A model with financial frictions and a banking system for the Portuguese economy

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Abstract
The recent financial crisis has made clear the importance of the linkages between the financial sector and the macroeconomy, both as a trigger to the crisis but also as having an instrumental role in the propagation of the initial shock to other sectors of the economies. This has led a reassessment of the need to introduce financial frictions into what was then the workhorse macroeconomic structural model and thus to a considerable number of contributions to the literature introducing financial frictions in structural models. The introduction of financial frictions in New-Keynesian DSGE models has led to the possibility to use this models to study new questions but it has also enriched the transmission channels embedded in these models. In this paper we take a large scale open economy dynamic structural model including frictions in the financial sector, called EAGLE-FLI, and calibrate it to the Portuguese economy. The EAGLE-FLI model is built on the New-Keynesian framework and incorporates financial frictions and country-specific banking sectors. The detailed structure of the model makes it an appropriate tool to assess domestic and cross-country macroeconomic effects of financial shocks. We run simulations of several shocks in order to understand their transmission mechanisms in the model and their macroeconomic impact. We analyse not only shocks originating in the financial sector but also explore the way other shocks transmit in this model where financial frictions matter. (JEL: E51; E32; E44; F45; F47.)

Introduction

The recent financial crisis has made clear the importance of the linkages between the financial sector and the macroeconomy, both as a trigger to the crisis but also as having an instrumental role in the propagation of the initial shock to other sectors of an economy. This has led a reassessment of the need to introduce financial frictions into what was then the workhorse macroeconomic structural model (e.g. Smets and Wouters (2003), Christiano *et al.* (2005), Smets and Wouters (2007) or Christoffel *et al.* (2008) models). A considerable number of contributions to the literature introduced financial frictions in structural models, both in theoretical models but also in models developed and used at policy institutions (see for example the extension of the ECB's NAWM in Lombardo and McAdam (2012)). The introduction of

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financial frictions in New-Keynesian dynamic general equilibrium models has led to the possibility to use this models to study new questions but it has also enriched the transmission channels embedded in these models.

In this paper we take a large scale open economy dynamic structural model including frictions in the financial sector and calibrate it to the Portuguese economy. The model we use is called the EAGLE-FLI (Euro Area and Global Economy with Financial LInkages) model. This is a multi-country model of the euro area economy within the world. It is built on the New-Keynesian framework and incorporates financial frictions and country-specific banking sectors. The model includes four blocs that in the current application are calibrated to Portugal, the rest of the euro area, the US and the rest of the world. Banks collect deposits from domestic households, raise capital to finance loans issued to domestic households and firms and participate and in a cross-country interbank market. In order to borrow from local (regional) banks, households use domestic real estate as collateral whereas firms use both domestic real estate and physical capital. The detailed structure of the model makes it an appropriate tool to assess domestic and cross-country macroeconomic effects of financial shocks. We run simulations of several shocks in order to understand their transmission mechanisms in the model and their macroeconomic impact. We analyse not only shocks originating in the financial sector but also explore the way other shocks transmit in this model where financial frictions matter.

The EAGLE-FLI setup builds on several earlier contributions. In particular, the distinction between borrowers that are more impatient than savers follows Iacoviello (2005) and the banks capital requirement ratio follows Kollmann (2013) and Kollmann *et al.* (2013). Regarding the modelling of the banking sector the are several earlier contributions that include a banking sector in DSGE models. Focusing on open economy models, differently from Kollmann (2013) and Kollmann *et al.* (2013) that consider the case of a global bank (i.e. on e bank that lends domestically and abroad), the EAGLE-FLI model considers instead country-specific banks that lend to and receive deposits from domestic agents.[1]. This setup with "region-specific" banking sectors is also used in Brzoza-Brzezina *et al.* (2015), but in a smaller scale model.

The remainder of the paper is organized in the following way. The next section presents the model. We then describe the simulations. Finally, the last section concludes.

1. Allowing banks to lend and borrow at international level is different from allowing households to do the same, as they maximize different objectives subject to different constraints, such as the capital requirement. EAGLE-FLI features financial spillovers that directly affect banks behavior, and only indirectly (via banks) the foreign borrowers while in Kollmann (2013) and Kollmann, Ratto and Roeger (2013) there is a direct spillover from bank to foreign borrowers.

The EAGLE-FLI model in a nutshell

The EAGLE-FLI model developed by Bokan *et al.* (2016) incorporates financial frictions and a banking sector into an existing multi-country dynamic general equilibrium model of the euro area (see Gomes *et al.* (2012)). In this section we briefly describe the novel features of the slightly modified version of the EAGLE-FLI model used here. For a detailed description of the model's features see Bokan *et al.* (2016).[2]

The EAGLE-FLI model is a multi-country model of a monetary union within the world economy. In the model the world consists of four blocs (that may represent a country or a region), labeled Home (the H bloc, i.e. the Portuguese bloc), the rest of the euro area (REA), the US (US) and the rest of the world (RW). The size of the world economy is normalized to one and $s^H, s^{REA}, s^{US} > 0$ are respectively the sizes of Home, REA and US blocs, $s^H + s^{REA} + s^{US} < 1$. For each bloc, the size of the economy corresponds to the size of population (sum of households, bankers, entrepreneurs) and to the size of each firms' sector (intermediate tradable, intermediate nontradable, final nontradable sectors). Blocs H and REA are members of a monetary union, the euro area (EA), thus sharing the monetary policy authority and the nominal exchange rates against the remaining two blocs.

We will focus our description on the H bloc. We describe the banking sector, households' and entrepreneurs' behaviour, the monetary authority, market clearing conditions, net foreign asset position and international relative prices. The remaining blocs are broadly similar, except that the US and RW blocs have a national monetary policy authority whereas for the other two blocs the monetary authority (and policy) is common.

In each bloc there are two types of infinitely lived households, entrepreneurs, firms, banks, a fiscal authority and a monetary authority (that in the case of the euro area blocs is common to the two blocs). We start by describing the banking sector. This sector is country-specific, meaning that banks intermediate funds between domestic agents. There is a continuum of banks (a fraction $0 < \omega_B < 1$ of the population of bloc H) that act under perfect competition and, hence, maximize profits taking interest rates as given. We assume that all banks have the same preferences, constraints and initial asset positions, thus they make the same optimal choices, and as such we can consider a representative bank that maximises its expected lifetime flow of (real) dividends. In order to have a meaningful banking sector we assume that a bank intermediates funds between agents that cannot directly lend to and borrow from each other. The bank extends loans to domestic impatient households (the "borrowers") and to domestic entrepreneurs,

2. For an application of the standard EAGLE model for the Portuguese economy see Gomes *et al.* (2013).

collects deposits from domestic patient households (the "savers") and raises capital as a way to finance the extended loans.[3] Interest rates paid on loans and deposits are predetermined (i.e. paid at the beginning of the next period but known in the current period). The bank faces quadratic costs the bank faces when adjusting the amount of loans granted and the excess bank capital, defined in the following way. As in Kollmann (2013), we assume that the bank faces a regulatory capital requirement, i.e., its period t nominal capital defined as loans minus deposits should not be less than a (possibly time-varying) fraction of its loans to domestic households and entrepreneurs in the same period. We assume it is costly for the bank to deviate from the long-run (steady-state) value of bank capital in excess to this requirement, according to a quadratic cost function.[4]

Focusing now on the household sector, the Home economy is populated by a continuum of two types of households that differ in terms of their discount factors. Patient households' (I-type) discount factor is larger than that of impatient households (I-type), i.e. $\beta_I > \beta_J$. Thus, in equilibrium, impatient households are net borrowers while patient households are net lenders *vis-à-vis* the domestic bank.[5] The savers are a fraction $(1 - \omega_J - \omega_E - \omega_B)$ of the H population, where ω_J and ω_E ($\omega_J, \omega_E > 0$, $\omega_J + \omega_E + \omega_B < 1$) are the shares of impatient households and entrepreneurs in bloc H population, respectively.[6] Both types of households maximize lifetime utility under its budget constraint. Households gain utility from consuming non-durables (subject to external habit formation) and housing services and disutility from working. Each household offers a differentiated labour service to domestic firms and acts as wage setter, under monopolistic competition. Each nominal wage is set according to a Calvo-type mechanism (Calvo (1983)) with indexation.[7] Savers own firms and have access to multiple financial assets while constrained households can only borrow from the domestic banking sector. Savers hold positions in euro-denominated domestic sovereign bonds, in internationally traded US dollar-denominated bonds and euro-denominated bonds (the last assumption holds only for households in

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3. Deposits and loans are all defined as one-period euro-denominated nominal assets or liabilities.

4. If we define period t capital as $K_t^B = L_t - D_t$, where L_t are loans and D_t deposits, then excess bank capital is defined as $X_t \equiv (1 - \Upsilon_{K,t})L_t - D_t$.

5. For discount factor heterogeneity, see Iacoviello (2005).

6. Within each type, agents have the same preferences, constraints and initial asset positions. We assume there is perfect wage risk-sharing across households of the same type. Thus, it is possible to assume a representative patient household and a representative impatient household.

7. Under this scheme each household is able to optimally reset wages in a given period t with a certain probability (say $1 - \xi_N$, $0 \leq \xi_N \leq 1$). All households that are able to re-optimize their wage contracts in a given period t choose the same price. Those households which do not re-optimize are allowed to adjust their wages according to a rule that indexes it to a weighted average of past and steady state inflation.

the two EA blocs). They also make deposits in the domestic bank. In contrast, impatient households, borrow funds from banks. To borrow funds, they need collateral, represented by the expected value of their housing stock. In other words, impatient household can borrow up to a fraction (the so-called loan-to-value, LTV, ratio) of the expected value of their housing stock. This borrowing constraint is akin to usual lending criteria for mortgage loans, which limit the amount lent to a fraction of the value of the asset. Consequently, when maximising utility the impatient households are also constrained by their borrowing limit, that is endogenously determined.

In each bloc there is also a representative entrepreneur (a fraction ω_E of the H population). The entrepreneur owns the physical capital stock (that depreciates at a constant rate) and part of the aggregate domestic stock of real estate (that also depreciates at a constant rate and is in fixed supply). Both are rented in a competitive market to firms operating in the domestic intermediate sectors. Entrepreneurs can borrow funds from domestic banks.[8] Entrepreneurs invest in physical capital, subject to quadratic adjustment costs. The entrepreneur can borrow funds from the domestic banking sector against collateral. In particular she can funds up to a fraction of the owned stock of real estate and a fraction of owned physical capital shock. The entrepreneur maximizes lifetime utility of consuming subject to the budget and borrowing constraints.[9]

Regarding the production setup, there are two types of firms: one type produces intermediate goods and the other type of firms produces nontradable final goods (the size of the sector is s^H). The intermediate goods are both internationally tradable or nontradable. Each intermediate good variety is produced by a firm belonging to the continuum of mass s^H ($h \in \left[0, s^H\right)$) in the case of tradable goods and s^N ($n \in \left[0, s^H\right)$) in the non-tradable case. Each nontradable and tradable intermediate good, respectively n and h, is produced using a Cobb-Douglas technology with three inputs: physical capital rented from domestic entrepreneurs; domestic labour; real estate rented from domestic entrepreneurs.[10] Each firm sells its differentiated output under monopolistic competition. The firm producing the tradable intermediate good charges different prices in local currency at home and in each foreign region (i.e. the local currency pricing assumption holds). There is

8. Changing the borrowing position is subject to an adjustment cost.

9. Like for impatient households, the choices of consumption and housing are directly affected by the introduction of the borrowing restriction. The borrowing constraint introduces a wedge between the price of the real estate and its rental rate.

10. The labour input is a combination of two types bundles of the labour varieties supplied by domestic households. I-type households represent a share $1 - \omega$ of domestic households and are indexed by $i \; \varepsilon \left[0, s^H(1-\omega)\right]$ while J-type households represent a share ω and are indexed by $j \; \varepsilon \left(s^H(1-\omega), s^H\right]$. Each firm n uses a CES combination of the two types of labour.

sluggish price adjustment due to staggered price contracts à la Calvo (1983) with indexation.[11]

The nontradable final goods are used for consumption and investment purposes. Firms producing final nontradable goods are symmetric, act under perfect competition and use nontradable as well as domestic and imported tradable intermediate goods as inputs. The intermediate goods are assembled according to a constant elasticity of substitution (CES) technology, using as inputs all intermediate goods (see Gomes *et al.* (2012) for details).

The monetary policy authorities in the model follow Taylor-type rules that are a function of inflation and output growth, with some smoothing of interest rate assumed. In particular case of the EA, there exists a single monetary authority that targets a weighted (by regional size) average of regional (Home, H, and REA) annual consumer price inflation and real quarterly output growth. In the other blocs the monetary authority responds to developments of country specific variables.

In each bloc there is also a fiscal authority that purchases a final good (which is a composite of nontradable intermediate goods only). The fiscal authority also makes transfers to households, issues bonds to refinance its debt, and levies taxes. There are several distortionary taxes in each bloc[12] but all tax tax rates are assumed to be exogenously set by the fiscal authority and for the current exercises are kept constant. There are also lump-sum taxes that are adjusted as a function of government debt to output ratio so to make public debt stable.

Calibration

The model is calibrated at a quarterly frequency. The world economy is composed of Portugal (the Home bloc), the rest of the euro area, the US and the rest of the world. In the current exercises we mostly take this bloc as residual as its main role here is to allow for a full and consistent calibration of the trade matrix. The parameterization is otherwise kept similar to the other blocs in the model.

11. Under this scheme each firm is able to optimally reset prices in a given period t with a certain probability (say $1 - \xi_F$, $0 \leq \xi_F \leq 1$). All firms that are able to re-optimize their price contracts in a given period t choose the same price. Those firms which do not re-optimize are allowed to adjust their prices according to a rule that indexes it to a weighted average of past and steady state inflation. The probability of being able to re-optimize and the degree of indexation are the same within a sector but may differ across sectors, namely the domestic tradable, non-tradable and export sectors.

12. Distortionary taxes include taxes on consumption, on capital, on dividend income and on wages, namely a pay-roll tax levied on household wage income and a tax levied on wages paid by firms (i.e. social contributions).

The parameters in the model are calibrated to be consistent with data obtained from several sources or to be consistent with empirical evidence or similar models in the related literature, such as EAGLE, GEM and NAWM. In particular, several parameters are calibrated in order to match the so-called "great ratios" and also the banking variables (as a ratio to GDP). The remaining parameters are calibrated in line with the literature, in particular with the calibration of models .

Tables 1 to 8 in the Appendix summarize the calibration of the model. Table 1 reports banks' balance sheet variables as a ratio to annualized GDP. The data to calibrate these ratios is taken from Eurostat Annual Sector Accounts and the Federal Reserve Board Financial Accounts and the 1999-2013 period is considered.[13] The calibration of the financial bloc of the model is challenging due to data availability issues. In particular, no data are available on collateralized loans for other purposes but housing. As such we choose to match the average share of total loans to households. Our calibration strategy follows Bokan *et al.* (2016) in emphasizing the role of bank loans. Therefore we give a broad interpretation to bank deposits, namely given the fact that there are no other financing sources such as bank bonds in the model. Consistently, given the matched values for steady state loans to households, the assumed zero excess bank capital in the steady state, the calibration of the capital requirement and the loan-to-value ratios (see below), we allow deposits to endogenously adjust consistently with the bank's balance sheet.

Table 2 reports the great ratios that are matched to the National Accounts data for the EA regions and the US taken from Eurostat. We set region sizes to match the share of world GDP (IMF data). The EA and US net foreign asset position data are calibrated with data from the Eurostat and the Bureau of Economic Analysis, respectively.[14]

The parameters driving financial frictions and describing the banking sector are reported in Table 3. We set the loan-to-value ratio of impatient households to 0.7 in both EA regions, in line with Lombardo and McAdam (2012) for the EA and Banco de Portugal (2017) for Portugal (see also Calza *et al.* (2013) for the case of Germany). The entrepreneurs' loan-to-value ratio associated with housing collateral is also set to 0.7, while the loan-to-value ratio associated with capital collateral is set to 0.30, broadly in line with the literature. Regarding adjustment costs, we set the adjustment costs related parameters to low values so to limit their role for the dynamics of the model, while, at the same time, preserving the model stationarity. Finally, the capital requirement parameter is set to 8% in the EA and the US, consistent with the BASEL III minimum requirement for total capital.

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13. All data refer to nominal outstanding amounts at the end of the year divided by annual nominal GDP.

14. Given the import shares, net foreign asset position and international interest rate, the steady-state trade balance and real exchange rate level endogenously adjust.

Table 4 reports population shares, preference and technology parameters. The share of patient households in each region is set to 30%, the share of impatient households to 50% while the share of entrepreneurs is set to 10% (as reported in Table 3, the share of bankers is set to 10%). Preferences are assumed to be the same across household types and regions and the parameterisation, as summarised in Table 4, is broadly in line with the related literature. Particular notice to the calibration of the discount factors since in our setup a necessary condition for entrepreneurs to be constrained is that their discount factor is lower than the inverse of the return on loans (see Iacoviello (2015)). When this condition is satisfied entrepreneurs will be constrained in a neighborhood of the steady state.[15] We set the discount factor of patient households so that it implies a steady-state annualized real interest rate of about 3%). The discount factor of impatient households and entrepreneurs are thus set to a lower value.

The production side parameters are summarized in Table 4. The bias towards capital in the Cobb-Douglas production functions of tradable and nontradable intermediate goods is set to around 0.30 and the bias towards housing to 0.01. As for the final goods baskets, the degree of substitutability between domestic and imported tradables is higher than that between tradables and nontradables, consistent with existing literature. The weight of domestic tradable goods in the consumption and investment tradable baskets is different across countries, to be coherent with multilateral import-to-GDP ratios.

Markups in the EA nontradables sector (a proxy for the services sector) and labour market are higher than the corresponding values in the US and RW (see Table 5). We assume that the tradable sector is as competitive in the euro area as in the US so the markup in the tradables sector (a proxy for the manufacturing sector) has the same value in all regions.[16]

Table 6 reports nominal and real rigidities. We set Calvo price parameters in the domestic tradables and nontradables sector to 0.83, correponding to an average duration of cantracts of around 6 quarters in the EA, broadly consistently with estimates by Christoffel *et al.* (2008) and Smets and Wouters (2003). Corresponding nominal rigidities outside the EA are equal to 0.75, implying an average frequency of adjustment equal to 4 quarters, in line with Faruqee *et al.* (2007). Calvo wage parameters are set to 0.75 in all regions and price parameters in the export sector are equal to 0.67 in all the regions

15. Similarly, banks are "constrained"by their capital requirement (which holds as strict equality in a neighborhood of the steady state) as long as their discount factor is lower than the returns on deposits.

16. Our calibration of the price markups is broadly in line with estimates by Høj *et al.* (2007), Christopoulou and Vermeulen (2012) and Bouis and Klein (2008). Given the lack of information on the wage markup, we assume that the wage markup is equal to the price markup in the non-tradable (services) sector.

(around 3 quarters). The indexation parameters on prices and wages are equal respectively to 0.50 and 0.75, so to get sufficiently hump-shaped response of wages and price. For real rigidities, we set adjustment costs on investment changes to 6 in the EA and to 4 in the case of the US and RW; and adjustment costs on consumption and investment imports to 2 and 1, respectively.

We set weights of bilateral imports on the bundles to match the trade matrix reported in Table 7.The trade matrix is calibrated using Eurostat and IMF trade statistics. Table 8 reports parameters in the monetary policy rules and fiscal rules. For fiscal rules, steady-state ratios of government debt over output are equal to 2.40 in all the regions (0.6 in annual terms). Tax rates are set to be consistent with empirical evidence (Coenen *et al.* (2008)).

Simulations

In this section we run several simulations that illustrate how the model works. First we run an expansionary monetary policy shock. In order to document the amplification role of the household sector financial frictions , we also run the monetary policy shock under an alternative loan-to-value ratio. Given the novel features of the model, we run a financial shock, in particular we show the results of a permanent change in the loan-to-value ratio faced by impatient households in the Portuguese economy. The simulations are carried out under perfect foresight.

The monetary policy shock

We simulate a shock that leads to a reduction of the euro area annualised monetary policy rate of 25 basis points on impact. Figures 1 and 2 report the results, focusing on the two euro area blocs. Given that this shock is common to both euro area regions and due to the fact that the two blocs are not fundamentally different, the responses of the two blocs to this shock are rather similar. The monetary policy shock has a broadly expansionary impact on the main macroeconomic variables, namely GDP, consumption and investment, that as expected shows a larger increase than GDP. The increased demand in the euro area induces an increase in imports and exports also increase, given the depreciation of the euro exchange rate.

The cut in the policy rate is transmitted into the loans and deposits interest rates, that also go down. Together with the drop in interest rates, the expansionary impact of the shock implies an increased demand for loans, both by impatient households and entrepreneurs. The higher bank lending is financed by an increase in deposits (bank capital, not shown in the figures, drops slightly). Given that loans are collateralized this pushed upwards the demand of housing and the housing price. The increased housing price

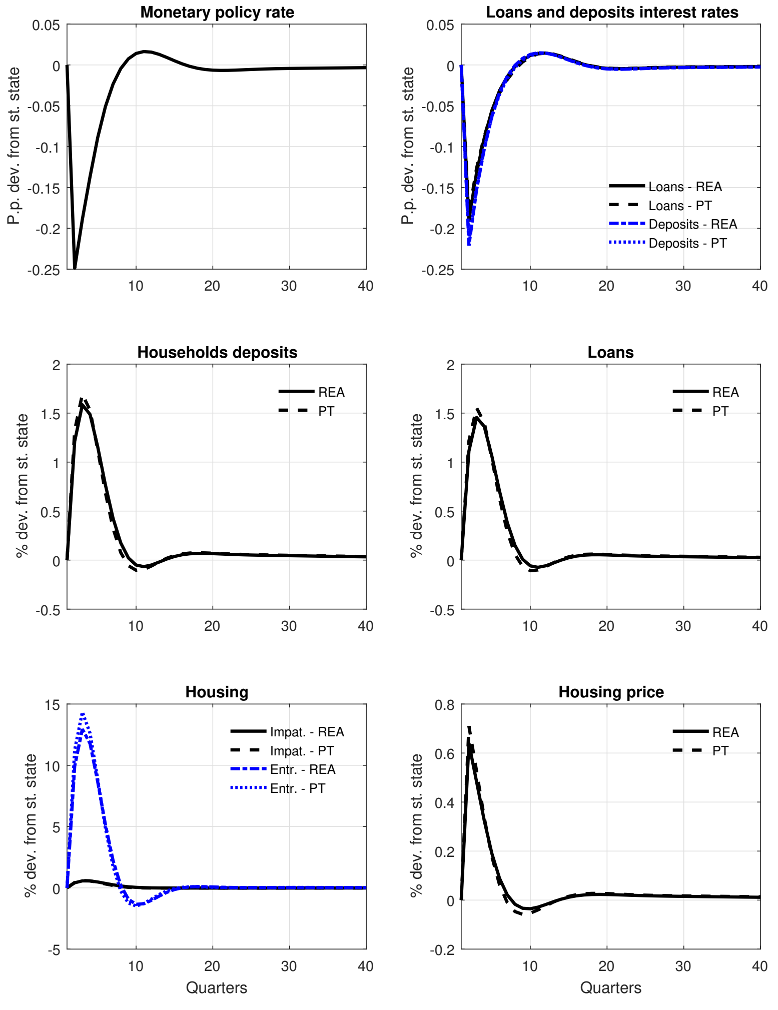

FIGURE 1: Reduction in the EA interest rate (0.25 p.p.)

reinforces impact of the shock given that the value of collateral increases thus allowing agents to borrow more against their housing stock.

To understand better the amplifying role of the households side financial frictions, we run an additional experiment where we run the same shock as above but considering an alternative calibration of the loan-to-value ratio. In particular we consider the alternative case where the loan-to-value ratio is set to a higher value. In this scenario impatient households are allowed to borrow ut to 90% of the (expected) value of their collateral, compared to 70% in the benchmark case. As shown in Figure 3 the expansionary effect of the shock is higher in the case of a higher loan-to-value ratio calibration. In terms of the GDP components, the amplification is larger for private consumption, as would be expected given that we increase the

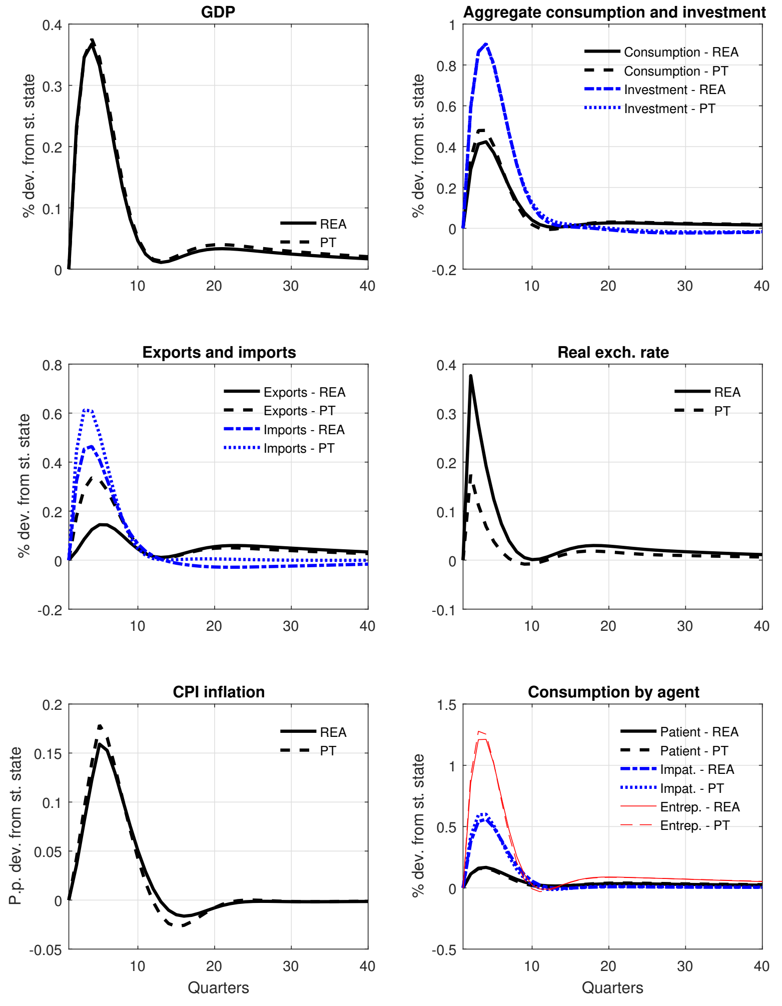

FIGURE 2: Reduction in the EA interest rate (0.25 p.p.) - Continued

loan-to-value of impatient households (but keep the loan-to-value ratios faced by entrepreneurs unchanged at their initial level). In fact the impact of increasing the loan-to-value calibration is more noticeable in lending to impatient households that are the ones facing a relaxation of the borrowing constraint.

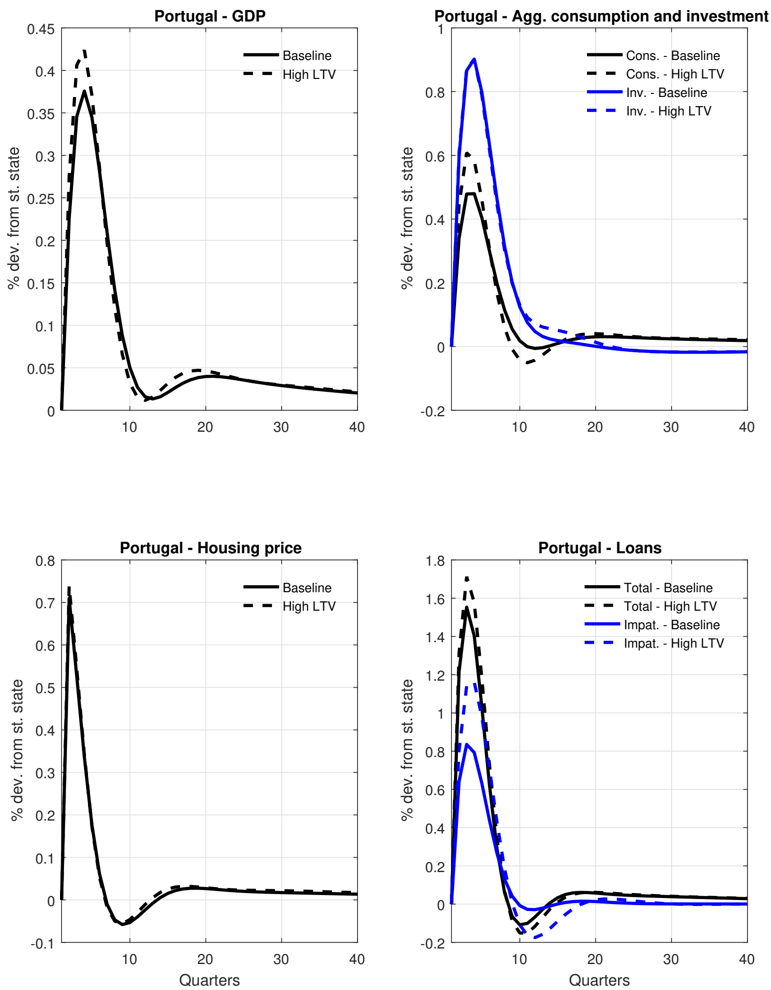

FIGURE 3: Reduction in the EA interest rate (0.25 p.p.) – Higher LTV

The loan-to-value shock

In this section we analyse the model impact of a decrease in the loan-to-value ratio for loans collateralized with the housing stock in Portugal. The loan-to-value ratio is decreased by 1 percentage point on impact and then returns gradually to the steady state level. In particular, the loan-to-value is assumed to return to steady sate following an AR(1) process with coefficient equal to 0.9. This means that after ten years the loan-to-value ratios are virtually back at the initial level (see Figure 4). The agents in the economy perfectly anticipate this adjustment path of the loan-to-value ratio.

Figures 5 and 6 summarise the results. This scenario illustrates a change in lending standards for reasons exogenous to the model, that could result from

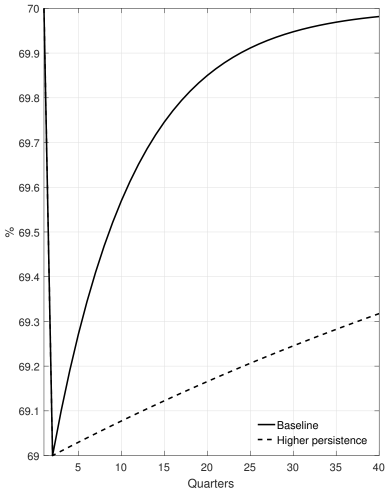

FIGURE 4: The loan-to-value paths

banks lending policy or from an change imposed by a regulatory authority. Either way, this change results in a decrease in the demand for loans, as it tightens the collateral constraint. The change leads impatient households and entrepreneurs to demand less loans at any given level of interest rates, since the loan-to.value ratio has decreased. The lower demand results in less loans being extended domestically at a lower interest rate. Given the decrease in loans extended, banks reduce their demand for deposits, pushing down the respective interest rate. Given the lower demand for loans, the demand for real estate also falls, driving down prices. The decrease in the value of the housing collateral further pressures down borrowing.

Overall the shock leads to a drop in GDP driven by the domestic demand components. After a few quarters, Portuguese exports decrease, given the real exchange rate appreciation. Imports fall as well, following the reduction in domestic aggregate demand. Given that the shock is on the loan-to-value ratios faced by borrowers, the main impact comes from their reduced borrowing capacity mainly depressing consumption of borrowers (both households and entrepreneurs).

Spillovers to the Home bloc are small. Given the small size of the Portuguese bloc, euro area GDP hardly changes, and the same happens with inflation. Since monetary policy reacts to union wide variables, the policy rate virtually does not change either. So in the case of a very small economy in a monetary union, monetary policy does not counteract the impact of the shock.

In this simulation we assume the loan-to-value is back to its initial level after ten years. To analyse the impact of this assumption on our results we run the same simulation again but assuming a much more gradual return of the loan-to-value ratio. In this case, after ten years the ratio is just adjusted by 0.3 percentage points (see Figure 4) . As shown in Figure 7, the drop in GDP is

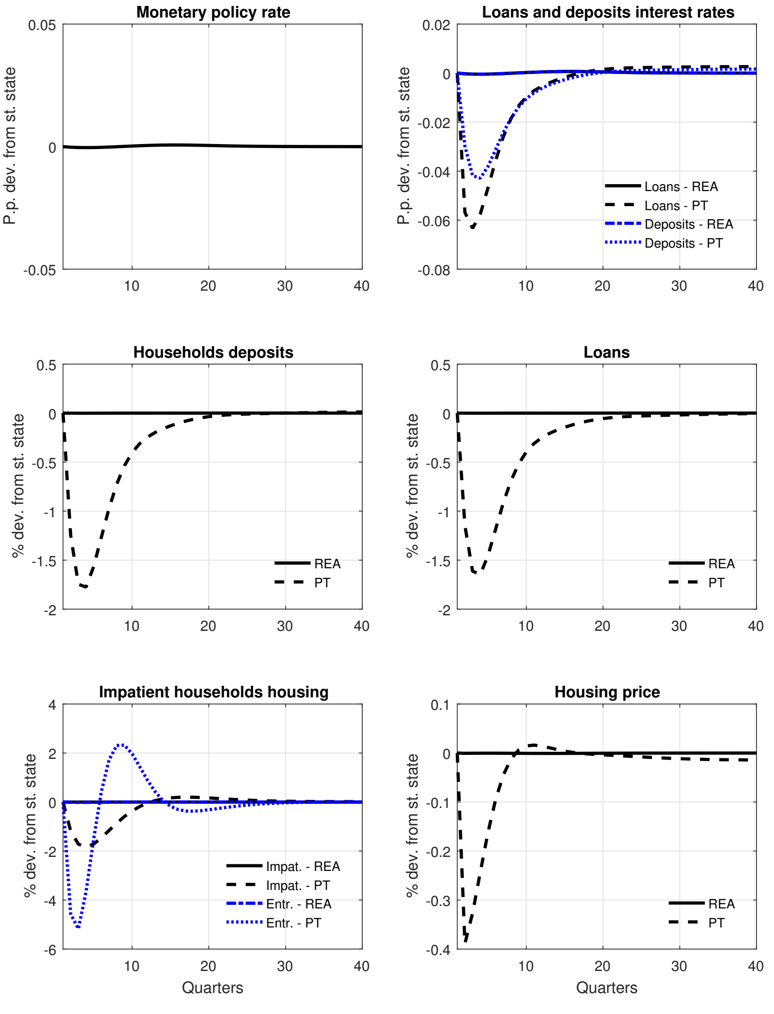

FIGURE 5: Reduction of the loan-to-value

much more pronounced and the responses of the variables to the shock are not only larger but also more persistent, as the shock is.

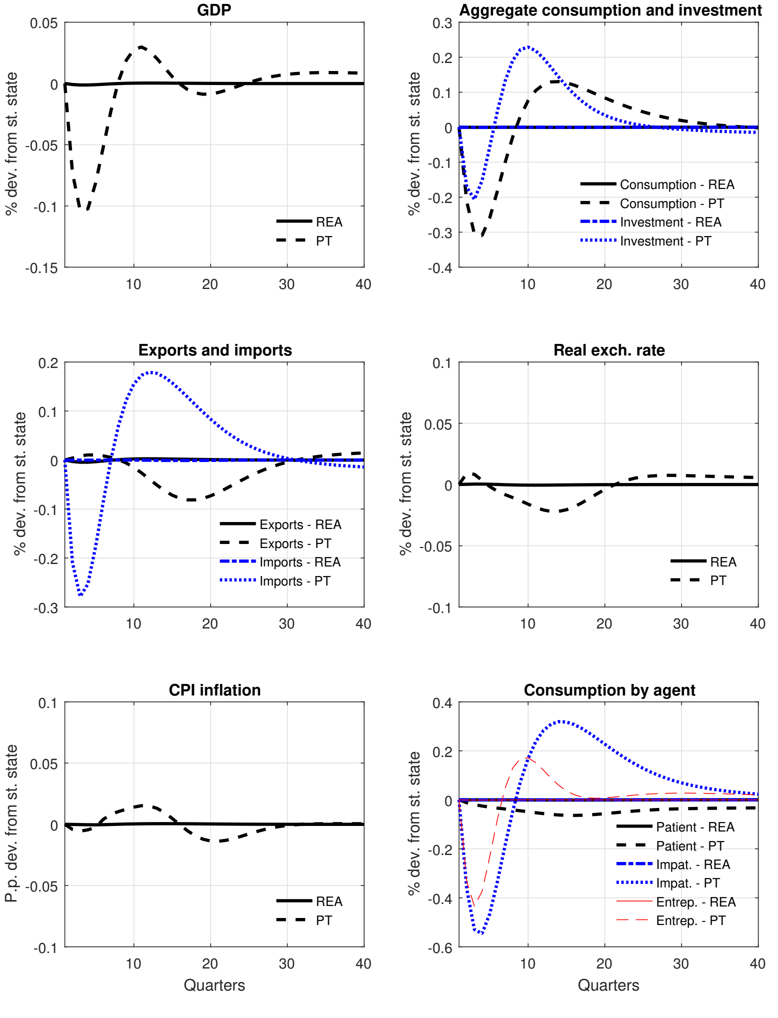

FIGURE 6: Reduction of the loan-to-value – Continued

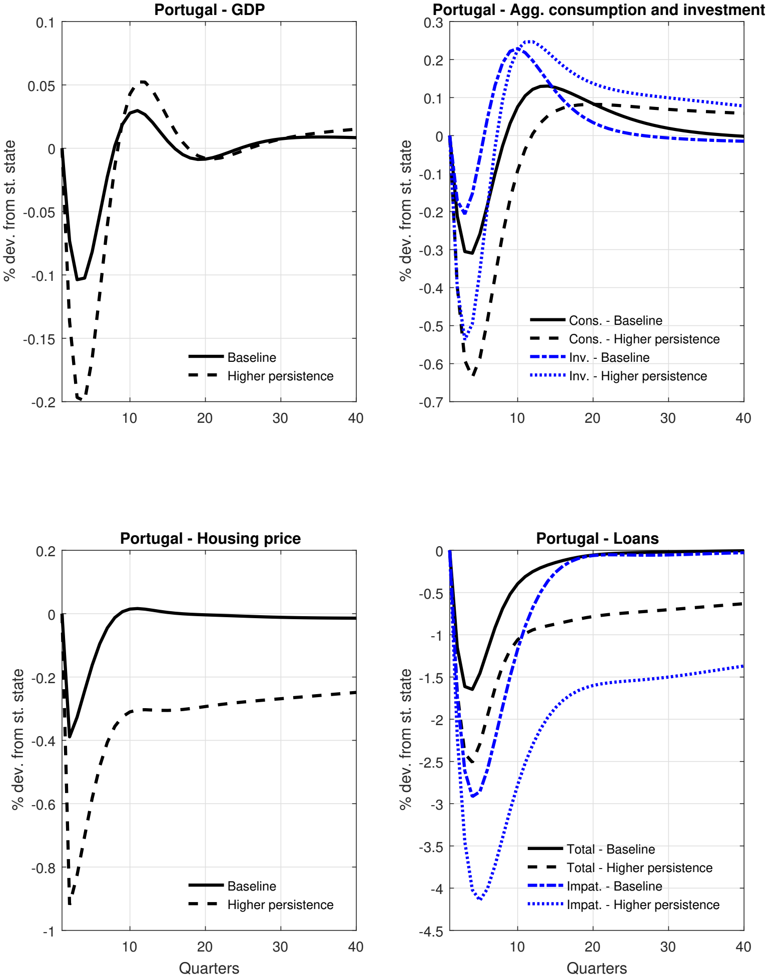

FIGURE 7: Reduction of the loan-to-value – Different persistence

Conclusions

The recent global financial crisis highlighted the importance of including real-financial linkages in structural models. In this paper we take a large scale multi-country model of the euro area that includes financial frictions. In the model the euro area is modelled as a two-bloc monetary union and for the current exercise we calibrate those blocs to a small economy in the union, namely Portugal, and the rest of the euro area. The version of the EAGLE model used here, namely the EAGLE-FLI model, allows us to analyse the behaviour of financial variables and to analyse different channels that originate from the inclusion of a financial sector in the model. We run several simulations in order to illustrate the transmission mechanisms of different shocks and how the financial features interact with the real side of the model. In fact, the large scale of the model together with its microfoundations makes it an interesting laboratory to analyse the macroeconomic implications of financial factors in euro area countries, in a theoretically consistent setup.

Our simulations illustrate how the macro-financial linkages present in the model are important for the interpretation of how macroeconomic variables respond to shocks. First we focus on a standard monetary policy shock to show that the model presents results that are consistent with earlier literature but also to illustrate how the impact of this shock may be amplified and made more persistent due to the presence of financial frictions. In addition, we also explore the transmission mechanism of a shock originating in the financial sector, in particular related to the tightness of the collateral constraint faced by borrowers.

Even though the model is already quite rich, further improvements could be envisaged. The literature on financial frictions and structural models has grown extensively over the last decade, including non-linear extensions (such as occasionally binding constraints) or the introduction of transmission channels related to unconventional monetary policy. The estimation of the model would make it even more useful for policy advice. We leave this for further research.

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Appendix

	PT	REA	US	RW
Loans	137	132	161	146
Loans to households	61	64	90	76
Loans to entrepreneurs	76	68	71	70
Interbank	0.0	0.0	n.a.	n.a.
Deposits	126	122	148	134
Excess bank capital	0.0	0.0	0.0	0.0

TABLE 1. Steady-State Financial Accounts (Ratio to annual GDP, %)

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	PT	REA	US	RW
Domestic demand				
Private consumption	55	59	63	62
Cons. patient households	23	28	28	30
Cons. impatient households	2	25	9	18
Private investment	23	20	21	21
Public consumption	20	21	15	18
Trade				
Imports (total)	38	20	15	12
Imports of consumption goods	24	12	8	5
Imports of investment goods	15	9	7	6
Net foreign assets (ratio to annual GDP)	-82	-8	-18	13
Production				
Tradables	63	43	44	41
Nontradables	37	57	56	59
Labour	44	43	48	47
Share of World GDP	3	21	21	58

TABLE 2. Steady-State National Accounts (Ratio to GDP, %)

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	Home	REA	US	RW
Households LTV ratio (V_J)	0.7	0.7	0.7	0.7
Entrepreneurs LTV ratio (V_{H_E})	0.7	0.7	0.7	0.7
Entrepreneurs LTV ratio (V_{K_E})	0.3	0.3	0.3	0.3
Households Loans smoothing (ρ_{B_J})	0.4	0.4	0.4	0.4
Entrepreneurs loans smoothing (ρ_{B_E})	0.4	0.4	0.4	0.4
Capital requirement (Υ^K)	0.08	0.08	0.08	0.08
Banks discount factor (β_B)	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$
Banks share in the population (ω_B)	0.10	0.10	0.10	0.10
Adjustment costs				
Deposits (γ_{DH})	0.0001	0.0001	0.0001	0.0001
Excess bank capital (γ_X)	0.001	0.001	0.001	0.001
Interbank (γ_{IB})	0.001	n.a.	n.a	n.a
Loans - banks (γ_L)	1.5	1.5	1.5	1.5
Loans - impatient hous. (γ^{BJ})	1.5	1.5	1.5	1.5
Loans - entrepreneurs (γ^{BE})	1.5	1.5	1.5	1.5

TABLE 3. Financial and Banks Parameters

Note: PT=Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	Home	REA	US	RW
Share in the population				
Patient households (ω_I)	0.30	0.30	0.30	0.30
Impatient households (ω_J)	0.50	0.50	0.50	0.50
Entrepreneurs (ω_E)	0.10	0.10	0.10	0.10
Households and entrepreneurs				
Patient hous. discount factor (β_I)	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$
Imp. households discount factor (β_J)	0.96	0.96	0.96	0.96
Entrepreneurs discount factor (β_E)	0.99	0.99	0.99	0.99
Intertemporal elasticity of substitution (σ^{-1})	1.00	1.00	1.00	1.00
Inverse of the Frisch elasticity of labour (ζ)	2.00	2.00	2.00	2.00
Housing services (ι_I, ι_J)	0.10	0.10	0.10	0.10
Habit persistence (κ)	0.70	0.70	0.70	0.70
Capital depreciation rate(δ_K)	0.025	0.025	0.025	0.025
Housing depreciation rate(δ_H)	0.01	0.01	0.01	0.01
Intermediate-good firms (trad. and nontrad. sectors)				
Substitution btw. labour and capital	1.00	1.00	1.00	1.00
Bias towards capital - tradables (α_T)	0.30	0.30	0.30	0.30
Bias towards housing - tradables (α_{HT})	0.01	0.01	0.01	0.01
Bias towards capital - nontradables (α_N)	0.37	0.40	0.31	0.43
Bias towards housing - nontradables (α_{HN})	0.01	0.01	0.01	0.01
Substitution btw. I-type and J-type labour (η)	3.86	3.86	5	5
Final consumption-good firms				
Substitution btw. domestic and imported trad. goods (μ_{TC})	2.50	2.50	2.50	2.50
Bias towards domestic tradables goods (υ_{TC})	0.22	0.52	0.54	0.84
Substitution btw. tradables and nontradables (μ_C)	0.50	0.40	0.35	0.35
Bias towards tradable goods (υ_C)	0.70	0.20	0.20	0.20
Substitution btw. consumption good imports (μ_{IMC})	2.50	2.50	2.50	2.50
Final investment-good firms				
Substitution btw. domestic and imported trad. goods (μ_{TI})	2.50	2.50	2.50	2.50
Bias towards domestic tradables goods (υ_{TI})	0.19	0.45	0.48	0.74
Substitution btw. tradables and nontradables (μ_I)	0.50	0.50	0.50	0.50
Bias towards tradable goods (υ_I)	0.85	0.85	0.85	0.85
Substitution btw. investment good imports (μ_{IMI})	2.50	2.50	2.50	2.50

TABLE 4. Households, Entrepreneurs and Firms Behavior

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	Tradables (θ_T)	Nontradables (θ_N)	Wages ($\eta_I = \eta_J$)
PT	1.15 (7.67)	1.35 (3.86)	1.35 (3.86)
REA	1.15 (7.67)	1.35 (3.86)	1.35 (3.86)
US	1.15 (7.67)	1.25 (5.0)	1.25 (5.0)
RW	1.15 (7.67)	1.25 (5.0)	1.25 (5.0)

TABLE 5. Price and Wage Markups (Implied Elasticities of Substitution)

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	PT	REA	US	RW
Adjustment costs				
Imports of consumption goods (γ_{IM^C})	2.00	2.00	2.00	2.00
Imports of investment goods (γ_{IM^I})	1.00	1.00	1.00	1.00
Capital utilization (γ_{u2})	2000	2000	2000	2000
Investment (γ_I)	6.00	6.00	4.00	4.00
Intermediation cost function - USD bond (γ_{B^*})	0.01	0.01	...	0.01
Intermediation cost function - Euro bond ($\gamma_{B^{EA}}$)	...	0.01	...	...
Calvo parameters				
Wages - households I and J (ξ_I and ξ_J)	0.75	0.75	0.75	0.75
Prices - domestic tradables (ξ_H) and nontradables (ξ_N)	0.83	0.83	0.75	0.75
Prices - exports (ξ_X)	0.67	0.67	0.67	0.67
Degree of indexation				
Wages - households I and J (χ_I and χ_J)	0.75	0.75	0.75	0.75
Prices - domestic tradables (χ_H) and nontradables (χ_N)	0.50	0.50	0.50	0.50
Prices - exports (χ_X)	0.50	0.50	0.50	0.50

TABLE 6. Real and Nominal Rigidities

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	Home	REA	US	RW
Consumption-good imports				
Substitution btw. consumption good imports (μ_{IMC})	2.50	2.50	2.50	2.50
Total consumption good imports	23.6	11.5	8.3	5.3
From partner				
PT	-	0.3	0.01	0.05
REA	15.6	-	1.1	3.2
US	0.3	0.9	-	2.1
RW	7.7	10.4	7.2	-
Investment-good imports				
Substitution btw. investment good imports (μ_{IMI})	2.50	2.50	2.50	2.50
Total investment good imports	14.7	9.0	6.9	6.2
From partner				
PT	-	0.1	0.01	0.03
REA	9.2	-	1.0	3.4
US	0.5	1.3	-	2.8
RW	5.0	7.5	5.9	-

TABLE 7. International Linkages (Trade Matrix, Share of Domestic GDP, %)

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World

	Home	REA	US	RW
Monetary authority				
Inflation target ($\overline{\Pi}^4$)	1.02	1.02	1.02	1.02
Interest rate inertia (φ_R)	0.87	0.87	0.87	0.87
Interest rate sensitivity to inflation gap (φ_Π)	1.70	1.70	1.70	1.70
Interest rate sensitivity to output growth (φ_Y)	0.10	0.10	0.10	0.10
Fiscal authority				
Government debt-to-output ratio ($\overline{B_Y}$)	2.40	2.40	2.40	2.40
Sensitivity of lump-sum taxes to debt-to-output ratio (φ_{B_Y})	5.00	5.00	5.00	5.00
Consumption tax rate (τ_C)	0.185	0.192	0.078	0.123
Dividend tax rate (τ_D)	0.00	0.00	0.00	0.00
Capital income tax rate (τ_K)	0.19	0.19	0.16	0.16
Labour income tax rate (τ_N)	0.079	0.151	0.154	0.100
Rate of social security contribution by firms (τ_{W_f})	0.092	0.15	0.078	0.109
Rate of social security contribution by households (τ_{W_h})	0.063	0.077	0.067	0.079

TABLE 8. Monetary and Fiscal Policy

Note: PT: Portugal; REA=Rest of Euro Area; US=United States; RW=Rest of World