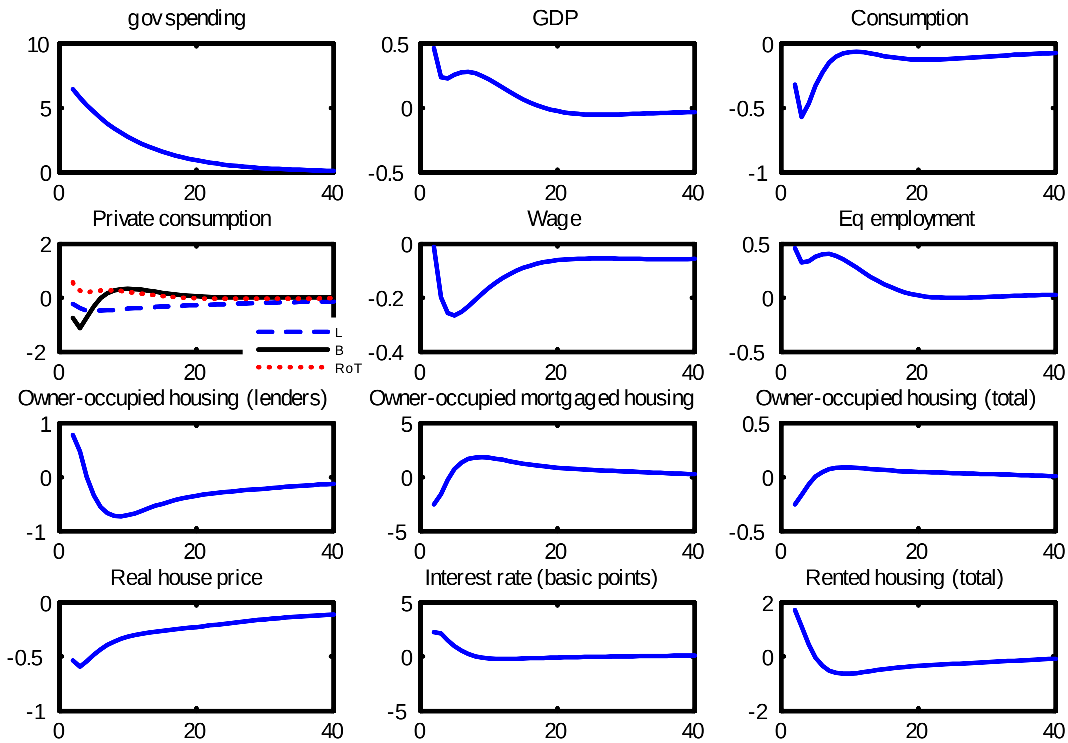

Fig. 2. Response to a 1 percent GDP increase in government spending

Finally, in Figure 3 we represent an exogenous increase in housing demand by shocking the parameter ϕ_x by 10 percent, which provokes a positive reaction of more than 1 percent on the real house price. This shift in preferences from consumption goods to housing boosts the volume of houses owned by credit-constrained households. These new houses can initially be used to access new credit to finance consumption. However, as the shock dissipates and the expected value of houses shrinks, private consumption declines dragging GDP down below the initial value.

3.2 Macroeconomic effects of the implementation of the 2014 tax reform

Law 26/2014 passed by the Spanish Parliament introduced a number of modifications essentially related to the way in which labour and capital income are treated in the personal income tax, IRPF. In this subsection we present the main simulated macroeconomic effects of the application of this law, which was first implemented in 2015.

Our simulations below are based on the assumptions about the ex-ante annual revenue effects in Table 2, which represent the difference with respect to the previous year, estimated according to the final announced timetable. It is

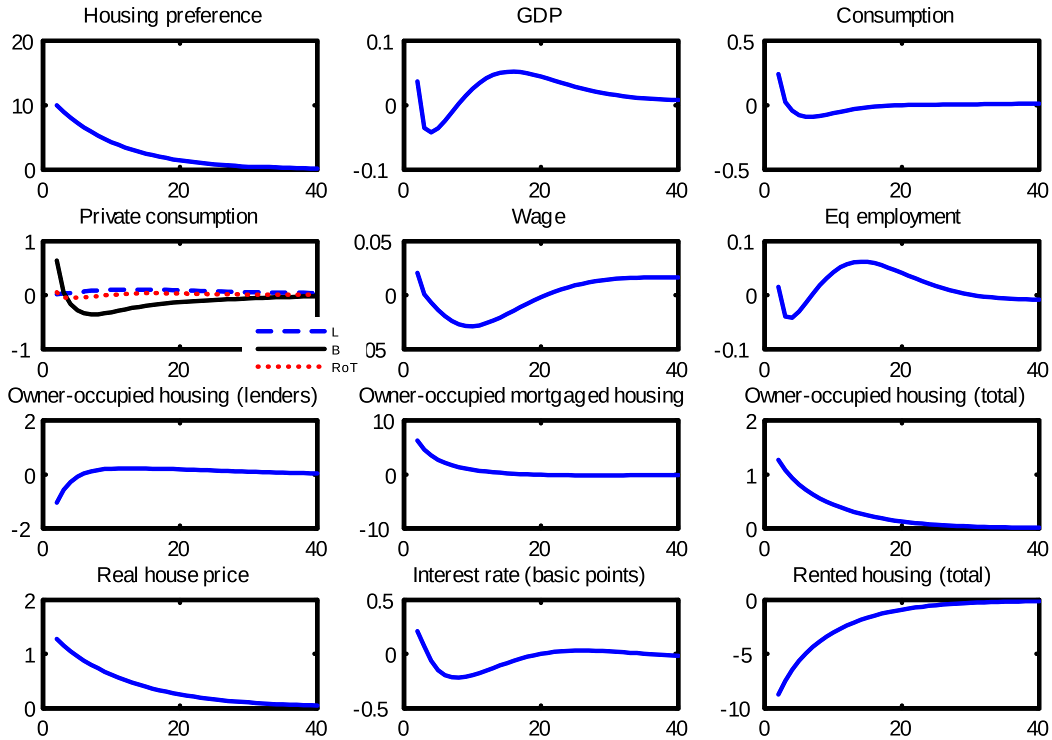

Fig. 3. Response to a shock favouring preferences for housing

assumed that this timetable was known by everyone in the economy as of 1st January, 2015.

Table 3 displays the results of the main variables 2 and 10 years after the beginning of 2015. The figures contained therein represent percentage deviations with respect to a benchmark economy with no tax reform. According to the results, the tax reform would create a positive impact on GDP which is reinforced as time goes on, due to the positive behaviour of investment and private consumption. The good performance of the latter, after two years, is entirely due to borrowers and liquidity-constrained consumption reaction, as lenders' consumption falls in the short run. Regarding the housing market, the tax reform would also favour an increase in mortgaged housing of about 1.5 percent and in rented houses of about 0.5 percent. Altogether, and focusing on output and employment, our simulations point to a rise in GDP of about 0.13 percent after two years (matched by a 40,000-person increase in employment) and 0.56 percent after 10 years, associated with a 110,000-person rise in employment. Finally, the last row in Table 3 presents the ex-post revenue effects of the tax measures. It is worth mentioning that after two years approximately half of the ex-ante cost of the reform has been recovered, with an 800 million rise in public revenues after ten years.

Year	2015	2016	2017	Accumulated
Total	-5,040	-3,599	-357	-8,996
- Labour income	-3,812	-3,250	-119	-7,181
- Capital income	-1,228	-349	-238	-1,815

Table 2: Ex-ante revenue effects of the fiscal reform (millions)

Variable	2 years	10 years
GDP	0.1262	0.5640
Consumption	0.2696	0.5699
- Lenders	-0.1705	0.0881
- Borrowers	0.8015	1.0746
- RoTs	0.7343	1.2968
Investment	-0.0453	0.4991
Mortgaged housing	1.3936	1.4748
RoTs rented housing	0.5254	0.5608
Employment (workers)	39,337	108,980
Public revenues (millions)	-4,277	800

Table 3: Macroeconomic effects of the fiscal reform (%)

4 Conclusions

This paper introduces an updated version of REMS, the model used in recent years by the Spanish Ministries of Economy and Finance for ex-ante policy evaluation. The new version of the model incorporates two new features: first, credit-constrained consumers, which are added to the existing optimizing consumers and liquidity-constrained (RoTs) consumers; and, second, a housing market. Credit-constrained consumers can borrow up to a limit defined by the expected value of their houses. In addition, part of the real estate accumulated by patient households is offered to impatient and liquidity-constrained households as houses to rent. Impatient households can decide between purchasing houses to occupy themselves or renting houses from patient households. Completely liquidity-constrained households only have access to rented houses.

The results presented above illustrate how macroeconomic aggregates react to different shocks, including those relating to technology, government consumption and preferences for housing. We show that the response in terms of consumption of the different types of households and the behaviour of the housing market can be very different depending on the particular shock hitting the economy. Finally, we also show the simulation results of the tax reform passed by the Spanish parliament in 2014 and implemented by the Spanish government starting in early 2015. Our results show positive effects on GDP and employment, with a long-run increase in output of around 0.5 percent, a 110,000-person rise in employment and a short-run (2 years) cost in public revenues of around €4.3 billion.

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