Documento de Trabajo - 2018/05

Financial and Fiscal Shocks in the Great Recession and Recovery of the Spanish Economy

J. E. Boscá
(University of Valencia and FEDEA)

R. Doménech
(BBVA Research and University of Valencia)

J. Ferri
(University of Valencia and FEDEA)

R. Méndez
(BBVA Research)

J. F. Rubio-Ramírez
(Emory University, Federal Reserve Bank of Atlanta, BBVA Research, and Fulcrum Asset Management)

fedea

Las opiniones recogidas en este documento son las de sus autores y no coinciden necesariamente con las de FEDEA.

Financial and Fiscal Shocks in the Great Recession and Recovery of the Spanish Economy

J. E. Boscá* R. Doménech† J. Ferri‡ R. Méndez § J. F. Rubio-Ramírez¶

May 2, 2020

Abstract

In this paper we develop a new DSGE model for a small open economy in a currency union, estimated with Bayesian methods, which incorporates a banking and a housing supply sector, consumers and entrepreneurs who accumulate debt, a rich structure of fiscal variables and monopolistic competition in products and labor markets. As an example of its capabilities, the model has been estimated for the Spanish economy, which is an interesting example of a booming economy before the Great Recession, and a country that particularly suffered from the negative consequences of the sovereign debt crisis and exhibited a robust recovery until 2019. Our results show the usefulness of DSGE models, conveniently designed and extended to account for the interaction of real and financial variables and other prominent characteristics of modern economies, as part of our toolkit to analyze the empirical evidence.

Keywords: collateral constraints, banks, bank capital, fiscal policy, sticky interest rates.

JEL Classification: E30, E32, E43, E51, E52, E62.

The authors thank A. Buesa, A. García and J. Redondo for research assistance, and the participants at the 2018 EEA and SAEe Annual Meetings, and attendants at seminars at the University of Valencia, IAE, UB, BGSE, UC3, Bank of Spain, MINECO and MINHAFP for comments. Online appendixes with the complete description of the model, data sources and impulse-response functions are available at the following url https://bit.ly/39QFny2. The financial support of BBVA Research, Fundación Rafael del Pino, MINECO and MINHAFP is gratefully acknowledged, as well as ECO2014-53150-R, ECO2017-84632-R and PROMETEO2016-097 projects.

*University of Valencia and FEDEA. Email: jose.e.bosca@uv.es

†BBVA Research and University of Valencia. Email: r.domenech@bbva.com

‡University of Valencia and FEDEA. Email: francisco.ferri@uv.es

§BBVA Research. Email: rodolfo.mendez@bbva.com

¶Emory University, Federal Reserve Bank of Atlanta, BBVA Research, and Fulcrum Asset Management. Email: juan.rubio-ramirez@emory.edu

1 Introduction

During the Great Recession there was a very intense debate about the effects of monetary, financial and fiscal shocks on economic activity, particularly in peripheral European countries. Although some of these questions may be partially addressed with previous macroeconomic models for the Spanish economy, none of them is able to simultaneously analyze the quantitative relevance of these factors and their contributions to the fall and recovery of output and employment.

In this paper we propose a DSGE model for the Spanish economy that estimates the contribution of different structural shocks to economic activity. We extend Gerali et al.'s (2010) model with financial frictions and an imperfectly competitive banking sector to a small open economy with a public sector and a rich detail of fiscal variables. In addition, monetary policy is being driven by a Taylor rule and, as explained below, we consider the effects of non-conventional measures through the inclusion of a shadow interest rate that measures the stance of monetary policy when the lower bound is not binding, as an observable in the estimated model. Additionally, given the importance of the housing bubble and its subsequent collapse after 2009, we also incorporate a housing supply sector.[1]

Hence, on top of having a financial sector in which banks operate in monopolistically competitive markets, managing their capital position while counting on the monetary authority to fully allot their funding requirements at the current policy rate, our model incorporates different nominal, real and financial frictions, and wages and price rigidities in non-competitive labor and product markets, whereas fiscal variables include different taxes on consumption, labor and capital incomes, and expenditures on public consumption and investment. External debt affects the cost of borrowing by increasing the sovereign risk premium that we model by a reduced-form relationship. Additionally, we consider an endogenous housing supply. In order to estimate the contribution of structural shocks to economic activity, we estimate the parameters and the shocks that explain the dynamics of the main macroeconomic aggregates of the Spanish economy from 1992 to 2019.

Although we can use different approaches to understand the economic complexity of the real world (see, for example, Reis (2018) or Blanchard (2018)), macroeconomic models should propose a good approximation of the empirical evidence they seek to analyze. To this end, we enrich our DSGE model in several directions that are crucial at the empirical level, as shown by our results. Compared to our model, previous DSGE models estimated for the Spanish economy do not include a banking sector and, additionally, do not consider fiscal

[1] Considering that the housing boom in Spain before 2008 involved not only housing prices but also construction (see Aspachs-Bracons and Rabanal, 2010), this may be an important feature of the model when analyzing the contribution of the different shocks to economic activity, as also shown by, for example, Pataracchia et al. (2013), Pintér (2019) or Ge et al. (2019). We thank a referee for making this point.

variables (for example, Aspachs-Bracons and Rabanal (2010)), real investment (Burriel et al. (2010)), residential investment (Andrés et al. (2010)), distortionary taxes, public investment and wage rigidities (Gómez-González and Rees (2018)) or price rigidities and monopolistic competition in product markets (in't Veld et al. (2015)).

An additional contribution to the previous literature is that we take into account non-conventional monetary policies implemented by the ECB. From the beginning of the financial crisis, monetary policy by the ECB has been crucial for reducing financial tensions, particularly since 2012. Measures implemented have been quite diverse, as shown by Rostagno et al. (2019). First, the ECB has provided liquidity through instruments such as LTRO, VLTRO and TLTROs, satisfying all requested demand (full allotment). Second, the ECB activated the programs of selective purchases of public debt (SMP) of 2010 and private (CBPP) of 2009, expanded in the following years. Third, in August 2012 the ECB announced its willingness to buy sovereign debt in secondary debt markets (OMT) of countries under financial assistance. This announcement completely changed the divergent trends of interest rates that increased risk premia among eurozone members and reduced significantly the existing differentials. Fourth, through the Asset Purchase Program (APP) of January 2015 the ECB extended previous programs to include the purchase of public debt in secondary markets (public sector purchase program, or PSPP). With this measure the ECB finally embarked on a quantitative expansion (QE) program with the purchase of public debt, as other central banks had previously done. In addition to keeping the risk premia contained, its purpose has been primarily to stabilize inflation expectations in the medium and long term, bringing them closer to the objective of the ECB. Finally, in 2014 the ECB pushed its deposit facility rate into negative territory and subsequent cuts brought the negative interest rate to -0.5 percent in September 2019.

Since we model monetary policy using a standard Taylor rule, if we use a standard measure of interest rates such as EONIA, our estimation would not be able to capture all non-conventional measures previously described, except the effects on the sovereign debt risk premium. For example, the estimation would capture the Spanish sovereign debt crisis in 2011 and 2012 and the effects of OMTs because both affected the risk premium of Spain. But, in general, it is not possible to exactly know how the measures listed above affect these two observables. For this reason we estimate the model using a shadow interest rate that takes into account non-conventional monetary policies, instead of the EONIA rate. We also present results using the EONIA rate as a robustness exercise.[2]

The estimation of the model allows us to decompose output growth per working-age population (WAP) and other variables in terms of the shocks that have driven the cycle, improving our understanding of the factors

[2]We thank the referee for making this point.

behind the financial crisis and the recovery. Our results show that shocks to housing demand contributed significantly to explaining both the expansion that preceded the Great Recession and the sovereign debt crisis. Exports also contributed to output growth during the Great Recession, while imports were countercyclical. Hence, it seems clear that GDP growth observed during pre-crisis times was due to the combination of internal and external demand shocks fueled by relatively favorable credit conditions to finance the housing bubble. It is also important to notice that supply shocks contributed negatively to pre-crisis growth, contributing to the large imbalance of the current account. This aligns very well with the fact that previous research reported that labor productivity was falling during that time.

During the first recession that followed 2008, we identify negative and export shocks, partly offset by expansionary fiscal policies, while import shocks also helped to make the recession less dramatic. Nevertheless, the expansionary fiscal policy increased current activity but at the cost of lower future growth. Additionally, negative supply shocks made the recession worse. The second recession during the sovereign debt crisis implied higher financial tensions (both risk premium and conventional monetary policy shocks contributed negatively to growth) and a significant fiscal adjustment due to the unsustainability of public finances. The large fall in housing demand contributed to worsening the crisis. The latter recovery after 2013 shows an intense improvement of activity given the positive contribution of supply shocks, despite some less favorable external trade conditions.

The structure of this paper is as follows. In the second section we present the details of the small open economy DSGE model with financial frictions, a banking sector, staggered prices and wage setting. In the third section, we discuss the model estimation. Then, in the fourth section we present the decomposition of output growth into the contribution of the main shocks. The fifth section performs some robustness analysis. Finally, the last section presents the main conclusions of the paper.

2 Model Description

The model represents a small open economy (Spain) that belongs to a trade and monetary union (EMU) along with a supra-national central bank (ECB) controlling the reference interest rate according to a Taylor rule linked to the aggregate inflation and output growth of the whole union, both taken as exogenous to the model (that is, the effect of the home economy on the rest of the union is negligible, as in Monacelli, 2004; Galí and Monacelli, 2005). In this section we describe the main features of the model, leaving the details to Appendix A.

The home economy is populated by four types of consumers (patient households, impatient households, hand-to-mouth households and entrepreneurs), a centralized government, four types of non-financial firms (intermediate good producers, capital producers, housing producers, and retailers), banks organized as holdings with lending and deposit branches, labor unions (one for each type of household) and, as a convenient way to incorporate monopolistic competition, "packagers" with monopolistic power who play an intermediary role in the goods, labor and banking services markets.

Patient households get utility from the consumption goods and housing services they buy with the wage income received in exchange for the differentiated labor supplied to labor unions and past deposit yields, and these households can even afford to save part of this income in additional bank deposits. Impatient households behave similarly except that they cannot afford to save and even need to take out bank loans to finance their purchases. Hand-to-mouth households get utility only from the consumption goods they can afford to buy spending all their wage income, because they do not have access to credit and they don't have enough income (and/or patience) to save.

Labor unions buy differentiated labor from households in competitive markets and re-sell it to monopolistic labor packagers that, in turn, re-sell it (after bundling it into a single homogeneous type of labor for each type of household) to intermediate good producers in competitive markets. Intermediate good producers combine the three types of labor bought with the capital rented from entrepreneurs and public capital (freely available) to produce differentiated intermediate goods that are sold to retailers. Retailers re-label (at no cost) and re-sell these differentiated intermediate goods to monopolistic packagers that (after bundling them into a single homogeneous type of final good) re-sell them to consumers for direct consumption, and to capital producers, who transform them in to capital goods to be sold to entrepreneurs under competitive conditions.

Each bank holding comprises a wholesale branch, a deposit branch and a lending branch. The wholesale branch accumulates capital and makes loans to the lending branch from the resources accumulated in the past as capital and loans taken from the deposit branch and the rest of the world. The deposit branch gets its resources (which it lends to the wholesale branch) from households through the intermediation of monopolistic deposit packagers. Specifically, the deposit branch sells differentiated "deposits" (saving products) to packagers that bundle them into a single homogeneous type of "deposit," which is sold to patient households in a competitive market. The lending branch gets resources by taking loans from the wholesale unit under competitive conditions and lends them to households through the intermediation of monopolistic loan packagers; specifically, the lending branch sells differentiated "loans" (i.e, bonds or other financing products) to packagers that re-sell them to impatient households and entrepreneurs (after bundling them into a single homogeneous type of bond).

At the currency union level there is a monetary authority that fixes the one-period nominal interest rate using a Taylor rule and supplies full-allotment refinancing to wholesale banks. Following Schmitt-Grohe and Uribe (2003), to ensure the stationarity of equilibrium, we assume that banks pay a risk premium that increases with the country's net foreign asset position. Thus, we close the model by assuming that the foreign borrowing interest rate is equal to an exogenous interest rate multiplied by a risk premium. Finally, there is a fiscal authority that consumes, invests, borrows (selling bonds to domestic banks, domestic households and the rest of the world), sets lump-sum transfers, and taxes consumption, housing services, labor earnings, capital earnings, bond holdings, and deposits. We will focus on a symmetric equilibrium. Hence, although we use an index j in the description of the model to index households, firms, banks, etc..., the index will be dropped in the equilibrium description (see Appendix A for details).

2.1 Patient households

There is a continuum of patient households in the economy indexed by j, with mass γ_p, whose utility depends on consumption, $c^p_{j,t}$; housing services, $h^p_{j,t}$; and hours worked, $\ell^p_{j,t}$ and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \left[(1-a_{cp})\varepsilon^z_t log(c^p_{j,t} - a_{cp}c^p_{t-1}) + a_{hp}\varepsilon^h_t log(h^p_{j,t}) - \frac{a_{\ell p} {\ell^p_{j,t}}^{1+\phi}}{1+\phi} \right],$$

where c^p_t denotes the average patient household's consumption, $c^p_t = \gamma_p^{-1} \left(\int_0^{\gamma_p} c^p_{j,t} dj \right)$, ε^z_t is a shock to the consumption preferences of all households with the law of motion:

$$\log \varepsilon^z_t = (1-\rho_z)\log \varepsilon^z_{ss} + \rho_z \log \varepsilon^z_{t-1} + \sigma_z e^z_t \quad \text{where } e^z_t \sim \mathcal{N}(0,1) \tag{i}$$

and ε^h_t is a shock to the housing preferences of all households with the law of motion:

$$\log \varepsilon^h_t = (1-\rho_h)\log \varepsilon^h_{ss} + \rho_h \log \varepsilon^h_{t-1} + \sigma_h e^h_t \quad \text{where } e^h_t \sim \mathcal{N}(0,1) \tag{ii}$$

The jth patient household is subject to the following budget constraint (expressed in terms of final goods):

$$
\begin{aligned}
&(1+\tau_t^c)c_{j,t}^p + (1+\tau_t^h)q_t^h(h_{j,t}^p - (1-\delta_h)h_{j,t-1}^p) + (1+\tau_t^{fd})d_{j,t}^p + \frac{\alpha_{RW}(1-\alpha_{B_g})Bg_t}{\gamma_p} = \\
&(1-\tau_t^w)w_{j,t}^p\ell_{j,t}^p + \left[\frac{1+(1-\tau_t^d)r_{t-1}^d}{\pi_t} + \tau_t^{fd}\right]d_{j,t-1}^p + \frac{(1-\omega_b)J_{t-1}^b}{\gamma_p} - \frac{T_t^{up}}{\gamma_p} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m} + \\
&\frac{\alpha_{RW}(1-\alpha_{B_g})(1+r_t^d)Bg_{t-1}}{\gamma_p},
\end{aligned}
$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is gross inflation of the consumption good, with P_t denoting the price of the consumption good and the variables τ_t^w, τ_t^c, τ_t^h, τ_t^d and τ_t^{fd} denoting taxes on labor income, consumption, accumulation of housing services, interest income from deposits and variation of deposits respectively; q_t^h is the price of housing services in terms of the consumption good; δ_h is the depreciation rate of housing; $w_{j,t}^p$ is the real wage in terms of the consumption good; and r_{t-1}^d is the nominal interest rate on deposits.

The flow of expenses, expressed in terms of the consumption good, is consumption (plus consumption taxes), $(1+\tau_t^c)c_{j,t}^p$; investment in housing services (plus taxes on housing services), $(1+\tau_t^h)q_t^h(h_{j,t}^p - (1-\delta_h)h_{j,t-1}^p)$; current deposits (plus deposit taxes), $(1+\tau_t^d)d_{j,t}^p$, and government bonds $\frac{\alpha_{RW}(1-\alpha_{B_g})Bg_t}{\gamma_p}$. The sources of income, also expressed in terms of the consumption good, are after-tax labor income, $(1-\tau_t^w)w_{j,t}^p\ell_{j,t}^p$; after-tax deposits gross return from the previous period, $\left[\frac{1+(1-\tau_t^d)r_{t-1}^d}{\pi_t} + \tau_t^d\right]d_{j,t-1}^p$; dividends from the banking sector, $\frac{(1-\omega_b)J_{t-1}^b}{\gamma_p}$ (where ω_b is the share of benefits that the banking sector does not distribute as dividends), the cost of participating in the labor union paid to the unions, $\frac{T_t^{up}}{\gamma_p}$; lump-sum taxes paid to the government, $\frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m}$, and payments on government bonds $\frac{\alpha_{RW}(1-\alpha_{B_g})(1+r_t^d)Bg_{t-1}}{\gamma_p}$, where γ_i, γ_e, and γ_m represent the mass of the rest of the consumers in the model (impatient, hand-to-mouth and entrepreneurs), α_{RW} is the share of public debt in the hands of resident agents (that is, "domestic" public debt) from which a share α_{B_g} is in the hands of banks and $(1-\alpha_{B_g})$ in the hands of patient households.[3]

2.2 Impatient households

There is a continuum of impatient households in the economy indexed by j, with mass γ_i, whose utility depends on consumption $c_{j,t}^i$, housing services $h_{j,t}^i$ and hours worked $\ell_{j,t}^i$, and has the following form:

$$
E_0\sum_{t=0}^{+\infty}\beta_i^t\left[(1-a_{ci})\varepsilon_t^z log(c_{j,t}^i - a_{ci}c_{t-1}^i) + a_{hi}\varepsilon_t^h log(h_{j,t}^i) - \frac{a_{\ell i}\ell_{j,t}^{i\,1+\phi}}{1+\phi}\right]
$$

[3]Households have access to Arrow-Debreu securities. We do not write the whole set of possible Arrow-Debreu securities in the budget constraint to save on notation. Since their net supply is zero, they are not traded in equilibrium. However, households could trade and price any of these securities. This will be true for all types of households we consider in this paper.

where c_t^i denotes the average patient household's consumption, $c_t^i = \gamma_i^{-1}\left(\int_0^{\gamma_i} c_{j,t}^i dj\right)$ and ε_t^z and ε_t^h are defined as in the patient household's problem above. The jth impatient household's budget constraint, expressed in terms of final goods, is given by:

$$\begin{aligned}&(1+\tau_t^c)c_{j,t}^i + (1+\tau_t^h)q_t^h(h_{j,t}^i - (1-\delta_h)h_{j,t-1}^i) + \left(\frac{1+r_{t-1}^{bi}}{\pi_t} - \tau_t^{fb}\right)b_{j,t-1}^i = \\ &(1-\tau_t^w)w_{j,t}^i\ell_{j,t}^i + (1-\tau_t^{fb})b_{j,t}^i - \frac{T_t^{ui}}{\gamma_i} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m},\end{aligned}$$

where τ_t^{fb} denotes taxes on the variation of loans, $w_{j,t}^i$ is the real wage in terms of the consumption good, and r_{t-1}^{bi} is the nominal interest rate on loans.

This budget constraint reflects the fact that impatient households do not receive any dividend. Having said that, their expenses and incomes are similar to the ones described for patient households. The main difference is $b_{j,t}^i$, which represents bank loans. In addition, impatient households face a borrowing constraint. In terms of final goods, they cannot borrow more than a certain proportion of the expected value in period t of the value in period $t+1$ of their housing stock at period t discounted by $(1+r_t^{bi})$:

$$(1+r_t^{bi})b_{j,t}^i \le m_t^i E_t\left\{q_{t+1}^h h_{j,t}^i \pi_{t+1}\right\},$$

where m_t^i is the stochastic loan-to-value ratio for all impatient households' mortgages with the law of motion:

$$\log\, m_t^i = (1-\rho_{mi})\log\, m_{ss}^i + \rho_{mi}\log m_{t-1}^i + \sigma_{mi}e_t^{mi} \quad \text{where } e_t^{mi} \sim \mathcal{N}(0,1) \tag{iii}$$

We assume that the shocks in the model are small enough so that we can solve the model by imposing the condition that the borrowing constraint always binds, as in Iacoviello (2005).

2.3 Hand-to-mouth households

There is a continuum of hand-to-mouth households in the economy indexed by j, with mass γ_m, whose utility function depends on consumption $c_{j,t}^m$ and hours worked $\ell_{j,t}^i$, and has the following form:

$$E_0\sum_{t=0}^{+\infty}\beta_m^t\left[(1-a_{cm})\varepsilon_t^z log(c_{j,t}^m - a_{cm}c_{t-1}^m) - \frac{a_{\ell m}{\ell_{j,t}^m}^{1+\phi}}{1+\phi}\right].$$

where c_t^m denotes the average hand-to-mouth household's consumption, $c_t^m = \gamma_m^{-1}\left(\int_0^{\gamma_m} c_{j,t}^m dj\right)$ and ε_t^z and ε_t^h are defined as in the patient household's problem above. The jth hand-to-mouth household's budget constraint is given by:

$$(1+\tau_t^c)c_{j,t}^m = (1-\tau_t^w)w_{j,t}^m\ell_{j,t}^m - \frac{T_t^{um}}{\gamma_m} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m}$$

where $w_{j,t}^m$ is the real wage in terms of the consumption good.

This budget constraint reflects the fact that hand-to-mouth households do not receive any dividend. Having said that, the only expense of hand-to-mouth households is after-tax consumption. The sources of income are labor income, net of the cost of participating in the labor union paid to the unions, and the lump-sum taxes paid to the government. Hand-to-mouth households do not have bank deposits or bank loans.

2.4 Labor unions and labor packers

There are three types of labor unions and three types of "labor packers," one for each type of household. Given the similarity of the problem of choosing wages and labor supply for the three types of households, we present a general derivation of the problem using the super-index s to denote patient households, $s = p$; impatient households, $s = i$; and hand-to-mouth households, $s = m$.

There is a continuum of labor unions of each type in the economy indexed by j. Each household (j, s) delegates its labor decision to labor unions (j, s). The labor union (j, s) sells labor in a monopolistically competitive market to the "labor packer" of type s. The labor packer of type s sells bundled labor in a competitive market to intermediate good producers. The labor packer of type s uses the following production function to bundle labor:

$$\ell_t^s = \left(\int_0^{\gamma_s} \left(\ell_{j,t}^s\right)^{\frac{\varepsilon_t^\ell-1}{\varepsilon_t^\ell}} dj\right)^{\frac{\varepsilon_t^\ell}{\varepsilon_t^\ell-1}},$$

where ℓ_t^s is labor from households of type s and ε_t^ℓ is the elasticity of substitution among different types of labor, which is stochastic and follows the law of motion:

$$\log\,\varepsilon_t^\ell = (1-\rho_\ell)\log\,\varepsilon_{ss}^\ell + \rho_\ell\log\,\varepsilon_{t-1}^\ell + \sigma_\ell e_t^\ell \quad \text{where } e_t^\ell \sim \mathcal{N}(0,1) \tag{iv}$$

The labor packer of type s chooses $l_{j,t}^s$ for all j in order to maximize:

$$w_t^s\ell_t^s - \int_0^{\gamma_s} w_{j,t}^s\ell_{j,t}^s dj.$$

subject to the production function and taking all wages as given. Both $w_{j,t}^s$ and w_t^s refer to real wages in terms of the consumption good. The standard input demand function associated with this problem is:

$$\ell_{j,t}^{s} = \left(\frac{w_{j,t}^{s}}{w_{t}^{s}}\right)^{-\varepsilon_{t}^{\ell}} \ell_{t}^{s}.$$

The standard aggregate real wage is $w_t^s = \left(\int_0^{\gamma_s} w_{j,t}^{s\,1-\varepsilon_t^\ell} dj\right)^{\frac{1}{1-\varepsilon_t^\ell}}$. The labor union of type (s,j) sets the nominal wage, $W_{j,t}^s$, by maximizing the following objective function, which represents the utility of the household supplying the labor from the resulting wage income net of a quadratic cost for adjusting the nominal wage:

$$E_0 \sum_{t=0}^{+\infty} \beta_s^t \left\{ U_{c,j,t}^s \theta_t^{wc} \left[w_{j,t}^s \ell_{j,t}^s - \frac{\eta_w}{2} \left(\pi_{j,t}^{ws} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right)^2 w_t^s \right] - \frac{a_{\ell s} \ell_{j,t}^{s\,1+\phi}}{1+\phi} \right\}$$

subject to:

$$\ell_{j,t}^{s} = \left(\frac{w_{j,t}^{s}}{w_{t}^{s}}\right)^{-\varepsilon_{t}^{\ell}} \ell_{t}^{s},\ w_{j,t}^s = \frac{W_{j,t}^s}{P_t},\ \text{and}\ \pi_{j,t}^{ws} = \left(\frac{w_{j,t}^s}{w_{j,t-1}^s}\right)\pi_t,$$

where $\theta_t^{wc} \equiv \left(\frac{1-\tau_t^w}{1+\tau_t^c}\right)$ and $U_{c,j,t}^s$ represents the instantaneous marginal utility of the household taken as given by unions. Finally, the cost of participating in the labor union is equal to the quadratic cost of changing the wage:

$$T_t^{us} = \gamma_s \frac{\eta_w}{2} \left(\pi_t^{ws} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right)^2 w_t^s$$

for all types of households.

2.5 Entrepreneurs

There is a continuum of entrepreneurs in the economy indexed by j, with mass γ_e, whose utility function depends on consumption $c_{j,t}^e$, and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_e^t (1-a_{ce}) \varepsilon_t^z log(c_{j,t}^e - a_{ce} c_{t-1}^e).$$

where c_t^e denotes the average entrepreneur's consumption, $c_t^e = \gamma_e^{-1}\left(\int_0^{\gamma_e} c_{j,t}^e dj\right)$. The jth entrepreneur's budget constraint is given by:

$$(1+\tau_t^c)c_{j,t}^e + \left(\frac{1+r_{t-1}^{be}}{\pi_t} - \tau_t^{fb}\right) b_{j,t-1}^e + q_t^k k_{j,t}^e =$$
$$(1-\tau_t^k) r_t^k k_{j,t}^e + q_t^k (1-\delta) k_{j,t-1}^e + (1-\tau_t^{fb}) b_{j,t}^e + \frac{J_t^R}{\gamma_e} + \frac{J_t^x}{\gamma_e} + \frac{J_t^k}{\gamma_e} + \frac{J_t^h}{\gamma_e} - \frac{T_t^g}{\gamma_p + \gamma_i + \gamma_e + \gamma_m}.$$

where τ_t^k denotes taxes on returns on capital, q_t^k is the price of the capital good in terms of the consumption good, r_t^k is the return on capital in terms of the consumption good, and r_{t-1}^{be} is the nominal interest rate on loans.

Entrepreneurs buy the capital good from the capital good producers and rent it to the intermediate good producers. They also own the intermediate good producers' firms, the capital good producers' firms and the housing producers' firms and have bank loans. The flow of expenses of entrepreneurs is given by consumption (plus consumption taxes) $(1+\tau_t^c)c_{j,t}^e$, capital purchases $q_t^k k_{j,t}^e$, and interest plus principal of loans taken out during the previous period $\left(\frac{1+r_{t-1}^{be}}{\pi_t} - \tau_t^{fb}\right) b_{j,t-1}^e$. The sources of income are determined by rental capital (minus capital taxes), $(1-\tau_t^k)r_t^k k_{j,t}^e$; loans (minus taxes on lending transactions), $(1-\tau_t^{fb})b_{j,t}^e$; capital from the previous period $q_t^k(1-\delta)k_{j,t-1}^e$; dividends from the retail firms, $\frac{J_t^R}{\gamma_e}$; dividends from intermediate good producers $\frac{J_t^x}{\gamma_e}$; dividends from capital good producers, $\frac{J_t^k}{\gamma_e}$, and dividends from housing producers, $\frac{J_t^h}{\gamma_e}$, net of lump-sum taxes paid to the government, $\frac{T_t^g}{\gamma_p+\gamma_i+\gamma_p}$.

In addition, impatient entrepreneurs face a borrowing constraint. In terms of final goods, they cannot borrow more than a certain proportion of the expected value in period t of the value in period $t+1$ of their capital stock in period $t+1$ discounted by $(1+r_t^{be})$:

$$(1+r_t^{be})b_{j,t}^e \leq m_t^e E_t \left\{ q_{t+1}^k \pi_{t+1}(1-\delta)k_{j,t}^e \right\},$$

where m_t^e is the stochastic loan-to-value ratio for capital with the law of motion:

$$\log\, m_t^e = (1-\rho_{me})\log\, m_{ss}^e + \rho_{me}\log m_{t-1}^e + \sigma_{me}e_t^{me} \quad \text{where } e_t^{me} \sim \mathcal{N}(0,1) \tag{v}$$

As in the case of impatient households, we assume that the shocks in the model are small enough so that we can solve the model by imposing the condition that the borrowing constraint always binds, as in Iacoviello (2005).

2.6 Intermediate good producers

There is a continuum of competitive intermediate good producers in the economy indexed by j, with mass γ_x. Intermediate good producers sell intermediate goods in a competitive market to retailers. The jth intermediate good producer has access to a technology represented by a production function:

$$y_{j,t}^x = A_t \left(k_{j,t-1}^{ee}\right)^{\alpha} \left[\left(\ell_{j,t}^{pp}\right)^{\mu_p} \left(\ell_{j,t}^{ii}\right)^{\mu_i} \left(\ell_{j,t}^{mm}\right)^{\mu_m} \right]^{1-\alpha} \left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g},$$

where $k^{ee}_{j,t-1}$ is the capital rented by the firm from entrepreneurs, $\ell^{pp}_{j,t}$ is the amount of "packed" patient labor input rented by the firm, $\ell^{ii}_{j,t}$ is the amount of "packed" impatient labor input rented by the firm, $\ell^{mm}_{j,t}$ is the amount of "packed" hand-to-mouth labor input rented by the firm, and K^g_{t-1} is public capital. A_t denotes an aggregate productivity shock with the law of motion:

$$\log A_t = (1-\rho_A)\log A_{ss} + \rho_A \log A_{t-1} + \sigma_A e^A_t \text{ where } e^A_t \sim \mathcal{N}(0,1) \tag{vi}$$

In addition to the cost of the inputs required for production, the intermediate good producers face a fixed cost of production, Φ_x, which guarantees that the economic profits are equal to zero in the steady state. Finally, the profits of the representative intermediate good producers are:

$$\frac{J^x_t}{\gamma_x} = \frac{y^x_t}{x_t} - w^p_t \ell^{pp}_t - w^i_t \ell^{ii}_t - w^m_t \ell^{mm}_t - r^k_t k^{ee}_{t-1} - \Phi_x.$$

2.7 Capital goods producers

There is a continuum of capital goods producers in the economy indexed by j, with mass γ_k. Capital goods producers sell new capital goods, $k_{j,t}$, in a competitive market, to entrepreneurs. The jth capital goods producer produces these new capital goods out of the non-depreciated portion of old capital goods, $(1-\delta)k_{j,t-1}$, bought from entrepreneurs at price q^k_t, and of gross investment goods, $i^z_{j,t}$, bought from investment good packers at price p^I_t. However, whereas old non-depreciated capital goods can be converted one to one to new capital, gross investment goods are subject to non-linear adjustment costs, which causes a one to less than one conversion, such that, all in all, the amount of new capital goods evolves according to the following law of motion:

$$k_{j,t} = (1-\delta)k_{j,t-1} + i_{j,t}.$$

where $i_{j,t}$ is effective investment, which is related to investment (gross of adjustment costs) through the following expression:

$$i^k_{j,t} = i_{j,t}\left[1 + \frac{\eta_i}{2}\frac{i_{j,t}}{k_{j,t-1}}\right],$$

so that $i_{j,t} \leq i^k_{j,t}$. Then, each capital good producer chooses $k_{j,t}$ and $i_{j,t}$ in order to maximize profit subject to the law of motion for capital. Because of complete markets we get $i_{j,t} = i_t$ and hence:

$$q^k_t - p^I_t\left(1 + \frac{\eta_i i_t}{k_{t-1}}\right) = 0 \text{ and } k_t = (1-\delta)k_{t-1} + i_t.$$

Finally, the profits of the representative capital good producer are:

$$\frac{J_t^k}{\gamma_k} = \left[q_t^k - p_t^I \left(1 + \frac{\eta_i}{2}\frac{i_t}{k_{t-1}}\right)\right] i_t.$$

2.8 Housing producers

Following Gómez-González and Rees (2018), production of housing is similar to productive capital production.[4] There is a continuum of housing producers with mass γ_h working in a competitive market and selling their production to patient and impatient households. Under the assumption of complete markets the evolution of housing is characterized by:

$$h_t = (1-\delta_h)h_{t-1} + i_t^{ho}\varepsilon_t^{ho}$$

where i_t^{ho} is *effective* housing investment, which is augmented by some adjustment costs to become gross of adjustment costs housing investment, i_t^{hz}:

$$i_t^{hz} = i_t^{ho}\left[1 + \frac{\eta_h}{2}\frac{i_t^{ho}}{h_{t-1}}\right]$$

where ε_t^{ho} is a housing investment productivity shock with the following dynamic behavior:

$$\log\, \varepsilon_t^{ho} = (1-\rho_{ho})\log\, \varepsilon_{ss}^{ho} + \rho_{ho}\log\, \varepsilon_{t-1}^{ho} + \sigma_{ho}e_t^{ho} \text{ where } e_t^{ho} \sim \mathcal{N}(0,1) \tag{vii}$$

Output and input housing prices are linked through the following expression:

$$q_t^h\varepsilon_t^{ho} = p_t^H\left(1 + \frac{\eta_h i_t^{ho}}{h_{t-1}}\right)$$

where p_t^H is the price of domestic-produced output in terms of consumption goods. Contrary to capital investment goods, housing is a non-tradable good. This price can differ from the price paid by households, q_t^h, not only due to adjustment costs, but also to the action of the housing specific productivity shock. Finally, the profits of the representative housing producer are:

$$\frac{J_t^h}{\gamma_h} = \left[q_t^h\varepsilon_t^{ho} - p_t^H\left(1 + \frac{\eta_h}{2}\frac{i_t^{ho}}{h_{t-1}}\right)\right] i_t^{ho}.$$

[4] The model and empirical results may change if the housing sector was modeled using a different technology than that of capital goods as, for example, in Iacoviello and Neri (2010). As these authors show, the slow technological progress in the housing sector relative to the rest of the economy explains the upward trend in real housing prices in the US economy.

2.9 Retailers

There is a continuum of retailers indexed by j, with mass γ. Each retailer buys the intermediate good from intermediate goods producers, differentiates it and sells the resulting varieties of intermediate goods, in a monopolistically competitive market, to goods packers, who, in turn, bundle the varieties together into a domestic good and sell it, in a competitive market, to consumption and investment goods packers that bundle home and imported production. We assume that retail prices are indexed by a combination of past and steady-state inflation of retail prices with relative weights parameterized by ι_p. In addition, retailers are subject to quadratic price adjustment costs, where η_p controls the size of these costs. Then, each retailer chooses the nominal price for its differentiated good, $P_{j,t}^H$ to maximize:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \lambda_{j,t}^p \left[p_t^H \frac{P_{j,t}^H y_{j,t}}{P_t^H} - \frac{y_{j,t}^{xx}}{x_t} - \frac{\eta_p}{2} \left(\frac{P_{j,t}^H}{P_{j,t-1}^H} - \left(\pi_{t-1}^H\right)^{\iota_p} \left(\pi_{ss}^H\right)^{1-\iota_p} \right)^2 y_t \right]$$

subject to:

$$y_{j,t} = y_{j,t}^{xx} \text{ and } y_{j,t} = \left(\frac{P_{j,t}^H}{P_t^H} \right)^{-\varepsilon_t^y} y_t,$$

here we have used $\lambda_{j,t}^p$ because capital goods producers are owned by patient households, $p_t^H = \frac{P_t^H}{P_t}$, $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$, and ε_t^y is the elasticity of substitution, which follows an AR(1) process with the law of motion:

$$\log \varepsilon_t^y = (1-\rho_y) \log \varepsilon_{ss}^y + \rho_y \log \varepsilon_{t-1}^y + \sigma_y e_t^y \text{ where } e_t^y \sim \mathcal{N}(0,1) \tag{viii}$$

The demand faced by retailers is derived from the optimization problem solved by goods packers. Finally, the representative retailer's profits are:

$$\frac{J_t^R}{\gamma} = y_t \left[1 - \frac{1}{x_t} - \frac{\eta_p}{2} \left(\pi_t^H - \left(\pi_{t-1}^H\right)^{\iota_p} \left(\pi_{ss}^H\right)^{1-\iota_p} \right)^2 \right],$$

where x_t is the inverse of the price of intermediate goods in terms of the consumption good.

2.10 Banks

There is a continuum of bank branches with mass γ_b. Each bank branch is composed of three units: a wholesale unit and two retail units. The two retail units are responsible for selling differentiated loans and differentiated deposits, in monopolistically competitive markets, to loan and deposit packers. The wholesale unit manages the capital position of the bank, receives loans from abroad, and raises wholesale domestic loans and deposits.

The loan-retailing unit also gives loans to the government in a competitive market.

2.10.1 Wholesale unit

The wholesale unit of branch j combines bank capital, $k^b_{j,t}$, wholesale deposits, $d^b_{j,t}$, and foreign borrowing, $-\frac{B^*_{j,t}}{\gamma_b}$, in order to issue wholesale domestic loans, $b^b_{j,t}$, in a competitive market and everything is expressed in terms of consumption goods. Thus, the balance sheet of the wholesale unit of branch j is:

$$b^b_{j,t} = d^b_{j,t} - \frac{B^*_{j,t}}{\gamma_b} + k^b_{j,t}.$$

The wholesale units pay a quadratic cost whenever the capital-to-assets ratio $\frac{k^b_{j,t}}{b^b_{j,t}}$ deviates from an exogenously given target, η_b. Finally, bank capital, in nominal terms, $\hat{k}^b_j$ evolves according to the following law of motion:

$$\hat{k}^b_{j,t} = \frac{(1-\delta_b)}{\varepsilon^{kb}_t}\hat{k}^b_{j,t-1} + \omega_b \hat{j}^b_{j,t-1},$$

where ε^{kb}_t is a shock to the bank's capital management and $\hat{j}^b_{j,t}$ represents the profits of the bank in nominal terms. The shock ε^{kb}_t follows the following law of motion:

$$\log\, \varepsilon^{kb}_t = (1-\rho_{kb})\log\, \varepsilon^{kb}_{ss} + \rho_{kb}\log\, \varepsilon^{kb}_{t-1} + \sigma_{kb}e^{kb}_t \text{ where } e^{kb}_t \sim \mathcal{N}(0,1) \tag{ix}$$

Given these definitions, the problem of the wholesale unit of branch j is to choose the amount of wholesale loans, $b^b_{j,t}$, and wholesale deposits, $d^b_{j,t}$, and foreign borrowing, B^*_t, in order to maximize cash flows:

$$\max_{b^b_{j,t}, d^b_{j,t}, B^*_{j,t}} r^b_t b^b_{j,t} - r_t d^b_{j,t} + r^*_t \frac{B^*_{j,t}}{\gamma_b} - \frac{\eta_b}{2}\left(\frac{k^b_{j,t}}{b^b_{j,t}} - \nu_b\right)^2 k^b_{j,t},$$

where r^b_t, r_t, and r^*_t are the gross real interest rates for wholesale lending, wholesale deposits, and foreign borrowing respectively, all of them taken as given and in terms of the consumption goods. The rate r_t is the monetary policy rate that follows from the assumption that wholesale units can obtain funds from the monetary authority at that rate. Following Schmitt-Grohe and Uribe (2003), to ensure the stationarity of equilibrium we assume that $r^*_t = \phi_t r_t$, where the risk premium ϕ_t increases with the external debt according to the expression:

$$\log \phi_t = -\widetilde{\phi}\left(\exp\left(B^*_t\right) - 1\right) + \theta^{rp}_t$$

and the shock θ_t^{rp} obeys the following law of motion:

$$\theta_t^{rp} = (1-\rho_{rp})\theta_{ss}^{rp} + \rho_{rp}\theta_{t-1}^{rp} + \sigma_{rp}\, e_t^{rp} \text{ where } e_t^{rp} \sim \mathcal{N}(0,1) \tag{x}$$

2.10.2 Deposit-retailing unit

The deposit-retailing unit of branch j combines bank capital and sells a differentiated type of deposit, $d_{j,t}^{pp}$, in a monopolistically competitive market, to deposit packers, who bundle the varieties together and sell the packed deposits, in a competitive market, to patient households, d_t^{pp}. Finally, each deposit-retailing unit uses its resources to buy $d_{j,t}^{b}$ from the wholesale banks. Thus, the balance sheet of the deposit-retailing unit of branch j is $d_{j,t}^{b} = d_{j,t}^{pp}$. The deposit-retailing unit of branch j chooses the real gross interest rate paid by its type of deposit, $r_{j,t}^{d}$ in order to maximize:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \lambda_t^p \left[r_t d_{j,t}^{b} - r_{j,t}^{d} d_{j,t}^{pp} - \frac{\eta_d}{2}\left(\frac{r_{j,t}^{d}}{r_{j,t-1}^{d}} - 1\right)^2 r_t^d d_t^{pp} \right]$$

subject to:

$$d_{j,t}^{b} = d_{j,t}^{pp} \text{ and } d_{j,t}^{pp} = \left(\frac{r_{j,t}^{d}}{r_t^d}\right)^{-\varepsilon_t^d} d_t^{pp},$$

where we have used $\lambda_{j,t}^{p}$ because capital goods producers are owned by patient households, and ε_t^d is the elasticity of substitution between types of deposits. In practice, we re-parameterize this elasticity as $\varepsilon_t^d \equiv \left(\frac{\theta_t^d}{\theta_t^d - 1}\right)$ with θ_t^d, obeying the following law of motion:

$$\log\, \theta_t^d = (1-\rho_d)\log\, \theta_{ss}^d + \rho_d \log\, \theta_{t-1}^d + \sigma_d e_t^d \text{ where } e_t^d \sim \mathcal{N}(0,1) \tag{xi}$$

The demand faced by deposit-retailing units is derived from the optimization problem solved by deposit packers, left implicit.

2.10.3 Loan-retailing unit

The loan-retailing unit of branch j borrows from the wholesale unit, $b_{j,t}^{b}$, creates differentiated loans and sells the resulting loan, in a monopolistically competitive market, to loan packers, who sell the packed loans to impatient households, $b_{j,t}^{ii}$ and entrepreneurs, $b_{j,t}^{ee}$. Each loan-retailing unit also lends to the government, B_t^g, in a competitive market at a rate $\theta_{ss}^g r_t^b$, i.e., charging a mark-up over the cost of the funds, but taking both the mark-up and the cost of the funds as given. Thus, the balancesheet of the loan-retailing unit of branch j is:

$$b_{j,t}^{ii} + b_{j,t}^{ee} + \frac{\alpha_{B_g} \alpha_{RW} B_t^g}{\gamma_b} = b_{j,t}^b.$$

The loan-retailing unit of branch j chooses the real gross interest rates for its loans to impatient households, $r_{j,t}^{bi}$, and entrepreneurs, $r_{j,t}^{be}$, in order to maximize profits subject to:

$$b_{j,t}^{ii} + b_{j,t}^{ee} + \frac{\alpha_{B_g} \alpha_{RW} B_t^g}{\gamma_b} = b_{j,t}^b,\ b_{j,t}^{ii} = \left(\frac{r_{j,t}^{bi}}{r_t^{bi}} \right)^{-\varepsilon_t^{bi}} b_t^{ii}, \text{ and } b_{j,t}^{ee} = \left(\frac{r_{j,t}^{be}}{r_t^{be}} \right)^{-\varepsilon_t^{be}} b_t^{ee},$$

where we have used $\lambda_{j,t}^p$ because capital goods producers are owned by patient households, ε_t^{bi} and ε_t^{be} are the elasticities of substitution between types of loans for impatient households and for entrepreneurs, respectively. In practice, we re-parameterize these elasticities as $\varepsilon_t^{bs} \equiv \left(\frac{\theta_t^{bs}}{\theta_t^{bs}-1} \right)$ for $s = i, e$ with θ_t^{bs}, obeying the following law of motion:

$$\log\, \theta_t^{bs} = (1 - \rho_{bs}) \log\, \theta_{ss}^{bs} + \rho_{bs} \log\, \theta_{t-1}^{bs} + \sigma_{bs} e_t^{bs} \text{ where } e_t^{bs} \sim \mathcal{N}(0, 1) \qquad \text{(xii - xiii)}$$

The demand faced by the loan-retailing unit is derived from the optimization problem solved by loan packers, left implicit.

2.10.4 Banks' profits

The profit of the representative bank branch in terms of consumption good units is given by:

$$\begin{aligned} j_t^b = {} & r_t^{bi} b_t^{ii} + r_t^{be} b_t^{ee} + \theta_{ss}^g r_t^b \left(\alpha_{RW} \frac{B_t^g}{\gamma_b} \right) - r_t^d d_t^{pp} + r_t^* \frac{B_t^*}{\gamma_b} - \frac{\eta_b}{2} \left(\frac{k_t^b}{b_t^b} - \nu_b \right)^2 k_t^b \\ & - \frac{\eta_d}{2} \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right)^2 r_t^d d_t - \frac{\eta_{bi}}{2} \left(\frac{r_t^{bi}}{r_{t-1}^{bi}} - 1 \right)^2 r_t^{bi} b_t^{ii} - \frac{\eta_{be}}{2} \left(\frac{r_t^{be}}{r_{t-1}^{be}} - 1 \right)^2 r_t^{be} b_t^{ee}. \end{aligned}$$

2.11 External sector

We consider a world of two asymmetric countries in which the home country is small relative to the other (the rest of the world), whose equilibrium is taken as exogenous (see Monacelli, 2004; Galí and Monacelli, 2005).

2.11.1 Imports

There is a continuum of consumption good packers in the economy indexed by j with mass γ_c that buy domestic goods from good packers, $c_{j,t}^h$, and import foreign goods, $c_{j,t}^f$, pack them and sell the bundle, in a competitive market, to households and entrepreneurs for consumption. The packing technology is expressed by the following CES composite baskets of home- and foreign-produced goods:

$$c_{j,t}^{c}=\left(\left(1-\omega^{c}\varepsilon_t^{\omega d}\right)^{\frac{1}{\sigma_c}}\left(c_{j,t}^{h}\right)^{\frac{\sigma_c-1}{\sigma_c}}+\left(\omega^{c}\varepsilon_t^{\omega d}\right)^{\frac{1}{\sigma_c}}\left(c_{j,t}^{f}\right)^{\frac{\sigma_c-1}{\sigma_c}}\right)^{\frac{\sigma_c}{\sigma_c-1}}.$$

There is also a continuum of investment good packers in the economy indexed by j with mass γ_z that buy domestic goods from good packers, $i_{j,t}^{h}$, and import foreign goods, $i_{j,t}^{f}$, pack them and sell the bundle, in a competitive market, to capital producers. The technology is given by:

$$i_{j,t}^{z}=\left(\left(1-\omega^{i}\varepsilon_t^{\omega d}\right)^{\frac{1}{\sigma_i}}\left(i_{j,t}^{h}\right)^{\frac{\sigma_i-1}{\sigma_i}}+\left(\omega^{i}\varepsilon_t^{\omega d}\right)^{\frac{1}{\sigma_i}}\left(i_{j,t}^{f}\right)^{\frac{\sigma_i-1}{\sigma_i}}\right)^{\frac{\sigma_i}{\sigma_i-1}},$$

where σ_c and σ_i are the consumption and investment elasticities of substitution between domestic and foreign goods and ω^c and ω^i are inversely related to the degree of home bias and, therefore, directly related to openness. These parameters are assumed to be affected by the same shock, $\varepsilon_t^{\omega d}$, which evolves over time according to the following expressions:

$$\log\,\varepsilon_t^{\omega d}=(1-\rho_{\omega d})\log\,\varepsilon_{ss}^{\omega d}+\rho_{\omega d}\log\,\varepsilon_{t-1}^{\omega d}+\sigma_{\omega d}e_t^{\omega d}\ \text{where}\ e_t^{\omega d}\sim\mathcal{N}(0,1) \tag{xiv}$$

Each period, the consumption goods packer j chooses $c_{j,t}^{h}$ and $c_{j,t}^{f}$ to minimize production costs subject to the technological constraint. A similar problem is faced by the investment good packers.

Because profits have to be zero, we have the following relationships:

$$1=\left(\left(1-\omega^{c}\varepsilon_t^{\omega d}\right)\left(p_t^{H}\right)^{1-\sigma_c}+\left(\omega^{c}\varepsilon_t^{\omega d}\right)\left(p_t^{M}\right)^{1-\sigma_c}\right)^{\frac{1}{1-\sigma_c}}\ \text{and}\ p_t^{I}=\left(\left(1-\omega^{i}\varepsilon_t^{\omega d}\right)\left(p_t^{H}\right)^{1-\sigma_i}+\left(\omega^{i}\varepsilon_t^{\omega d}\right)\left(p_t^{M}\right)^{1-\sigma_i}\right)^{\frac{1}{1-\sigma_i}}.$$

Given the small open economy assumption, the price of imports in domestic currency is defined as $p_t^M = er_t(1+\tau_t^m)$, where er_t is the real exchange rate.[5] Hence, the price of imports will inherit any stickiness associated with er_t. We define:

$$C_t=\gamma_c c_t^c,\ C_t^h=\gamma_c c_t^h,\ I_t=\gamma_z i_t^z,\ \text{and}\ I_t^h=\gamma_z i_t^h,$$

[5] One could define $er_t=\frac{ER_tP_t^*}{P_t}$, where τ_t^m represents the import tariff, ER_t is the nominal exchange rate, and P_t^* stands for the exogenous world price index. We do not use this definition in the solution of the model. Given the law of motion of P_t, the product $ER_tP_t^*$ will adjust to match the observed er_t. In a full custom union such as the EU, the tariff rate is zero.

where C_t is aggregate consumption and I_t is aggregate investment. Aggregate imports are defined as:

$$IM_t = \gamma_c c_t^f + \gamma_z i_t^f = C_t^f + I_t^f.$$

Therefore, the following equalities hold in aggregate:

$$C_t = \gamma_c c_t^c = p_t^H \gamma_c c_t^h + p_t^M \gamma_c c_t^f = \gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m \text{ and } I_t = \gamma_z i_t^z = \frac{p_t^H}{p_t^I}\gamma_z i_t^h + \frac{p_t^M}{p_t^I}\gamma_z i_t^f = \gamma_k i_t.$$

2.11.2 Exports

Good packers are the ones that export. We assume that there is some degree of imperfect exchange rate pass through. To make this assumption operational, we consider a fraction $(1 - ptm)$ of good packers whose prices at home and abroad differ. The remaining fraction of good packers, ptm, sets a unified price across countries (i.e., the law of one price holds). Thus, the export price deflator relative to consumption goods, p_t^{EX}, is defined as:

$$p_t^{EX} = (1 - \tau_t^x) p_t^{H(1-ptm)} er_t^{ptm},$$

where τ_t^x is an export subsidy and the parameter ptm determines the degree of pass through. Hence, the price of exports will inherit any stickiness associated with p_t and er_t.

There is a continuum of foreign consumers and investors with mass γ^* whose demands for domestic goods from good packers are given by:

$$c_t^{*f} = \omega_t^f \left(\frac{p_t^{EX}}{er_t}\right)^{-\sigma_c^*} c_t^* \text{ and } i_t^{*f} = \omega_t^f \left(\frac{p_t^{EX}}{er_t}\right)^{-\sigma_c^*} i_t^*,$$

where c_t^* and i_t^* represent the (exogenous) aggregate consumption and investment demand in the rest of the world, and ω_t^f captures the impact of factors other than prices affecting Spanish exports that is assumed to obey the following law of motion:

$$\omega_t^f = (1 - \rho_{\omega f})\omega_{ss}^f + \rho_{\omega f}\omega_{t-1}^f + \sigma_{\omega f}\, e_t^{\omega f} \text{ where } e_t^{\omega f} \sim \mathcal{N}(0,1) \tag{xv}$$

Therefore, exports of the home economy $ex_t = c_t^{*f} + i_t^{*f}$ can be written as $ex_t = \omega_t^f \left(\frac{p_t^{EX}}{er_t}\right)^{-\sigma_c^*} (c_t^* + i_t^*)$. Finally, we can define aggregate exports as $EX_t = \gamma^* ex_t$.

2.11.3 Accumulation of foreign assets

The net foreign asset position B_t^* evolves according to the following expression (denominated in the home currency):

$$B_t^* = \frac{\left(1 + r_{t-1}^*\right)}{\pi_t} B_{t-1}^* + \left[p_t^{EX} \gamma^* ex_t - p_t^M \left(\gamma_c c_t^f + \gamma_z i_t^f\right)\right]$$

where a negative/positive sign for B_t^* implies a borrowing/lending position for the domestic economy with respect to the rest of the world and r_t^* stands for the interest rate paid/received for borrowing/lending abroad. Also, the trade balance TB_t is defined as:

$$TB_t = p_t^{EX} \gamma^* ex_t - p_t^M \left(\gamma_c c_t^f + \gamma_z i_t^f\right).$$

2.12 Prices in the model

Prices in the model are written relative to P_t. This means that in the data we will need to deflate all prices by the before-consumption-tax CPI. Here we establish some relationships between prices and inflation rates, where P_t^H is the (absolute) price of domestic-produced output and $p_t^H = \frac{P_t^H}{P_t}$ is the corresponding relative price. The gross inflation rate for the relative price is $\widetilde{\pi}_t^H = \frac{p_t^H}{p_{t-1}^H}$.

The inflation rate considered by the central bank in the Taylor rule is π_t' (the post-consumption-tax gross inflation rate). We obtain π_t' from π_t^H and $\widetilde{\pi}_t^H$ as:

$$\pi_t' = \frac{P_t}{P_{t-1}} \frac{1 + \tau t^c}{1 + \tau_{t-1}^c} = \frac{\frac{P_t}{P_t^H}}{\frac{P_{t-1}}{P_{t-1}^H}} \frac{P_t^H}{P_{t-1}^H} \frac{1 + \tau t^c}{1 + \tau t - 1^c} = \frac{\pi_t^H}{\widetilde{\pi}_t^H} \frac{1 + \tau t^c}{1 + \tau t - 1^c},$$

and the before-consumption-tax inflation rate as $\pi_t = \frac{\pi_t^H}{\widetilde{\pi}_t^H}$.

2.13 Monetary authority

The domestic economy belongs to a monetary union (say, the EMU), and monetary policy is managed by the central bank (say, the ECB) through the following Taylor rule that sets the nominal area-wide reference interest rate allowing for some smoothness of the interest rate's response to inflation and output:

$$(1 + r_t) = (1 + r_{ss})^{(1-\phi_r)} (1 + r_{t-1})^{\phi_r} \left(\frac{\pi_t^{emu}}{\pi_{ss}^{emu}}\right)^{\phi_\pi (1-\phi_r)} \left(\frac{y_t^{emu}}{y_{t-1}^{emu}}\right)^{\phi_y (1-\phi_r)} (1 + e_t^r),$$

where π_t^{emu} is EMU inflation as measured in terms of the consumption price deflator and $\frac{y_t^{emu}}{y_{t-1}^{emu}}$ measures the gross rate of growth of EMU output. There is also some inertia in setting the nominal interest rate, and the shock to the central bank interest rate is characterized by:

$$e_t^r \sim \mathcal{N}(0, \sigma_r) \tag{xvi}$$

The domestic economy contributes to EMU inflation and output growth according to its economic size in the Eurozone, ω_{Sp}:

$$\pi_t^{emu} = (1-\omega_{Sp})\left(\overline{\pi_t^{remu}}\right) + \omega_{Sp}\pi_t' \text{ and } \frac{y_t^{emu}}{y_{t-1}^{emu}} = (1-\omega_{Sp})\left(\overline{\left(\frac{y_t^{remu}}{y_{t-1}^{remu}}\right)}\right) + \omega_{Sp}\frac{y_t}{y_{t-1}},$$

where $\overline{\pi_t^{remu}}$ and $\overline{\left(\frac{y_t^{remu}}{y_{t-1}^{remu}}\right)}$ are average (exogenous) inflation and output growth in the rest of the Eurozone.

The real exchange rate is given by the ratio of relative prices between the domestic economy and the remaining EMU members, so real appreciation/depreciation developments are driven by the inflation differential of the domestic economy vis-à-vis the euro area:

$$\frac{er_t}{er_{t-1}} = \frac{\overline{\pi_t^{remu}}}{\pi_t}.$$

2.14 Fiscal authority

There is also a fiscal authority with a flow of expenses determined by government consumption, government investment, and interests plus the old debt borrowed during the previous period. The fiscal authority collects revenues with new debt, lump-sum taxes, and distortionary taxation on consumption, housing services, labor income, loans, and deposits. Hence, we have:

$$\begin{aligned}
&C_t^g + I_t^g + \left(\frac{1+\theta_{ss}^b r_{t-1}^b}{\pi_t}\right) B_{t-1}^g = B_t^g + T_t^g + \tau_t^c\left(\gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m\right) + \\
&\frac{\tau_t^m}{1+\tau_t^m} p_t^M IM_t - \frac{\tau_t^x}{1-\tau_t^x} p_t^{EX} EX_t + \\
&\tau_t^h q_t^h\left[\gamma_p(h_t^p - (1-\delta_h)h_{t-1}^p) + \gamma_i(h_t^i - (1-\delta_h)h_{t-1}^i)\right] + \tau_t^w\left(w_t^p\gamma_p\ell_t^p + w_t^i\gamma_i\ell_t^i + w_t^m\gamma_m\ell_t^m\right) + \tau_t^k r_t^k K_t + \\
&\tau_t^{fb}\left(\gamma_i\Delta b_t^i + \gamma_e\Delta b_t^e\right) + \tau_t^{fd}\gamma_p\Delta d_t^p + \tau_t^d\left(\frac{r_{t-1}^d}{\pi_t}\right)\gamma_p d_{t-1}^p.
\end{aligned}$$

For simplicity tax rates are assumed to be constant:

$$\tau_t^s = \tau^s \text{ for } s = c, h, w, d, fd, fb, k, m, x.$$

Government consumption and investment are considered to be random proportions of potential GDP. Given that this model does not feature growth in terms of the detrended variables, this is equivalent to saying that both public consumption and public investment move randomly along a constant:

$$C_t^g = \psi^{cg}\varepsilon_t^{cg} \text{ and } I_t^g = \psi^{ig}\varepsilon_t^{ig}$$

where ψ^{cg} and ψ^{ig} are two parameters and both ε_t^{cg} and ε_t^{ig} are shocks that move according to the following law of motion:

$$\log\,\varepsilon_t^{cg} = (1-\rho_{cg})\log\,\varepsilon_{ss}^{cg} + \rho_{cg}\log\,\varepsilon_{t-1}^{cg} + \sigma_{cg}e_t^{cg} \text{ where } e_t^{cg} \sim \mathcal{N}(0,1) \tag{xvii}$$

and

$$\log\,\varepsilon_t^{ig} = (1-\rho_{ig})\log\,\varepsilon_{ss}^{ig} + \rho_{ig}\log\,\varepsilon_{t-1}^{ig} + \sigma_{ig}e_t^{ig} \text{ where } e_t^{ig} \sim \mathcal{N}(0,1) \tag{xviii}$$

Lump-sum taxes adjust to guarantee the non-explosiveness of government debt according to the following rule:

$$T_t^g = T_{t-1}^g + \rho_{tgb1}\left(\psi_t^{bg} - \psi_{ss}^{bg}\right) + \rho_{tgb2}\left(\psi_t^{bg} - \psi_{t-1}^{bg}\right),$$

where ψ_t^{bg} represents the proportion of public debt over aggregate output, namely, $\psi_t^{bg} = \frac{B_t^g}{Y_t}$ and ψ_{ss}^{bg} refers to its steady-state target value. In turn, public debt adjusts to satisfy the budget constraint given the above levels of C_t^g, I_t^g and T_t^g. Finally, public capital evolves with investment according to the law of motion:

$$K_t^g = (1-\delta_g)K_{t-1}^g + I_t^g.$$

Aggregation and market clearing in equilibrium conditions are described in Appendix A. In any case, the aggregate resource constraint is:

$$\begin{aligned} p_t^H Y_t^1 &= C_t + p_t^I I_t + p_t^H I_t^{ho} + p_t^H C_t^g + p_t^H I_t^g + p_t^{EX} EX_t - p_t^M IM_t = \\ &= p_t^H C_{ht} + p_t^H I_{ht} + p_t^H I_t^{ho} + p_t^H C_t^g + p_t^H I_t^g + p_t^{EX} EX_t, \end{aligned}$$

where Y_t^1 is GDP.

3 Model Parameters and Estimation

There are a large number of structural parameters in the model, including those determining the dynamics of the 18 structural shocks. In practice, given the problems of estimating all parameters in the model, we implement an alternative strategy. First, we normalize to zero the mean of all structural shocks, except the exports shock, the two shocks related to the elasticities of substitution, the loan-to-value shock and the three bank mark-up and mark-down shocks. Second, we normalize to one the size of most groups of agents: γ_x, γ_k, γ, γ_b, γ_c, γ_z, and γ^*. Third, we calibrate a large set of parameters, using different sources. Finally, the rest of the parameters are estimated by means of Bayesian inference using the Metropolis-Hastings algorithm implemented in Dynare 4.5.7.

We divide our explanation of how we choose these calibrated parameters into two parts. First, we explain the sources for the values of calibrated parameters. Second, we discuss the particular values of the calibrated parameters.

3.1 Sources of calibrated parameters

There is a set of calibrated parameters that we borrow from the previous literature. In particular, the following parameter values β_p, β_i, β_e, β_m, a_{lp}, a_{li}, a_{lm}, ϕ, η_b, ε_{ss}^l, θ_{ss}^d, θ_{ss}^{be}, θ_{ss}^{bi}, and ν_b are taken from Gerali et al. (2010). The calibrated parameters controlling the measures of agents, γ_p, γ_i, γ_e, and γ_m are set as in Kaplan et al. (2014). The value of η_i is also calibrated and it is set as in Groth and Khan (2010). We follow Montero and Urtasun (2014) to calibrate ε_{ss}^y. The calibrated parameter δ_h is obtained from García et al. (2019).

There is a set of calibrated parameters that we estimate outside our model using the REMSDB, the database of the Spanish Ministry of Finance, which was created to serve as a consistent framework for REMS calibration.[6] These parameters are the tax rates and η_h, ϕ_y, ϕ_π, ρ_{tgb1}, ρ_{tgb2}, α, α_g, ω^c, ω^i, σ^c, σ^i, ptm, ω_{ss}^f, σ^{c*}, $\widetilde{\phi}$, and ω_b.

There is a final set of calibrated parameters that we choose in order to match some first-order moments of the data at the steady state of the model. Hence, the following parameters[7] μ_p, μ_i, μ_m, $a_{hp} = a_{hi}$, δ, δ_g, ψ^{cg}, ψ^{ig}, θ_{ss}^g, c^*, i^*, α_{RW}, α_{Bg}, m_{ss}^i, m_{ss}^e, and δ_b match the set of moments described in Table 1. Finally, Φ_x is chosen to make profits equal to zero in the steady state.

[6] See Boscá et al. (2007) for details.

[7] The reader should note that we set $a_{hp} = a_{hi}$.

Table 1: Steady-state first-order moments

	Data	Model
$\gamma_p c_p / C$	0.23	0.23
$\gamma_i c_i / C$	0.19	0.19
$\gamma_m c_m / C$	0.19	0.19
i/k	0.10	0.10
i^{ho}/Y^1	0.05	0.05
C^g/Y^1	0.18	0.18
I^g/K^g	0.06	0.06
TB/Y^1	0.00	0.00
c^*/i^*	2.70	2.70
Public debt held by domestic agents	0.55	0.55
Domestic public debt held by banks	0.36	0.36
J^x	0.00	0.00
r^g/r^{bi}	0.80	0.80
I^g/Y^1	0.03	0.03
B^i/Y^1	0.37	0.39
B^e/Y^1	0.45	0.43
Bank capital to assets	0.09	0.09

Note: Credit to households and firms, B^i and B^e, is defined in Appendix A in Equations (97) and (98). The consumption shares ($\gamma_p c_p/C$, $\gamma_i c_i/C$, $\gamma_m c_m/C$) are not based on real data, but on our beliefs about the distribution of per capita consumption across the different household types.

3.2 Discussion on the values of the calibrated parameters

Tables 2-8 present the values of the calibrated parameters.[8] The preference parameters are reported in Table 2. For the discount factors we assume that patient households' discount factor is higher than that of the impatient household and entrepreneurs. Our hand-to-mouth households are assumed to have the same rate as impatient consumers. The parameters related to the disutility of labor, as well as the inverse of the Frisch elasticity, are set to 1, following Gerali et al. (2010). Finally, housing utility parameters for patient and impatient households are assumed to be equal, and their value is calibrated to match the observed ratio of housing investment over GDP in our data sample. Weights are reported in Table 3. According to Kaplan et al. (2014) the share of hand-to-mouth households (both rich and poor) in Spain ranges between 0.2 and 0.6, depending on the criterion used to classify them. To set our parameters we assume that the sum of pure hand-to-mouth and impatient households (the two categories with the lowest level of consumption) is 0.55. This number is close to the 0.5 share of financially constrained households in REMS. We assume that unconstrained households represent 20 percent of the total population.

[8] As the reader will see, there is a set of parameters that we estimate outside the model. We consider this set of parameters part of the calibrated parameters. There is also a set of parameters that we choose in order to match some first-order moments of the data at the steady state of the model. We also consider this set of parameters part of the calibrated parameters.

The calibration of adjustment cost parameters is reported in Table 4. For the parameter governing the cost for banks deviating from the targeted capital-to-assets ratio, we set a value of 60. This value yielded impulse response functions in our model more consistent with the ones produced with REMS. For the investment adjustment costs of productive capital we set a value of 0.2. This low value is consistent with some empirical findings that indicate small costs associated with changing the flow of investment at the industry level (see Groth and Khan, 2010). However, we assume that the adjustment costs of residential investment are higher, so we set this parameter equal to 5.5 as in REMS.

As regards the production parameters reported in Table 5, the elasticities of private and public capital come from REMS and have quite standard values. The elasticities of the different labor types in the labor composite are set to match our priors about the relative distribution of per capita consumption across households' types. Depreciation rates are also quite standard and are chosen to match the observed ratios of investment over public and non-residential private capital. As commented previously, the depreciation rate of housing capital and the elasticities of substitution between goods and labor types come also from the previous literature (see Gerali et al., 2010; Montero and Urtasun, 2014; García et al., 2019, respectively).

Tax rates in Table 6 are equal to the averages over the last 25 years calculated using the database Taxation Trends of the European Commission. Government expenditure ratios replicate REMSDB average data. Monetary policy parameters have been borrowed from the estimations of a closed economy version of the model. We set θ_{ss}^{g} to 0.8 to take into account the difference in yields between government bonds and loans to the private sector. The fiscal policy rule and the implied parameters are akin to REMS.

Table 7 shows the calibrated parameters related to the external sector. To obtain the elasticities and weights in the import and export functions we have used the same methodology employed in the calibration of REMS (see Boscá et al., 2010). Thus, we estimate a set of equations with the updated information in REMSDB. Foreign (exogenous) rest of the world consumption and investment have been calibrated to guarantee a zero steady-state trade balance. To set the share of public debt in domestic hands we use information from the Bank of Spain Statistical Bulletin (see Bank of Spain, 2019).

The banking sector parameters are in Table 8. The bank capital depreciation rate has been calibrated from steady-state equations to match the regulatory capital-to-assets ratio, which we take from Gerali et al. (2010). In our model we assume that foreign debt is fully held by banks. Gerali et al. (2010) consider that banks retain all profits. Instead, we allow banks to distribute a 20 percent dividend, which is a conservative figure according to the observed behavior of the Spanish banking system. As the Spanish banking sector is, on average, more competitive than in the rest of the Eurozone, we slightly lower the values of mark-ups, mark-downs, and the bank capital depreciation rate with respect to their counterparts in Gerali et al. (2010). Loan-to-values for impatient households and entrepreneurs are calibrated to match the observed ratios of mortgage loans and credit to firms to GDP in the steady state. As compared to Gerali et al. (2010) the loan-to-value for firms coincides with theirs, but the one for mortgages is slightly higher in our case.

Table 2: Preference Parameters

Parameter	Description	Value
β_p	Discount factor patient	0.995
β_i	Discount factor impatient	0.980
β_e	Discount factor entrepreneurs	0.985
β_m	Discount factor HtM	0.980
a_{lp}	Disutility labor patients	1.000
a_{li}	Disutility labor impatient	1.000
a_{lm}	Disutility labor HtM	1.000
a_{hp}	Utility housing patient	0.441
a_{hi}	Utility housing impatient	0.441
ϕ	Frisch elasticity (inverse)	1.000

Table 3: Weight Parameters

Parameter	Description	Value
γ_p	Patient over total households	0.200
γ_i	Impatient over total households	0.250
γ_e	Entrepreneurs over total households	0.250
γ_m	HtM over total households	0.300
γ_x	Intermediate good producers	1.000
γ_k	Capital good producers	1.000
γ	Retailers	1.000
γ_b	Banks	1.000
γ_c	Consumption good packers	1.000
γ_z	Investment good packers	1.000
γ^*	Foreign consumers and investors	1.000

Table 4: Adjustment Cost Parameters

Parameter	Description	Value
η_b	Target bank capital	60.00
η_i	Investment	0.200
η_h	Housing	5.5

3.3 Estimation

We estimate all the parameters related to the 18 structural shocks (except the calibrated means that are not normalized to zero), plus price and wage adjustment costs and indexation parameters, the parameter

Table 5: Production Parameters

Parameter	Description	Value
α	Elasticity physical capital	0.426
α_g	Elasticity public capital	0.060
μ_p	Elasticity patient in labor composite	0.375
μ_i	Elasticity impatient in labor composite	0.375
μ_m	Elasticity HtM in labor composite	0.250
δ	Depreciation rate physical capital	0.025
δg	Depreciation rate public capital	0.016
δh	Depreciation rate housing	0.008
ε^y_{ss}	Elasticity of substitution between goods	7.000
ε^l_{ss}	Elasticity of substitution between labor types	5.000
Φ_x	Fixed costs	0.000

Table 6: Fiscal and Monetary Policy Parameters

Parameter	Description	Value
τ^c	Consumption tax	0.150
τ^h	Housing tax	0.085
τ^w	Labor income tax	0.310
τ^{fd}	Tax on bank deposits accumulation	0.000
τ^{fb}	Tax on bank loans accumulation	0.000
τ^d	Tax on interest rates on bank deposits	0.000
τ^k	Tax on capital returns	0.280
τ^m	Import tariff	0.000
τ^x	Export subsidy	0.000
θ^g_{ss}	Mark-up over loan-rate for public debt	0.800
ρ_{tgb1}	Adjustment to debt/GDP (transfer rule)	0.020
ρ_{tgb2}	Adjustment to debt growth (transfer rule)	0.100
Ψ^{cg}	Government spending over GDP	0.175
Ψ^{ig}	Government investment over GDP	0.030
ϕ_π	Inflation weight	1.982
ϕ_y	Output weight	0.346

of consumption habits (set equal for all consumers) and the three parameters that determine deposit and credit interest rates adjustment costs. Using quarterly data for the Spanish economy from 1992Q4 to 2019Q4 (see Appendix B for a description of the data and their sources), we estimate a first-order approximation around the steady state to the solution of the model, taking as observables the demeaned year-over-year first difference of the following five variables: $r^{bi}_t, r^{be}_t, r^d_t, r_t, \phi_t$; plus the demeaned growth rates approximated by the year-over-year logarithmic difference of the following thirteen variables (the first ten in per WAP terms): C_t, Y^1_t, C^g_t, I^g_t, I_t, I^{ho}_t, $L_t = (\gamma_p \ell^p_t + \gamma_i \ell^i_t + \gamma_m \ell^m_t)/(\gamma_p + \gamma_i + \gamma_m)$, IM_t, $B_t = B^i_t + B^e_t$, K^b_t, q^h_t, P^H_t and w_t. To deflate nominal variables we have used observed deflators consistent with prices in the model.

All the observables used in the estimation of the model are represented in Figure 1. We plot them as they

Table 7: External Sector Parameters

Parameter	Description	Value
ω^c	Weight foreign goods in consumption pack	0.360
σ^c	Elasticity substitution domestic/foreign cons. goods	0.857
ω^i	Weight foreign invest. goods in consumption pack	0.471
σ^i	Elasticity substitution domestic/foreign invest. goods	1.016
ptm	Degree of pass-through	0.741
ω_{ss}^f	Scale factor exports function	0.023
σ^{c*}	Price elasticity of exports	0.651
c^*	Exogenous aggregate consump. demand in RoW	7.308
i^*	Exogenous aggregate investment demand in RoW	3.654
$\widetilde{\phi}$	Risk premium response to external debt	0.001
α_{RW}	Share of public debt in domestic hands	0.55

Table 8: Banking Sector Parameters

Parameter	Description	Value
δ_b	Bank capital depreciation rate	0.047
ω_b	Share of non-distributed bank profits	0.800
ν_b	Target capital-to-assets ratio	0.090
m_{ss}^i	Impatient loan-to-value	0.700
m_{ss}^e	Entrepreneurs loan-to-value	0.250
θ_{ss}^d	Mark-down deposits	0.614
θ_{ss}^{be}	Mark-up loans entrepreneurs	1.157
θ_{ss}^{bi}	Mark-up loans impatient households	1.317
α_{Bg}	Share of domestic public debt in banks' hands	0.364

enter in the estimation. The top left panel plots the growth rates of GDP (Y^1) and private consumption (C) and government consumption (C^g) over WAP. Both private and public consumption are slightly more volatile than GDP. The top right panel plots the growth rates of public investment (I^g), housing (I^{ho}) and non-residential investment (I), also per WAP. Both private consumption and non-residential investment are more synchronized with GDP than public consumption and investment. As can be seen in the two top graphs, GDP and private consumption display the well-known double-dip behavior during the Great Recession. However, non-residential and housing investment present mainly a sustained deep fall, followed by a slow and long-lasting recovery afterwards. Public consumption and public investment were countercyclical at the beginning of the crisis, but contributed to the slowdown in the sovereign debt crisis. The middle left panel plots the rates of growth of three prices: housing (q^h), GDP deflator (P^H) and real wages (w). We can see that GDP deflator and real wage inflation rates have been like mirror images during many periods in the sample, whereas housing inflation has been procyclical but more volatile than GDP growth. The middle right panel plots bank capital (K^b, in the right axis) together with the differences over four quarters of the shadow rate

(r) and the risk premium (r^p). The shadow rate and the risk premium show a negative correlation between them (-0.49) and, therefore, the risk premium has offset part of the changes in the shadow rate. Bank capital growth has no correlation with GDP growth and a variance similar to non-residential investment. In the lower left panel of the figure we can see that the demeaned first difference of interest rates of deposit (r^d), credit to households (r^{bi}), and credit to firms (r^{be}) move together. The variance of these three interest rates has fallen significantly in the last decade compared to the nineties. Finally, in the lower right panel we can appreciate the clear procyclicality of imports (IM, with a correlation with GDP equal to 0.85) and, particularly, employment growth (L, with a correlation with GDP equal to 0.95). This graph also shows the rate of growth of total credit, its long expansion before the Great Recession and the deleveraging process after the crisis.

Regarding the shadow rate, we use the series estimated by De Rezende and Ristiniemi (2020) for the eurozone as the observable[9] for r_t. Since the beginning of the Great Recession, the ECB has adopted a wide range of policies. Some of them affected the EONIA rate, but other measures, such as asset purchases, are more clearly reflected by the shadow rate, which has been used to obtain the main results. Nevertheless, we also discuss the robustness of our results to the inclusion of the EONIA rate instead of the shadow rate. It is important to take into account that we include the Spanish risk premium (ϕ_t) as an observable. As we will see in Section 4, this will allow us to capture some of the effects of the sovereign debt crisis on GDP growth.

The priors and posteriors are shown in Tables 9 and 10. Our shock decomposition exercise is performed using a very diffuse set of priors. Columns labelled "Prior" describe the prior distribution and its mean and standard deviation (Std). All the priors for the autocorrelation and the standard deviation of the shocks have the same prior standard deviations. We do this in order to leave our posterior distribution of the shocks to match the different observables. We also assume that the consumption habit parameters of the four agents are restricted to be the same.

Columns labelled "Posterior" describe the mean of the posterior and the 90 percent highest posterior density interval (HPDI). As can be seen in the tables, the data have information about most of the estimated parameters, especially so in the case of standard deviations. In general, the estimated autocorrelation coefficients of shocks are relatively high, with the exception of shocks to bank capital and to the risk premium, which show low persistence.

[9] We take the shadow rate estimated by these authors using the first three principal components of yields as pricing factors.

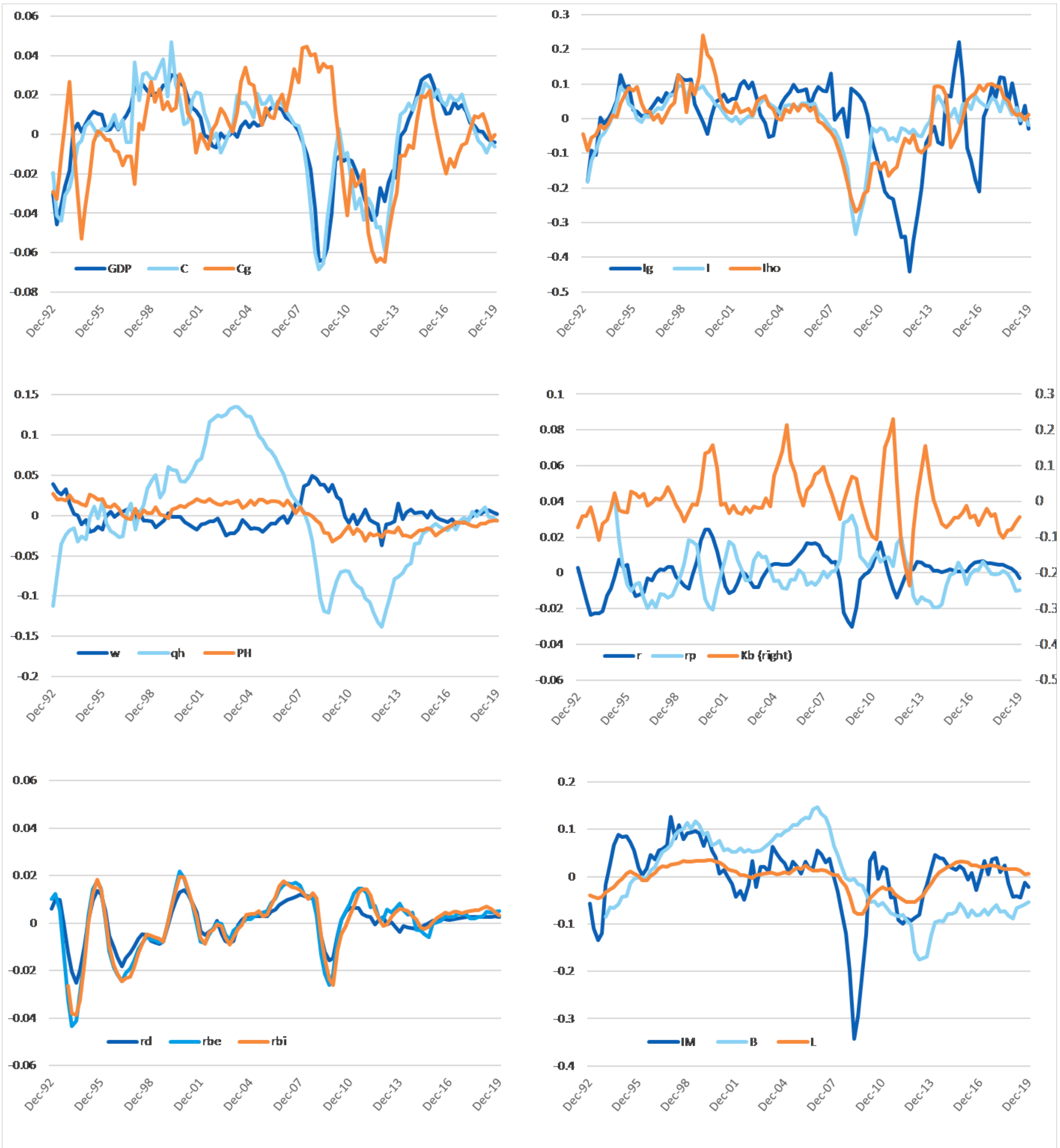

FIGURE 1: *Observables used in the estimation of the model. See the text for a more detailed description.*

Table 9: Priors and Posteriors

Parameter	Prior			Posterior	
	Distribution	Mean	Std	Mean	90 HPDI
ρ_z	*Beta*	0.50	0.20	0.826	[0.741; 0.913]
ρ_h	*Beta*	0.50	0.20	0.9994	[0.9989; 0.9998]
ρ_{mi}	*Beta*	0.50	0.20	0.991	[0.984; 0.998]
ρ_{me}	*Beta*	0.50	0.20	0.988	[0.980; 0.998]
ρ_l	*Beta*	0.50	0.20	0.973	[0.953; 0.994]
ρ_A	*Beta*	0.50	0.20	0.472	[0.350; 0.594]
ρ_{ho}	*Beta*	0.50	0.20	0.998	[0.997; 0.999]
ρ_y	*Beta*	0.50	0.20	0.991	[0.987; 0.995]
ρ_{kb}	*Beta*	0.50	0.20	0.441	[0.334; 0.547]
ρ_{rp}	*Beta*	0.50	0.20	0.360	[0.225; 0.498]
ρ_d	*Beta*	0.50	0.20	0.733	[0.668; 0.801]
ρ_{bi}	*Beta*	0.50	0.20	0.951	[0.928; 0.974]
ρ_{be}	*Beta*	0.50	0.20	0.967	[0.946; 0.990]
$\rho_{\omega d}$	*Beta*	0.50	0.20	0.946	[0.921; 0.972]
$\rho_{\omega f}$	*Beta*	0.50	0.20	0.918	[0.896; 0.940]
ρ_r	*Beta*	0.50	0.20	0.748	[0.667; 0.832]
ρ_{cg}	*Beta*	0.50	0.20	0.967	[0.946; 0.990]
ρ_{ig}	*Beta*	0.50	0.20	0.970	[0.952; 0.990]
ι_p	*Beta*	0.30	0.10	0.049	[0.017; 0.080]
ι_w	*Beta*	0.50	0.10	0.456	[0.297; 0.616]
a_{cp}=a_{ci}=a_{ce}=a_{cm}	*Beta*	0.90	0.08	0.618	[0.551; 0.686]
η_p	*Gamma*	50	8	17.73	[14.51; 20.81]
η_w	*Gamma*	20	4	20.70	[14.80; 26.61]
η_d	*Gamma*	3.50	0.50	4.446	[3.655; 5.218]
η_{be}	*Gamma*	9.36	0.50	10.21	[9.35; 11.05]
η_{bi}	*Gamma*	10	0.50	10.77	[9.92; 11.63]

Table 10: Priors and Posteriors

Parameter	Prior			Posterior	
	Distribution	Mean	Std	Mean	90 HPDI
σ_z	$Inv-Gamma$	0.05	0.15	0.033	$[0.027; 0.039]$
σ_h	$Inv-Gamma$	0.05	0.15	0.045	$[0.040; 0.050]$
σ_{mi}	$Inv-Gamma$	0.05	0.15	0.023	$[0.021; 0.026]$
σ_{me}	$Inv-Gamma$	0.05	0.15	0.014	$[0.012; 0.016]$
σ_l	$Inv-Gamma$	0.05	0.15	0.169	$[0.139; 0.199]$
σ_A	$Inv-Gamma$	0.05	0.15	0.011	$[0.019; 0.013]$
σ_{ho}	$Inv-Gamma$	0.05	0.15	0.019	$[0.017; 0.021]$
σ_y	$Inv-Gamma$	0.05	0.15	0.139	$[0.118; 0.159]$
σ_{kb}	$Inv-Gamma$	0.05	0.15	0.035	$[0.031; 0.039]$
σ_{rp}	$Inv-Gamma$	0.05	0.15	0.0063	$[0.0061; 0.0065]$
σ_d	$Inv-Gamma$	0.05	0.15	0.185	$[0.157; 0.212]$
σ_{bi}	$Inv-Gamma$	0.05	0.15	0.253	$[0.220; 0.285]$
σ_{be}	$Inv-Gamma$	0.05	0.15	0.243	$[0.213; 0.272]$
$\sigma_{\omega d}$	$Inv-Gamma$	0.05	0.15	0.021	$[0.019; 0.024]$
$\sigma_{\omega f}$	$Inv-Gamma$	0.05	0.15	0.032	$[0.028; 0.036]$
σ_r	$Inv-Gamma$	0.05	0.15	0.0062	$[0.0061; 0.0064]$
σ_{cg}	$Inv-Gamma$	0.05	0.15	0.011	$[0.009; 0.012]$
σ_{ig}	$Inv-Gamma$	0.05	0.15	0.046	$[0.041; 0.051]$

4 Results

Our model allows us to obtain the historical decomposition of all observables used in the estimation of structural shocks. For space reasons, we will present only the historical decomposition of the demeaned year-over-year logarithmic change of GDP per WAP. In Appendix C we plot the impulse response functions (IRFs) of GDP to nine shocks. We have chosen the nine shocks that contribute to 92 percent of the unconditional per capita GDP growth variance. As the reader can see, all the IRFs have the expected shape.

Since we have 18 shocks in our model, it is not practical to present the decomposition into all the shocks. For illustrative reasons we will group them into sensible sets. Table 11 shows the eight groups of shocks and how we label them.

Table 11: Group of Shocks

Name of Group	Shocks	Equation Number
Demand Shocks	Consumption + Housing Demand	i+ii
Supply Shocks	Mark-up labor + Mark-up retailers + TFP + Housing investment	iv+vi+vii+viii
Credit Shocks	Loan to value households + Loan to value entrepreneurs	iii+iv
Bank Shocks	Bank capital + Mark-up deposits + Mark-up loans (two types)	ix+xi+xii+xiii
Import Shocks	Imports	xiv
Export Shocks	Exports	xv
Financial Shocks	Risk premium + Shadow Interest Rate	x+xvi
Fiscal Shocks	Government Consumption + Government Investment	xvii+xviii

Demand shocks include shocks to both consumption and housing faced by households. Supply shocks comprise both technology shocks and the mark-up to labor and retailers' shocks. Credit shocks put together the loan-to-value shocks faced by both households and entrepreneurs. The bank shocks group the bank capital shock and both the deposits and loans mark-up shocks. Import shocks are just the elasticity of substitution shock faced by importers. Export shocks include the shock to exports faced by exporters. Financial shocks are shocks to both the interest rate and the risk premium. Finally, fiscal shocks are the shocks to both public consumption and public investment.

Figure 2.a presents the contributions of demand shocks. It is clear that demand shocks played a very important role in the period of the economic boom over and above GDP growth, particularly after 2002, contributing to the deterioration of the current account. This figure also shows that demand shocks were more important in the sovereign debt crisis than in the initial years of the financial crisis. A closer look at the results (not shown here) shows that housing shocks made a greater contribution than consumption shocks to GDP growth.

The blue bars in Figure 2.b represent the contribution to GDP growth of supply shocks. Quite the opposite

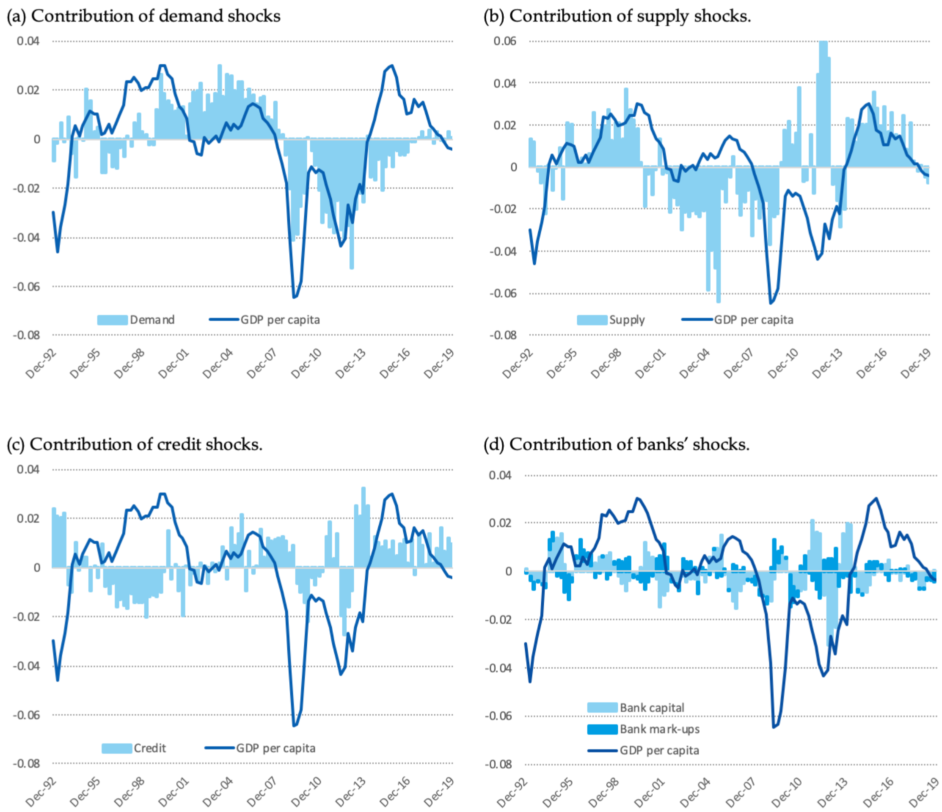

FIGURE 2: *Contribution of demand, supply, credit and banks' shocks.*

to what we observe with demand shocks, this figure reveals that supply shocks have displayed countercyclical behavior during the boom and the sovereign crisis, and procyclical bahavior during the first part of financial crisis and the recovery period until 2019, when supply shocks make a positive contribution to GDP growth. Interestingly, a detailed inspection of supply shocks (not shown here) reveals that TFP and housing investment shocks were prominent during the boom and the crisis, but real wage shocks contributed decisively to the recovery of the Spanish economy since 2013. This is consistent with the relevance of the disinflation process experienced after the crisis and the surplus of the current account. In fact, the recovery from 2013 to 2019 has been the first time in which the Spanish economy has been growing and reducing the unemployment rate, without any deterioration in the current account balance. Nevertheless, the contribution of supply shocks is diminishing at the end of the sample.

In Figures 2.c and 2.d we present the contributions of those groups of shocks that are more directly related to the presence of the banking sector in our model. Figure 2.c shows the positive contribution of credit shocks to GDP rate of growth during the financial boom years. Its contribution was negative during the Great Recession and positive during the economic recovery after 2013. This result shows that the deleveraging process of the Spanish economy during the (creditless) recovery has been driven mainly by the demand for rather than by the supply of credit.

Figure 2.d captures the contribution of banks' capital and mark-up shocks to GDP per capita growth. As we can see, bank capital was very relevant during the sovereign debt crisis. In 2012 banks provisioned non-performing loans on their balance sheets as a result of the banking restructuring process and the financial assistance program by the ESM, contributing to the deepening of the crisis by 2 percentage points. But their recapitalization (using considerable public resources in some savings banks) paved the way to the recovery, with a significant positive contribution to GDP growth in 2013. With the exception of this particular episode, in general, banks capital and mark-ups growth contributions have been acyclical and less persistent than GDP growth, and have offered a relatively neutral influence over the business cycle.

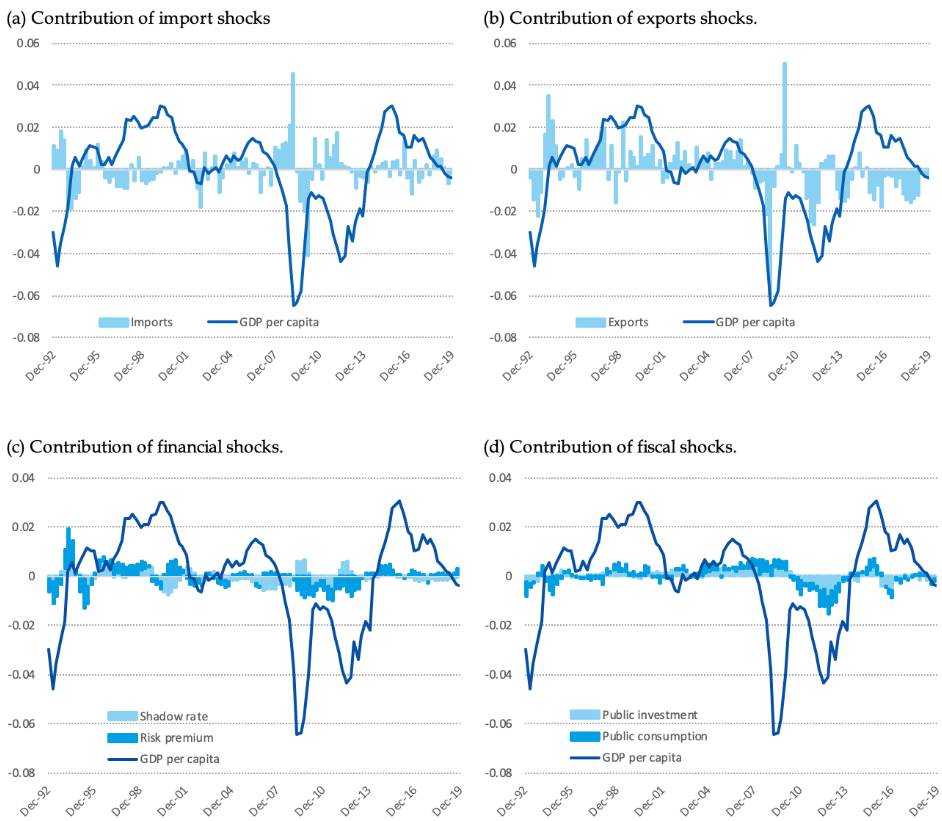

FIGURE 3: *Contribution of import, export, financial and fiscal shocks.*

In Figures 3.a and 3.b we present the contribution of the external sector shocks, that is, the contribution of import and export shocks to GDP per capita growth. To interpret results here it is important to remember that the observables used to estimate the model are demeaned rates of growth. This means that the model is not able to capture the contribution of the trade balance to growth due to different growth trends of exports and imports. Keeping this point in mind, we observe that the contribution of the import shock has been clearly countercyclical during the financial and sovereign debt recessions. Export shocks, on the other hand, contributed negatively to GDP growth in 2008 and 2009 and in the sovereign debt crisis. Compared to the years before the Great Recession, characterized by an intense globalization, external demand has made a negative contribution during the recent recovery, as a consequence of the lower growth of international trade. Again, this result is consistent with the hypothesis that the large growth of Spanish exports during the recovery has been mainly the consequence of the domestic devaluation that eventually took place.

Figure 3.c presents the results for the financial shocks. In this figure we also distinguish between the role played by risk premium shocks and shocks to the shadow rate, which have also been affected by non-conventional monetary measures. Risk premium shocks have made a relatively small contribution in most of the period, with the exception of the sovereign debt crisis, explaining almost a percentage point of the fall in GDP growth at some moments of the economic crisis. Our results also suggest that the effects of unconventional monetary policies on Spanish GDP growth during the recovery have been more important through the risk premium than the shadow rate, but close to zero. This suggests that monetary policy has not been an important obstacle but neither has it been a stimulus for the recovery.

Figure 3.d presents the results for the fiscal shocks. Discretionary fiscal policy is represented in the model by the shocks affecting variables C_t^g and I_t^g. These shocks can be interpreted as perturbations that change the difference in the rate of growth of government consumption and investment with respect to potential GDP. This is so because, in the steady state, public spending in our model is growing at the same rate as GDP. A passive fiscal policy is then one that leaves unchanged the rate of growth of government purchases with respect to GDP, letting public consumption and investment grow more than observed output in economic recessions and less in expansions. According to Figure 3.d, fiscal policy was expansionary before the crisis and at the beginning of it until the middle of 2010, offsetting the fall in per capita GDP growth by little less than one percentage point. Nonetheless, the fast escalation of the fiscal deficit compelled the government to start a fiscal adjustment that subtracted an average of almost 1.5 percentage points in 2012. Starting at the beginning of 2014, government consumption and public investment made on average a positive contribution to the economic recovery, pointing to a fiscal adjustment looser than the one that economic conditions would have allowed.

Before finishing this section, we present the results of an additional exercise in which we show the role of the housing sector in explaining the double dip of the Spanish economy. In Figure 4 we present the estimated demand and supply shocks that affected the housing sector. Not surprisingly, shocks to housing demand contributed significantly to explaining both the expansion that preceded the Great Recession and the sovereign debt crisis. These shocks continued to have a negative effect on GDP growth in the recovery period, disappearing at a slow pace in late 2019.

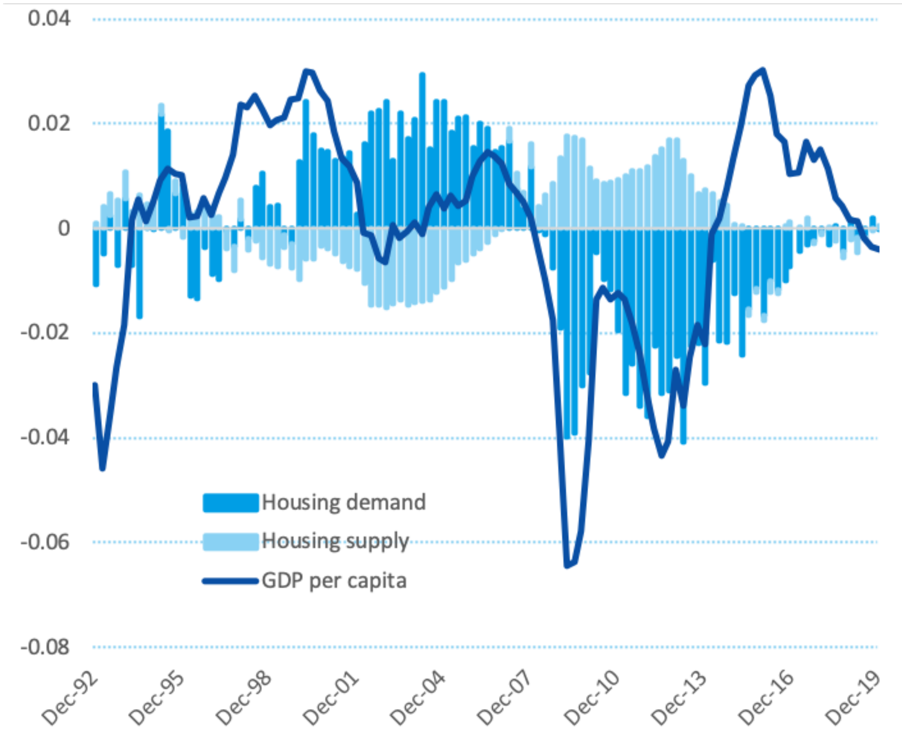

FIGURE 4: *Contribution of housing demand and supply shocks.*

5 Robustness

This section analyzes the robustness of previous results when we use the EONIA (ECB) rate as the observable variable for r_t, instead of the shadow rate. As shown in Figure 5 from the second quarter 2009 onward the EONIA and the shadow rates started to diverge, as a result of the non-conventional policy measures implemented by the ECB. From the middle of 2011 onward the shadow rate has been permanently below the official policy rate (on average 0.65 percentage point) reflecting a more expansive monetary policy stance than that implied by the EONIA rate.

Tables 12 and 13 show the priors and posteriors of the estimated parameters when the shadow rate is replaced by the EONIA rate. We observe that the posterior means of autocorrelation, standard deviation and the rest of the estimated parameters do not change very much. A closer look at the historical shock decomposition of GDP growth shows that the variance of shocks is higher when the model uses the ECB rate as observable.

Figure 6 represents GDP growth (left axis) and the difference in the contribution of the shadow rate with respect to the EONIA rate from 2007 onward (right axis). The contribution of shadow rate shocks is more

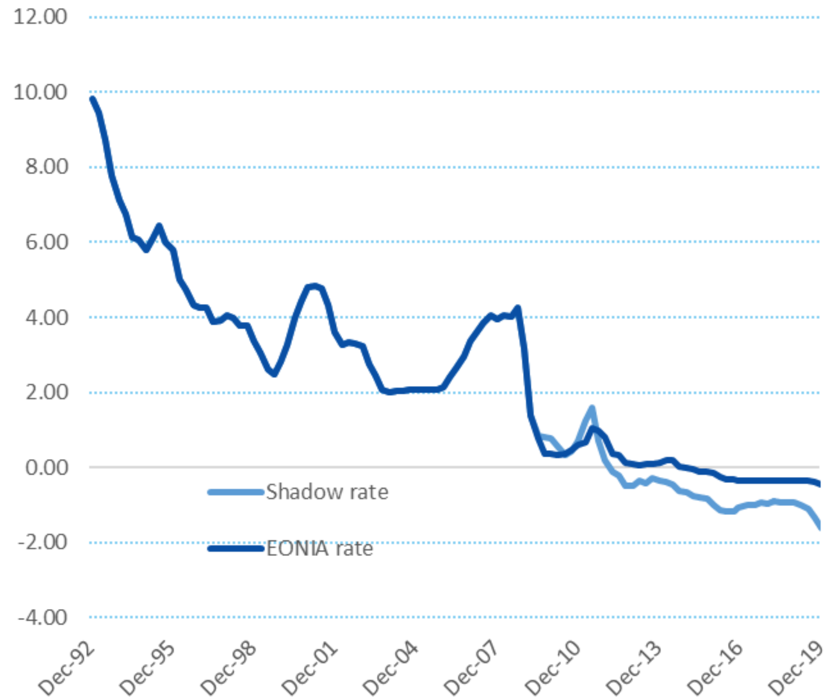

FIGURE 5: *EONIA and shadow rates.*

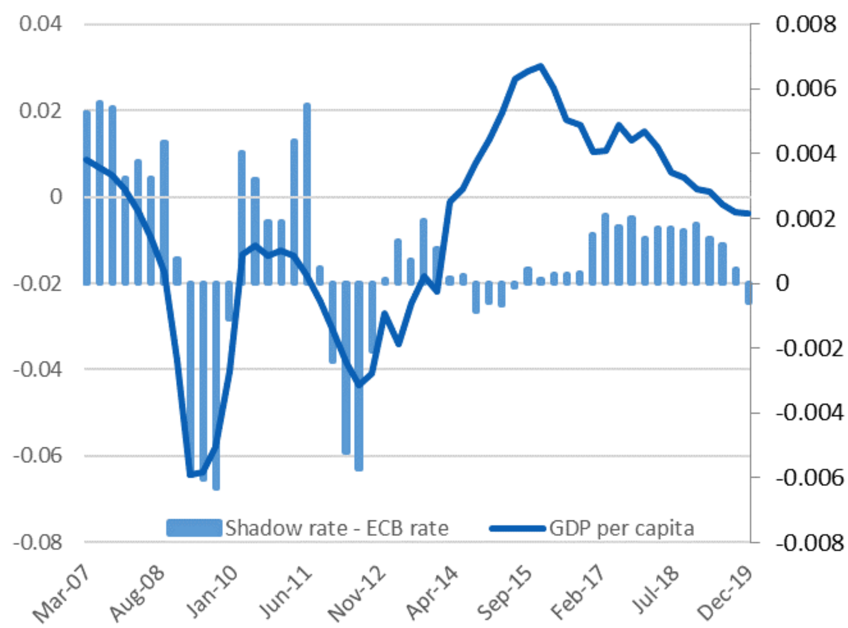

FIGURE 6: *Interest rate shock difference and GDP per WAP growth.*

procyclical than that of EONIA shocks, allowing the monetary shocks, through unconventional policies that affect the shadow rate, to explain a larger part of GDP growth.

Table 12: Priors and Posteriors

Parameter	Prior			Posterior	
	Distribution	Mean	Std	Mean	90 HPDI
ρ_z	*Beta*	0.50	0.20	0.837	[0.746; 0.931]
ρ_h	*Beta*	0.50	0.20	0.9989	[0.9981; 0.9998]
ρ_{mi}	*Beta*	0.50	0.20	0.993	[0.987; 0.999]
ρ_{me}	*Beta*	0.50	0.20	0.990	[0.983; 0.998]
ρ_l	*Beta*	0.50	0.20	0.980	[0.964; 0.996]
ρ_A	*Beta*	0.50	0.20	0.410	[0.290; 0.532]
ρ_{ho}	*Beta*	0.50	0.20	0.997	[0.996; 0.998]
ρ_y	*Beta*	0.50	0.20	0.986	[0.978; 0.993]
ρ_{kb}	*Beta*	0.50	0.20	0.437	[0.390; 0.545]
ρ_{rp}	*Beta*	0.50	0.20	0.353	[0.217; 0.488]
ρ_d	*Beta*	0.50	0.20	0.732	[0.662; 0.804]
ρ_{bi}	*Beta*	0.50	0.20	0.946	[0.923; 0.969]
ρ_{be}	*Beta*	0.50	0.20	0.967	[0.946; 0.990]
$\rho_{\omega d}$	*Beta*	0.50	0.20	0.942	[0.914; 0.971]
$\rho_{\omega f}$	*Beta*	0.50	0.20	0.922	[0.901; 0.944]
ρ_r	*Beta*	0.50	0.20	0.804	[0.737; 0.873]
ρ_{cg}	*Beta*	0.50	0.20	0.967	[0.946; 0.990]
ρ_{ig}	*Beta*	0.50	0.20	0.970	[0.952; 0.990]
ι_p	*Beta*	0.30	0.10	0.046	[0.016; 0.074]
ι_w	*Beta*	0.50	0.10	0.457	[0.295; 0.622]
a_{cp}=a_{ci}=a_{ce}=a_{cm}	*Beta*	0.90	0.08	0.619	[0.547; 0.690]
η_p	*Gamma*	50	8	21.66	[16.39; 26.92]
η_w	*Gamma*	20	4	20.46	[14.48; 26.23]
η_d	*Gamma*	3.50	0.50	4.406	[3.612; 5.188]
η_{be}	*Gamma*	9.36	0.50	10.15	[9.31; 11.99]
η_{bi}	*Gamma*	10	0.50	10.71	[9.84; 11.55]

Table 13: Priors and Posteriors

Parameter	Prior			Posterior	
	Distribution	Mean	Std	Mean	90 HPDI
σ_z	$Inv-Gamma$	0.05	0.15	0.035	$[0.027; 0.042]$
σ_h	$Inv-Gamma$	0.05	0.15	0.046	$[0.041; 0.052]$
σ_{mi}	$Inv-Gamma$	0.05	0.15	0.027	$[0.023; 0.030]$
σ_{me}	$Inv-Gamma$	0.05	0.15	0.012	$[0.010; 0.014]$
σ_l	$Inv-Gamma$	0.05	0.15	0.173	$[0.141; 0.204]$
σ_A	$Inv-Gamma$	0.05	0.15	0.014	$[0.013; 0.016]$
σ_{ho}	$Inv-Gamma$	0.05	0.15	0.019	$[0.017; 0.021]$
σ_y	$Inv-Gamma$	0.05	0.15	0.155	$[0.130; 0.180]$
σ_{kb}	$Inv-Gamma$	0.05	0.15	0.035	$[0.031; 0.039]$
σ_{rp}	$Inv-Gamma$	0.05	0.15	0.0063	$[0.0061; 0.0065]$
σ_d	$Inv-Gamma$	0.05	0.15	0.177	$[0.150; 0.204]$
σ_{bi}	$Inv-Gamma$	0.05	0.15	0.252	$[0.220; 0.284]$
σ_{be}	$Inv-Gamma$	0.05	0.15	0.237	$[0.208; 0.265]$
$\sigma_{\omega d}$	$Inv-Gamma$	0.05	0.15	0.021	$[0.019; 0.023]$
$\sigma_{\omega f}$	$Inv-Gamma$	0.05	0.15	0.032	$[0.028; 0.036]$
σ_r	$Inv-Gamma$	0.05	0.15	0.0062	$[0.0061; 0.0064]$
σ_{cg}	$Inv-Gamma$	0.05	0.15	0.011	$[0.009; 0.012]$
σ_{ig}	$Inv-Gamma$	0.05	0.15	0.046	$[0.041; 0.051]$

6 Conclusions

In this paper we have developed a DSGE model of a small open economy within a monetary union with a banking sector and a rich representation of fiscal variables. We introduce banks following Gerali et al. (2010), who distinguish between a wholesale and a retail branch. Retail banks operate under monopolistic competition, issuing colleteralized loans to impatient households and entrepreneurs. Banks also interact with the fiscal authority, buying part of the public debt. Interest rates in the retail sector are sticky due to the presence of convex costs of adjustment. The wholesale branch collects deposits from domestic households and loans from the rest of the world, and manages bank capital, which increases with non-distributed profits. The interest rate for the wholesale branch is determined by the central bank policy rate augmented by a risk premium, which evolves according to the foreign position of the economy. Altogether, balance-sheet constraints, endogenous markups and staggered interest rates open a stimulating transmission mechanism through the banking sector for different shocks affecting the economy.

As an example of its capabilities, the model has been estimated for the Spanish economy, which is an interesting example of a booming economy before the Great Recession, and a country that particularly suffered from the negative consequences of the sovereign debt crisis and exhibited a robust recovery until 2019. After we estimate the model using Bayesian techniques, our historical decomposition analysis highlights the different contributions of structural shocks to these episodes and provides a coherent and robust explanation of the Spanish business cycle. These results show the usefulness of DSGE models, conveniently designed and extended to account for the interaction of real and financial variables and other prominent characteristics of modern economies, as part of our toolkit to analyze the empirical evidence.

References

Andrés, J., S. Hurtado, E. Ortega, and C. Thomas (2010): "Spain in the Euro: A general equilibrium analysis," *SERIEs*, 1(1–2), 67–95.

Aspachs-Bracons, O. and P. Rabanal (2010): "The Drivers of Housing Cycles in Spain," *International Review of Economics*, 1, 101–130.

Bank of Spain (2019): *Statistical Bulletin*, Bank of Spain, www.bde.es/webbde/es/estadis/infoest/a1113.pdf.

Blanchard, O. (2018): "On the future of macroeconomic models," *Oxford Review of Economic Policy*, 34, 43–54.

Boscá, J., A. Bustos, A. Díaz, R. Doménech, J. Ferri, E. Pérez, and L. Puch (2007): "The REMSDB Macroeconomic Database of the Spanish Economy," Working Papers 0704, International Economics Institute, University of Valencia.

Boscá, J., A. Díaz, R. Doménech, J. Ferri, E. Pérez, and L. Puch (2010): "A Rational Expectations Model for Simulation and Policy Evaluation of the Spanish Economy," *SERIEs*, 1(1–2), 135–169.

Burriel, P., J. Fernández-Villaverde, and J. F. Rubio-Ramírez (2010): "MEDEA: A DSGE Model for the Spanish Economy," *SERIEs*, 1(1–2), 175–243.

De Rezende, R. and A. Ristiniemi (2020): "A shadow rate without a lower bound constraint," *Working Paper 355, Sveriges Riksbank.*

Galí, J. and T. Monacelli (2005): "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 72, 707–734.

García, F. P., M. M. Ivars, L. S. Martínez, and E. U. Jiménez (2019): "El stock de capital en España y sus comunidades autónomas," Documento de Trabajo 1, Fundación BBVA.

Ge, X., X.-L. Li, and L. Zheng (2019): "The transmission of financial shocks in an estimated DSGE model with housing and banking," *Economic Modelling.*

Gerali, A., S. Neri, L. Sessa, and F. M. Signoretti (2010): "Credit and Banking in a DSGE Model of the Euro Area," *Journal of Money, Credit and Banking*, 42(s1), 107–141.

Gómez-González, P. and D. M. Rees (2018): "Same Spain, less pain?" *European Economic Review*, 110, 78–107.

Groth, C. and H. Khan (2010): "Investment Adjustment Costs: An Empirical Assessment," *Journal of Money, Credit and Banking*, 42, 1469–1494.

Iacoviello, M. (2005): "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle," *American Economic Review*, 95, 739–764.

Iacoviello, M. and S. Neri (2010): "Housing market spillovers: evidence from an estimated DSGE model," *American Economic Journal: Macroeconomics*, 2, 125–64.

in't Veld, J., A. Pagano, R. Raciborski, M. Ratto, and W. Roeger (2015): "Imbalances and Rebalancing in an Estimated Structural Model for Spain," *International Journal of Central Banking*, 11, 1–41.

Kaplan, G., G. L. Violante, and J. Weidner (2014): "The Wealthy Hand-to-Mouth," *Brookings Papers on Economic Activity*, 45, 77–153.

Monacelli, T. (2004): "Into the Mussa puzzle: Monetary policy regimes and the real exchange rate in a small open economy," *Journal of International Economics*, 62, 191–217.

Montero, J. M. and A. Urtasun (2014): "Price-cost mark-ups in the Spanish economy: A microeconomic perspective," Working Papers 1407, Banco de España;Working Papers Homepage.

Pataracchia, B., R. Raciborski, M. Ratto, and W. Roeger (2013): "Endogenous housing risk in an estimated DSGE model of the Euro Area," European Economy - Economic Papers 2008 - 2015 505, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.

Pintér, G. (2019): "House Prices and Job Losses," *Economic Journal*, 129, 991–1013.

Reis, R. (2018): "Is something really wrong with macroeconomics?" *Oxford Review of Economic Policy*, 34, 132–155.

Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, A. Saint Guilhem, and J. Yiangou (2019): "A tale of two decades: The ECB's monetary policy at 20," Working Paper Series 2346, European Central Bank.

Schmitt-Grohe, S. and M. Uribe (2003): "Closing small open economy models," *Journal of International Economics*, 61, 163–185.

A Online Appendix: Model Description

The model represents a small open economy (Spain) that belongs to a trade and monetary union (EMU) along with a supra-national central bank (ECB) controlling the reference interest rate according to a Taylor rule linked to the aggregate inflation and output growth of the whole union, both taken as exogenous to the model (that is, the effect of the home economy on the rest of the union is negligible, as in Monacelli (2004) and Galí and Monacelli (2005)).

The home economy is populated by four types of consumers (patient households, impatient households, hand-to-mouth households and entrepreneurs), a centralized government, three types of non-financial firms (intermediate good producers, capital producers and retailers), banks organized as holdings with lending and deposit branches, labor unions (one for each type of household) and, as a convenient way to incorporate monopolistic competition, "packagers" with monopolistic power who play an intermediary role in goods, labor and banking services markets.

Patient households get utility from the consumption goods and housing services they buy with the wage income received in exchange for the differentiated labor supplied to labor unions and past deposit yields, and these households can even afford to save part of this income in additional bank deposits. Impatient households behave similarly except that they can't afford to save and even need to take bank loans to finance their purchases. Hand-to-mouth households get utility only from the consumption goods they can afford to buy spending all their wage income, because they don't have access to credit and they don't have enough income (and/or patience) to save.

Labor unions buy differentiated labor from households in competitive markets and re-sell it to monopolistic labor packagers which, in turn, re-sell it (after bundling it in to a single homogeneous type of labor for each type of household) to intermediate good producers in competitive markets. Intermediate good producers combine the three types of labor bought with the capital rented from entrepreneurs and public capital (freely available) to produce differentiated intermediate goods that are sold to retailers. Retailers re-label (at no cost) and re-sell these differentiated intermediate goods to monopolistic packagers that (after bundling them into a single homogeneous type of final good) re-sell them to consumers for direct consumption, and to capital producers, who transform them in to capital goods to be sold to entrepreneurs under competitive conditions.

Each bank holding comprises a wholesale branch, a deposit branch and a lending branch. The wholesale branch accumulates capital and makes loans to the lending branch from the resources accumulated in the past as capital and loans taken from the deposit branch and the rest of the world. The deposit branch gets its resources (which it lends to the wholesale branch) from households through the intermediation of monopolistic deposit packagers; specifically, the deposit branch sells differentiated "deposits" (saving products) to packagers that bundle them into a single homogeneous type of "deposit," which is sold to patient households in a competitive market. The lending branch gets resources by taking loans from the wholesale unit under competitive conditions and lends them to households through the intermediation of monopolistic loan packagers; specifically, the lending branch sells differentiated "loans" (i.e., bonds or other financing products) to packagers that re-sell them to impatient households and entrepreneurs (after bundling them into a single homogeneous type of bond).

There is at the union level a monetary authority that fixes the one-period nominal interest rate using a Taylor rule and supplies full-allotment refinancing to wholesale banks, following Schmitt-Grohe and Uribe (2003), to ensure the stationarity of equilibrium we assume that banks pay a risk premium that increases with the country's net foreign asset position. Thus, we close the model by assuming that the foreign borrowing interest rate is equal to an exogenous interest rate multiplied by a risk premium. Finally, there is a fiscal authority that consumes, invests, borrows (selling bonds to domestic banks, domestic households and the rest of the world), sets lump-sum transfers, and taxes consumption, housing services, labor earnings, capital earnings, bond holdings, and deposits.

A.1 Patient households

There is a continuum of patient households in the economy indexed by j, with mass γ_p, whose utility depends on consumption, $c^p_{j,t}$; housing services, $h^p_{j,t}$; and hours worked, $\ell^p_{j,t}$ and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \left[(1-a_{cp})\varepsilon_t^z log(c^p_{j,t} - a_{cp} c^p_{t-1}) + a_{hp}\varepsilon^h_t log(h^p_{j,t}) - \frac{a_{\ell p} {\ell^p_{j,t}}^{1+\phi}}{1+\phi} \right],$$

where c^p_t denotes the average patient household's consumption, $c^p_t = \gamma_p^{-1} \left(\int_0^{\gamma_p} c^p_{j,t} dj \right)$, ε^z_t is a shock to the consumption preferences of all households with the law of motion:

$$\log\, \varepsilon^z_t = (1-\rho_z)\log\, \varepsilon^z_{ss} + \rho_z \log\, \varepsilon^z_{t-1} + \sigma_z e^z_t \quad \text{where } e^z_t \sim \mathcal{N}(0,1) \tag{i}$$

and ε^h_t is a shock to the housing preferences of all households with the law of motion:

$$\log\, \varepsilon^h_t = (1-\rho_h)\log\, \varepsilon^h_{ss} + \rho_h \log\, \varepsilon^h_{t-1} + \sigma_h e^h_t \quad \text{where } e^h_t \sim \mathcal{N}(0,1) \tag{ii}$$

The jth patient household is subject to the following budget constraint (expressed in terms of final goods):

$$(1+\tau_t^c)c_{j,t}^p + (1+\tau_t^h)q_t^h(h_{j,t}^p - (1-\delta_h)h_{j,t-1}^p) + (1+\tau_t^{fd})d_{j,t}^p + \frac{\alpha_{RW}(1-\alpha_{B_g})Bg_t}{\gamma_p} =$$
$$(1-\tau_t^w)w_{j,t}^p\ell_{j,t}^p + \left[\frac{1+(1-\tau_t^d)r_{t-1}^d}{\pi_t} + \tau_t^{fd}\right]d_{j,t-1}^p + \frac{(1-\omega_b)J_{t-1}^b}{\gamma_p} - \frac{T_t^{up}}{\gamma_p} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m} +$$
$$\frac{\alpha_{RW}(1-\alpha_{B_g})(1+r_t^d)Bg_{t-1}}{\gamma_p}, \tag{1}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is gross inflation of the consumption good, with P_t denoting the price of the consumption good and the variables, τ_t^w, τ_t^c, τ_t^h, τ_t^d and τ_t^{fd} denoting taxes on labor income, consumption, accumulation of housing services, interest income from deposits and variation of deposits respectively; q_t^h is the price of housing services in terms of the consumption good; δ_h is the depreciation rate of housing; $w_{j,t}^p$ is the real wage in terms of the consumption good; and r_{t-1}^d is the nominal interest rate on deposits.

The flow of expenses, expressed in terms of the consumption good, is consumption (plus consumption taxes), $(1+\tau_t^c)c_{j,t}^p$; investment in housing services (plus taxes on housing services), $(1+\tau_t^h)q_t^h(h_{j,t}^p-(1-\delta_h)h_{j,t-1}^p)$; current deposits (plus deposit taxes), $(1+\tau_t^d)d_{j,t}^p$, and government bonds $\frac{\alpha_{RW}(1-\alpha_{B_g})Bg_t}{\gamma_p}$. The sources of income, also expressed in terms of the consumption good, are after-tax labor income , $(1-\tau_t^w)w_{j,t}^p\ell_{j,t}^p$; after-tax deposits gross return from the previous period, $\left[\frac{1+(1-\tau_t^d)r_{t-1}^d}{\pi_t} + \tau_t^d\right]d_{j,t-1}^p$; dividends from the banking sector, $\frac{(1-\omega_b)J_{t-1}^b}{\gamma_p}$ (where ω_b is the share of benefits that the banking sector does not distribute as dividends), the cost of participating in the labor union paid to the unions, $\frac{T_t^{up}}{\gamma_p}$; lump-sum taxes paid to the government, $\frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m}$, and payments on government bonds $\frac{\alpha_{RW}(1-\alpha_{B_g})(1+r_t^d)Bg_{t-1}}{\gamma_p}$, where γ_i, γ_e, and γ_m represent the mass of the rest of consumers in the model (impatient, hand-to-mouth and entrepreneurs), α_{RW} is the share of public debt in the hands of resident agents (that is, "domestic" public debt) from which a share α_{B_g} is in the hands of banks and $(1-\alpha_{B_g})$ in the hands of patient households.[1]

The patient household chooses $c_{j,t}^p$, $d_{j,t}^p$, $h_{j,t}^p$ (decision on $w_{j,t}^p$ and $l_{j,t}^p$ is delegated to a "labor union" whose decision is described below) in order to maximize utility subject to the budget constraint. The corresponding

[1]Households have access to a Arrow-Debreu securities. We do not write the whole set of possible Arrow-Debreu securities in the budget constraint to save on notation. Since their net supply is zero, they are not traded in equilibrium. However, households could trade and price any of these securities. This will be true for all types of households we consider in this paper.

FOCs are:

$$
\begin{aligned}
\lambda_t^p(1+\tau_c) - \frac{(1-a_{cp})\varepsilon_t^z}{c_t^p - a_{cp}c_{t-1}^p} &= 0, & (2)\\
\frac{a_{hp}\varepsilon_t^h}{h_t^p} - \lambda_t^p(1+\tau_h)q_t^h + \beta_p E_t\left\{\lambda_{t+1}^p(1+\tau_h)(1-\delta_h)q_{t+1}^h\right\} &= 0, \text{ and} & (3)\\
\text{and } \lambda_t^p(1+\tau_{fd}) - \beta_p E_t\left\{\lambda_{t+1}^p\left[\frac{1+(1-\tau_d)r_t^d}{\pi_{t+1}} + \tau_{fd}\right]\right\} &= 0, & (4)
\end{aligned}
$$

where we focus on symmetric equilibrium.

A.2 Impatient households

There is a continuum of impatient households in the economy indexed by j, with mass γ_i, whose utility depends on consumption $c_{j,t}^i$, housing services $h_{j,t}^i$ and hours worked $\ell_{j,t}^i$, and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_i^t \left[(1-a_{ci})\varepsilon_t^z log(c_{j,t}^i - a_{ci}c_{t-1}^i) + a_{hi}\varepsilon_t^h log(h_{j,t}^i) - \frac{a_{\ell i}\ell_{j,t}^{i\,1+\phi}}{1+\phi}\right]$$

where c_t^i denotes the average patient household's consumption, $c_t^i = \gamma_i^{-1}\left(\int_0^{\gamma_i} c_{j,t}^i dj\right)$ and ε_t^z and ε_t^h are defined as in the patient household's problem above. The jth impatient household budget constraint, expressed in terms of final goods, is given by:

$$
\begin{aligned}
&(1+\tau_t^c)c_{j,t}^i + (1+\tau_t^h)q_t^h(h_{j,t}^i - (1-\delta_h)h_{j,t-1}^i) + \left(\frac{1+r_{t-1}^{bi}}{\pi_t} - \tau_t^{fb}\right)b_{j,t-1}^i = \\
&(1-\tau_t^w)w_{j,t}^i\ell_{j,t}^i + (1-\tau_t^{fb})b_{j,t}^i - \frac{T_t^{ui}}{\gamma_i} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m},
\end{aligned}
$$

where τ_t^{fb} denotes taxes on the variation of loans, $w_{j,t}^i$ is the real wage in term of the consumption good, and r_{t-1}^{bi} is the nominal interest rate on loans.

This budget constraint reflects the fact that impatient households do not receive any dividend. Having said that, the expenses and incomes are similar to the ones described for patient households. The main difference is $b_{j,t}^i$, which represents bank loans. In addition, impatient households face a borrowing constraint. In terms of final goods, they cannot borrow more than a certain proportion of the expected value in period t of the value in period $t+1$ of their housing stock at period t discounted by $(1+r_t^{bi})$:

$$(1+r_t^{bi})b_{j,t}^i \leq m_t^i E_t\left\{q_{t+1}^h h_{j,t}^i \pi_{t+1}\right\},$$

where m_t^i is the stochastic loan-to-value ratio for all impatient households' mortgages with the law of motion:

$$\log\, m_t^i = (1-\rho_{mi})\log\, m_{ss}^i + \rho_{mi}\log m_{t-1}^i + \sigma_{mi}e_t^{mi} \quad \text{where } e_t^{mi} \sim \mathcal{N}(0,1) \tag{iii}$$

We assume that the shocks in the model are small enough so that we can solve the model imposing the condition that the borrowing constraint always binds, as in Iacoviello (2005).

The impatient household chooses $c_{j,t}^i$, $b_{j,t}^i$, $h_{j,t}^i$ (decision on $w_{j,t}^i$ and $l_{j,t}^i$ is delegated to a "labor union" whose decision is described below) in order to maximize utility subject to thge budget constraint. The corresponding FOCs are:

$$\lambda_t^i(1+\tau_c) - \frac{(1-a^{ci})\varepsilon_t^z}{c_t^i - a^{ci}c_{t-1}^i} = 0, \tag{5}$$

$$\frac{a^{hi}\varepsilon_t^h}{h_t^i} - \lambda_t^i(1+\tau_h)q_t^h + \xi_t^i m_t^i E_t\left\{q_{t+1}^h\pi_{t+1}\right\} + \beta_i E_t\left\{\lambda_{t+1}^i(1+\tau_h)(1-\delta_h)q_{t+1}^h\right\} = 0, \text{ and} \tag{6}$$

$$\text{and } \lambda_t^i(1-\tau_b) - \beta_i E_t\left\{\lambda_{t+1}^i\left(\frac{1+r_t^{bi}}{\pi_{t+1}} - \tau_b\right)\right\} - \xi_t^i(1+r_t^{bi}) = 0 \tag{7}$$

where we focus on symmetric equilibrium again. Also, the binding borrowing constraint can be written as:

$$(1+r_t^{bi})b_t^i = m_t^i E_t\left\{q_{t+1}^h h_t^i \pi_{t+1}\right\}. \tag{8}$$

A.3 Hand-to-mouth households

There is a continuum of hand-to-mouth households in the economy indexed by j, with mass γ_m, whose utility function depends on consumption $c_{j,t}^m$ and hours worked $\ell_{j,t}^i$, and has the following form:

$$E_0\sum_{t=0}^{+\infty}\beta_m^t\left[(1-a_{cm})\varepsilon_t^z log(c_{j,t}^m - a_{cm}c_{t-1}^m) - \frac{a_{\ell m}\ell_{j,t}^{m\,1+\phi}}{1+\phi}\right].$$

where c_t^m denotes the average hand-to-mouth household's consumption, $c_t^m = \gamma_m^{-1}\left(\int_0^{\gamma_m} c_{j,t}^m dj\right)$ and ε_t^z and ε_t^h are defined as in the patient household's problem above. The jth hand-to-mouth household budget constraint is given by:

$$(1+\tau_t^c)c_{j,t}^m = (1-\tau_t^w)w_{j,t}^m\ell_{j,t}^m - \frac{T_t^{um}}{\gamma_m} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m} \tag{9}$$

where $w_{j,t}^m$ is the real wage in terms of the consumption good.

This budget constraint reflects the fact that hand-to-mouth households do not receive any dividend. Having said that, the only expense of hand-to-mouth households is after-tax consumption. The sources of income are labor income net of the cost of participating in the labor union paid to the unions and the lump-sum taxes paid to the government. Hand-to-mouth households do not have bank deposits or bank loans.

The hand-to-mouth household chooses $c^m_{j,t}$ (decision on $w^m_{j,t}$ and $l^m_{j,t}$ is delegated to a "labor union" whose decision is described below) in order to maximize utility subject to thebudget constraint. But not having alternative uses for its income, the only condition for maximizing the hand-to-mouth household's utility is spending it all, i.e., satisfying its binding budget constraint.

A.4 Labor unions and labor packers

There are three types of labor unions and three types of "labor packer," one for each type of household. Given the similarity of the problem of choosing wages and labor supply for the three types of households, we present a general derivation of the problem using the super-index s to denote patient households, $s = p$; impatient households, $s = i$; and hand-to-mouth households, $s = m$.

There is a continuum of labor unions of each type in the economy indexed by j. Each household (j, s) delegates its labor decision to labor unions (j, s). The labor union (j, s) sells labor in a monopolistically competitive market to the "labor packer" of type s. The labor packer of type s sells bundled labor in a competitive market to intermediate good producers. The labor packer of type s uses the following production function to bundle labor:

$$\ell^s_t = \left(\int_0^{\gamma_s} \left(\ell^s_{j,t}\right)^{\frac{\varepsilon^\ell_t - 1}{\varepsilon^\ell_t}} dj \right)^{\frac{\varepsilon^\ell_t}{\varepsilon^\ell_t - 1}},$$

where ℓ^s_t is labor from households of type s and ε^ℓ_t is the elasticity of substitution among different types of labor, which is stochastic and follows the law of motion:

$$\log \varepsilon^\ell_t = (1 - \rho_\ell)\log \varepsilon^\ell_{ss} + \rho_\ell \log \varepsilon^\ell_{t-1} + \sigma_\ell e^\ell_t \quad \text{where } e^\ell_t \sim \mathcal{N}(0, 1) \tag{iv}$$

The labor packer of type s chooses $l^s_{j,t}$ for all j in order to maximize:

$$w^s_t \ell^s_t - \int_0^{\gamma_s} w^s_{j,t} \ell^s_{j,t} dj.$$

subject to the production function and taking as given all wages. Both, $w^s_{j,t}$ and w^s_t refer to real wages in terms of the consumption good. The corresponding FOC is:

$$w_t^s \frac{\varepsilon_t^\ell}{\varepsilon_t^\ell - 1} \left(\int_0^{\gamma_s} \left(\ell_{j,t}^s\right)^{\frac{\varepsilon_t^\ell - 1}{\varepsilon_t^\ell}} \right)^{\frac{\varepsilon_t^\ell}{\varepsilon_t^\ell - 1} - 1} \frac{\varepsilon_t^\ell - 1}{\varepsilon_t^\ell} \left(\ell_{j,t}^s\right)^{\frac{\varepsilon_t^\ell - 1}{\varepsilon_t^\ell} - 1} - w_{j,t}^s = 0.$$

Dividing the FOCs for two members of the s-type household group, we obtain:

$$w_{j,t}^s = \left(\frac{\ell_{i,t}^s}{\ell_{j,t}^s} \right)^{\frac{1}{\varepsilon_t^\ell}} w_{i,t}^s.$$

Using the zero profits condition of labor packers implied by perfect competition, $w_t^s \ell_t^s = \int_0^{\gamma_s} w_{j,t}^s \ell_{j,t}^s dj$, we get the input demand functions associated with this problem:

$$\ell_{j,t}^s = \left(\frac{w_{j,t}^s}{w_t^s} \right)^{-\varepsilon_t^\ell} \ell_t^s.$$

To find the aggregate real wage for each type of labor we use again the zero profit condition and the demand functions to obtain:

$$w_t^s = \left(\int_0^{\gamma_s} w_{j,t}^{1-\varepsilon_t^\ell} dj \right)^{\frac{1}{1-\varepsilon_t^\ell}}.$$

The labor union of type (s, j) sets the nominal wage, $W_{j,t}^s$, by maximizing the following objective function, which represents the utility of the household supplying the labor from the resulting wage income net of a quadratic cost for adjusting the nominal wage:

$$E_0 \sum_{t=0}^{+\infty} \beta_s^t \left\{ U_{c,j,t}^s \theta_t^{wc} \left[w_{j,t}^s \ell_{j,t}^s - \frac{\eta_w}{2} \left(\pi_{j,t}^{ws} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right)^2 w_t^s \right] - \frac{a_{\ell s} {\ell_{j,t}^s}^{1+\phi}}{1+\phi} \right\}$$

subject to:

$$\ell_{j,t}^s = \left(\frac{w_{j,t}^s}{w_t^s} \right)^{-\varepsilon_t^\ell} \ell_t^s, \text{ and } w_{j,t}^s \equiv \frac{W_{j,t}^s}{P_t}$$

where:

$$\pi_{j,t}^{ws} \equiv \left(\frac{w_{j,t}^s}{w_{j,t-1}^s} \right) \pi_t,$$

and $\theta_t^{wc} \equiv \left(\frac{1-\tau_t^w}{1+\tau_t^c} \right)$ and $U_{c,j,t}^s$ represents the instantaneous marginal utility of the household taken as given by unions. Denoting $U^s_{j,t}$ as the instantaneous utility function, we have that:

$$U^s_{j,t} \equiv \begin{cases} (1-a_{cs})\varepsilon^z_t log(c^s_{j,t} - a_{cs}c^s_{t-1}) + a_{hs}\varepsilon^z_t log(h^s_{j,t}) - \frac{a_{\ell s}{\ell^s_{j,t}}^{1+\phi}}{1+\phi} \text{ for } s = p, i \\ \\ (1-a_{cs})\varepsilon^z_t log(c^s_{j,t} - a_{cs}c^s_{t-1}) - \frac{a_{\ell s}{\ell^s_{j,t}}^{1+\phi}}{1+\phi} \text{ for } s = m. \end{cases}$$

Thus, we have that:

$$U^s_{c,j,t} \equiv \frac{\partial U^s_{j,t}}{\partial c^s_{j,t}} = \frac{(1-a_{cs})\varepsilon^z_t}{c^s_{j,t} - a_{cs}c^s_{t-1}}. \tag{10}$$

In equilibrium $U^s_{c,j,t} = (1+\tau^c_t)\lambda^s_{j,t}$ for $s = p, i$. Hence, when we focus on symmetric equilibrium, the FOC of the labor union of type $s = p, i$ with respect to the nominal wage is:

$$\begin{aligned} &\left[(1-\varepsilon^\ell_t)\ell^s_t - \eta_w \left(\pi^{ws}_t - \pi^{\iota^w}_{t-1}\pi^{1-\iota^w}\right)\pi^{ws}_t\right] + \frac{a^{\ell s}\varepsilon^\ell_t {\ell^s_t}^{1+\phi}}{\lambda^s_t(1-\tau^w_t)w^s_t} + \\ &\beta_s E_t \left\{\frac{\lambda^s_{t+1}}{\lambda^s_t}\left[\eta_w \left(\pi^{ws}_{t+1} - \pi^{\iota^w}_t \pi^{1-\iota^w}\right)\frac{{\pi^{ws}_{t+1}}^2}{\pi_{t+1}}\right]\right\} = 0. \end{aligned} \tag{11}$$

In the case of the labor union of type hand-to-mouth we have:

$$\begin{aligned} &\left(\frac{1-\tau_w}{1+\tau_c}\right)\left[(1-\varepsilon^\ell_t)\ell^m_t - \eta_w \left(\pi^{wm}_t - \pi^{\iota^w}_{t-1}\pi^{1-\iota^w}\right)\pi^{wm}_t\right] + \frac{a^{\ell m}\varepsilon^\ell_t {\ell^m_t}^{1+\phi}}{U^m_{c,t}w^m_t} + \\ &\beta_m E_t \left\{\frac{U^m_{c,t+1}}{U^m_{c,t}}\left[\eta_w \left(\frac{1-\tau_w}{1+\tau_c}\right)\left(\pi^{wm}_{t+1} - \pi^{\iota^w}_t \pi^{1-\iota^w}\right)\frac{{\pi^{wm}_{t+1}}^2}{\pi_{t+1}}\right]\right\} = 0. \end{aligned} \tag{12}$$

This implies that:

$$\ell^s_t = \left(\int_0^{\gamma_s} \left(\ell^s_{j,t}\right)^{\frac{\varepsilon^\ell_t - 1}{\varepsilon^\ell_t}} dj\right)^{\frac{\varepsilon^\ell_t}{\varepsilon^\ell_t - 1}} = \ell^s_{j,t}$$

for $s = p, i, m$. Finally, the cost of participating in the labor union is equal to the quadratic cost of changing the wage:

$$T^{us}_t = \gamma_s \frac{\eta_w}{2}\left(\pi^{ws}_t - \pi^{\iota_w}_{t-1}\pi^{1-\iota_w}\right)^2 w^s_t \tag{13}$$

for all types of households.

A.5 Entrepreneurs

There is a continuum of entrepreneurs in the economy indexed by j, with mass γ_e, whose utility function depends on consumption $c^e_{j,t}$, and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_e^t (1-a_{ce}) \varepsilon_t^z log(c^e_{j,t} - a_{ce} c^e_{t-1}).$$

where c^e_t denotesthe average entrepreneur's consumption, $c^e_t = \gamma_e^{-1}\left(\int_0^{\gamma_e} c^e_{j,t} dj\right)$. The jth entrepreneur's budget constraint is given by:

$$\begin{aligned} &(1+\tau_t^c)c^e_{j,t} + \left(\frac{1+r^{be}_{t-1}}{\pi_t} - \tau_t^{fb}\right) b^e_{j,t-1} + q^k_t k^e_{j,t} = \\ &(1-\tau^k_t) r^k_t k^e_{j,t} + q^k_t (1-\delta) k^e_{j,t-1} + (1-\tau_t^{fb}) b^e_{j,t} + \frac{J^R_t}{\gamma_e} + \frac{J^x_t}{\gamma_e} + \frac{J^k_t}{\gamma_e} + \frac{J^h_t}{\gamma_e} - \frac{T^g_t}{\gamma_p+\gamma_i+\gamma_e+\gamma_m}. \end{aligned} \tag{14}$$

where τ^k_t denotes taxes on returns on capital, q^k_t is the price of the capital good in terms of the consumption good, r^k_t is the return on capital in terms of the consumption good, and r^{be}_{t-1} is the nominal interest rate on loans.

Entrepreneurs buy/sell the capital good from the capital good producers and rent it to the intermediate good producers. They also own the intermediate good producers' firms, the capital good producers' firms and the housing producers' firms and have bank loans. The flow of expenses of entrepreneurs is given by consumption (plus consumption taxes) $(1+\tau^c_t)c^e_{j,t}$, capital purchases $q^k_t k^e_{j,t}$, and interest plus principal of loans taken out during the previous period $\left(\frac{1+r^{be}_{t-1}}{\pi_t} - \tau_t^{fb}\right) b^e_{j,t-1}$. The sources of income are rental capital (minus capital taxes), $(1-\tau^k_t) r^k_t k^e_{j,t}$; loans (minus taxes on lending transactions), $(1-\tau^{fb}_t) b^e_{j,t}$; capital from the previous period $q^k_t(1-\delta)k^e_{j,t-1}$; dividends from the retail firms, $\frac{J^R_t}{\gamma_e}$; dividends from intermediate good producers $\frac{J^x_t}{\gamma_e}$; dividends from capital good producers, $\frac{J^k_t}{\gamma_e}$, and dividends from housing producers, $\frac{J^h_t}{\gamma_e}$, net of lump-sum taxes paid to the government, $\frac{T^g_t}{\gamma_p+\gamma_i+\gamma_p}$.

In addition, impatient entrepreneurs face a borrowing constraint. In terms of final goods, they cannot borrow more than a certain proportion of the expected value in period t of the value in period $t+1$ of their capital stock in period $t+1$ discounted by $(1+r^{be}_t)$:

$$(1+r^{be}_t) b^e_{j,t} \leq m^e_t E_t \left\{ q^k_{t+1} \pi_{t+1} (1-\delta) k^e_{j,t} \right\},$$

where m_t^e is the stochastic loan-to-value ratio for capital with the law of motion:

$$\log\, m_t^e = (1-\rho_{me})\log\, m_{ss}^e + \rho_{me}\log m_{t-1}^e + \sigma_{me} e_t^{me} \quad \text{where } e_t^{me} \sim \mathcal{N}(0,1) \tag{v}$$

As in the case of impatient households, we assume that the shocks in the model are small enough so that we can solve the model imposing the condition that the borrowing constraint always binds, as in Iacoviello (2005). The entrepreneur chooses $c_{j,t}^e$, $k_{j,t}^e$, and $b_{j,t}^e$. The corresponding FOC are:

$$\lambda_t^e(1+\tau_c) - \frac{(1-a_{ce})\varepsilon_t^z}{c_t^e - a_{ce}c_{t-1}^e} = 0, \tag{15}$$

$$q_t^k - (1-\tau_k)r_t^k - \beta_e E_t\left\{\frac{\lambda_{t+1}^e}{\lambda_t^e}\left[q_{t+1}^k(1-\delta)\right]\right\} - \left(\frac{\xi_t^e}{\lambda_t^e}\right) m_t^e E_t\left\{q_{t+1}^k(1-\delta)\pi_{t+1}\right\} = 0 \tag{16}$$

$$\lambda_t^e(1-\tau^{fb}) - \xi_t^e(1+r_t^{be}) - \beta_e E_t\left\{\lambda_{t+1}^e\left(\frac{1+r_t^{be}}{\pi_{t+1}} - \tau^{fb}\right)\right\} = 0, \tag{17}$$

where we focus on symmetric equilibrium again. Also, the binding borrowing constraint can be written as:

$$(1+r_t^{be})b_t^e = m_t^e E_t\left\{q_{t+1}^k\pi_{t+1}(1-\delta)k_t^e\right\}. \tag{18}$$

A.6 Intermediate good producers

There is a continuum of competitive intermediate good producers in the economy indexed by j, with mass γ_x. Intermediate good producers sell intermediate goods in a competitive market to retailers.

The jth intermediate good producer has access to a technology represented by a production function:

$$y_{j,t}^x = A_t\left(k_{j,t-1}^{ee}\right)^\alpha\left[\left(\ell_{j,t}^{pp}\right)^{\mu_p}\left(\ell_{j,t}^{ii}\right)^{\mu_i}\left(\ell_{j,t}^{mm}\right)^{\mu_m}\right]^{1-\alpha}\left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g},$$

where $k_{j,t-1}^{ee}$ is the capital rented by the firm from entrepreneurs, $\ell_{j,t}^{pp}$ is the amount of "packed" patient labor input rented by the firm, $\ell_{j,t}^{ii}$ is the amount of "packed" impatient labor input rented by the firm, $\ell_{j,t}^{mm}$ is the amount of "packed" hand-to-mouth labor input rented by the firm, and K_{t-1}^g is the amount of public capital controlled by the government. A_t denotes an aggregate productivity shock with the law of motion:

$$\log\, A_t = (1-\rho_A)\log\, A_{ss} + \rho_A\log\, A_{t-1} + \sigma_A e_t^A \text{ where } e_t^A \sim \mathcal{N}(0,1) \tag{vi}$$

In addition to the cost of the inputs required for production, the intermediate good producers face a fixed cost of production, Φ_x, which guarantees that the economic profits are roughly equal to zero in the steady-state.

Intermediate good producers choose $k^{ee}_{j,t-1}$, $\ell^{pp}_{j,t}$, $\ell^{ii}_{j,t}$, and $\ell^{mm}_{j,t}$ to maximize profits taken all prices as given. The FOCs are:

$$w^p_t = \frac{\mu^p(1-\alpha)}{x_t}\frac{y^x_{j,t}}{\ell^{pp}_{j,t}}, \tag{19}$$

$$w^i_t = \frac{\mu^i(1-\alpha)}{x_t}\frac{y^x_{j,t}}{\ell^{ii}_{j,t}}, \tag{20}$$

$$w^m_t = \frac{\mu^m(1-\alpha)}{x_t}\frac{y^x_{j,t}}{\ell^{mm}_{j,t}}, \tag{21}$$

$$r^k_t = \alpha\frac{y^x_{j,t}}{x_t k^{ee}_{j,t-1}}, \tag{22}$$

where x_t is the inverse of the of price intermediate goods in terms of the consumption good.

After integrating out both sides of Equations (19)-(21) with respect to j we get:

$$w^p_t = \frac{\mu^p(1-\alpha)}{x_t}\frac{y^x_t}{\ell^{pp}_t},$$

$$w^i_t = \frac{\mu^i(1-\alpha)}{x_t}\frac{y^x_t}{\ell^{ii}_t},$$

$$w^m_t = \frac{\mu^m(1-\alpha)}{x_t}\frac{y^x_t}{\ell^{mm}_t},$$

where $y^x_t = \int_0^{\gamma_x} y^x_{j,t}dj$ and $\ell^{ss}_t = \int_0^{\gamma_x} \ell^{ss}_{j,t}dj$ for all $s \in \{p, i, m\}$. It also follows that the ratio of capital to labor is independent of j:

$$\frac{k^{ee}_{j,t-1}}{\ell^{pp}_{j,t}} = \frac{\alpha}{(1-\alpha)}\frac{1}{\mu^p}\frac{w^p_t}{(r^k_t)} \equiv \frac{1}{\kappa_{p,t}},$$

$$\frac{k^{ee}_{j,t-1}}{\ell^{ii}_{j,t}} = \frac{\alpha}{(1-\alpha)}\frac{1}{\mu^i}\frac{w^i_t}{(r^k_t)} \equiv \frac{1}{\kappa_{i,t}}, \text{ and}$$

$$\frac{k^{ee}_{j,t-1}}{\ell^{mm}_{j,t}} = \frac{\alpha}{(1-\alpha)}\frac{1}{\mu^m}\frac{w^m_t}{(r^k_t)} \equiv \frac{1}{\kappa_{m,t}}.$$

These equations also imply that:

$$\frac{k_{t-1}^{ee}}{\ell_t^{pp}} = \frac{1}{\kappa_{p,t}},$$
$$\frac{k_{t-1}^{ee}}{\ell_t^{ii}} = \frac{1}{\kappa_{i,t}}, \text{ and}$$
$$\frac{k_{t-1}^{ee}}{\ell_t^{mm}} = \frac{1}{\kappa_{m,t}},$$

where $k_t^{ee} = \int_0^{\gamma_x} k_{j,t}^{ee} dj$. Substituting these ratios into the production function yields:

$$\begin{aligned}
y_{j,t}^x &= A_t \left(k_{j,t-1}^{ee}\right)^\alpha \left[\left(k_{j,t-1}^{ee}\kappa_{p,t}\right)^{\mu_p} \left(k_{j,t-1}^{ee}\kappa_{i,t}\right)^{\mu_i} \left(k_{j,t-1}^{ee}\kappa_{m,t}\right)^{\mu_m}\right]^{1-\alpha} \left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g} \\
&= A_t \left(k_{j,t-1}^{ee}\right)^\alpha \left(k_{j,t-1}^{ee}\right)^{(1-\alpha)(\mu_p+\mu_i+\mu_m)} \left[(\kappa_{p,t})^{\mu_p} (\kappa_{i,t})^{\mu_i} (\kappa_{m,t})^{\mu_m}\right]^{1-\alpha} \left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g} \\
&= k_{j,t-1}^{ee} A_t (k_{j,t-1}^{ee})^{-(1-\alpha)+(1-\alpha)(\mu_p+\mu_i+\mu_m)} \left[(\kappa_{p,t})^{\mu_p} (\kappa_{i,t})^{\mu_i} (\kappa_{m,t})^{\mu_m}\right]^{1-\alpha} \left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g} \\
&= k_{j,t-1}^{ee} A_t \frac{1}{\left(k_{j,t-1}^{ee}\right)^{(1-\alpha)(1-(\mu_p+\mu_i+\mu_m))}} \left[(\kappa_{p,t})^{\mu_p} (\kappa_{i,t})^{\mu_i} (\kappa_{m,t})^{\mu_m}\right]^{1-\alpha} \left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g} \\
&= k_{j,t-1}^{ee} A_t \frac{\left(k_{j,t-1}^{ee}\right)^{\alpha_g}}{\left(k_{j,t-1}^{ee}\right)^{(1-\alpha)(1-(\mu_p+\mu_i+\mu_m))}} \left[(\kappa_{p,t})^{\mu_p} (\kappa_{i,t})^{\mu_i} (\kappa_{m,t})^{\mu_m}\right]^{1-\alpha} \left(\frac{K_{t-1}^g}{k_{j,t-1}^{ee}\gamma_x}\right)^{\alpha_g}
\end{aligned}$$

After some algebra, this implies that:

$$y_t^x = A_t \left(k_{t-1}^{ee}\right)^\alpha \left[(\ell_t^{pp})^{\mu_p} \left(\ell_t^{ii}\right)^{\mu_i} (\ell_t^{mm})^{\mu_m}\right]^{1-\alpha} \left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g}. \tag{23}$$

Finally, the profits of the individual intermediate good producers are:

$$\frac{J_t^x}{\gamma_x} = \frac{y_t^x}{x_t} - w_t^p \ell_t^{pp} - w_t^i \ell_t^{ii} - w_t^m \ell_t^{mm} - r_t^k k_{t-1}^{ee} - \Phi_x.$$

A.7 Capital good producers

There is a continuum of capital goods producers in the economy indexed by j, with mass γ_k. Capital goods producers sell new capital goods, $k_{j,t}$, in a competitive market, to entrepreneurs.

The jth capital goods producer produces these new capital goods out of the non-depreciated portion of old capital goods, $(1-\delta)k_{j,t-1}$, bought from entrepreneurs at price q_t^k, and of gross investment goods, $i_{j,t}^z$, bought from investment good packers at price p_t^I. However, whereas old non-depreciated capital goods can be converted one to one to new capital, gross investment goods are subject to non-linear adjustment costs, which causes a one to less than one conversion, such that, all in all, the amount of new capital goods evolves according to the following law of motion,

$$k_{j,t} = (1-\delta)k_{j,t-1} + i_{j,t}.$$

where $i_{j,t}$ is *effective* investment, which is related to investment (*gross of adjustment costs*) through the following expression,

$$i^k_{j,t} = i_{j,t}\left[1 + \frac{\eta_i}{2}\frac{i_{j,t}}{k_{j,t-1}}\right] \tag{24}$$

so that $i_{j,t} \leq i^k_{j,t}$. Then, each capital good producer chooses $k_{j,t}$ and $i_{j,t}$ in order to maximize profit subject to the law of motion for capital. The corresponding FOCs are reduced to:

$$q^k_t - p^I_t\left(1 + \frac{\eta_j i_{j,t}}{k_{j,t-1}}\right) = 0$$

Because of complete markets we get $i_{j,t} = i_t$ and hence:

$$q^k_t - p^I_t\left(1 + \frac{\eta_i i_t}{k_{t-1}}\right) = 0 \tag{25}$$

and

$$k_t = (1-\delta)k_{t-1} + i_t \tag{26}$$

Finally, the profits of the representative capital good producer are:

$$\frac{J^k_t}{\gamma_k} = \left[q^k_t - p^I_t\left(1 + \frac{\eta_i}{2}\frac{i_t}{k_{t-1}}\right)\right] i_t. \tag{27}$$

A.8 Housing producers

Following Gómez-González and Rees (2018), production of housing is analogous to productive capital production. There is a continuum of housing producers with mass γ_h working in a competitive market and selling their production to patient and impatient households. Under the assumption of complete markets the evolution of housing is characterized by:

$$h_t = (1-\delta_h)h_{t-1} + i^{ho}_t \varepsilon^{ho}_t \tag{28}$$

where i^{ho}_t is *effective* housing investment, which is augmented by some adjustment costs to become *gross* *of adjustment costs* housing investment, i_t^{hz}:

$$i_t^{hz} = i_t^{ho}\left[1 + \frac{\eta_h}{2}\frac{i_t^{ho}}{h_{t-1}}\right] \tag{29}$$

ε_t^{ho} is a housing investment productivity shock with the following dynamic behavior:

$$\log\, \varepsilon_t^{ho} = (1-\rho_{ho})\log\, \varepsilon_{ss}^{ho} + \rho_{ho}\log\, \varepsilon_{t-1}^{ho} + \sigma_{ho}e_t^{ho} \text{ where } e_t^{ho} \sim \mathcal{N}(0,1) \tag{vii}$$

Output and input housing prices are linked by means of the following expression:

$$q_t^h\varepsilon_t^{ho} = p_t^H\left(1 + \frac{\eta_h i_t^{ho}}{h_{t-1}}\right) \tag{30}$$

where p_t^H is the price of domestic-produced output in terms of consumption goods. Contrary to capital investment goods, housing is a non-tradable good. This price can differ from the price paid by households, q_t^h, not only due to adjustment costs, but also to the action of the housing specific productivity shock.

Finally, the profits of the representative housing producer are:

$$\frac{J_t^h}{\gamma_h} = \left[q_t^h\varepsilon_t^{ho} - p_t^H\left(1 + \frac{\eta_i}{2}\frac{i_t^{ho}}{h_{t-1}}\right)\right] i_t^{ho}. \tag{31}$$

A.9 Retailers

There is a continuum of retailers indexed by j, with mass γ. Each retailer buys the intermediate good from intermediate goods producers, differentiates it and sells the resulting varieties of intermediate goods, in a monopolistically competitive market, to goods packers, who, in turn, bundle the varieties together into a domestic good and sell it, in a competitive market, to consumption and investment goods packers that bundle home and imported production.

We assume that retail prices are indexed by a combination of past and steady-state inflation of retail prices with relative weights parameterized by ι_p. In addition, retailers are subject to quadratic price adjustment costs, where η_p controls the size of these costs.

Then, each retailer chooses the nominal price for its differentiated good, $P_{j,t}^H$ to maximize:

$$E_0\sum_{t=0}^{+\infty}\beta_p^t\lambda_{j,t}^p\left[p_t^H\frac{P_{j,t}^H y_{j,t}}{P_t^H} - \frac{y_{j,t}^{xx}}{x_t} - \frac{\eta_p}{2}\left(\frac{P_{j,t}^H}{P_{j,t-1}^H} - \left(\pi_{t-1}^H\right)^{\iota_p}\left(\pi_{ss}^H\right)^{1-\iota_p}\right)^2 y_t\right]$$

subject to:

$$
\begin{aligned}
y_{j,t} &= y_{j,t}^{xx} \\
y_{j,t} &= \left(\frac{P_{j,t}^H}{P_t^H}\right)^{-\varepsilon_t^y} y_t,
\end{aligned}
$$

here we have used $\lambda_{j,t}^p$ because capital good producers are owned by patient households, $p_t^H = \frac{P_t^H}{P_t}$, $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$, and ε_t^y is the elasticity of substitution, which follows an AR(1) process with the law of motion:

$$
\log\, \varepsilon_t^y = (1-\rho_y)\log\, \varepsilon_{ss}^y + \rho_y \log\, \varepsilon_{t-1}^y + \sigma_y e_t^y \text{ where } e_t^y \sim \mathcal{N}(0,1) \tag{viii}
$$

The demand faced by retailers is derived from the optimization problem solved by goods packers, left implicit. The FOC of retailers is:

$$
\begin{aligned}
p_t^H\left(1-\varepsilon_t^y\right) + \frac{\varepsilon_t^y}{x_t} - \eta_p \pi_t^H \left(\pi_t^H - \left(\pi_{t-1}^H\right)^{\iota_p}\left(\pi_{ss}^H\right)^{1-\iota_p}\right) + \\
\beta_p E_t \left\{ \frac{\lambda_{t+1}^p}{\lambda_t^p} \left[\left(\pi_{t+1}^H\right) \left(\frac{Y_{t+1}}{Y_t}\right) \eta_p \left(\pi_{t+1}^H - \left(\pi_t^H\right)^{\iota_p}\left(\pi_{ss}^H\right)^{1-\iota_p}\right)\right]\right\} = 0,
\end{aligned} \tag{32}
$$

where we have omitted the sub-indexes j in the FOC because of complete markets and the construction of a symmetric equilibrium, which also implies that $\lambda_{j,t}^p = \lambda_t^p$ and $P_{j,t}^H = P_t^H$. Hence we have that:

$$
y_t = \left(\int_0^\gamma y_{j,t}^{\frac{\varepsilon_t^y}{1-\varepsilon_t^y}}\, dj\right)^{\frac{1-\varepsilon_t^y}{\varepsilon_t^y}} = y_{j,t}.
$$

Finally, the individual retailer's profits are:

$$
\frac{J_t^R}{\gamma} = y_t \left[1 - \frac{1}{x_t} - \frac{\eta_p}{2}\left(\pi_t^H - \left(\pi_{t-1}^H\right)^{\iota_p}\left(\pi_{ss}^H\right)^{1-\iota_p}\right)^2\right]. \tag{33}
$$

A.10 Banks

There is a continuum of bank branches with mass γ_b. Each bank branch is composed of three units: a wholesale unit and two retail units. The two retail units are responsible for selling differentiated loans and differentiated deposits, in monopolistically competitive markets, to loan and deposit packers. The wholesale unit manages the capital position of the bank, receives loans from abroad, and raises wholesale domestic loans and deposits. The loan-retailing unit also gives loans to the government in a competitive market.

A.10.1 Wholesale unit

The wholesale unit of branch j combines bank capital, $k^b_{j,t}$, wholesale deposits, $d^b_{j,t}$, and foreign borrowing, $-\frac{B^*_{j,t}}{\gamma_b}$, in order to issue wholesale domestic loans, $b^b_{j,t}$, in a competitive market and everything expressed in terms of consumption goods. Thus, the balance sheet of the wholesale unit of branch j is:

$$b^b_{j,t} = d^b_{j,t} - \frac{B^*_{j,t}}{\gamma_b} + k^b_{j,t}.$$

The wholesale units pay a quadratic cost whenever the capital-to-assets ratio $\frac{k^b_{j,t}}{b^b_{j,t}}$ deviates from an exogenously given target, η_b. Finally, bank capital, in nominal terms, $\hat{k}^b_j$ evolves according to the following law of motion:

$$\hat{k}^b_{j,t} = \frac{(1-\delta_b)}{\varepsilon^{kb}_t}\hat{k}^b_{j,t-1} + \omega_b \hat{j}^b_{j,t-1},$$

where ε^{kb}_t is a shock to the bank capital management and $\hat{j}^b_{j,t}$ represents the profits of the bank in nominal terms. In terms of $k^b_{j,t} \equiv \frac{\hat{k}^b_{j,t}}{P_t}$ and $j^b_{j,t} \equiv \frac{\hat{j}^b_{j,t}}{P_t}$ the latter expression becomes:

$$P_t k^b_{j,t} = \frac{(1-\delta_b)}{\varepsilon^{kb}_t} P_{t-1} k^b_{j,t-1} + \omega_b P_t j^b_{j,t-1},$$

or equivalently:

$$\pi_t k^b_{j,t} = \frac{(1-\delta_b)}{\varepsilon^{kb}_t} k^b_{j,t-1} + \omega_b \pi_t j^b_{j,t-1}.$$

Finally ε^{kb}_t follows the following law of motion:

$$\log\, \varepsilon^{kb}_t = (1-\rho_{kb})\log\, \varepsilon^{kb}_{ss} + \rho_{kb}\log\, \varepsilon^{kb}_{t-1} + \sigma_{kb} e^{kb}_t \text{ where } e^{kb}_t \sim \mathcal{N}(0,1) \tag{ix}$$

Given these definitions, the problem of the wholesale unit of branch j is to choose the amount of wholesale loans, $b^b_{j,t}$, and wholesale deposits, $d^b_{j,t}$, and foreign borrowing, B^*_t, in order to maximize cash flows:

$$\max_{b^b_{j,t}, d^b_{j,t}, B^*_{j,t}} r^b_t b^b_{j,t} - r_t d^b_{j,t} + r^*_t \frac{B^*_{j,t}}{\gamma_b} - \frac{\eta_b}{2}\left(\frac{k^b_{j,t}}{b^b_{j,t}} - \nu_b\right)^2 k^b_{j,t},$$

where r^b_t, r_t, and r^*_t are the gross real interest rates for wholesale lending, wholesale deposits, and foreign borrowing respectively, all of them taken as given and in terms of the consumption goods. The rate r_t is the monetary policy rate that follows from the assumption that wholesale units can obtain funds from the monetary authority at that rate. The FOC displays the following results:

$$(r_t^b - r_t^*) = -\eta_b \left(\frac{k_t^b}{b_t^b} - \nu_b \right) \left(\frac{k_t^b}{b_t^b} \right)^2. \tag{34}$$

We can drop the sub-index j from the FOCs because we focus on a symmetric equilibrium where each wholesale bank unit decides its optimal capital-to-loans ratio, taking as given the capital-to-loans ratios of other banks. Accordingly, we can drop the sub-index from the law of motion for bank capital:

$$\pi_t k_t^b = \frac{(1-\delta_b)}{\varepsilon_t^{kb}} k_{t-1}^b + \omega_b \left(\frac{\pi_t J_{t-1}^b}{\gamma_b} \right), \tag{35}$$

and the balance-sheet equation of each wholesale unit:

$$b_t^b = d_t^b - \frac{B_t^*}{\gamma_b} + k_t^b. \tag{36}$$

Following Schmitt-Grohe and Uribe (2003), to ensure the stationarity of equilibrium we assume that:

$$r_t^* = \phi_t r_t, \tag{37}$$

where the risk premium ϕ_t increases with the external debt according to the expression:

$$\log \phi_t = -\widetilde{\phi} \left(\exp\left(B_t^*\right) - 1 \right) + \theta_t^{rp} \tag{38}$$

and the shock θ_t^{rp} obeys the following law of motion:

$$\theta_t^{rp} = (1-\rho_{rp})\theta_{ss}^{rp} + \rho_{rp}\theta_{t-1}^{rp} + \sigma_{rp}\, e_t^{rp} \text{ where } e_t^{rp} \sim \mathcal{N}(0,1) \tag{x}$$

A.10.2 Deposit-retailing unit

The deposit-retailing unit of branch j combines bank capital and sells a differentiated type of deposit, $d_{j,t}^{pp}$, in a monopolistically competitive market, to deposit packers, who bundle the varieties together and sell the packed deposits, in a competitive market, to patient households, d_t^{pp}. Finally, each deposit-retailing unit uses its resources to buy $d_{j,t}^b$ from the wholesale banks. Thus, the balance sheet of the deposit-retailing unit of branch j is:

$$d_{j,t}^b = d_{j,t}^{pp}.$$

The deposit-retailing unit of branch j chooses the real gross interest rate paid by its type of deposit, $r^d_{j,t}$ in order to maximize:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \lambda_t^p \left[r_t d^b_{j,t} - r^d_{j,t} d^{pp}_{j,t} - \frac{\eta_d}{2} \left(\frac{r^d_{j,t}}{r^d_{j,t-1}} - 1 \right)^2 r^d_t d^{pp}_t \right]$$

subject to:

$$\begin{aligned} d^b_{j,t} &= d^{pp}_{j,t}, \\ d^{pp}_{j,t} &= \left(\frac{r^d_{j,t}}{r^d_t} \right)^{-\varepsilon^d_t} d^{pp}_t, \end{aligned}$$

where we have used $\lambda^p_{j,t}$ because capital good producers are owned by patient households, and ε^d_t is the elasticity of substitution between types of deposits. In practice, we re-parameterize this elasticity as $\varepsilon^d_t \equiv \left(\frac{\theta^d_t}{\theta^d_t - 1} \right)$ with θ^d_t, obeying the following law of motion:

$$\log \theta^d_t = (1 - \rho_d) \log \theta^d_{ss} + \rho_d \log \theta^d_{t-1} + \sigma_d e^d_t \text{ where } e^d_t \sim \mathcal{N}(0,1) \tag{xi}$$

The demand faced by deposit-retailing units is derived from the optimization problem solved by deposits packer, left implicit. The FOCs of deposit-retailing units are:

$$\begin{aligned} & 1 + \frac{r_t}{r^d_t} \left(\frac{\theta^d_t}{\theta^d_t - 1} \right) - \left(\frac{\theta^d_t}{\theta^d_t - 1} \right) + \eta_d \left(\frac{r^d_t}{r^d_{t-1}} - 1 \right) \frac{r^d_t}{r^d_{t-1}} \\ & - \beta_p E_t \left\{ \frac{\lambda^p_{t+1}}{\lambda^p_t} \left[\eta_d \left(\frac{r^d_{t+1}}{r^d_t} - 1 \right) \left(\frac{r^d_{t+1}}{r^d_t} \right)^2 \frac{d^{pp}_{t+1}}{d^{pp}_t} \right] \right\} = 0, \end{aligned} \tag{39}$$

where we have omitted the subindexes j in the FOC because of complete markets and the construction of a symmetric equilibrium, which also implies that $\lambda^p_{j,t} = \lambda^p_t$ and $r^d_{j,t} = r^d_t$. Hence we have that:

$$d^{pp}_t = \left(\int_0^{\gamma} \left(d^{pp}_{j,t} \right)^{\frac{\varepsilon^d_t}{1-\varepsilon^d_t}} dj \right)^{\frac{1-\varepsilon^d_t}{\varepsilon^d_t}} = d^{pp}_{j,t}$$

and:

$$d^b_t = d^{pp}_t. \tag{40}$$

A.10.3 Loan-retailing unit

The loan-retailing unit of branch j borrows from the wholesale unit, $b^b_{j,t}$, creates differentiated loans and sells the resulting loan, in a monopolistically competitive market, to loan packers, who sell the packed loans to impatient households, $b^{ii}_{j,t}$ and entrepreneurs, $b^{ee}_{j,t}$. Each loan-retailing unit also lends to the government, B^g_t, in a competitive market at a rate $\theta^g_{ss}r^b_t$, i.e., charging a mark-up over the cost of the funds, but taking both the mark-up and the cost of the funds as given. Thus, the balance-sheet of the loan-retailing unit of branch j is:

$$b^{ii}_{j,t} + b^{ee}_{j,t} + \frac{\alpha_{B_g}\alpha_{RW}B^g_t}{\gamma_b} = b^b_{j,t}.$$

The loan-retailing unit of branch j chooses the real gross interest rates for its loans to impatient households, $r^{bi}_{j,t}$, and entrepreneurs, $r^{be}_{j,t}$, in order to maximize profits subject to:

$$b^{ii}_{j,t} + b^{ee}_{j,t} + \frac{\alpha_{B_g}\alpha_{RW}B^g_t}{\gamma_b} = b^b_{j,t},\ b^{ii}_{j,t} = \left(\frac{r^{bi}_{j,t}}{r^{bi}_t}\right)^{-\varepsilon^{bi}_t} b^{ii}_t, \text{ and } b^{ee}_{j,t} = \left(\frac{r^{be}_{j,t}}{r^{be}_t}\right)^{-\varepsilon^{be}_t} b^{ee}_t,$$

where we have used $\lambda^p_{j,t}$ because capital good producers are owned by patient households, ε^{bi}_t and ε^{be}_t are the elasticities of substitution between types of loans for impatient households and for entrepreneurs, respectively. In practice, we re-parameterize these elasticities as $\varepsilon^{bs}_t \equiv \left(\frac{\theta^{bs}_t}{\theta^{bs}_t - 1}\right)$ for $s = i, e$ with θ^{bs}_t, obeying the following law of motion:

$$\log\,\theta^{bs}_t = (1-\rho_{bs})\log\,\theta^{bs}_{ss} + \rho_{bs}\log\,\theta^{bs}_{t-1} + \sigma_{bs}e^{bs}_t \text{ where } e^{bs}_t \sim \mathcal{N}(0,1) \qquad \text{(xii - xiii)}$$

The demand faced by the loan-retailing unit is derived from the optimization problem solved by loan packers, left implicit.

A.10.4 Profits

The profit of the bank branch j in terms of consumption good units is given by:

$$\begin{aligned} j^b_t = {} & r^{bi}_t b^{ii}_t + r^{be}_t b^{ee}_t + \theta^g_{ss} r^b_t \left(\alpha_{RW}\frac{B^g_t}{\gamma_b}\right) - r^d_t d^{pp}_t + r^*_t \frac{B^*_t}{\gamma_b} - \frac{\eta_b}{2}\left(\frac{k^b_t}{b^b_t} - \nu_b\right)^2 k^b_t \\ & - \frac{\eta_d}{2}\left(\frac{r^d_t}{r^d_{t-1}} - 1\right)^2 r^d_t d_t - \frac{\eta_{bi}}{2}\left(\frac{r^{bi}_t}{r^{bi}_{t-1}} - 1\right)^2 r^{bi}_t b^{ii}_t - \frac{\eta_{be}}{2}\left(\frac{r^{be}_t}{r^{be}_{t-1}} - 1\right)^2 r^{be}_t b^{ee}_t, \end{aligned} \qquad (41)$$

where again we drop the sub-index j for the reasons mentioned above.

A.11 External sector

We consider a world of two asymmetric countries in which the home country is small relative to the other (the rest of the world), whose equilibrium is taken as exogenous (see Monacelli, 2004; Galí and Monacelli, 2005).

A.11.1 Imports

There is a continuum of consumption good packers in the economy indexed by j with mass γ_c that buy domestic goods from good packers, $c^h_{j,t}$, and import foreign goods, $c^f_{j,t}$, pack them and sell the bundle, in a competitive market, to households and entrepreneurs for consumption. The packing technology is expressed by the following CES composite baskets of home- and foreign-produced goods:

$$c^c_{j,t} = \left((1 - \omega^c \varepsilon^{\omega d}_t)^{\frac{1}{\sigma_c}} \left(c^h_{j,t} \right)^{\frac{\sigma_c - 1}{\sigma_c}} + (\omega^c \varepsilon^{\omega d}_t)^{\frac{1}{\sigma_c}} \left(c^f_{j,t} \right)^{\frac{\sigma_c - 1}{\sigma_c}} \right)^{\frac{\sigma_c}{\sigma_c - 1}}.$$

There is also a continuum of investment good packers in the economy indexed by j with mass γ_z that buy domestic goods from good packers, $i^h_{j,t}$, and import foreign goods, $i^f_{j,t}$, pack them and sell the bundle, in a competitive market, to capital producers. The technology is given by

$$i^z_{j,t} = \left((1 - \omega^i \varepsilon^{\omega d}_t)^{\frac{1}{\sigma_i}} \left(i^h_{j,t} \right)^{\frac{\sigma_i - 1}{\sigma_i}} + (\omega^i \varepsilon^{\omega d}_t)^{\frac{1}{\sigma_i}} \left(i^f_{j,t} \right)^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i - 1}},$$

where σ_c and σ_i are the consumption and investment elasticities of substitution between domestic and foreign goods and, ω^c and ω^i, are inversely related to the degree of home bias and, therefore, directly with openness. These parameters are assumed to be affected by the same shock, $\varepsilon^{\omega d}_t$, which evolves over time according to the following expressions:

$$\log \varepsilon^{\omega d}_t = (1 - \rho_{\omega d}) \log \varepsilon^{\omega d}_{ss} + \rho_{\omega d} \log \varepsilon^{\omega d}_{t-1} + \sigma_{\omega d} e^{\omega d}_t \text{ where } e^{\omega d}_t \sim \mathcal{N}(0, 1) \tag{xiv}$$

Each period, the consumption goods packer chooses $c^h_{j,t}$ and $c^f_{j,t}$ to minimize production costs subject to the technological constraint. The FOCs are:

$$c^h_{j,t} = (1 - \omega^c \varepsilon^{\omega d}_t) \left(p^H_t \right)^{-\sigma_c} c^c_{j,t},$$
$$c^f_{j,t} = (\omega^c \varepsilon^{\omega d}_t) \left(p^M_t \right)^{-\sigma_c} c^c_{j,t},$$

where p^H_t is the price of domestic goods relative to consumption goods and p^M_t is the price of imported goods relative to consumption goods. Similarly, the FOCs for the investment goods packer are:

$$i_{j,t}^{h} = (1 - \omega^{i}\varepsilon_{t}^{\omega d}) \left(\frac{p_{t}^{H}}{p_{t}^{I}}\right)^{-\sigma_{i}} i_{j,t}^{z},$$
$$i_{j,t}^{f} = (\omega^{i}\varepsilon_{t}^{\omega d}) \left(\frac{p_{t}^{M}}{p_{t}^{I}}\right)^{-\sigma_{i}} i_{j,t}^{z},$$

where p_t^I is the price of investment goods relative to consumption goods.

By assuming a symmetric equilibrium we can drop the sub-index j to get:

$$c_{t}^{h} = (1 - \omega^{c}\varepsilon_{t}^{\omega d}) \left(p_{t}^{H}\right)^{-\sigma_{c}} c_{t}^{c}, \tag{42}$$
$$c_{t}^{f} = (\omega^{c}\varepsilon_{t}^{\omega d}) \left(p_{t}^{M}\right)^{-\sigma_{c}} c_{t}^{c}, \tag{43}$$
$$i_{t}^{h} = (1 - \omega^{i}\varepsilon_{t}^{\omega d}) \left(\frac{p_{t}^{H}}{p_{t}^{I}}\right)^{-\sigma_{i}} i_{t}^{z}, \tag{44}$$
$$i_{t}^{f} = (\omega^{i}\varepsilon_{t}^{\omega d}) \left(\frac{p_{t}^{M}}{p_{t}^{I}}\right)^{-\sigma_{i}} i_{t}^{z}. \tag{45}$$

Because profits have to be zero, we have the following relationships:

$$1 = \left((1 - \omega^{c}\varepsilon_{t}^{\omega d}) \left(p_{t}^{H}\right)^{1-\sigma_{c}} + (\omega^{c}\varepsilon_{t}^{\omega d}) \left(p_{t}^{M}\right)^{1-\sigma_{c}}\right)^{\frac{1}{1-\sigma_{c}}}, \tag{46}$$
$$p_{t}^{I} = \left((1 - \omega^{i}\varepsilon_{t}^{\omega d}) \left(p_{t}^{H}\right)^{1-\sigma_{i}} + (\omega^{i}\varepsilon_{t}^{\omega d}) \left(p_{t}^{M}\right)^{1-\sigma_{i}}\right)^{\frac{1}{1-\sigma_{i}}}. \tag{47}$$

Given the small open economy assumption, the price of imports in domestic currency is defined as:

$$p_{t}^{M} = er_{t}(1 + \tau_{t}^{m}), \tag{48}$$

where er_t is the real exchange rate (and ER_t the nominal exchange rate), i.e., $er_t = \frac{ER_t P_t^*}{P_t}$, τ_t^m represents the import tariff, and P_t^* stands for the exogenous world price index.[2] Hence, the price of imports will inherit any stickiness associated with P_t^*. Since we model P_t^* from

[2] In a full monetary union the tariff rate is zero.

Some definitions follow from the previous equations:

$$C_t = \gamma_c c_t^c, \tag{49}$$

$$C_t^h = \gamma_c c_t^h, \tag{50}$$

$$I_t = \gamma_z i_t^z, \text{ and} \tag{51}$$

$$I_t^h = \gamma_z i_t^h, \tag{52}$$

where C_t is aggregate consumption and I_t is aggregate investment. Aggregate imports are:

$$IM_t = \gamma_c c_t^f + \gamma_z i_t^f = C_t^f + I_t^f. \tag{53}$$

Therefore, the following equalities hold in aggregate:

$$C_t = \gamma_c c_t^c = p_t^H \gamma_c c_t^h + p_t^M \gamma_c c_t^f = \gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m,$$
$$I_t = \gamma_z i_t^z = \frac{p_t^H}{p_t^I} \gamma_z i_t^h + \frac{p_t^M}{p_t^I} \gamma_z i_t^f = \gamma_k i_t.$$

A.11.2 Exports

Good packers are the ones that export. We assume that there is some degree of imperfect exchange rate pass through. To make this assumption operational, we consider a fraction $(1 - ptm)$ of good packers whose prices at home and abroad differ. The remaining fraction of good packers, ptm, sets a unified price across countries (i.e., the law of one price holds). Thus, the export price deflator relative to consumption goods, p_t^{EX}, is defined as:

$$p_t^{EX} = (1 - \tau_t^x) p_t^{H(1-ptm)} \left(er_t\right)^{ptm}, \tag{54}$$

where τ_t^x is an export subsidy and the parameter ptm determines the degree of pass through.

There is a continuum of foreign consumers and investors with mass γ^* whose demands for domestic goods from good packers are given by:

$$c_t^{*f} = \omega_t^f \left(\frac{p_t^{EX}}{er_t} \right)^{-\sigma_c^*} c_t^*, \tag{55}$$

$$i_t^{*f} = \omega_t^f \left(\frac{p_t^{EX}}{er_t} \right)^{-\sigma_c^*} i_t^*, \tag{56}$$

where c_t^* and i_t^* represent the (exogenous) aggregate consumption and investment demand in the rest of the world, and ω_t^f captures the impact of factors other than prices affecting Spanish exports that is assumed to obey the following law of motion:

$$\omega_t^f = (1-\rho_{\omega f})\omega_{ss}^f + \rho_{\omega f}\omega_{t-1}^f + \sigma_{\omega f}\ e_t^{\omega f} \text{ where } e_t^{\omega f} \sim \mathcal{N}(0,1) \tag{xv}$$

Therefore, exports of the home economy $ex_t = c_t^{*f} + i_t^{*f}$ can be written as:

$$ex_t = \omega_t^f \left(\frac{p_t^{EX}}{er_t}\right)^{-\sigma_c^*} (c_t^* + i_t^*). \tag{57}$$

Plugging (54) into (57) yields:

$$ex_t = \omega_t^f \left((1-\tau_t^x)\left(\frac{p_t^H}{er_t}\right)^{(1-ptm)}\right)^{-\sigma_c^*} (c_t^* + i_t^*).$$

Finally, we can define aggregate exports as:

$$EX_t = \gamma^* ex_t. \tag{58}$$

A.11.3 Accumulation of foreign assets

The net foreign asset position B_t^* evolves according to the following expression (denominated in the home currency):

$$B_t^* = \frac{\left(1+r_{t-1}^*\right)}{\pi_t} B_{t-1}^* + \left[p_t^{EX}\gamma^* ex_t - p_t^M\left(\gamma_c c_t^f + \gamma_z i_t^f\right)\right] \tag{59}$$

where a negative/positive sign for B_t^* implies a borrowing/lending position for the domestic economy with respect to the rest of the world and r_t^* stands for the interest rate paid/received for borrowing/lending abroad. Also, trade balance TB_t is defined as:

$$TB_t = p_t^{EX}\gamma^* ex_t - p_t^M\left(\gamma_c c_t^f + \gamma_z i_t^f\right). \tag{60}$$

A.12 Prices in the model

Prices in the model are written relative to before-consumption-tax CPI. Thus, the numeraire is P_t. Here we establish some relationships between prices and inflation rates, where P_t^H is the (absolute) price of domestic-produced output and $p_t^H = \frac{P_t^H}{P_t}$ is the corresponding relative price. Also, π_t^H, the gross inflation rate that appears in the New Phillips curve, is defined as $\frac{P_t^H}{P_{t-1}^H}$. Correspondingly, the gross inflation rate for the relative price is:

$$\widetilde{\pi}_t^H = \frac{p_t^H}{p_{t-1}^H}. \tag{61}$$

Notice that both π_t^H and $\widetilde{\pi}_t^H$ are identified in the equations of the model, the former in the New Phillips curve and the latter because we write some equations in terms of p_t^H. However, we cannot identify P_t^H or P_t. The inflation rate considered by the central bank in the Taylor rule is π_t' (the post-consumption-tax gross inflation rate). We cannot obtain π_t' directly from P_t, because it is not identified, but we can recover it from π_t^H and $\widetilde{\pi}_t^H$ as

$$\pi_t' = \frac{P_t}{P_{t-1}} \frac{1+\tau t^c}{1+\tau_{t-1}^c} = \frac{\frac{P_t}{P_t^H}}{\frac{P_{t-1}}{P_{t-1}^H}} \frac{P_t^H}{P_{t-1}^H} \frac{1+\tau t^c}{1+\tau t-1^c} = \frac{\pi_t^H}{\widetilde{\pi}_t^H} \frac{1+\tau t^c}{1+\tau t-1^c}, \tag{62}$$

and the before-consumption-tax inflation rate as

$$\pi_t = \frac{\pi_t^H}{\widetilde{\pi}_t^H}. \tag{63}$$

A.13 Monetary authority

The domestic economy belongs to a monetary union (say, the EMU), and monetary policy is managed by the central bank (say, the ECB) through the following Taylor rule that sets the nominal area-wide reference interest rate allowing for some smoothness of the interest rate's response to inflation and output:

$$(1+r_t) = (1+r_{ss})^{(1-\phi_r)}(1+r_{t-1})^{\phi_r} \left(\frac{\pi_t^{emu}}{\pi_{ss}^{emu}}\right)^{\phi_\pi(1-\phi_r)} \left(\frac{y_t^{emu}}{y_{t-1}^{emu}}\right)^{\phi_y(1-\phi_r)} (1+e_t^r), \tag{64}$$

where π_t^{emu} is EMU inflation as measured in terms of the consumption price deflator and $\frac{y_t^{emu}}{y_{t-1}^{emu}}$ measures the gross rate of growth of EMU output. There is also some inertia in setting the nominal interest rate, and the shock to the central bank interest rate is characterized by:

$$e_t^r \sim \mathcal{N}(0, \sigma_r) \tag{xvi}$$

The domestic economy contributes to EMU inflation and output growth according to its economic size in the Eurozone, ω_{Sp}:

$$\pi_t^{emu} = (1-\omega_{Sp})\left(\overline{\pi_t^{remu}}\right) + \omega_{Sp}\pi_t' \text{ and} \tag{65}$$

$$\frac{y_t^{emu}}{y_{t-1}^{emu}} = (1-\omega_{Sp})\left(\overline{\left(\frac{y_t^{remu}}{y_{t-1}^{remu}}\right)}\right) + \omega_{Sp}\frac{y_t}{y_{t-1}} \tag{66}$$

where $\overline{\pi_t^{remu}}$ and $\overline{\left(\frac{y_t^{remu}}{y_{t-1}^{remu}}\right)}$ are average (exogenous) inflation and output growth in the rest of the Eurozone.

The real exchange rate is given by the ratio of relative prices between the domestic economy and the remaining EMU members, so real appreciation/depreciation developments are driven by the inflation differential of the domestic economy vis-à-vis the euro area:

$$\frac{er_t}{er_{t-1}} = \frac{\overline{\pi_t^{remu}}}{\pi_t}. \tag{67}$$

A.14 Fiscal authority

There is also a fiscal authority with a flow of expenses determined by government consumption, government investment, and interest plus principal borrowed during the previous period. The fiscal authority collects revenues with new debt, lump-sum taxes, and distortionary taxation on consumption, housing services, labor income, loans, and deposits. Hence, we have:

$$\begin{aligned}
&C_t^g + I_t^g + \left(\frac{1+\theta_{ss}^b r_{t-1}^b}{\pi_t}\right) B_{t-1}^g = B_t^g + T_t^g + \tau_t^c \left(\gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m\right) + \\
&\frac{\tau_t^m}{1+\tau_t^m} p_t^M IM_t - \frac{\tau_t^x}{1-\tau_t^x} p_t^{EX} EX_t + \\
&\tau_t^h q_t^h \left[\gamma_p (h_t^p - (1-\delta_h) h_{t-1}^p) + \gamma_i (h_t^i - (1-\delta_h) h_{t-1}^i)\right] + \tau_t^w \left(w_t^p \gamma_p \ell_t^p + w_t^i \gamma_i \ell_t^i + w_t^m \gamma_m \ell_t^m\right) + \tau_t^k r_t^k K_t + \\
&\tau_t^{fb} \left(\gamma_i \Delta b_t^i + \gamma_e \Delta b_t^e\right) + \tau_t^{fd} \gamma_p \Delta d_t^p + \tau_t^d \left(\frac{r_{t-1}^d}{\pi_t}\right) \gamma_p d_{t-1}^p.
\end{aligned} \tag{68}$$

Tax rates are constant:

$$\tau_t^s = \tau^s \text{ for } s = c, h, w, d, fd, fb, k, m, x.$$

Government consumption and investment are considered to be random proportions of potential GDP. Given that this model does not feature growth in the variables, this is equivalent to saying that both public consumption and public investment move randomly along a constant, i.e.,

$$C_t^g = \psi^{cg} \varepsilon_t^{cg} \tag{69}$$

$$I_t^g = \psi^{ig} \varepsilon_t^{ig} \tag{70}$$

where ψ^{cg} and ψ^{ig} are two parameters and both ε_t^{cg} and ε_t^{ig} are shocks that move according to the following law of motion:

$$\log\,\varepsilon_t^{cg} = (1-\rho_{cg})\log\,\varepsilon_{ss}^{cg} + \rho_{cg}\log\,\varepsilon_{t-1}^{cg} + \sigma_{cg}e_t^{cg} \text{ where } e_t^{cg} \sim \mathcal{N}(0,1) \tag{xvii}$$

$$\log\,\varepsilon_t^{ig} = (1-\rho_{ig})\log\,\varepsilon_{ss}^{ig} + \rho_{ig}\log\,\varepsilon_{t-1}^{ig} + \sigma_{ig}e_t^{ig} \text{ where } e_t^{ig} \sim \mathcal{N}(0,1) \tag{xviii}$$

Lump-sum taxes adjust to guarantee the non-explosiveness of government debt according to the following rule,

$$T_t^g = T_{t-1}^g + \rho_{tgb1}\left(\psi_t^{bg} - \psi_{ss}^{bg}\right) + \rho_{tgb2}\left(\psi_t^{bg} - \psi_{t-1}^{bg}\right), \tag{71}$$

where ψ_t^{bg} represents the proportion of public debt over aggregate output, namely,

$$\psi_t^{bg} = \frac{B_t^g}{Y_t} \tag{72}$$

and ψ_{ss}^{bg} refers to its steady-state objective value. In turn, public debt adjusts to satisfy the budget constraint given the above levels of C_t^g, I_t^g and T_t^g.

Finally, public capital evolves with investment according to the law of motion:

$$K_t^g = (1-\delta_g)K_{t-1}^g + I_t^g. \tag{73}$$

A.15 Aggregation and market clearing in equilibrium

The supply of labor equals the corresponding demand for the three types of households:

$$\int_0^{\gamma_p} \ell_{j,t}^p dj = \int_0^{\gamma_x} \ell_{j,t}^{pp} dj \Rightarrow \gamma_p \ell_t^p = \gamma_x \ell_t^{pp}, \tag{74}$$

$$\int_0^{\gamma_i} \ell_{j,t}^i dj = \int_0^{\gamma_x} \ell_{j,t}^{ii} dj \Rightarrow \gamma_i \ell_t^i = \gamma_x \ell_t^{ii}, \text{ and} \tag{75}$$

$$\int_0^{\gamma_m} \ell_{j,t}^m dj = \int_0^{\gamma_x} \ell_{j,t}^{mm} dj \Rightarrow \gamma_m \ell_t^m = \gamma_x \ell_t^{mm}. \tag{76}$$

The supply of capital by capital producers equals the corresponding demand by entrepreneurs, while the supply of capital services by the latter equals the demand of these services by intermediate good producers:

$$\int_0^{\gamma_e} k_{j,t}^e dj = \int_0^{\gamma_k} k_{j,t} dj \Rightarrow \gamma_e k_t^e = \gamma_k k_t \text{ and} \tag{77}$$

$$\int_0^{\gamma_x} k_{j,t}^{ee} dj = \int_0^{\gamma_e} k_{j,t}^e dj \Rightarrow \gamma_x k_t^{ee} = \gamma_e k_t^e. \tag{78}$$

A.15.1 Housing market

The supply of housing by housing producers equals the corresponding demand by patient and impatient households:

$$\int_0^{\gamma_h} h_{j,t} dj = \int_0^{\gamma_p} h_{j,t}^p dj + \int_0^{\gamma_i} h_{j,t}^i dj \Rightarrow \gamma_h h_t = H_t = \gamma_p h_t^p + \gamma_i h_t^i. \tag{79}$$

A.15.2 Intermediate goods

The demand for intermediate goods by retailers equals the supply of them by intermediate good producers:

$$\int_0^{\gamma_x} y_{j,t}^x dj = \int_0^{\gamma} y_{j,t}^{xx} dj \Rightarrow \gamma_x y_t^x = \gamma y_t, \tag{80}$$

where the last equality follows from the production function for final goods, $y_{j,t} = y_{j,t}^{xx}$.

A.15.3 Labor market

We can define aggregate real wage as

$$w_t = \frac{\gamma_p w_t^p + \gamma_i w_t^i + \gamma_m w_t^m}{\gamma_p + \gamma_i + \gamma_m} \tag{81}$$

Thus, the quarter-on-quarter rate of growth of the real wage is:

$$\pi_t^w = \frac{w_t}{w_{t-1}} \tag{82}$$

A.15.4 Loan and deposits

The loan demand by impatient households and entrepreneurs equals the corresponding supply by loan-retailing units:

$$\int_0^{\gamma_i} b_{j,t}^i dj = \int_0^{\gamma_b} b_{j,t}^{ii} dj \Rightarrow \gamma_i b_t^i = \gamma_b b_t^{ii} \text{ and} \tag{83}$$

$$\int_0^{\gamma_e} b_{j,t}^e dj = \int_0^{\gamma_b} b_{j,t}^{ee} dj \Rightarrow \gamma_e b_t^e = \gamma_b b_t^{ee}. \tag{84}$$

The demand for deposits by patient households equals the deposit supply by deposit-retailing banks:

$$\int_0^{\gamma_p} d_{j,t}^p dj = \int_0^{\gamma_b} d_{j,t}^{pp} dj \Rightarrow \gamma_p d_t^p = \gamma_b d_t^{pp}. \tag{85}$$

A.15.5 Consumption and investment

The supply of consumption goods by consumption packers equals the demand by households and entrepreneurs:

$$\int_0^{\gamma_c} c_t^c dj = \gamma_c c_t^c = \gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m. \tag{86}$$

The demand for investment goods by capital producers equals the supply of them by investment goods packers:

$$\int_0^{\gamma_z} i_t^z dj = \gamma_z i_t^z = \gamma_k i_t. \tag{87}$$

A.15.6 Aggregate resource constraint

GDP, Y_t^1, can be defined as:

$$\begin{aligned} p_t^H Y_t^1 &= C_t + p_t^I I_t + p_t^H I_t^{ho} + p_t^H C_t^g + p_t^H I_t^g + p_t^{EX} EX_t - p_t^M IM_t = \\ &= p_t^H C_{ht} + p_t^H I_{ht} + p_t^H I_t^{ho} + p_t^H C_t^g + p_t^H I_t^g + p_t^{EX} EX_t \end{aligned} \tag{88}$$

By aggregating the budget constraints of households and plugging in the market clearing conditions, we can derive the following expression for the effective aggregate demand for final goods in equilibrium:

$$
\begin{aligned}
p_t^H Y_t \quad = \quad & p_t^H Y_t^1 + \tfrac{\tau_t^x}{1-\tau_t^x} p_t^{EX} EX_t - \tfrac{\tau_t^m}{1+\tau_t^m} p_t^M IM_t \\
+ \quad & \left[\psi_{u_1}(u_t - 1) + \tfrac{\psi_{u_2}}{2}(u_t-1)^2\right] K_{t-1} + \delta_b \tfrac{K_{t-1}^b}{\pi_t} + \tfrac{\eta_p}{2}\left(\pi_t - \pi_{t-1}^{\iota_p}\pi^{1-\iota_p}\right)^2 Y_t \\
+ \quad & \tfrac{1}{\pi_t}\left[\tfrac{\eta_d}{2}\left(\tfrac{r_{t-1}^d}{r_{t-2}^d} - 1\right)^2 r_{t-1}^p D_{t-1} + \tfrac{\eta_{bi}}{2}\left(\tfrac{r_{t-1}^{bi}}{r_{t-2}^{bi}} - 1\right)^2 r_{t-1}^{bi} B_{t-1}^i + \tfrac{\eta_{be}}{2}\left(\tfrac{r_t^{be}}{r_{t-2}^{be}} - 1\right)^2 r_{t-1}^{be} B_{t-1}^e\right] \\
+ \quad & \tfrac{\eta_b}{2}\left(\tfrac{K_{t-1}^b}{B_{t-1}} - \nu_b\right)^2 \tfrac{K_{t-1}^b}{\pi_t} + \tfrac{\gamma_p \eta_w}{2}\left(\pi_t^{wp} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2 w_t^p + \tfrac{\gamma_i \eta_w}{2}\left(\pi_t^{wi} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2 w_t^i \\
+ \quad & \tfrac{\gamma_m \eta_w}{2}\left(\pi_t^{wm} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2 w_t^m + \Phi_x + p_t^I\left(\tfrac{\eta_i}{2}\tfrac{I_t^2}{K_{t-1}}\right) + p_t^H\left(\tfrac{\eta_h}{2}\tfrac{\left(I_t^{ho}\right)^2}{H_{t-1}}\right) \\
+ \quad & (1-\alpha_{RW})\tfrac{B_{t-1}^g}{\pi_t} + \left[(1-\alpha_{RW})\theta_{ss}^g r_{t-1}^b\right]\tfrac{B_{t-1}^g}{\pi_t} - \left[\alpha_{RW}(1-\alpha_{Bg})(r_{t-1}^d - \theta_{ss}^g r_{t-1}^b)\right]\tfrac{B_{t-1}^g}{\pi_t} \\
- \quad & (1-\alpha_{RW}) B_t^g,
\end{aligned}
\tag{89}
$$

where

$$Y_t = \gamma y_t = \gamma_x y_t^x, \tag{90}$$

$$C_t = \gamma_p c_t^p + \gamma_i c_t^i + \gamma_m c_t^m + \gamma_e c_t^e = p_t^H C_{ht} + p_t^M C_{ft}, \tag{91}$$

$$I_t = \gamma_z i_t^z = \frac{p_t^H}{p_t^I} I_{ht} + \frac{p_t^M}{p_t^I} I_{ft}, \tag{92}$$

$$I_t^{ho} = \gamma_h i_t^{ho} \tag{93}$$

$$K_t = \gamma_k k_t = \gamma k_t, \tag{94}$$

$$K_t^b = \gamma_b k_t^b, \tag{95}$$

$$D_t = \gamma_p d_t^b, \tag{96}$$

$$B_t^i = \gamma_i b_t^i, \tag{97}$$

$$B_t^e = \gamma_e b_t^e, \text{ and} \tag{98}$$

$$B_t = B_t^e + B_t^i + B_t^g. \tag{99}$$

B Online Appendix: Data description and sources

The data used in the estimation of the model comprehend the (demeaned) interannual changes of the 18 quaterly time series enumerated below (after logged in the first 13 cases). For each variable we describe the economic indicators used in its construction along with their sources. The sample period is 1992Q4-2019Q4[3].

1. **Per capita households consumption** (C_t/γ^{all}): real private consumption divided by working-age population

    - **Real private consumption**: final consumption expenditure of households and non-profit institutions serving households at constant prices, seasonal and calendar effect adjusted (INE)
    - **Working-age population**: Population in family dwellings of 16 years old and over (INE)

2. **Per capita output** (Y_t^1/γ^{all}): real output divided by working-age population

    - **Real output**: gross domestic product at constant market prices, seasonal and calendar effect adjusted (INE)

3. **Per capita government consumption** (C_t^g/γ^{all}): nominal public consumption divided by GDP-deflator and additionally divided by working-age population

    - **Nominal public consumption**: final consumption expenditure of the Public Administrations at current prices, seasonal and calendar effect adjusted (INE)
    - **GDP-deflator**: Implicit deflator of gross domestic product. Seasonally adjusted by the authors.

4. **Per capita Government investment** (I_t^g/γ^{all}): nominal public investment divided by gdp-deflator and additionally divided by working-age population

    - **Nominal public investment**: General Government's gross fixed capital formation at current prices(INE). Seasonally adjusted by the authors.

5. **Per capita non-residential investment** (I_t/γ^{all}): nominal total investment minus nominal public investment and residential investment, divided by total-investment-deflator and additionally divided by working-age population

[3] Recall that $\gamma^{all} = \gamma^p + \gamma^i + \gamma^m + \gamma^e$ denotes the total population of consumers (patient + impatient + hand-to-mouth+entrepreneurs).

- **Nominal total investment**: gross fixed capital formation at current prices, seasonal and calendar effect adjusted (INE)

- **Total investment deflator**: Implicit deflator of gross fixed capital formation, seasonal and calendar effect adjusted (INE)

6. **Per capita residential investment** (I_t^{ho}/γ^{all}): residential investment, divided by total-investment-deflator and additionally divided by working-age population

7. **Employment rate** (L_t/γ^{all}): Full time equivalent employment divided by working-age population

   - **Full time equivalent employment**: Full time equivalent employment, seasonal and calendar effect adjusted (INE)

8. **Per capita imports** (IM_t/γ^{pime}): real imports divided by working-age population

   - **Real imports**: Imports of goods and services at constant prices, seasonal and calendar effect adjusted (INE)

9. **Per capita households and entrepreneurs lending** ($B_t/\gamma^{pime} = B_t^i/\gamma^{pime} + B_t^e/\gamma^{pime}$): total nominal lending divided by working-age population: sum of households nominal lending (housing and non-housing) divided by the private-consumption-deflator and additionally divided by working-age population, plus nominal entrepreneurs lending divided by the private-consumption-deflator and additionally divided by working-age population.

   - **Households nominal housing lending:**
     - ENTIDADES DE CRÉDITO Y EFC. OSR. Crédito para adquisición de vivienda propia (BdE Statistical Bulletin)
     - ENTIDADES DE CRÉDITO Y EFC. OSR. Crédito para rehabilitación de vivienda (BdE Statistical Bulletin)
     - ENTIDADES DE CRÉDITO RESIDENTES. Financiación a los hogares e instituciones sin fines de lucro que prestan servicios a los hogares. Préstamos titulizados fuera de balance para vivienda (BdE Economic Indicators)
   - **Households nominal non-housing lending:**

- ENTIDADES DE CRÉDITO Y EFC. OSR. Crédito para adquisición de bienes de consumo duradero (BdE Statistical Bulletin)
- ENTIDADES DE CRÉDITO Y EFC. OSR. Crédito para adquisición de bienes de consumo no duradero (BdE Statistical Bulletin)
- OIFM. PRÉSTAMOS Y CRÉDITOS A LAS FAMILIAS. Resto de crédito excepto financiación actividades productivas (BdE Statistical Bulletin)
- ENTIDADES DE CRÉDITO RESIDENTES. Financiación a los hogares e instituciones sin fines de lucro que prestan servicios a los hogares. Préstamos titulizados fuera de balance distintos de vivienda (BdE Economic Indicators)

- **Nominal entrepreneurs lending:**
  - ENTIDADES DE CRÉDITO Y EFC. OSR. Crédito para financiación de actividades productivas (BdE Statistical Bulletin)
  - ENTIDADES DE CRÉDITO Y EFC. OSR. Crédito para financiación a las sociedades no financieras. Préstamos titulizados fuera de balance (BdE Statistical Bulletin)

- **Private consumption deflator**: Implicit deflator of final consumption expenditure of households and non-profit institutions serving households(INE)

10. **Per capita banks capital** (K_t^b/γ^{pime}): nominal bank capital divided by private-consumption-deflator and additionally divided by working-age population.

    - **Nominal banks capital:** ENTIDADES DE CRÉDITO Y EFC. Capital y reservas. Patrimonio neto. Total fondos propios (BdE Statistical Bulletin).

11. **Housing price** (q_t^h): nominal housing price divided by private-consumption-deflator

    - **Nominal housing price**: Price m2 free housing (INE from Ministry of Development)

12. **GDP deflator** (P_t^H): GDP deflator (INE).

13. **Real wage** (w_t): ratio of the total remuneration of employees over the total number of wage earners, seasonal and calendar effect adjusted (INE), divided by the GDP deflator (INE).

14. **Interest rate for Households lending** (r_t^{bi}): it is the weighted average of the interest rates for housing loans and non-housing loans given, respectively, by the following two indicators:

- **Interest rates for housing loans**: Tipo de interés (medias ponderadas). Nuevas operaciones. ENTIDADES DE CRÉDITO Y EFC. TEDR. A los hogares. Crédito a la vivienda (BdE Statistical Bulletin)
- **Interest rates for non-housing loans**: Tipo de interés (medias ponderadas). Nuevas operaciones.ENTIDADES DE CRÉDITO Y EFC. TEDR. A los hogares. Crédito al consumo (BdE Statistical Bulletin)

Weights are given by nominal households housing lending and nominal households non-housing lending respectively.

15. **Interest rate for Entrepreneurs lending** (r_t^{be}): Tipos de interés. Nuevas operaciones. ENTIDADES DE CRÉDITO Y EFC. TEDR. Crédito a sociedades no financieras.Descubiertos encuenta y créditos renovables (BdE Statistical Bulletin).

16. **Interest rate for deposits** (r_t^d): Tipos interés (medio ponderado). Nuevas operaciones. ENTIDADES DE CRÉDITO Y EFC. TEDR. Depósitos a plazo de los hogares (BdE Statistical Bulletin).

17. **Monetary policy interest rate** (r_t): The shadow short interest rate (p=3) estimated by De Rezende and Ristiniemi (2020) for the Euro Area or, alternatively, the EONIA (ECB) rate, such that these two rates only differ in the periods where the ECB has had in place unconventional monetary policies.

18. **Risk premium on foreign lending** (ϕ_t): difference between sovereign-bond-yield and monetary policy interest rate, the former given by:

    - **Sovereign-bond-yield**: Spain: 10-Year Government Bond Yield, average, percentage (HAVER-EUDATA).

C Online Appendix: Impulse Response Functions

In Figure 7 we draw the GDP IRFs to nine shocks of a 1 percent magnitude, except for the interest rate, in which case the shock doubles its initial value. The nine shocks contribute to 92 percent of the unconditional GDP variance. The qualitative response of GDP to each shock follows the economic intuition. So, higher economic efficiency, more competition in the different markets, easier borrowing or a more friendly context for exporting push aggregate output up, whilst higher interest rates, a sudden increase in imports or a shock increasing more bank capital provisions pulling it down .

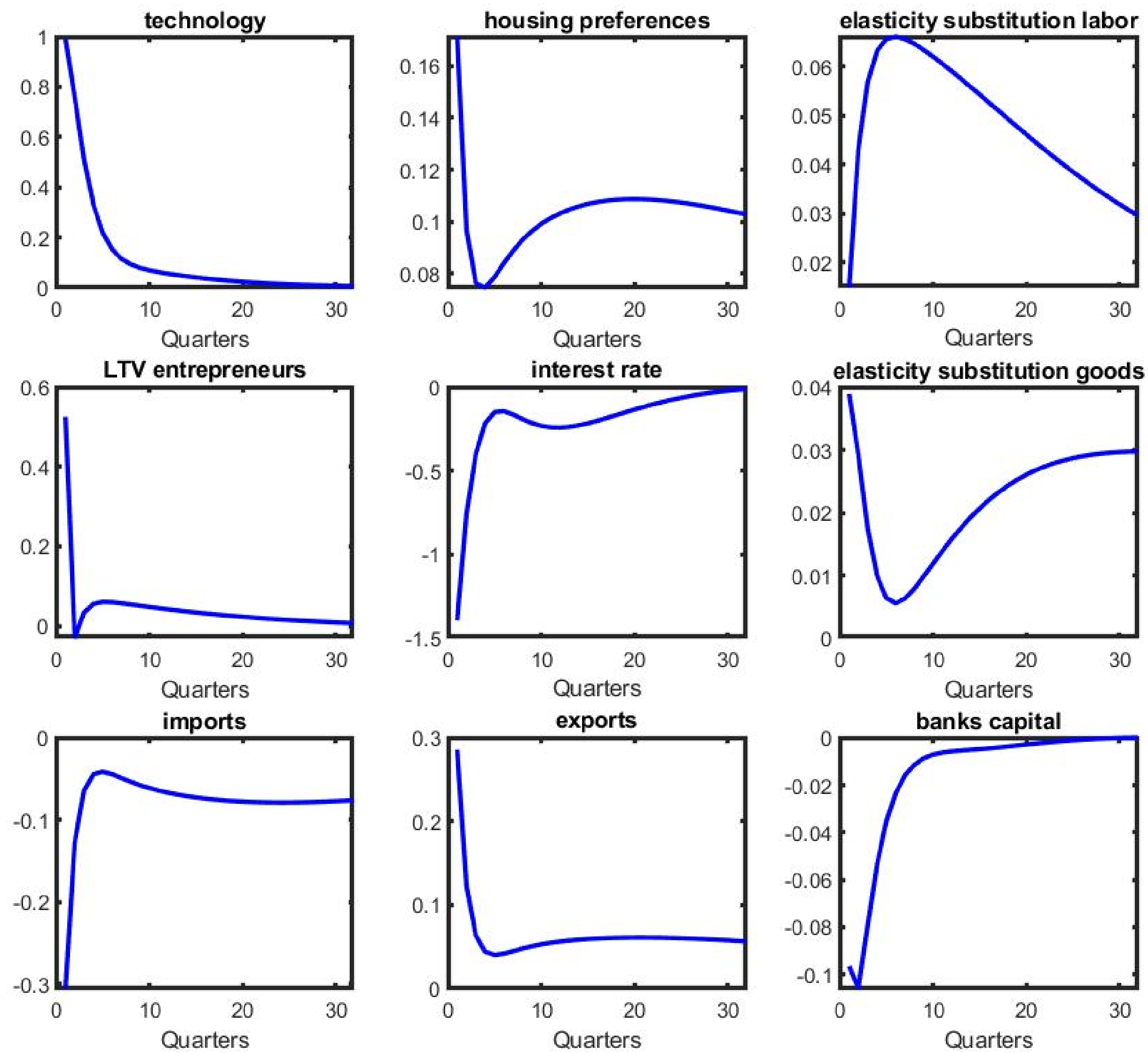

FIGURE 7: *GDP IRFs to different shocks.*