JOSE: Joint Spain Euro-area DSGE model

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Abstract

This paper presents JOSE, the new estimated JOint Spain Euro-Area dynamic stochastic general equilibrium (DSGE) model developed and used by the Banco de España. The model follows a large-scale New Keynesian setup. The model consists of three regions: two countries in a monetary union - Spain and the rest of the Euro-area - and the rest of the world. The new feature that differentiates JOSE from previous DSGE models developed by the Banco de España is the presence of financial frictions. In each country there are constrained households and constrained entrepreneurs that can access credit subject to a borrowing constraint. These agents can borrow up to an exogenous fraction of their collateral value, which consists of housing, and also of capital in the case of the entrepreneur. We use the model to understand the quantitative sources of the housing bust experienced by the Spanish economy from 2008 until 2012. The model identifies the channels through which the drop in house prices has spilled over to the real economy.

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*The views expressed in this paper are those of the authors and do not necessarily represent the views of the Banco de España or the Eurosystem.
1 Introduction

Nowadays medium- and large-scale estimated DSGE models are widely used by central banks and policy institutions. DSGE models are used for forecasting purposes, developing scenario analysis, and the derivation of exercises that assess the positive and normative effects of different policies. Although DSGE models are not the only tool used by central banks to evaluate the state of the economy, they represent a crucial approach that allow to validate the results of reduced-form models, and interpret them through the lenses of their economic structure.

This paper presents JOSE, the new estimated JOint Spain Euro-Area dynamic stochastic general equilibrium (DSGE) model developed and used by the Banco de España. The model consists of three regions: two countries in a monetary union - Spain and the rest of the Euro-area - and the rest of the world. The new feature that differentiates JOSE from previous DSGE models developed by the Banco de España is the presence of financial frictions. In each country there are constrained households and constrained entrepreneurs that can access credit subject to a borrowing constraint. These agents can borrow up to an exogenous fraction of their collateral value, which consists of housing, as well as capital in the case of the entrepreneur.

With the estimated model, we are able to run accounting exercises on some salient events of the Spanish economy. In particular, we use the model to identify the sources that have triggered the 2008 - 2012 housing price bust. Indeed, in the model a drop in the house price can be driven by both housing market specific shocks, but also by either demand, supply, and financial shocks. In this way, we are able to disentangle the contribution of each innovation to the observed fall in the house price.

The model can also be used to understand the effects that the drop in the house price has generated on the real economy. Since constrained households and constrained entrepreneurs borrow capacity is tied to the value of housing, we can shed light on the channel through which a housing market bust can generate a drop in consumption and investment.

Finally, the model can be used as a laboratory to run counterfactual experiments to understand whether fiscal policy or direct credit subsidies could have been able in mitigating both the reduction in house prices and the drop in output.

2 The Model

JOSE consists of three regions: two in a monetary union, Spain and the Rest of the Euro-area (RE), and the Rest of the World (RW). All variables are in per capita terms according to the following notation. All quantities produced in Spain or imported from the RW to Spain are normalized by the population size of Spain, $n$. Conversely, all variables produced in RE or imported from the RW to RE are normalized by its population size, $1 - n$. The total population size of the monetary union is therefore set to 1.

In each region of the monetary union, there is a continuum of households and entrepreneurs, a labour agency, a continuum of intermediate goods producers, a competitive final goods producer, a competitive capital producer, a competitive housing producer, and a government. Private consumers and the government consume a basket composed of oil imported from the RW and goods produced in Spain, in RE and in RW.

The housing market can be described as follows. Each period, housing producers add to the undepreciated stock of housing using a technology subject to investment adjustment costs and investment-specific shocks. The household and the entrepreneur put in orders for the stock of housing they choose to purchase. The household derive utility from housing, while
entrepreneurs can pledge the value of housing they own as collateral. In both cases, housing depreciates within each period. The price of housing is therefore determined by the competing demand for housing by the household and the entrepreneur.

The capital market, albeit simpler, works in a similar fashion. Each period, capital producers add new capital to the undepreciated stock of capital using a technology subject to investment adjustment costs and investment-specific shocks. The entrepreneur puts in an order for the stock of capital he wishes to own at the beginning of the following period. The entrepreneur uses capital to produce goods and to pledge as collateral. Capital depreciates within each period.

2.1 Unconstrained Households

There is a continuum of measure \( \kappa_u \) of household members indexed by \( i \in [0, \kappa_u] \). They consume a final good and their utility is subject to habits. The household supplies labour services to a labour agency, trades in domestic nominal bonds and in non-contingent bonds denominated in the currency of the RW. The household also receives utility from owning housing. Each period, households have to decide how much housing they want to order from housing producers, in excess of the undepreciated housing they already own. All the profits from labour agencies and intermediate non-durable goods producers are rebated to the household.

2.1.1 Optimal decisions over consumption, bonds and housing

Household members are assumed to pool labour income risk perfectly, and therefore equalise consumption and housing. The household member \( i \) life-time utility is given by:

\[
\max_{C_{u,t}, B_{u,t}, D_{u,t}, H_{u,t}, W_{u,t}, \tau} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \psi_{1,t} \left\{ \psi_{2,t} \left[ \frac{(C_{u,t} - \lambda_u \tilde{C}_{u,t})^{1-\sigma_u}}{1-\sigma_u} + \psi_{3,t} \frac{(H_{u,t})^{1-\sigma_{uh}}}{1-\sigma_{uh}} \right] - \zeta_u \frac{N_{u,t} (i)^{1+\eta_u}}{1+\eta_u} \right\}
\]

subject to the budget constraint:

\[
(1 + \tau_c) P_t C_{u,t} + P_{h,t} (H_{u,t} - (1 - \delta_h) H_{u,t-1}) + B_{u,t} + S_t D_{u,t-1} R_{t-1}^{RW} \Psi_{t-1} = (1 - \tau_n) W_{u,t} (i) N_{u,t} (i) + B_{u,t-1} R_{t-1} + S_t D_{u,t} + \text{Profits}_{u,t} + P_t T_{u,t}
\]

where \( \tilde{C}_{h,t} = C_{h,t-1} \), \( B_{h,t} \) are loans to constrained households and to entrepreneurs and \( D_{h,t} \) are bonds traded with RW. \( R_t \) is the domestic nominal rate, \( S_t \) is the nominal exchange rate vis-a-vis RW, and \( \Psi_t \) is a country specific spread that depends on its aggregate net foreign asset position. Households pay labour income tax, \( \tau_n \), and consumption tax, \( \tau_c \), and receive profits, \( \text{Profits}_{u,t} \), from labour unions, capital and housing producers, retailers, import and export firms, as well as lump-sum transfers from the government, \( T_{u,t} \). The stationary exogenous processes \( \psi_{1,t} \), \( \psi_{2,t} \) and \( \psi_{3,t} \) denote an intertemporal preferences shock, an aggregate private demand shock, and a housing demand shock, respectively.

The first order conditions (in real terms\(^2\)) with respect to consumption, domestic bonds, foreign bonds and housing are given by:

\[
[wrt \ C_{u,t}]
\lambda_{u,t} (1 + \tau_c) = \psi_{1,t} \psi_{2,t} (C_{u,t} - \lambda_u C_{u,t-1})^{-\sigma_u}
\]

\(^1\)For simplicity, we assume that each region in the monetary union only holds a net foreign asset position against the RW, abstracting for the possibility of cross-holdings within the union. Trade in goods, however, occurs between all the three regions.

\(^2\)We use the consumption price index \( P_t \) in each region as the numeraire.
\[
\Lambda_{u,t} p_{h,t} = \psi_1, t \psi_2, t \psi_3, t (H_{u,t})^{-\sigma_u} + \beta \mathbb{E}_t \left[ \Lambda_{u,t+1} p_{h,t+1} (1 - \delta_h) \right] \tag{2}
\]

\[
1 = \beta \mathbb{E}_t \frac{\Lambda_{u,t+1}}{\Lambda_{u,t}} r_t \tag{3}
\]

\[
1 = \beta \mathbb{E}_t \frac{\Lambda_{u,t+1} e_{esrw,t+1}}{\Lambda_{u,t} e_{esrw,t}} \frac{R_{RW,t}}{\pi_{t+1}} \Psi_{t+1} \tag{4}
\]

where \( \Lambda_u \) is the multiplier on the budget constraint and \( e_{esrw} \) is the bilateral real exchange rate between Spain and the RW.

### 2.1.2 Labour agencies and wage setting

A competitive labour agency specializes in combining a continuum of labour services supplied by unconstrained household members in an aggregated labour input used in production. The aggregation technology is given by

\[
N_{u,t} = \left[ \int_0^1 (N_{u,t}(i))^{\frac{\epsilon_w - 1}{\epsilon_w}} di \right]^{\frac{\epsilon_w}{\epsilon_w - 1}}
\]

Household member \( i \) charges \( W_{u,t}(i) \) to the labour agency for the labour service she provides. The labour agency maximizes profits, setting optimal demand for labour service \( N_{u,t}(i) \) accordingly:

\[
N_{u,t}(i) = \left( \frac{W_{u,t}(i)}{W_{u,t}} \right)^{-\epsilon_w} N_{u,t}
\]

Plugging in the demand functions into the aggregation technology, we obtain the wage index:

\[
W_{u,t} = \left[ \int_0^1 (W_{u,t}(i))^{1 - \epsilon_w} di \right]^{\frac{\epsilon_w}{\epsilon_w - 1}}
\]

Household members set wages subject to a Calvo friction, such that, in every period wages can be optimally adjusted by only a fraction \( 1 - \phi_w \) of labour service providers. When resetting wages, household members maximize life-time utility subject to the budget constraint and the respective labour demand schedule. The first order condition writes:

\[
E_t \sum_{j=0}^\infty (\beta \phi_w)^j \Lambda_{u,t+j} N_{u,t+j} \left[ (1 - \tau_n) W_{u,op,t+j} - \frac{\epsilon_w}{\epsilon_w - 1} \right] \psi_{1,t+j} \Lambda_{u,t+j} (N_{u,t+j})^{\eta_u} = 0
\]

with

\[
N_{u,t+j} = \kappa_u \left( \frac{W_{u,op,t+j}}{W_{u,t+j}} \right)^{-\epsilon_w} N_{u,t+j}
\]

Rearranging, the optimal real wage is given by:

\[
(w_{u,op,t})^{1 + \epsilon_w \eta_u} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{W_{u,1,t}}{W_{u,2,t}} \tag{5}
\]

with

\[
W_{u,1,t} = \zeta_u \psi_{1,t} (w_{u,t})^{\epsilon_w (1 + \eta_u)} (N_{u,t})^{(1 + \eta_u)} + \beta \phi_w (\pi_{t+1})^{\epsilon_w (1 + \eta_u)} W_{u,1,t+1} \tag{6}
\]

\[
W_{u,2,t} = \Lambda_{u,t} (1 - \tau_n) (w_{u,t})^{\epsilon_w} N_{u,t} + \beta \phi_w (\pi_{t+1})^{\epsilon_w - 1} W_{u,2,t+1} \tag{7}
\]

and where \( w_{u,t} = W_{u,t}/P_t \). The law of motion of the wage index and wage inflation are given by:

\[
1 = (1 - \phi_w) \left( \frac{w_{u,op,t}}{w_{u,t}} \right)^{1 - \epsilon} + \phi_w (\pi_{uw,t})^{\epsilon - 1} \tag{8}
\]
\[
\frac{\pi_{u,t}}{\pi_t} = \frac{w_{u,t}}{w_{u,t-1}}
\]  

2.2 Constrained Households

There is a continuum of measure \( \kappa_c \) of constrained household members indexed by \( i \in [\kappa_u, \kappa_u + \kappa_c] \). They consume a final good and their utility is subject to habits. The constrained household also receives utility from owning housing. Each period, constrained households have to decide how much housing they want to order from housing producers, in excess of the undepreciated housing they already own.

Constrained households finance their expenditures by borrowing in nominal bonds from unconstrained households. Importantly, constrained household are subject to a borrowing constraint such that the loans they take cannot exceed the collateral value. The collateral value is given by an exogenous fraction of the expected future value of the housing stock owned by the constrained household. The pledgeability parameter of the borrowing constraint moves exogenously over time.

2.2.1 Optimal decisions over consumption, bonds and housing

Constrained household members are assumed to pool labour income risk perfectly, and therefore equalise consumption and housing. The constrained household member \( i \) life-time utility is given by:

\[
\max_{C_{c,t}, B_{c,t}, H_{c,t}, W_c(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \psi_{1,t} \left\{ \psi_{2,t} \left[ \left( C_{c,t} - \lambda_c \tilde{C}_{c,t} \right)^{1-\sigma_c} \right] + \psi_{3,t} \left( H_{c,t} \right)^{1-\sigma_{ch}} \right\} - \zeta_c \frac{N_{c,t}(i)^{1+\eta_c}}{1 + \eta_c} 
\]

subject to the budget constraint:

\[
(1 + \tau_c) P_t C_{c,t} + P_{h,t} (H_{c,t} - (1 - \delta_h) H_{c,t-1}) + B_{c,t-1} R_{t-1} = (10)
\]

\[
(1 - \tau_n) W_c(i) N_c(i) + B_{c,t} + \text{Profits}_{c,t} + \pi T_{c,t}
\]

and to the borrowing constraint:

\[
B_{aux,c,t} = \theta_c \mathbb{E}_t \left\{ \frac{P_{h,t+1} H_{c,t}}{R_t} \right\}
\]

\[
B_{c,t} = \rho_{cb} B_{c,t-1} + (1 - \rho_{cb}) B_{aux,c,t}
\]

which is assumed to be always binding in the steady state around which we linearise the model. In this problem, \( \tilde{C}_{c,t} = C_{c,t-1} \), \( B_{c,t} \) are loans from the unconstrained households, and \( \text{Profits}_{c,t} \) are profits from labour unions.

The first order conditions (in real terms) with respect to consumption, domestic bonds, and housing are given by:

[wrt \( C_{c,t} \)]

\[
\Lambda_{c,t} (1 + \tau_c) = \psi_{1,t} \psi_{2,t} (C_{c,t} - \lambda_c C_{c,t-1})^{-\sigma_c}
\]

[wrt \( H_{c,t} \)]

\[
\Lambda_{c,t} \psi_{3,t} = \psi_{3,t} (H_{h,t})^{-\sigma_{ch}} + (1 - \rho_{cb}) \xi_{c,t} \theta_{c,t} \mathbb{E}_t \left\{ \frac{P_{h,t+1}}{R_t} \right\} + \beta_c \mathbb{E}_t \Lambda_{c,t+1} p_{h,t+1} (1 - \delta_h)
\]

[wrt \( B_{c,t+1} \)]

\[
\Lambda_{c,t} = \beta_c \mathbb{E}_t \Lambda_{c,t+1} r_t + \xi_{c,t} - \rho_{cb} \xi_{c,t+1}
\]

where \( \Lambda_c \) is the multiplier on the budget constraint and \( \xi_c \) the multiplier on the borrowing.
2.2.2 Labour agencies and wage setting

A competitive labour agency specializes in combining labour services supplied by constrained household members in an aggregated labour output which is then used by the entrepreneur. The aggregation technology is given by

\[ N_{c,t} = \left[ \int_0^1 (N_{c,t}(i))^{\frac{\epsilon_w - 1}{\epsilon_w}} di \right]^{\frac{1}{\epsilon_w}} \]

Constrained household member \( i \) charges \( W_{c,t}(i) \) to the labour agency for the labour service she provides. The labour agency maximizes profits, setting optimal demand for labour service \( N_{c,t}(i) \) according to:

\[ N_{c,t}(i) = \left( \frac{W_{c,t}(i)}{W_{c,t}} \right)^{-\epsilon_w} N_{c,t} \]

Plugging in the demand functions into the aggregation technology, we obtain the wage index:

\[ W_{c,t} = \left[ \int_0^1 (W_{c,t}(i))^{1-\epsilon_w} di \right]^{1 \over 1-\epsilon_w} \]

Constrained household members set wages subject to a Calvo friction, such that, in every period wages can be optimally adjusted by only a fraction \( 1 - \phi_w \) of labour service providers. When resetting wages, constrained household members maximize life-time utility subject to the budget constraint and the respective labour demand schedule. The first order condition writes:

\[ \mathbb{E}_t \sum_{j=0}^{\infty} (\beta_c \phi_w)^j \Lambda_{c,t+j} N_{c,t,t+j} \left[ (1 - \tau_n) \frac{W_{c,op,t}}{P_{t+j}} - \frac{\epsilon_w}{\epsilon_w - 1} \zeta_{1,t+j}^{\psi_{1,t+j}} (N_{c,t,t+j})^{\eta_c} \right] = 0 \]

with

\[ N_{c,t,t+j} = \left( \frac{W_{c,op,t}}{W_{c,t+j}} \right)^{-\epsilon_w} N_{c,t+j} \]

Rearranging, the optimal real wage is given by:

\[ (w_{c,op,t})^{1+\epsilon_w \eta_c} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{W_{c,1,t}}{W_{c,2,t}} \]

with

\[ W_{c,1,t} = \zeta_{c,1,t} (w_{c,t})^{\epsilon_w (1+\eta_c)} (N_{c,t})^{(1+\eta_c)} + \beta_c \phi_w (\pi_{t+1})^{\epsilon_w (1+\eta_c)} W_{c,1,t+1} \]

\[ W_{c,2,t} = \Lambda_{c,t} (1 - \tau_n) (w_{c,t})^{\epsilon_w} N_{c,t} + \beta_c \phi_w (\pi_{t+1})^{\epsilon_w - 1} W_{c,2,t+1} \]

and where \( w_{ch,t} = W_{ch,t}/P_t \). The law of motion of the wage index and wage inflation are given by:

\[ 1 = (1 - \phi_w) \left( \frac{w_{c,op,t}}{w_{c,t}} \right)^{1-\epsilon} + \phi_w (\pi_{cwt})^{\epsilon - 1} \]

\[ \frac{\pi_{cwt}}{\pi_t} = \frac{w_{c,t}}{w_{c,t-1}} \]

2.3 Entrepreneur

There is a continuum of measure \( 1 - \kappa_u - \kappa_c \) of entrepreneurs indexed by \( i \in [\kappa_u + \kappa_c, 1] \). They consume a final good and their utility is subject to habits. Entrepreneurs derive disutility from labour supply. We assume that entrepreneurs’ labour services are paid the same wage as households’, i.e., they take wages as given.

Entrepreneurs have access to two different production functions: one for the production of goods and one for the production of housing investment goods. Both technologies use labour and
are subject to a technology shock. Every period entrepreneurs hire workers from the labour agencies. Entrepreneurs decide how much capital to order from capital producers to be delivered in the following period, in excess of the undepreciated capital they already own. In addition, the rate of depreciation depends on the utilization rate entrepreneurs choose. Entrepreneurs can use the value of capital they own as collateral both for borrowing and for working capital. Similarly, they can also use the value of housing they owns as collateral. They decide each period how much housing to order from housing producers for the following period, in excess of the undepreciated housing they already own.

Entrepreneurs finance their expenditures by borrowing in nominal bonds from households. Importantly, entrepreneurs are subject to a borrowing constraint such that the sum of the loans they take and the working capital required to finance part of the wage bill in advance cannot exceed the collateral value. The collateral value is given by an exogenous fraction of the expected future value of the capital and housing stock owned by the entrepreneur. The pledgeability parameter of the borrowing constraint moves exogenously over time.

### 2.3.1 Optimal decisions over... everything

The entrepreneur life-time utility is of the form:

$$\max \text{ } \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \psi_{1,t} \left \{ \psi_{2,t} \left ( \frac{C_{e,t} - \lambda_e \tilde{C}_{e,t}}{1 - \sigma_e} \right )^{1-\sigma_e} - \tilde{c}_e \right \}$$

with $\tilde{Z}_t = \{C_{e,t}, B_{e,t+1}, H_{e,t}, N_{e,t}, t_1, K_1, M_{nd,t}, N_{ndu,t}, N_{du,t}, N_{ndc,t}, N_{dc,t} \}$ and where $\tilde{C}_{e,t} = C_{e,t-1}$. The entrepreneur is subject to the budget constraint:

$$(1 + \tau_t) P_{e,t} C_{e,t} + P_{h,t} (K_t - (1 - \delta_k (u_t)) K_{t-1}) + P_{h,t} (H_{e,t} - (1 - \delta_h) H_{e,t-1}) + B_{e,t-1} R_{t-1} + W_{u,t} (N_{ndu,t} + N_{du,t}) + W_{c,t} (N_{ndc,t} + N_{dc,t}) + P_{m,t} M_{nd,t} = (1 - \tau_n) W_{c,t} N_{e,t} + P_{nd,t} Y_{nd,t} + P_{d,t} Y_{d,t} + B_{e,t}$$

(20)

to technology:

$$Y_{nd,t} = e^{Z_{nd,t}} \left ( \left ( u_t K_{t-1} \right )^{1-\alpha_{nd}-\alpha_m} \left ( (N_{ndu,t})^{1-\alpha_e} (N_{ndc,t})^{\alpha_e} \right )^{\alpha_{nd}} \left ( M_{nd,t} \right )^{\alpha_m} \right )^{1-\nu_e} (H_{e,t-1})^{\nu_e}$$

(21)

to capital utilization:

$$\delta_k (u_t) = \delta_{k0} + \delta_{k1} (u_t - 1) + \delta_{k2} \frac{1}{2} (u_t - 1)^2$$

(23)

and to the borrowing constraint:

$$B_{e,t}^{aux} = \theta_1 \mathbb{E}_t \left \{ \frac{P_{h,t+1} K_t + P_{h,t+1} H_{e,t}}{R_t} \right \} - \omega \{W_{u,t} (N_{ndu,t} + N_{du,t}) + W_{c,t} (N_{ndc,t} + N_{dc,t})\}$$

$$B_{e,t} = \rho_{eb} B_{e,t-1} + (1 - \rho_{eb}) B_{e,t}^{aux}$$

(24)

which is assumed to be always binding in the steady state around which we linearise the model.

The first order conditions (in real terms) with respect to consumption, bonds, labour supply and housing are given by:

[wrt $C_{e,t}$]

$$\Lambda_{c,t} (1 + \tau_e) = \psi_{1,t} \psi_{2,t} (C_{e,t} - \lambda_e C_{e,t-1})^{-\sigma_e}$$

(25)
\[
\frac{\text{wrt } B_{c,t+1}}{\text{wrt } B_{c,t+1}} \quad \Lambda_{c,t} = \beta_c E_t \Lambda_{c,t+1} r_t + \xi_{c,t} - \rho_{eb} \xi_{e,t+1} \tag{26}
\]
\[
\frac{\text{wrt } N_{e,t}}{\text{wrt } N_{e,t}} \quad \zeta_{e,t} \psi_{e,t} (N_{e,t})^{\beta_n} = (1 - \tau_n) w_{e,t} \Lambda_{c,t} \tag{27}
\]
\[
\frac{\text{wrt } H_{e,t+1}}{\text{wrt } H_{e,t+1}} \quad \Lambda_{c,t} p_{h,t} = (1 - \rho_{eb}) \xi_{e,t} \theta_{e,t} \left\{ \frac{p_{h,t+1}}{r_t} \right\} + \beta_c E_t \Lambda_{c,t+1} \left\{ p_{h,t+1} (1 - \delta_h) + \nu_e \frac{p_{nd,t+1} Y_{nd,t+1}}{H_{e,t}} \right\} \tag{28}
\]

where \( \Lambda_e \) is the multiplier on the budget constraint and \( \xi_e \) the multiplier on the borrowing constraint.

The first order conditions (in real terms) with respect to capital, labour demand, materials and utilization are given by:

\[
\frac{\text{wrt } K_{t+1}}{\text{wrt } K_{t+1}} \quad \Lambda_{c,t} p_{k,t} = (1 - \rho_{eb}) \xi_{e,t} \theta_{e,t} \left\{ \frac{p_{k,t+1}}{r_t} \right\} + \beta_c E_t \Lambda_{c,t+1} \left\{ p_{k,t+1} (1 - \delta_k (u_{t+1})) p_{k,t+1} + \beta_c E_t \Lambda_{c,t+1} (1 - \alpha_{nd} - \alpha_m) \right\} \frac{Y_{nd,t+1}}{K_t} \tag{29}
\]
\[
\frac{\text{wrt } N_{ndu,t}}{\text{wrt } N_{ndu,t}} \quad w_{u,t} \left( 1 + (1 - \rho_{eb}) \omega \frac{\xi_{e,t}}{\Lambda_{c,t}} \right) = (1 - \nu_e) \alpha_{nd} (1 - \alpha_c) \frac{p_{nd,t} Y_{nd,t}}{N_{ndu,t}} \tag{30}
\]
\[
\frac{\text{wrt } N_{du,t}}{\text{wrt } N_{du,t}} \quad w_{u,t} \left( 1 + (1 - \rho_{eb}) \omega \frac{\xi_{e,t}}{\Lambda_{c,t}} \right) = (1 - \nu_e) \alpha_d (1 - \alpha_c) \frac{p_{dt,t} Y_{dt,t}}{N_{du,t}} \tag{31}
\]
\[
\frac{\text{wrt } N_{ndc,t}}{\text{wrt } N_{ndc,t}} \quad w_{c,t} \left( 1 + (1 - \rho_{eb}) \omega \frac{\xi_{e,t}}{\Lambda_{c,t}} \right) = (1 - \nu_e) \alpha_{nd} \alpha_c \frac{p_{nd,t} Y_{nd,t}}{N_{ndc,t}} \tag{32}
\]
\[
\frac{\text{wrt } N_{dc,t}}{\text{wrt } N_{dc,t}} \quad w_{c,t} \left( 1 + (1 - \rho_{eb}) \omega \frac{\xi_{e,t}}{\Lambda_{c,t}} \right) = (1 - \nu_e) \alpha_{dc} \frac{p_{dt,t} Y_{dt,t}}{N_{dc,t}} \tag{33}
\]
\[
\frac{\text{wrt } M_{nd,t}}{\text{wrt } M_{nd,t}} \quad p_{m,t} = (1 - \nu_e) \alpha_m \frac{p_{nd,t} Y_{nd,t}}{M_{nt,t}} \tag{34}
\]
\[
\frac{\text{wrt } u_{t}}{\text{wrt } u_{t}} \quad (1 - \nu_e) (1 - \alpha_{nd} - \alpha_m) \frac{p_{nd,t} Y_{nd,t}}{u_t K_{t-1}} = (\delta_{k1} + \delta_{k2} (u_{t-1}) - 1) p_{k,t} \tag{35}
\]

### 2.4 Housing and Capital Producers

#### 2.4.1 Housing producers

Housing producers purchase housing investment goods from the entrepreneur at price \( P_{d,t} \) to invest in new housing. They sell new housing to the household and to the entrepreneur at price \( P_{h,t} \). The production of new housing is subject to investment adjustment costs and to investment-specific technology shocks. Housing producers solve:

\[
\max_{I_{h,t}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_{h,t} (P_{h,t} (H_t - (1 - \delta_h) H_{t-1}) - P_{d,t} I_{h,t})
\]

subject to the production of new housing:

\[
H_t = (1 - \delta_h) H_{t-1} + \chi_t^h \left[ 1 - \frac{\Delta h}{2} \left( \frac{I_{h,t}}{I_{h,t-1}} - 1 \right) \right] I_{h,t} \tag{36}
\]
where:

\[ H_t = \kappa_u H_{u,t} + \kappa_c H_{c,t} + (1 - \kappa_u - \kappa_c) H_{e,t} \]  

(37)

The first order condition writes:

\[ p_{d,t} = p_{h,t} \chi_{h,t} \left[ 1 - \Delta_h \left( \frac{I_{h,t}}{I_{h,t-1}} - 1 \right)^2 - \Delta_h \left( \frac{I_{h,t}}{I_{h,t-1}} - 1 \right) \right] \]

\[ + \beta \frac{\Delta_{k+1}}{\Delta_{k,t}} p_{h,t+1} \pi_{t+1} \chi_{h,t+1} \Delta_h \left( \frac{I_{h,t+1}}{I_{h,t}} - 1 \right) \left( \frac{I_{h,t+1}}{I_{h,t}} \right)^2 \]  

(38)

2.4.2 Capital producers

Capital producers purchase goods from the non-durable goods aggregator at price \( P_t \) to invest in new capital. They sell new capital to the entrepreneur at price \( P_{k,t} \). The production of new capital is subject to investment adjustment costs and to investment-specific technology shocks.

Capital producers solve:

\[ \max_{I_{k,t}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Lambda_{h,t} (P_{k,t} [K_t - (1 - \delta_k (u_t)) K_{t-1}] - P_{f,k,t} I_{k,t}) \]

subject to:

\[ K_t = (1 - \delta_k (u_t)) K_{t-1} + \chi_k \left[ 1 - \frac{\Delta_k}{2} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 \right] I_{k,t} \]  

(39)

The first order condition writes:

\[ p_{f,k,t} = p_{k,t} \chi_{k,t} \left[ 1 - \frac{\Delta_k}{2} \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right)^2 - \Delta_k \left( \frac{I_{k,t}}{I_{k,t-1}} - 1 \right) \right] \]

\[ + \beta \frac{\Delta_{k+1}}{\Delta_{k,t}} p_{h,t+1} \pi_{t+1} \chi_{k,t+1} \Delta_k \left( \frac{I_{h,t+1}}{I_{h,t}} - 1 \right) \left( \frac{I_{h,t+1}}{I_{h,t}} \right)^2 \]  

(40)

2.5 Intermediate goods

2.5.1 Competitive goods aggregator

A competitive goods aggregator buys different varieties of intermediate goods from domestic retailers, packages them in an homogeneous good which is in turn sold at price \( P_{r,t} \) to final goods producers in Spain, the RE and to export to the RW. The aggregation technology is given by:

\[ Y_{r,t} = \left[ \int_0^1 (Y_{r,t} (i))^{\epsilon_p - 1} di \right]^{1/\epsilon_p} \]

where the demand for each type of retail variety \( i \) writes:

\[ Y_{r,t} (i) = \left( \frac{P_{r,t} (i)}{P_{r,t}} \right)^{-\epsilon_p} Y_{r,t} \]

and the price index of the aggregated good:

\[ P_{r,t} = \left[ \int_0^1 (P_{r,t} (i))^{1-\epsilon_p} di \right]^{1/\epsilon_p} \]  

2.5.2 Retailers

There is a continuum of retailers indexed by \( i \in [0, 1] \). They purchase the non-tradeable good from the entrepreneur at price \( P_{n_d,t} \) and produce diversified retail varieties which are sold to the goods aggregator at price \( P_{r,t} (i) \) for each \( i \) variety. Retailers have monopolistic power and are subject to Calvo price frictions, such that, in every period only a fraction \( 1 - \phi_p \) of retailers
can optimally adjust prices. The remaining fraction $\phi_p$ update prices to lagged inflation, that is:

$$P_{r,t+s}(i) = \begin{cases} 
  P_{op,t+s} & \text{with prob. } 1 - \phi_p \\
  P_{op,t}(\prod_{k=1}^{t+k-1})^\gamma & \text{with prob. } \phi_p
\end{cases}$$

Intermediate goods producers solve:

$$\max_{P_{r,t}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \left( \beta \phi_p \right)^j \frac{\Lambda_{h,t+j}}{\Lambda_{h,t}} \left[ \frac{P_{r,t}(i)}{P_{1,t}} - \frac{P_{nd,t+j}}{P_{1,t}} \right] Y_{r,t+j}(i)$$

subject to the demand curve for variety $i$ from the goods aggregator. The first order condition writes:

$$\frac{p_{op,t}}{p_{r,t}} = \frac{\epsilon_p - 1}{\epsilon_p - 1} P_{2,t}$$

with:

$$P_{1,t} = p_{nd,t} Y_{r,t} + \beta \phi_p \mathbb{E}_t \frac{\Lambda_{h,t}}{\Lambda_{h,t}} (\Pi_{r,t+1})^{\gamma_p} P_{1,t+1}$$

$$P_{2,t} = p_{r,t} Y_{r,t} + \beta \phi_p \frac{\Lambda_{h,t}}{\Lambda_{h,t}} (\Pi_{r,t+1})^{\gamma_p-1} P_{2,t+1}$$

$$\Pi_{r,t+1} = \frac{\pi_{r,t+1}}{(\pi_{r,t})^\gamma}$$

Profits of retailers are given by $\int_0^1 [P_{r,t}(i) - P_{nd,t}] Y_{r,t}(i) di$. Aggregation implies:

$$(1 - \kappa_u - \kappa_c) Y_{nd,t} = Y_{r,t} P_{3,t}$$

with price dispersion given by:

$$P_{3,t} = (1 - \phi_p) \left( \frac{p_{op,t}}{p_{r,t}} \right)^{-\epsilon_p} + \phi_p (\Pi_{r,t+1})^{\gamma_p} P_{3,t-1}$$

Finally, using the price index $P_{r,t} = \left[ \int_0^1 (P_{r,t}(i))^{1-\epsilon_p} \right]^{\epsilon_p}$ we can express inflation as:

$$1 = (1 - \phi_p) \left( \frac{p_{op,t}}{p_{r,t}} \right)^{1-\epsilon_p} + \phi_p (\Pi_{r,t+1})^{\gamma_p-1}$$

We assume the law of one price holds within the monetary union, such that:

$$p_{r,t} = e_t P_{src,t}$$

where $P_{src,t}$ is the price faced by firms in the RE.

### 2.6 Final goods producers

#### 2.6.1 Final consumption goods producers

A competitive final goods producer combines domestic and foreign retail goods and oil into a final good which is sold to Spanish households and entrepreneurs. The aggregation technology consists of a CES basket of goods (non-oil) and oil:

$$C_t = \left[ \mu_{co} \left( Y_{c,o,t} \right)^{\frac{\omega_{co}-1}{\omega_{co}}} + (1 - \mu_{co}) \left( Y_{c,no,t} \right)^{\frac{\omega_{co}-1}{\omega_{co}}} \right]^{\frac{\omega_{co}}{\omega_{co}-1}}$$
with consumption goods consisting of a further CES basket of goods produced in Spain, the RE and in the RW:

\[ Y_{no,t} = \left[ \mu_{cl} (Y_{c,es,t})^{-\frac{1}{\nu_c}} + \mu_{crw} (\tau Y_{c,re,t})^{-\frac{1}{\nu_c}} + (1 - \mu_{cl} - \mu_{crw}) \frac{1}{\nu_c} (Y_{c,rw,t})^{-\frac{1}{\nu_c}} \right]^{-\frac{1}{\nu_c}} \]

with \( \tau = (1 - n)/n \) adjusting the amount of imported goods from the RE to the population size of Spain. They solve:

\[ \max_{Y_{c,o,t}, Y_{c,es,t}, Y_{c,re,t}, Y_{c,rw,t}} \quad \Pi C_k - P_{oes,t} Y_{c,o,t} - P_{r,t} Y_{c,es,t} - P_{rees,t} \tau Y_{c,re,t} - P_{rwes,t} Y_{c,rw,t} \]

The resulting demands are given by:

\[ Y_{c,o,t} = \mu_{co} (p_{oes,t})^{-\nu_{co}} C_t \quad (47) \]
\[ Y_{c,no,t} = (1 - \mu_{co}) (p_{no,t})^{-\nu_{co}} C_t \quad (48) \]
\[ Y_{c,es,t} = \mu_{cl} \left( \frac{P_{r,t}}{P_{no,t}} \right)^{-\nu} Y_{c,no,t} \quad (49) \]
\[ Y_{c,re,t} = \frac{\mu_{crw}}{\tau} \left( \frac{P_{rees,t}}{P_{no,t}} \right)^{-\nu} Y_{c,no,t} \quad (50) \]
\[ Y_{c,rw,t} = (1 - \mu_{cl} - \mu_{crw}) \left( \frac{P_{rwes,t}}{P_{no,t}} \right)^{-\nu} Y_{c,no,t} \quad (51) \]

whereas the composite price indices are given by:

\[ 1 = \left[ \mu_{co} (p_{oes,t})^{1-\nu_{co}} + (1 - \mu_{co}) (p_{no,t})^{1-\nu_{co}} \right]^{\frac{1}{1-\nu_{co}}} \quad (52) \]

\[ p_{no,t} = \left[ \mu_{cl} (p_{r,t})^{1-\nu} + \mu_{crw} (p_{rees,t})^{1-\nu} + (1 - \mu_{cl} - \mu_{crw}) (p_{rwes,t})^{1-\nu} \right]^{\frac{1}{1-\nu}} \quad (53) \]

and where:

\[ p_{rees,t} = c_{t} p_{r,RE}^{t} \quad (54) \]
\[ p_{oes,t} = c_{esrw,t} p_{RW}^{t} \quad (55) \]

### 2.6.2 Final investment goods producers

Competitive final goods producers combine domestic and foreign goods and oil into a final good which is sold to Spanish capital producers. The aggregation technology is similar to that of final consumption goods producers, albeit with different weights and elasticities. The respective demands are given by:

\[ Y_{k,o,t} = \mu_{ko} \left( \frac{p_{oes,t}}{p_{k,t}} \right)^{-\nu_{ko}} (1 - \kappa_{u} - \kappa_{c}) I_{k,t} \quad (56) \]
\[ Y_{k,no,t} = (1 - \mu_{ko}) \left( \frac{p_{no,t}}{p_{k,t}} \right)^{-\nu_{ko}} (1 - \kappa_{u} - \kappa_{c}) I_{k,t} \quad (57) \]
\[ Y_{k,es,t} = \mu_{kl} \left( \frac{P_{r,t}}{p_{kno,t}} \right)^{-\nu_{k}} Y_{k,no,t} \quad (58) \]
\[ Y_{k,re,t} = \frac{\mu_{krw}}{\tau} \left( \frac{P_{rees,t}}{p_{kno,t}} \right)^{-\nu_{k}} Y_{k,no,t} \quad (59) \]
\[ Y_{k,rw,t} = (1 - \mu_{kl} - \mu_{krw}) \left( \frac{P_{rwes,t}}{p_{kno,t}} \right)^{-\nu_{k}} Y_{k,no,t} \quad (60) \]

whereas the composite price indices are given by:

\[ p_{k,t} = \left[ \mu_{ko} (p_{oes,t})^{1-\nu_{ko}} + (1 - \mu_{ko}) (p_{kno,t})^{1-\nu_{ko}} \right]^{\frac{1}{1-\nu_{ko}}} \quad (61) \]
\[ p_{kno,t} = \left[ \mu_{kl} (p_{r,t})^{1-\nu_{k}} + \mu_{krw} (p_{rees,t})^{1-\nu_{k}} + (1 - \mu_{kl} - \mu_{krw}) (p_{rwes,t})^{1-\nu_{k}} \right]^{\frac{1}{1-\nu_{k}}} \quad (62) \]
2.6.3 Materials producers

Perfectly competitive materials producers bundle into a composite intermediate input goods produced domestically and abroad using the following technology:

\[(1 - \kappa_u - \kappa_c) M_{nd,t} = \left[ \mu_{ml} (Y_{m,es,t})^{\frac{1}{\nu_m}} + \mu_{mru} (Y_{m,es,t})^{\frac{1}{\nu_m}} + (1 - \mu_{ml} - \mu_{mru}) \frac{1}{\nu_m} (Y_{m,rw,t})^{\frac{1}{\nu_m}} \right]^{\frac{\nu_m}{\nu_m-1}}\]

They solve:

\[
\max_{Y_{m,es,t}, Y_{m,re,t}, Y_{m,rw,t}} P_{m,t} (1 - \kappa_u - \kappa_c) M_{nd,t} - P_{r,t} Y_{m,es,t} - P_{rees,t} Y_{m,re,t} - P_{rwes,t} Y_{m,rw,t}
\]

and respective demands are given by:

\[
Y_{m,es,t} = \mu_{ml} \left( \frac{p_{r,t}}{p_{m,t}} \right)^{-\nu_m} (1 - \kappa_u - \kappa_c) M_{nd,t}
\]

\[
Y_{m,re,t} = \mu_{mru} \left( \frac{P_{rees,t}}{P_{m,t}} \right)^{-\nu_m} (1 - \kappa_u - \kappa_c) M_{nd,t}
\]

\[
Y_{m,rw,t} = (1 - \mu_{ml} - \mu_{mru}) \left( \frac{P_{rwes,t}}{P_{m,t}} \right)^{-\nu_m} (1 - \kappa_u - \kappa_c) M_{nd,t}
\]

whereas the composite price index is given by:

\[
p_{m,t} = \left[ \mu_{ml} (p_{r,t})^{1-\nu_m} + \mu_{mru} (p_{rees,t})^{1-\nu_m} + (1 - \mu_{ml} - \mu_{mru}) (p_{rwes,t})^{1-\nu_m} \right]^{\frac{1}{1-\nu_m}}
\]

2.6.4 Government consumption producers

The government combines domestic and foreign goods into its final consumption bundle. The aggregation technology is similar to that of final material goods producers, albeit with different weights and elasticities. The resulting demands are given by:

\[
Y_{g,es,t} = \mu_{gl} \left( \frac{p_{r,t}}{p_{g,t}} \right)^{-\nu_g} G_t
\]

\[
Y_{g,re,t} = \mu_{gru} \left( \frac{P_{rees,t}}{P_{g,t}} \right)^{-\nu_g} G_t
\]

\[
Y_{g,rw,t} = (1 - \mu_{gl} - \mu_{gru}) \left( \frac{P_{rwes,t}}{P_{g,t}} \right)^{-\nu_g} G_t
\]

whereas the composite price index is given by:

\[
p_{g,t} = \left[ \mu_{gl} (p_{r,t})^{1-\nu_g} + \mu_{gru} (p_{rees,t})^{1-\nu_g} + (1 - \mu_{gl} - \mu_{gru}) (p_{rwes,t})^{1-\nu_g} \right]^{\frac{1}{1-\nu_g}}
\]

2.7 Incomplete pass-through

2.7.1 Import firms

There is a continuum of firms indexed by \( i \in [0,1] \) importing an homogeneous good produced outside the monetary union at the price \( P_{RW,r,t} \). These importing firms produce diversified varieties of intermediate importing goods \( Y_{rwes,t}(i) \), which are then sold to aggregator firms at price \( P_{ruces,t}(i) \) for each \( i \) varieties. Aggregator firms buy these different varieties and pack them in a unique good which is then sold to final goods producers at the price \( P_{ruces,t} \):

\[
Y_{ruces,t} = Y_{c,rw,t} + Y_{k,rw,t} + Y_{m,rw,t} + Y_{g,rw,t}
\]

The aggregation technology is given by:

\[
Y_{ruces,t} = \left[ \int_0^1 (Y_{ruces,t}(i))^{\frac{1}{\nu_m}} \, di \right]^{\frac{\nu_m}{\nu_m-1}}
\]
Import firms solve: 

$$Y_{rwes,t}(i) = \left( \frac{P_{rwes,t}(i)}{P_{rwes,t}} \right)^{-\epsilon_m} Y_{rwes,t}$$

and the price index of the aggregated good:

$$P_{rwes,t} = \left[ \int_0^1 (P_{rwes,t}(i))^{1-\epsilon_m} di \right]^{1/1-\epsilon_m}$$

Import firms have monopolistic power and are subject to Calvo price frictions, such that, in every period only a fraction $1 - \phi_m$ of firms can optimally adjust their prices (local currency price stickiness). The remaining fraction $\phi_m$ of firms update prices to lagged inflation, that is:

$$P_{rwes,t+s}(i) = \begin{cases} P_{rwes,op,t+s} & \text{with prob. } 1 - \phi_m \\ P_{rwes,op,t}(\Pi_{k=1}^s \pi_{m,t+k-1})^{\phi_m} & \text{with prob. } \phi_m \end{cases}$$

Import firms solve:

$$\max_{P_{rwes,t}(i)} \frac{\epsilon_m}{(\epsilon_m - 1)} \text{E} \left[ \sum_{j=0}^{\infty} (\beta \phi_m)^j \frac{\lambda_{h,t+j}}{\lambda_{h,t}} e_{sRW,t+j} P_{t+j}^{-\phi_m} Y_{rwes,t+j}(\Pi_{k=1}^s \pi_{m,t+k-1})^{\epsilon_m} \frac{P_{rwes,t}(i)}{P_{t+j}} - s_{rw,t+j} \frac{P_{RW,s,t+j}}{P_{t+j}} Y_{rwes,t+j}(i) \right]$$

subject to the demand curve for variety $i$ and where $s_{rw,t}$ denotes the nominal exchange rate. The first order condition writes:

$$\frac{P_{rwes,op,t}}{P_{rwes,t}} = \frac{\epsilon_m}{(\epsilon_m - 1)} \text{E} \left[ \sum_{j=0}^{\infty} (\beta \phi_m)^j \frac{\lambda_{h,t+j}}{\lambda_{h,t}} e_{sRW,t+j} Y_{rwes,t+j}(\Pi_{k=1}^s \pi_{m,t+k-1})^{\epsilon_m} \frac{P_{rwes,t}(i)}{P_{t+j}} - s_{rw,t+j} \frac{P_{RW,s,t+j}}{P_{t+j}} Y_{rwes,t+j}(i) \right]$$

The optimal real reset price can be expressed as:

$$\frac{P_{rwes,op,t}}{P_{rwes,t}} = \frac{\epsilon_m}{(\epsilon_m - 1)} \frac{P_{m1,t}}{P_{m2,t}}$$

with:

$$P_{m1,t} = e_{sRW,t} P_{s,t} Y_{rwes,t} + \beta \phi_m \text{E} \left[ \frac{\lambda_{h,t+1}}{\lambda_{h,t}} (\Pi_{m,t+1})^{\epsilon_m} P_{m1,t+1} \right]$$

$$P_{m2,t} = P_{rwes,t} Y_{rwes,t} + \beta \phi_m \frac{\lambda_{h,t+1}}{\lambda_{h,t}} (\Pi_{m,t+1})^{\epsilon_m - 1} P_{m2,t+1}$$

$$\Pi_{m,t+1} = \frac{\pi_{m,t+1}}{(\pi_{m,t})^{\phi_m}}$$

Aggregation implies:

$$\bar{Y}_{rwes,t} = Y_{rwes,t} P_{m3,t}$$

with price dispersion given by:

$$P_{m3,t} = (1 - \phi_m) \left( \frac{P_{rwes,op,t}}{P_{rwes,t}} \right)^{-\epsilon_m} + \phi_m (\Pi_{m,t+1})^{\epsilon_m} P_{m3,t-1}$$

Finally, using the price index $P_{rwes,t} = \left[ \int_0^1 (P_{rwes,t}(i))^{1-\epsilon_m} di \right]^{1/1-\epsilon_m}$ we can write it as:

$$1 = (1 - \phi_m) \left( \frac{P_{rwes,op,t}}{P_{rwes,t}} \right)^{1-\epsilon_m} + \phi_m (\Pi_{m,t+1})^{\epsilon_m - 1}$$

Finally,

$$\pi_{m,t} = \frac{P_{rwes,t}}{P_{rwes,t-1}}$$

### 2.7.2 Export firms

Similarly, there is a continuum of firms indexed by $i \in [0,1]$ exporting the domestic produced homogeneous good outside the monetary union. These exporting firms produce diversified vari-
Export firms solve:

\[ Y_{esrw,t}(i) = \left( \frac{P_{esrw,t}(i)}{P_{esrw,t}} \right)^{-\epsilon_x} Y_{esrw,t} \]

where \( Y_{esrw,t} \) denotes foreign aggregate demand and \( P_{esrw,t} \) is the exported goods price index (denominated in foreign currency):

\[ P_{esrw,t} = \left[ \int_0^1 (P_{esrw,t}(i))^{1-\epsilon_x} \, di \right]^{1/\epsilon_x} \]

Export firms have monopolistic power and are subject to Calvo price frictions, such that, in every period only a fraction \( 1 - \phi_x \) of firms can optimally adjust their prices (foreign currency price stickiness). The remaining fraction \( \phi_x \) of firms update prices to lagged inflation, that is:

\[ P_{esrw,t+s}(i) = \begin{cases} 
P_{esrw,op,t+s} & \text{with prob. } 1 - \phi_x \\
P_{esrw,t}(i)(\Pi_{k=1}^{k+1} \pi_{x,t+k-1})^{\theta_n} & \text{with prob. } \phi_x
\end{cases} \]

Export firms solve:

\[ \max_{P_{esrw,t}(i)} E_t \sum_{j=0}^{\infty} (\beta \phi_x)^j \frac{\Lambda_{h,t+j}}{\Lambda_{h,t}} \left[ \frac{P_{esrw,t}(i)}{P_{esrw,t}} - \frac{P_{rt+j}}{s_{rw,t+j}^{\pi_{rw,t+j}}} \right] Y_{esrw,t+j}(i) \]

subject to the demand curve for variety \( i \) and where \( s_{rw,t} \) denotes the nominal exchange rate.

The first order condition writes:

\[ \frac{P_{esrw,op,t}}{P_{esrw,t}} = \frac{\epsilon_x}{(\epsilon_x - 1)} \frac{E_t \sum_{j=0}^{\infty} (\beta \phi_x)^j \frac{\Lambda_{h,t+j}}{\Lambda_{h,t}} P_{esrw,t+j} Y_{esrw,t+j}(\Pi_{k=1}^{k+1} \pi_{x,t+k-1})^{\theta_n(1-\epsilon_x)} \left( \frac{P_{esrw,t}}{P_{esrw,t+j}} \right)^{-\epsilon_x}}{\sum_{j=0}^{\infty} (\beta \phi_x)^j \frac{\Lambda_{h,t+j}}{\Lambda_{h,t}} Y_{esrw,t+j}(\Pi_{k=1}^{k+1} \pi_{x,t+k-1})^{\theta_n(1-\epsilon_x)} \left( \frac{P_{esrw,t}}{P_{esrw,t+j}} \right)^{1-\epsilon_x}} \]

The optimal real reset price can be expressed as:

\[ \frac{p_{op,t}}{p_{esrw,t}} = \frac{\epsilon_x}{\epsilon_x - 1} \frac{P_{x1,t}}{P_{x2,t}} \]

with:

\[ P_{x1,t} = \frac{p_{rt}}{s_{rw,t}} Y_{esrw,t} + \beta \phi_x E_t \frac{\Lambda_{h,t+1}}{\Lambda_{h,t}} (\Pi_{x,t+1})^{\epsilon_x} P_{x1,t+1} \]

\[ P_{x2,t} = p_{esrw,t} Y_{esrw,t} + \beta \phi_x \frac{\Lambda_{h,t+1}}{\Lambda_{h,t}} (\Pi_{x,t+1})^{\epsilon_x - 1} P_{x2,t+1} \]

Aggregation implies:

\[ \hat{Y}_{esrw,t} = Y_{esrw,t} P_{x3,t} \]

with price dispersion given by:

\[ P_{x3,t} = (1 - \phi_x) \left( \frac{p_{esrw,op,t}}{p_{esrw,t}} \right)^{-\epsilon_x} + \phi_x (\Pi_{x,t+1})^{\epsilon_x} P_{x3,t-1} \]

Finally, using the price index \( P_{esrw,t} \) we can write it as:

\[ 1 = (1 - \phi_x) \left( \frac{p_{esrw,op,t}}{p_{esrw,t}} \right)^{-\epsilon_x} + \phi_x (\Pi_{x,t+1})^{\epsilon_x - 1} \]

Finally,

\[ \pi_{x,t} = \frac{P_{esrw,t}}{p_{esrw,t-1}} \pi_{rw,t} \]
2.8 Government

2.8.1 Budget constraint

The government’s budget constraint is given by:

\[ p_{g,t}G_t + \kappa_u T_{u,t} + \kappa_c T_{c,t} = \tau_c C_t + \tau_n \left\{ \kappa_u w_{u,t} N_{u,t} + \kappa_c w_{c,t} N_{c,t} + (1 - \kappa_u - \kappa_c) w_{e,t} N_{e,t} \right\} \] (86)

2.9 Market clearing

The market for aggregated retail goods clears when:

\[ Y_{r,t} = Y_{c,es,t} + Y_{k,es,t} + Y_{m,es,t} + Y_{g,es,t} + Y^{RE}_{c,es,t} + Y^{RE}_{k,es,t} + Y^{RE}_{m,es,t} + Y^{RE}_{g,es,t} + \tilde{Y}_{esrw,t} \] (87)

whereas the market for housing investment verifies:

\[ (1 - \kappa_u - \kappa_c) Y_{d,t} = I_{h,t} \] (88)

In turn, labour markets clearing implies:

\[ \kappa_u N_{u,t} = (1 - \kappa_u - \kappa_c)(N_{ndu,t} + N_{du,t}) \] (89)

and

\[ \kappa_c N_{c,t} + (1 - \kappa_u - \kappa_c) N_{e,t} = (1 - \kappa_u - \kappa_c)(N_{ndc,t} + N_{dc,t}) \] (90)

Aggregate consumption is given by:

\[ C_t = \kappa_u C_{u,t} + \kappa_c C_{c,t} + (1 - \kappa_u - \kappa_c) C_{e,t} \] (91)

whereas loans from the unconstrained household equal credit demanded by constrained households and entrepreneurs:

\[ \kappa_u B_{u,t} = \kappa_c B_{c,t} + (1 - \kappa_u - \kappa_c) B_{e,t} \]

CPI inflation is given by:

\[ \pi_t = \frac{p_{r,t-1}}{p_{r,t}} \pi_{r,t} \] (92)

and the Fisher equation holds:

\[ r_t = \frac{R_t}{\pi_{t+1}} \] (93)

2.10 Net Foreign Assets

The net foreign asset position is obtained by aggregating the budget constraints of households, entrepreneurs and the government, and using the resource constraints:

\[ e_{esrw,t} \left( D_{t-1} R_{rw,t-1} \Psi_{t-1} - D_t \right) = NE_t \] (94)

with \( D_t = \kappa_u D_{h,t} \) and where net exports are given by:

\[ NE_t = \left\{ p_{r,t} \left\{ Y^{RE}_{c,es,t} + Y^{RE}_{k,es,t} + Y^{RE}_{m,es,t} + Y^{RE}_{g,es,t} \right\} \right\} \]

\[ + e_{esrw,t} \left\{ Y^{ES}_{c,es,t} + Y^{ES}_{k,es,t} + Y^{ES}_{m,es,t} + Y^{ES}_{g,es,t} \right\} + e_{esrw,t} \left\{ p_{r,t} \tilde{Y}_{esrw,t} \right\} \]

Imports of Oil and of goods from Core and RoW

2.11 Absorption

Real GDP is given by:

\[ rgdp_t = C_t + p_{g,t} G_t + (1 - \kappa_u - \kappa_c) p_{f,k,t} I_{k,t} + p_{d,t} I_{h,t} + NE_t \] (96)
2.12 Monetary authority

In the monetary union there is a single monetary authority, which sets the nominal interest rate of the union following a Taylor rule which reacts to inflation and output growth:

\[ R_{EA}^{t} = (R_{EA}^{t-1})^{\rho_{r}} \left[ (\pi_{t}^{\nu})^{\phi_{r}} (g_{t}^{u})^{\phi_{y}} \right]^{1-\rho_{r}} \left( 1/\beta \right)^{1-\rho_{r}} e_{t}^{p} \]  \hspace{1cm} (97)

where aggregated output and inflation is given by:

\[ g_{t}^{u} = n \frac{rgdp_{t}}{rgdp_{t-1}} + (1-n) \frac{rgdp_{t}^{e}}{rgdp_{t-1}^{e}} \]  \hspace{1cm} (98)

\[ \pi_{t}^{u} = n \pi_{t} + (1-n) \pi_{t}^{e} \]  \hspace{1cm} (99)

The real exchange rate between Spain and the RE, \( e_{t} \), verifies:

\[ e_{esrw,t} = e_{t} e_{rerw,t} \]  \hspace{1cm} (100)

and the nominal exchange rate between Spain and the RE is fixed:

\[ \frac{e_{t}}{e_{t-1}} = \frac{\pi_{t}^{e}}{\pi_{t}} \]  \hspace{1cm} (101)

Finally, the domestic nominal interest rate is given by:

\[ R_{t} = R_{EA}^{t} \Psi_{t} \]  \hspace{1cm} (102)

where the country-specific spread evolves according to:

\[ \Psi_{t} = \exp \left( \Gamma (D_{t} - D) \right) \]  \hspace{1cm} (103)

2.13 Rest of the World

The demand of goods produced in Spain by the RW is modelled as an exogenous process. Hence, exports to the RW are given by:

\[ Y_{esrw,t} = \mu_{srw} (p_{esrw,t})^{-\mu_{srw}} rgdp_{t}^{RW} \]  \hspace{1cm} (104)

where:

\[ rgdp_{t}^{RW} = \text{exogenous} \]  \hspace{1cm} (105)

Analogously, the price of goods from the RW consumed in Spain is also exogenous:

\[ P_{t}^{RW} = \text{exogenous} \]  \hspace{1cm} (106)

as are oil prices and the nominal interest rate:

\[ P_{o,t}^{RW} = \text{exogenous} \]  \hspace{1cm} (107)

\[ R_{t}^{RW} = \text{exogenous} \]  \hspace{1cm} (108)

3 Calibration and dynamic properties

The objectives behind the development of JOSE include taking the model to the data in order to estimate a subset of its parameters, to use the model to construct risk scenarios around macroeconomic forecasting exercises and to run counterfactual experiments of shocks and economic policies. Given these goals, the model needs to preform well along several dimensions, including to be able to match a range of empirical moments. This is achieved with the introduction of a number of nominal and real rigidities, as well as distinct compositions of aggregate variables which, although improving the empirical fit of the model, increase the size of JOSE. As a result, the full version of the model contains more than 270 variables, 250 parameters and 32 exogenous shocks.
In an effort to abstract from some aspects of the model, and in order to gain a better understanding of the economic mechanisms behind a wide range of experiments and shocks, JOSE has been developed in three parallel versions: a closed economy, a small open economy, and the full version consisting of a two-country monetary union with trade and financial linkages to a reduced form rest of the World block. Also, to gain insight into the main dynamic properties of JOSE before turning to a fully fledged estimation exercise, we compute a set of impulse responses obtained after calibrating the model using standard parameter values from the literature as well as national accounts data from Spain. Table 1 provides a list of the potential parameters that can be estimated using JOSE, with the provisional, calibrated parametrization that is used to obtain the impulse responses reported below.

Table 1: Calibration

<table>
<thead>
<tr>
<th>Common Parameters</th>
<th>ES</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>population shares</td>
<td>( n )</td>
<td>0.10</td>
</tr>
<tr>
<td>discount factor patient hh</td>
<td>( \beta )</td>
<td>0.9925</td>
</tr>
<tr>
<td>discount factor impatient hh</td>
<td>( \beta_{ch} )</td>
<td>0.97</td>
</tr>
<tr>
<td>discount factor entrepreneurs</td>
<td>( \beta_{e} )</td>
<td>0.97</td>
</tr>
<tr>
<td>elas. home/imports consump.</td>
<td>( \nu )</td>
<td>1.2</td>
</tr>
<tr>
<td>elas. country premium</td>
<td>( \Gamma )</td>
<td>0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>National Accounts</th>
<th>ES</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>share patient hh</td>
<td>( \kappa_{u} )</td>
<td>0.50</td>
</tr>
<tr>
<td>share impatient hh</td>
<td>( \kappa_{ch} )</td>
<td>0.30</td>
</tr>
<tr>
<td>real GDP per capita</td>
<td>( rgdp )</td>
<td>1.00</td>
</tr>
<tr>
<td>housing sector to GDP</td>
<td>( p_{h}I_{d}/rgdp )</td>
<td>0.08</td>
</tr>
<tr>
<td>real price of housing</td>
<td>( p_{h} )</td>
<td>1.00</td>
</tr>
<tr>
<td>net foreign assets</td>
<td>( D/rgdp )</td>
<td>( 4 \times (0.25) )</td>
</tr>
<tr>
<td>hours ((j \in {h, ch, e}))</td>
<td>( N_{j} )</td>
<td>1/3</td>
</tr>
<tr>
<td>patient hh housing % total</td>
<td>( H_{hp} )</td>
<td>0.50</td>
</tr>
<tr>
<td>public spending % final good</td>
<td>( p_{g}G/rgdp )</td>
<td>0.20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utility</th>
<th>ES</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>habits patient hh</td>
<td>( \lambda_{u} )</td>
<td>0.75</td>
</tr>
<tr>
<td>habits impatient hh</td>
<td>( \lambda_{c} )</td>
<td>0.75</td>
</tr>
<tr>
<td>habits entrepreneurs</td>
<td>( \lambda_{e} )</td>
<td>0.75</td>
</tr>
<tr>
<td>inter. elas. patient hh</td>
<td>( \sigma_{u} )</td>
<td>1.00</td>
</tr>
<tr>
<td>inter. elas. impatient hh</td>
<td>( \sigma_{c} )</td>
<td>1.00</td>
</tr>
<tr>
<td>inter. elas. entrepreneurs</td>
<td>( \sigma_{e} )</td>
<td>1.00</td>
</tr>
<tr>
<td>elas. ( C/H ) patient hh</td>
<td>( \sigma_{uh} )</td>
<td>0.20</td>
</tr>
<tr>
<td>elas. ( C/H ) impatient hh</td>
<td>( \sigma_{ch} )</td>
<td>0.20</td>
</tr>
<tr>
<td>labour supply elasticity</td>
<td>( \eta )</td>
<td>1.00</td>
</tr>
<tr>
<td>Production</td>
<td>ES</td>
<td>RE</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>impatient labour share</td>
<td>$\alpha_c$</td>
<td>0.40</td>
</tr>
<tr>
<td>labour in wholesale production</td>
<td>$\alpha_{nd}$</td>
<td>0.65</td>
</tr>
<tr>
<td>materials in wholesale production</td>
<td>$\alpha_m$</td>
<td>0.20</td>
</tr>
<tr>
<td>housing in wholesale production</td>
<td>$\nu_c$</td>
<td>0.04</td>
</tr>
<tr>
<td>labour in housing investment</td>
<td>$\alpha_d$</td>
<td>0.90</td>
</tr>
<tr>
<td>capital depreciation rate</td>
<td>$\delta_{k0}$</td>
<td>0.023</td>
</tr>
<tr>
<td>quadratic capital depreciation</td>
<td>$\delta_{k2}$</td>
<td>2.00</td>
</tr>
<tr>
<td>housing depreciation</td>
<td>$\delta_h$</td>
<td>0.01</td>
</tr>
<tr>
<td>capital investment adj. costs</td>
<td>$\Delta_k$</td>
<td>2.00</td>
</tr>
<tr>
<td>housing investment adj. costs</td>
<td>$\Delta_h$</td>
<td>2.00</td>
</tr>
<tr>
<td>loan-to-value ratio</td>
<td>$\theta$</td>
<td>0.75</td>
</tr>
<tr>
<td>working capital ratio</td>
<td>$\omega$</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trade</th>
<th>ES</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>elas. oil/goods consumption</td>
<td>$\nu_o$</td>
<td>0.1</td>
</tr>
<tr>
<td>oil-bias in consumption</td>
<td>$\iota_o$</td>
<td>0.05</td>
</tr>
<tr>
<td>home-bias in consumption</td>
<td>$\iota_l$</td>
<td>0.84</td>
</tr>
<tr>
<td>Rest of Union-bias in consumption</td>
<td>$\iota_{ru}$</td>
<td>0.08</td>
</tr>
<tr>
<td>elas. oil/goods investment</td>
<td>$\nu_{ko}$</td>
<td>0.1</td>
</tr>
<tr>
<td>elas. home/imports investment</td>
<td>$\nu_k$</td>
<td>3.0</td>
</tr>
<tr>
<td>oil-bias in investment</td>
<td>$\mu_{ko}$</td>
<td>0.01</td>
</tr>
<tr>
<td>home-bias in investment</td>
<td>$\mu_{kl}$</td>
<td>0.50</td>
</tr>
<tr>
<td>Rest of Union-bias in investment</td>
<td>$\mu_{kru}$</td>
<td>0.25</td>
</tr>
<tr>
<td>elas. home/imports materials</td>
<td>$\nu_m$</td>
<td>1.2</td>
</tr>
<tr>
<td>home-bias in materials</td>
<td>$\mu_{ml}$</td>
<td>0.25</td>
</tr>
<tr>
<td>Rest of Union-bias in materials</td>
<td>$\mu_{mrw}$</td>
<td>0.38</td>
</tr>
<tr>
<td>elas. home/imports gov. consump.</td>
<td>$\nu_g$</td>
<td>0.1</td>
</tr>
<tr>
<td>home-bias in gov. consump.</td>
<td>$\mu_{gl}$</td>
<td>0.90</td>
</tr>
<tr>
<td>Rest of Union-bias in gov. consump.</td>
<td>$\mu_{gru}$</td>
<td>0.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nominal Rigidities</th>
<th>ES</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>wage monopolistic elas.</td>
<td>$\epsilon_w$</td>
<td>6.00</td>
</tr>
<tr>
<td>wage Calvo lottery</td>
<td>$\phi_w$</td>
<td>0.75</td>
</tr>
<tr>
<td>domestic price monopolistic elas.</td>
<td>$\epsilon_p$</td>
<td>11.0</td>
</tr>
<tr>
<td>domestic price Calvo lottery</td>
<td>$\phi_p$</td>
<td>0.60</td>
</tr>
<tr>
<td>domestic price indexation</td>
<td>$\Phi_p$</td>
<td>0.25</td>
</tr>
<tr>
<td>import price monopolistic elas.</td>
<td>$\epsilon_m$</td>
<td>11.0</td>
</tr>
<tr>
<td>import price Calvo lottery</td>
<td>$\phi_m$</td>
<td>0.75</td>
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<td>import price indexation</td>
<td>$\Phi_m$</td>
<td>0.15</td>
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<tr>
<td>export price monopolistic elas.</td>
<td>$\epsilon_x$</td>
<td>11.0</td>
</tr>
<tr>
<td>export price Calvo lottery</td>
<td>$\phi_x$</td>
<td>0.75</td>
</tr>
<tr>
<td>export price indexation</td>
<td>$\Phi_x$</td>
<td>0.10</td>
</tr>
</tbody>
</table>
### Table 2: Exogenous Shocks

<table>
<thead>
<tr>
<th>ES &amp; RE intertemporal preferences</th>
<th>EA monetary policy shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES &amp; RE demand shock</td>
<td>RW real GDP</td>
</tr>
<tr>
<td>ES &amp; RE housing demand</td>
<td>RW nominal interest rate</td>
</tr>
<tr>
<td>ES &amp; RE tfp shock wholesale</td>
<td>RW oil price</td>
</tr>
<tr>
<td>ES &amp; RE tfp shock housing</td>
<td>RW price of goods</td>
</tr>
<tr>
<td>ES &amp; RE markup shock wages</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE markup shock domestic prices</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE markup shock import prices</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE markup shock export prices</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE loan-to-value ratio</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE capital investment</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE housing investment</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE wasteful spending</td>
<td></td>
</tr>
<tr>
<td>ES &amp; RE country spreads</td>
<td></td>
</tr>
</tbody>
</table>

In general, our calibration follows the recent literature on DSGE models with an housing sector and borrowing constrains (add references here). For the steady state ratios and trade weights, we have used long-run averages of Spanish national accounts data and of EA aggregate data. For the parameters in the utility and technology functions, we picked standard values found in the DSGE literature, making sure, however, that the input weights in the production functions are kept consistent with the relative size of each type of household and the distribution of housing ownership. Likewise, in choosing the trade weights, we made sure that they are consistent with the steady state ratios of net-foreign assets over GDP in Spain and in the rest of the EA. Regarding the elasticities of substitution in the composite bundles of final goods, we assumed lower values for the elasticities between oil and non-oil goods, as well as between different goods in the government consumption bundle. Also, we assumed the elasticities between goods in the composite investment bundle to be higher than in the final consumption good bundle. Lastly, we followed the common practice in the literature and assumed a higher markup in wages relative to prices, no indexation in wage setting (as evidence shows that indexation become residual in Spain add references here), and Calvo parameters implying that, on average, nominal adjustments take one year.

Table 2 reports the set of exogenous shocks currently available in JOSE. These will be the shocks used in estimation. In the reminder of this section, we report impulse responses to a selected sample of shocks and discuss their main dynamic properties. Figure 1 reports the responses to a temporary, neutral technology shock in the production of wholesale goods. This shock causes the supply of goods to expand and the marginal productivity to rise. The return on production inputs increases, pushing the demand for capital investment, labour, and housing upwards. While capital and housing investment do go up, hours fall and remain below steady state throughout the entire horizon. With investment adjustment costs, habits in consumption, and nominal rigidities, households prefer to reduce labour supply in response to the positive wealth effect generated by the shock, despite the increase in real wages. Delving into the credit market, the rise in productivity together with its subsequent wealth effect increase the demand for loans. With rising house prices and the increase in the housing and capital stocks, constrained households and entrepreneurs are able to raise more credit. This will act as an amplification...
Responses are in percentage deviations from steady state, except for inflation and interest rates, which are shown in annual rates.

Figure 1: TFP in goods sector in Spain

Figure 2 shows the responses to an increase in the nominal interest rate at the EA level, affecting both Spain and the RE. Due to price stickiness, the monetary policy contraction increases the real interest rates and generates a negative wealth effect affecting all households and the entrepreneur. This causes consumption to fall. The increase in real interest rates reduces the present value of collateral and, as a result, reduces the amount of credit available to constrained agents. Hence, borrowing constraints amplify the responses of the economy to a monetary policy shock as well. Together with the fall in demand, tighter borrowing constraints also affect the supply side of the economy. Note as well that, because of the weaker incentives to hold houses, real house prices and housing investment fall substantially. Figure 3 reports the impulse responses to an intertemporal preferences shock that has Spanish consumers bringing future consumption to today. This demand shock crowds out capital and housing investment and reduces net exports. Consumer prices increase and, because of Spain’s small relative size within the monetary union, the real interest rate falls almost by the same amount. Despite this, credit gradually falls, as house prices and the stock of capital and housing shrink. The behaviour of house prices is of particular interest: despite the increase in demand (as the shock affects all items in the utility function) and the fall in real interest rates, this shock causes consumers to prioritise consumption in goods and, therefore, to sell off their housing stock. Finally, GDP initially increases, coinciding the peak of the consumption boom, but then falls below its steady state level when the impact of the fall in investment becomes dominant.

Looking at the housing sector more closely, Figures 4 and 5 show the impulse responses to a positive housing demand shock and an unexpected increase in the loan-to-value ratio for constrained agents. Both shocks are expansionary and spillover to the wholesale sector. However, while an increase in the demand for housing produces a small and short-lived increase in
Figure 2: Monetary Policy shock in the EA

Responses are in percentage deviations from steady state, except for inflation and interest rates, which are shown in annual rates.

Figure 3: Discount factor shock in Spain

Responses are in percentage deviations from steady state, except for inflation and interest rates, which are shown in annual rates.
Responses are in percentage deviations from steady state, except for inflation and interest rates, which are shown in annual rates.

Responses are in percentage deviations from steady state, except for inflation and interest rates, which are shown in annual rates.
consumption, an increase in the loan-to-value ratio pushes consumption up more substantially and, therefore, brings about a bigger increase in GDP. In fact, the housing demand shock affects the wholesale sector only during this short-lived consumption increase. This movement in consumption comes entirely from entrepreneurs: they are not subject to the shock directly (they do not derive utility from housing), but because house prices increase, their borrowing constraint loosens and therefore they are able to increase consumption. On the contrary, an increase in the loan-to-value ratio allows both constrained households and entrepreneurs to increase consumption against their collateral. The rise in private demand is in turn responsible for the increase in wholesale production, capital investment and real wages. Finally, because the pledgeability of housing increases (same for capital in the case of entrepreneurs), housing demand expands, house prices rise, and housing investment increases.

4 Estimation and next steps

One of the main purposes of JOSE is to aid in the forecasting process at Banco de España, which means that the model has to be estimated, and has to be successful at explaining recent macroeconomic developments both in Spain and in the rest of the euro area. The model will provide a historical decomposition for the evolution of observed variables used in the estimation both over the sample period and for the forecast generated by the expert staff at Banco de España. The implicit structural shocks that allow the model to replicate those official projections provide a measure of the plausibility of the forecast. Risk scenarios and policy simulations around these projections will also be generated. It could also provide model-based forecasts that can serve as a starting point that informs the official projections.

TO BE COMPLETED.

<table>
<thead>
<tr>
<th>Table 3: Observable variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES &amp; EA GDP</td>
</tr>
<tr>
<td>ES &amp; EA private consumption</td>
</tr>
<tr>
<td>ES &amp; EA housing investment</td>
</tr>
<tr>
<td>ES &amp; EA priv.prod.investment</td>
</tr>
<tr>
<td>ES &amp; EA total exports</td>
</tr>
<tr>
<td>ES &amp; EA total imports</td>
</tr>
<tr>
<td>ES &amp; EA employment</td>
</tr>
<tr>
<td>ES &amp; EA total real credit</td>
</tr>
<tr>
<td>ES &amp; EA headline inflation</td>
</tr>
<tr>
<td>ES &amp; EA core inflation</td>
</tr>
<tr>
<td>ES &amp; EA nominal house prices</td>
</tr>
<tr>
<td>ES &amp; EA nominal wages</td>
</tr>
</tbody>
</table>

3 These variables are listed in Table 3