EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

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Macroprudential policy in a monetary union with cross-border banking

No 2260 / March 2019

Abstract

We analyse the interaction between monetary and macroprudential policies in the euro area by means of a two-country DSGE model with financial frictions and cross-border spillover effects. We calibrate the model for the four largest euro area countries (i.e. Germany, France, Italy, and Spain), with particular attention to the calibration of cross-country financial and trade linkages and country specific banking sector characteristics. We find that countercyclical macroprudential interventions are supportive of monetary policy conduct through the cycle. This complementarity is significantly reinforced when there are asymmetric financial cycles across the monetary union, which provides a case for targeted country-specific macroprudential policies to help alleviate the burden on monetary policy. At the same time, our findings point to the importance of taking into account cross-border spillover effects of macroprudential measures within the Monetary Union.

JEL classification: E32; E44; E52; F36; F41.

Keywords: monetary policy, macroprudential policy, DSGE, banking

Non-technical summary

This paper provides new evidence on the interaction between national macroprudential policy measures and a common monetary policy within a monetary union. It also quantifies potential cross-border spillover effects from the introduction of national macroprudential policy measures in the largest euro area countries and disentangles different transmission channels.

The understanding of the interaction between macroprudential and monetary policies is particularly relevant in this historical moment, as macroprudential policy authorities are increasingly active. Following the crisis a set of macroprudential policy instruments targeted at reducing systemic risks to financial stability was established, but only now with a wide recovery and increased risk of build-up of new imbalances these instruments are implemented for the first time. The new set of macroprudential instruments was set-up after the financial crisis as it became clear that the objectives of price and financial stability present not only complementarities, but also trade-offs and, therefore, cannot be achieved with a unique instrument. Even if implemented via different instruments, the effectiveness of macroprudential policies is affected by the monetary policy stance and vice-versa. In the euro area, the task of understanding the interactions between macroprudential and monetary policies is more complex than in other jurisdictions due to the particular institutional setup, country heterogeneity and the strong trade and financial linkages across countries.

In the euro area, the macroprudential policy mandate is assigned both to national designated authorities (coinciding often but not always with the central bank) and to supranational authorities. In this context, the argument for proactive macroprudential policies may even be stronger in a monetary union than elsewhere due to their targeted nature and the fact that they can be adjusted to reflect the heterogeneous economic and financial developments across countries within the monetary union. At the same time, one also needs to consider the potential for significant cross-border spillover effects from national measures that may have unintended side effects on other countries within the Union or may render the measures less effective (due to regulatory leakages).[1] The potential for such cross-border spillover effects provides the rationale for a strong institutional framework to help internalise potential unintended consequences of macroprudential measures in the decision-making process.

With the aim of casting more light on the nature and relevance of these countervailing forces, in this paper we develop a structural two-country macro model with financial frictions calibrated to reflect the heterogeneity of individual euro area countries. Our modelling framework allows for analysing the inward and outwards effects of different types of macroprudential policy measures (system-wide capital requirements, sectoral capital requirements and loan-to-value (LTV) ratio caps).

The main findings are that the implementation of macroprudential policies targeting country-specific imbalances within the monetary union can help to achieve Pareto-superior policy outcomes in terms of price and financial stability. We also show that national macroprudential policy measures can have non-negligible cross-border spillover effects channelled via international financial and trade linkages. Finally, the impact of macroprudential measures (national as well as cross-border) and the interaction with monetary policy

[1] For a high level overview, see e.g. the European Systemic Risk Board's (ESRB) "Handbook on Operationalising Macro-prudential Policy in the Banking Sector" (chapter 11).

varies across different macroprudential instruments and this latter plays a relevant role in explaining the cross-border spillover effects. These findings call for a careful calibration of macroprudential and monetary policies and demonstrate the importance of close cooperation between monetary and macroprudential policy decisions. The potential for cross-border spillovers of national macroprudential actions also provides a rationale for coordinated action among national authorities as well as a coordination role for the central monetary and macroprudential authority to help minimise any unintended negative spillover effects.

1 Introduction

The global financial crisis revealed that price stability may be a necessary but not a sufficient condition for financial stability. At the same time, the recent years' crisis experiences made evident that financial instability can feedback on the real economy and impinge on the ability of monetary policy to secure price stability. As a result, in the aftermath of the financial crisis, policymakers have taken initiatives to establish adequate institutional policy setups that can help ensure the concomitant achievement of price stability and financial stability objectives. One of the main innovations in this regard has been the establishment of a macroprudential policy function targeted at reducing systemic risks to financial stability.

Macroprudential policies aiming at increasing the resilience of the financial system as a whole and at mitigating the build-up of financial imbalances can be considered a complementary policy function to monetary policy, focused on price stability, and micro-prudential supervision, focused on the stability of individual financial institutions. The complementarity of macroprudential policies to other policy functions, however, may not hold at all times. For instance, as both macroprudential policies and monetary policy tend to operate via real-financial interlinkages, trade-offs could emerge between the two policy functions. This paper provides new evidence on the possibly macroprudential and monetary policy trade-offs with a focus on the nexus between national macroprudential policy measures and a common monetary policy within a monetary union.[2] It also provides evidence of potential cross-border spillover effects from the introduction of national macroprudential policy measures, which creates a case for a strong coordination function of macroprudential policies within the Monetary Union.

The predominantly decentralised organisation of macroprudential policymaking in the euro area inter alia reflects the still incomplete integration of national banking sectors and heterogeneous financial cycles across euro area countries. In addition, as the single monetary policy mandate is to deliver price stability over the medium term for the euro area as a whole, it may actually look through financial stability risks building up in specific market segments, jurisdictions or individual countries. Such risks could also have implications for financial stability at the area-wide level. Hence, in a monetary union setting such as the euro area, nationally-oriented macroprudential policies have a role to play in ensuring financial stability for all jurisdictions and supporting monetary policy conduct through the cycle.[3]

In the same vein, the argument for proactive macroprudential policies may even be stronger in a monetary union than elsewhere due to their targeted nature and the fact that they can be adjusted to reflect the heterogeneous economic and financial developments across countries within the monetary union.[4] Macroprudential policies are well suited to take into account national factors, such as the build-up of financial

[2]This paper focuses on the interaction between macroprudential policy and monetary policy with a cross-country dimension. For a review of macroprudential policy interactions with micro-prudential supervision, see e.g. Angelini et al. [2012b] and Boissay and Cappiello [2014].

[3]See Draghi, M. "Hearing at the European Parliament's Economic and Monetary Affairs Committee", speech, Brussels, March 2015.

[4]See e.g. Constâncio, V., "Financial stability risks, monetary policy and the need for macroprudential policy", speech at the Warwick Economics Summit, February 2015.

imbalances and the financial system's degree of resilience.[5]

While there is a strong case for nationally-oriented macroprudential policies within a monetary union, one also needs to be mindful of the potential for significant cross-border spillover effects from national measures that may have unintended side effects on other countries within the Union or may render the measures less effective (due to regulatory leakages).[6] The potential for such cross-border spillover effects provides the rationale for a strong institutional framework to help internalise potential unintended consequences of macroprudential measures in the decision-making process. Within Europe, the institutional setup should help mitigate the risk of cross-border spillover effects both via the mandatory and voluntary policy reciprocity arrangements coordinated by the ESRB[7] and via the central coordination role of the ECB within the Banking Union[8]

With the aim of casting more light on the nature and relevance of these channels, in this paper we develop a structural two-country macro model with financial frictions and calibrated to individual euro area countries. The model is a two-country DSGE model where the individual economies are modelled following Darracq Pariès et al. [2011]. The model has been calibrated for the four largest euro area countries (i.e. Germany, France, Italy and Spain) using ECB proprietary banking sector data. We use the model to run various simulations that illustrate the importance of country-specific macroprudential policies, also incorporating cross-border spillovers, and how they may potentially complement and interact with the single monetary policy in the context of monetary union. Our modelling framework allows for analysing the effects of different types of macroprudential policy measures, ranging from borrower-based measures such as loan-to-value (LTV) ratio caps to lender-based measures such as total and portfolio-specific capital requirements.

The main findings are that there are synergies and trade-offs between monetary and macroprudential policies and that these interactions may become even more pronounced in a monetary union where monetary policy, by definition, is focused on area-wide economic and financial conditions. In such circumstances, macroprudential policies targeting imbalances building up at the national level within the monetary union can help to achieve better policy outcomes in terms of price and financial stability. We also show that national macroprudential policy measures can have non-negligible cross-border spillover effects channelled via international financial and trade linkages. Finally, the impact of macroprudential measures (national as well as cross-border) and the interaction with monetary policy varies across different macroprudential instruments. These findings call for a careful calibration of macroprudential and monetary policies and demonstrate the importance of close cooperation between monetary and macroprudential policy decisions. The potential for cross-border spillovers of national macroprudential actions also provides a rationale for coordinated action among national authorities as well as a coordination role for the central monetary and macroprudential authority to help minimise any unintended negative spillover effects.

[5]See Deutsche Bundesbank, "The importance of macroprudential policy for monetary policy", Monthly Report, March 2015.

[6]For a high level overview, see e.g. the European Systemic Risk Board's (ESRB) "Handbook on Operationalising Macroprudential Policy in the Banking Sector" (chapter 11).

[7]See Recommendation ESRB/2015/2 on the assessment of cross-border effects of and voluntary reciprocity for macroprudential policy measures and Decision ESRB/2015/4 on a coordination framework regarding the notification of national macroprudential policy measures by relevant authorities.

[8]As stipulated in the SSM Regulation.

The paper is organised as follows: section 2 provides an overview of the relevant literature. In section 3, the general structure of the model is presented. In section 4, we illustrate the calibration strategy for the four largest euro area countries. In section 5, we illustrate how shocks propagate in the banking sector and across countries in the two-country model and in section 6 we illustrate some policy applications of the model. In section 7, we provide and overview on how the model can be used to assess the interaction between macroprudential and monetary policies.

2 Literature

Our paper is related to the emerging literature on monetary and macroprudential policy interactions as well as to studies examining spillovers of national policy measures across borders.

For what concerns the interaction between macroprudential and monetary policies there are conflicting views about the extent to which in particular monetary policy should provide some support to help achieving financial stability objectives. Two opposing viewpoints call for either keeping the two policy functions separate which also implies that pre-crisis price stability-oriented monetary policy frameworks should remain largely unaffected or to fully merge the monetary policy and macroprudential policy objectives. For proponents of the former viewpoint see e.g. Bean et al. [2010] and Svensson [2012]. For proponents of the latter viewpoint see e.g. Brunnermeier and Sannikov [2015]. In between those polar views, arguments can be made for assigning some role for monetary policy to complement the new macroprudential policies. This owes to strong mutual dependencies between the two policy functions and reflects uncertainty about whether macroprudential policy will be able to fulfil all its objectives and get into all the cracks of the financial system.[9] In the same vein, according to Smets [2014] , the need for incorporating a role (albeit secondary) for financial stability concerns among the monetary policy objectives hinges on (i) the effectiveness of macroprudential policies (e.g. the ability to manage the financial cycle); (ii) the extent to which monetary policy (incl. conventional and unconventional measures) can be a source of financial instability for example by incentivising bank risk-taking; and (iii) the extent to which monetary policy can avoid being drawn into financial stability concerns, especially in crisis times.[10]

A number of studies have analysed the macroprudential and monetary policy interactions in closed economy settings.[11] A common thread among those studies, while being subject to concrete model specifications overall, seems to be that macroprudential and monetary policies in many instances can be expected to complement and support each other (as also mentioned above). However, there is also potential for a conflict of interest, or at least trade-offs, between them, such as a monetary policy that is too loose amplifying the financial cycle or, conversely, a macroprudential policy that is too restrictive having detrimental effects on credit provision and hence monetary policy transmission. This underlines the need to ensure an appropriate

[9] See e.g. Woodford [2012], Stein [2012], Borio [2014] and Habermeier et al. [2015].

[10] To the extent that an extended monetary policy mandate including financial stability concerns, as a complement to macroprudential policies, can help prevent the build-up of excessive debt overhangs in pre-crisis periods it could alleviate the need for monetary policy to engage in post-crisis resolution policies; see also Borio [2014].

[11] See also Carboni et al. [2013] for a review.

institutional framework with effective coordination mechanisms among the different policy functions, with clear delineations of responsibility.[12]

From a research perspective, the investigation of the strategic interaction between macroprudential and monetary policy has predominantly been carried out using DSGE models incorporating financial frictions. A general conclusion emerging from this literature is that counter-cyclical macroprudential tools - such as time-varying capital requirements, counter-cyclical capital buffers and caps on loan-to-value ratios – can play a useful role in dampening the volatility of business cycles and can thus potentially be welfare enhancing.[13] For instance, the early contribution by Angeloni and Faia [2013] finds that, in a DSGE model where banks can be subject to runs, the optimal policy mix offers some role for monetary policy to lean against asset prices or bank leverage in combination with a counter-cyclical capital buffer rule.[14] However, the specific calibration (design and magnitude) of the macroprudential rule determines its effectiveness in contributing to macroeconomic stabilisation. Angelini et al. [2012a] likewise find that the mutual interaction of monetary policy and macroprudential policy can be beneficial, especially during times when the economy is subject to large shocks, while a lack of coordination between the two policy functions can lead to conflicts of interest. Beau et al. [2012] in turn emphasise that the extent to which monetary policy and macroprudential oversight conflict largely depends on the nature of the underlying shocks affecting the economy at a given juncture.[15] Moreover, Lambertini et al. [2013] suggest that using a lean-against-the-wind monetary policy or a counter-cyclical macroprudential policy can be welfare improving but may have different welfare implications for different economic agents (e.g. borrowers vs. lenders).[16] In a similar vein, Gertler et al. [2012] show that macroprudential policy in the form of a pigouvian-type subsidy on banks' outside equity can help alleviate the need for monetary policy to lean against the cycle. Gurio et al. [2017] show in a standard DSGE model, which includes a financial crisis risk component that depends on "excess credit", that a leaning against the wind policy can be beneficial. They argue that the extent to which monetary policy should lean against the wind depends on a variety of factors including the severity of financial crises, the sensitivity of crisis probability to excess credit, the volatility of excess credit and the level of risk aversion.

Gelain et al. [2012] in a DSGE model with housing and imperfect expectations the authors show that monetary policy rules embedding macroprudential instruments, such as debt-to-income and LTV ratios, can help reduce macroeconomic volatility. Paoli and Paustian [2013] furthermore highlights the welfare benefits of coordinated action by monetary and macroprudential policies.

Darracq Pariès et al. [2011] find that macroprudential policy can be more effective than monetary policy in addressing destabilising fluctuations in the credit markets, thereby alleviating somewhat the need for monetary policy to lean against the wind. Similarly, Beneš et al. [2014] in a model embedding non-linear credit dynamics which amplifies the role of financial frictions show that a macroprudential policy pursuing

[12] See e.g. Cecchetti and Kohler [2012], Ueda and Valencia [2014], Classens and van Horen [2014] and Fahr and Fell [2017].

[13] As current state-of-the-art DSGE models are linear in nature and typically operate with representative agents, they have difficulties encompassing the multi-dimensional and potentially non-linear nature of systemic risk. This limits the scope for carrying out welfare analysis on simulated macroprudential policies within this model set-up.

[14] Another early paper, which focused on housing bubbles, is Kannan et al. [2012].

[15] See also Christensen et al. [2011].

[16] For a comparable study incorporating intra-sectoral distributional affects, see also Rubio and Carrasco-Gallego [2014].

a countercyclical capital buffer approach reduces the volatility of the monetary policy rate over the cycle. Angelini et al. [2014] show, by means of simple rules in a dynamic general equilibrium model featuring a banking sector, that in "normal" times an active use of capital requirements generates modest benefits in terms of volatility of the target variables compared to the case in which only the central bank carries out stabilization policies. The benefits of introducing capital requirements become sizeable when financial shocks are important drivers of economic dynamics.

Our paper is also closely related to the emerging literature examining the potential for cross-border spillover effects of macroprudential policies. There are various channels through which macroprudential policies could induce cross-border effects. Generally, one can distinguish between "inward" and "outward" transmission channels. Inward transmission refers to the effects of macroprudential policies on the domestic (i.e. policy activating) economy. The inward transmission of domestic macroprudential policy describes how regulation affects domestic banks or foreign affiliates (bank branches or subsidiaries) located in the host country. Accordingly, inward spillover effects will, among other things, include leakages of domestic policies related to the inability of the domestic supervisor to impose or monitor compliance on institutions not directly affected by the policy, such as foreign branches operating in the activating country, foreign banks through cross-border lending, and/or foreign non-bank institutions. Inward transmission of cross-border spillovers thus reflects circumvention of the targeted national macroprudential measure that may render it less effective. Outward transmission of cross-border spillover effects refers to the effects of domestic policies on other economies (so-called receiving countries). The outward transmission of domestic macroprudential policy is related, but not restricted to, international activities of domestic banking groups. It can be understood as export of domestic policies (or as "import" of foreign policies, if seen from the perspective of the receiving, policy passive country). Both inward and outward spillover effects may thus create unintended consequences that may reduce the effectiveness and distort the intention of the macroprudential measure.

A number of recent studies suggest that (macro-)prudential measures enacted at national level may entail cross-border effects. In terms of empirical evidence, studies based on aggregate macroeconomic data sources include Houston et al. [2012], Bremus and Fratzscher [2015], Reinhardt and Sowerbutts [2015], Kang et al. [2017], Beirne and Friedrich [2017] and Cerutti et al. [2017]. Broadly speaking, these studies suggest that macroprudential measures targeting national lenders tend to generate inward spillover effects, while measures targeting national borrowers (e.g. loan to value ratio caps) tend to generate outward spillovers. A number of studies have also made use of micro (bank) level data that allow for more precisely disentangle loan supply and demand effects and to isolate the impact of specific policy measures. These studies include Ongena et al. [2013], Aiyar et al. [2014a], Aiyar et al. [2014b], Danisewicz et al. [2017], and Buch and Goldberg [2017] and accompanying national studies published in the March 2017 edition of the International Journal of Central Banking. Key findings from these micro-empirical studies suggest that both outward and inward transmission channels may be relevant. Moreover, it is found that prudential instruments spill over internationally via the lending channel but there is heterogeneity in the size and direction of transmission. In addition, the effects of prudential instruments on lending varies depending on individual bank characteristics such as balance sheet size and composition, business models of banks, or internal liquidity management via banks' internal capital markets.

Recently, also a number of multi-country DSGE models have been developed, allowing for studying cross-border effects of prudential policies. However, many of these models incorporate only a rudimentary, and often exclusively domestically-focused banking sector. Rubio [2014], Rubio and Carrasco-Gallego [2016], Mendicino and Punzi [2014] and Brzoza-Brzezina et al. [2015] develop two-country DSGE models to study the effectiveness of (predominantly rule-based) LTV policies, whereas Quint and Rabanal [2014] and Palek and Schwanebeck [2015] analyse the effects of a stylised instrument that results in an increase in borrowing costs in the economy. However, a banking sector in these models is either missing or its role is limited. In these models, international propagation of macroprudential policies happens via trade channel and international financial markets. A macroprudential policy affects a domestic bank (or directly savers and borrowers) that, in turn, is passed-through onto domestic economy, including exports and imports. Changes in trade account are matched one-to-one by an increase or reduction of a country borrowing needs and its current account. In contrast, in the two-country DSGE model of Dedola et al. [2013] explore cross-border transmission of shocks in a (somewhat unrealistic) setting of full financial integration.

Our paper contributes to the literature in various ways. First, we present a multi-country DSGE model with an explicit banking sector specification allowing for cross-border lending which may be better suited to simultaneously study outward and inward lending channels to and from a foreign country.[17] This model considers a monetary union with two countries which are interconnected via trade and bank lending channels. The individual economies are modelled following Darracq Pariès et al. [2011] implying that each economy consists of three agents (households, firms and banks) and two sectors producing residential and non-residential goods, respectively. In the model, the two countries are interconnected via trade and banking sector linkages. On the trade side, residential goods are treated as durable goods and are non-tradable, while non-residential goods can be traded across countries. For what concerns cross-border credit linkages it is assumed that households and firms can borrow abroad (as well as at home). The model allows for conducting a variety of macroprudential policy simulations including total capital requirements (e.g. CCyB), sectoral capital requirements and LTV caps. The outward spillovers to other countries depend on direct transmission channels like the financial and trade openness of the country, but also on the interaction with the monetary policy response which is allowed to react endogenously in the model. Overall, cross-country spillovers are largest for broad-based capital measures and depend on the amount of domestic deleveraging (which directly affects cross-country lending) and also on the size of the country (which affects both the exports of the foreign country and the reaction of monetary policy within the monetary union).

[17] A related DSGE model by Potineau and Vermandel [2015] with interbank and corporate cross-border lending contains similar dimensions but does not consider any macroprudential instrument.

3 A Monetary Union with International Trade and Cross-border Lending

We consider a monetary union with two countries which are interconnected via trade and financial markets. We calibrated this model so that the home country represents one country of the euro area and the foreign country represents the aggregation of the other euro area member states (see section 4). We calibrated the model four times so that, each time the home country was calibrated in order to target the main features of one of the four largest euro area economies (Germany, France, Italy and Spain).

The individual economies are modelled following Darracq Pariès et al. [2011] implying that each economy consists of three agents (households, firms and banks) and two sectors producing residential and non-residential goods, respectively. Households are of two types (see Kiyotaki and Moore [1997]), differing in their relative intertemporal discount factor. Impatient households are financially constrained and borrow from banks in order to buy the residential goods. Residential goods are treated as durable goods, and serve two purposes: they can be either directly consumed or used as collateral in the mortgage market.

Banks are affected by three layers of financial frictions, which have important implications for the propagation of shocks in the economy. First, banks face risk-sensitive capital requirements as well as adjustment costs related to their capital structure. Second, banks have some degree of market power in the retail market which generates imperfect pass-through of market rates to bank deposit and lending rates. Third, due to banks' imperfect information about their borrowers and hence monitoring costs on their credit contracts, firms and impatient households face external financing premia which depend on their leverage (see Darracq Pariès et al. [2011]).

Monetary policy in the model is formalised in terms of an interest rate rule that prescribes a response to inflation, output growth and asset prices.

In the model, the two countries are interconnected via trade and banking sector linkages. On the trade side, residential goods are treated as durable goods and are non-tradable, while non-residential goods can be traded across countries. For what concerns cross-border credit linkages it is assumed that households and firms can borrow abroad (as well as at home).[18] Figure 1 presents a schematic overview of the key model ingredients including the relevant cross-border linkages.

[18]In practice, cross-border lending can occur through direct lending across borders by domestic banks, through establishment of affiliates abroad, and through interbank cross-border lending; see also Niepmann [2015] and Niepmann [2017]. In the calibration of the model, we try to account for this range of cross-border activities; see below.

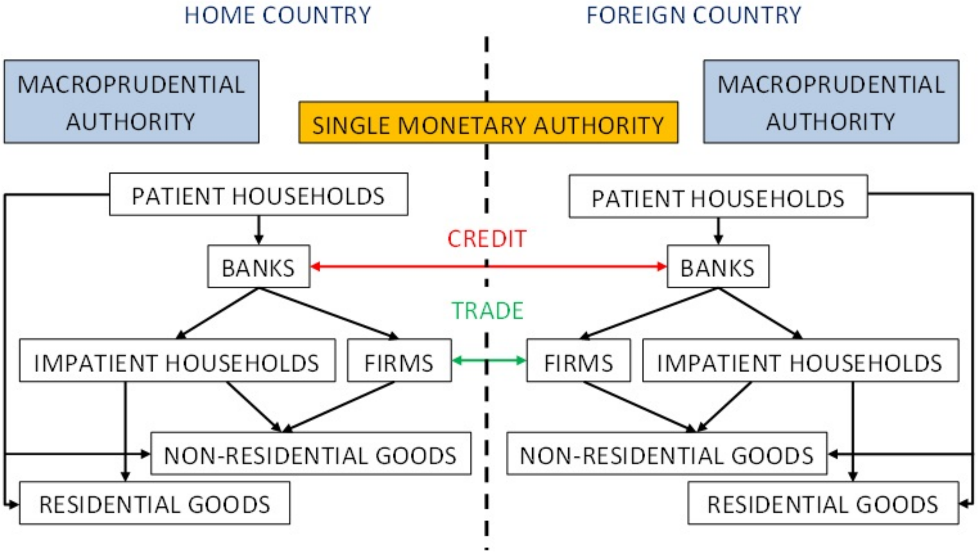


Figure 1: Overview of the model.

3.1 Households

3.1.1 The Saver's Problem

The representative saving household $j \in [\omega_i, 1]$ with $i \in \{h, f\}$ works, consumes and saves intertemporally by maximizing its utility function,

$$\mathcal{W}_{i,t}(j) = \mathbb{E}_t \left\{ \sum_{\tau=0}^{\infty} \beta^{\tau} \varepsilon_{i,t+\tau}^{U^s} \left[\frac{X_{i,t+\tau}(j)^{1-\sigma_i^X}}{1-\sigma_i^X} - \frac{\varepsilon_{i,t+\tau}^{L} \chi_i^C}{1+\sigma_i^{L^C}} N_{i,t+\tau}^C(j)^{1+\sigma_i^{L^C}} - \frac{\varepsilon_{i,t+\tau}^{L} \chi_i^D}{1+\sigma_i^{L^D}} N_{i,t+\tau}^D(j)^{1+\sigma_i^{L^D}} \right] \right\} \quad (1)$$

The utility function depends directly on an index of consumption, $X_{i,t+\tau}(j)$, derived from (domestic and foreign) non-residential goods $C_{i,t}(j)$,and (domestic) residential goods $D_{i,t}(j)$ and defined as,

$$X_{i,t}(j) \equiv \left[\left(1-\varepsilon_{i,t}^D \eta_i^D\right)^{\frac{1}{\epsilon}} \left(C_{i,t}(j) - h_i^C C_{i,t-1}(j)\right)^{\frac{\epsilon-1}{\epsilon}} + \left(\varepsilon_{i,t}^D \eta_i^D\right)^{\frac{1}{\epsilon}} D_{i,t}(j)^{\frac{\epsilon-1}{\epsilon_D}} \right]^{\frac{\epsilon}{\epsilon-1}}. \quad (2)$$

The parameter h_i^C captures the habit formation in consumption of non-residential goods, while the parameter η_i^D denotes the relative preference for consumption of residential goods. Non-residential goods are constituted by bundles of both domestic and foreign non-residential goods which are mixed together the distribution firms, as explained in Section 3.3.3).

Households supply working hours to both sectors of the economy producing non-residential and residential goods, respectively $N_{i,t+\tau}^C(j)$ and $N_{i,t+\tau}^D(j)$. Hours worked are perfectly substitutable across sectors and generate some disutility to households. In the utility function, χ_i^C, $\chi_i^D > 0$ denote the level-shift terms needed to ensure that the patient's labour supply is normalized to one in steady state in the monetary union.

Households' preferences are affected by an intertemporal preference shock $\varepsilon_{i,t}^{U^s}$, a labour supply shock $\varepsilon_{i,t}^{L}$ (common across sectors) and a housing preference shock $\varepsilon_{i,t}^{D}$. The latter affects the relative share of residential stock, η_i^D, and modifies the marginal rate of substitution between non-residential and residential goods consumption. All the shocks are assumed to follow stationary AR(1) processes log-normally distributed with mean zero.

The optimization problem of the saving households is subject to the following budget constraint,

$$\begin{aligned} C_{i,t}(j) + T_{i,t}^h Q_{i,t}^h I_{i,t}^h + Dep_{i,t}(j) &= \\ \frac{R_{i,t-1}^{Dep}}{1+\pi_{i,t}} Dep_{i,t-1}(j) + \Pi_{i,t}(j) + TR_{i,t}(j) + (1-\tau_i^w)\, \varepsilon_{i,t}^W \left(w_{i,t}^C N_{i,t}^C(j) + w_{i,t}^D N_{i,t}^D(j)\right) \end{aligned} \tag{3}$$

where $T_{i,t}^h Q_{i,t}^h$ stands for the real price of housing stock in terms of non-residential goods, $I_{i,t}$ is the investment in residential goods, $R_{i,t-1}^{Dep}$ is the gross nominal interest rate paid on the one-period real deposits denoted $Dep_{i,t}(j)$, $\pi_{i,t}$ is the domestic non-residential good inflation rate, $\Pi_{i,t}(j)$ are real distributed profits and $TR_{i,t}(j)$ are real government transfers. The real hourly wages from working in the domestic non-durable and durable sectors are denoted by $w_{i,t}^C$ and $w_{i,t}^D$ respectively, τ_i^w is the wage tax and $\varepsilon_{i,t}^W$ a shock to wages. Investment in residential goods is defined by the following law of motion,

$$I_{i,t}^h(j) = D_{i,t}(j) - \left(1-\delta_i^D\right) D_{i,t-1}(j) \tag{4}$$

The optimality conditions characterizing the solution of the saver's problem are reported in the Appendix A.1.

3.1.2 The Borrower's Problem

Each impatient agent $j \in [0, \omega_i]$ with $i \in \{h, f\}$ is characterized by preferences similar to the ones of the patient households, but with a lower intertemporal discount factor, such that $\beta_i > \tilde{\beta}_i$[19],

$$\widetilde{\mathcal{W}}_{i,t}(j) = \mathbb{E}_t \left\{ \sum_{\tau=0}^{\infty} \widetilde{\beta}_i^{\tau} \varepsilon_{i,t+\tau}^{U^b} \left[\frac{\widetilde{X}_{i,t+\tau}(j)^{1-\sigma_i^X}}{1-\sigma_i^X} - \frac{\varepsilon_{i,t+\tau}^L \widetilde{\chi}_i^C}{1+\sigma_i^L} \widetilde{N}_{i,t+\tau}^C(j)^{1+\sigma_i^L} - \frac{\varepsilon_{i,t+\tau}^L \widetilde{\chi}_i^D}{1+\sigma_i^L} \widetilde{N}_{i,t+\tau}^D(j)^{1+\sigma_i^L} \right] \right\} \tag{5}$$

where $\widetilde{N}_{i,t}^D$, $\widetilde{N}_{i,t}^C$, $\widetilde{X}_{i,t}(j)$, $\widetilde{\chi}_i^C$ and $\widetilde{\chi}_i^D$ are defined similarly to Equation 2. The index of consumption $\widetilde{X}_{i,t}(j)$ is defined as

$$\widetilde{X}_{i,t}(j) \equiv \left[\left(1-\varepsilon_{i,t}^D \eta_i^D\right)^{\frac{1}{\epsilon}} \left(\widetilde{C}_{i,t}(j) - h_i^C \widetilde{C}_{i,t-1}(j)\right)^{\frac{\epsilon-1}{\epsilon}} + \left(\varepsilon_{i,t}^D \eta_i^D\right)^{\frac{1}{\epsilon}} \widetilde{D}_{i,t}(j)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{6}$$

[19] Variables related to the borrowing household are denoted with the superscript ~

where $\widetilde{C}_{i,t}$ and $\widetilde{D}_{i,t}$ denote the consumption of (domestic and foreign) non-residential and (domestic) residential goods, respectively. The impatient households maximize their utility function in Equation 5 under the following budget constraint:

$$\widetilde{C}_{i,t}(j) + T^h_{i,t}\widetilde{Q}^h_{i,t}\widetilde{I}^h_{i,t}(j) + \widetilde{A}^H_{i,t-1}(j) = B^H_{i,t}(j) + (1-\tau^w_i)\,\varepsilon^W_{i,t}\left(\widetilde{w}^C_{i,t}\widetilde{N}^C_{i,t}(j) + \widetilde{w}^D_{i,t}\widetilde{N}^D_{i,t}(j)\right) + \widetilde{TR}_{i,t}, \quad (7)$$

where

$$\widetilde{I}^h_{i,t}(j) = \left[\widetilde{D}_{i,t}(j) - \left(1-\delta^D_i\right)\widetilde{D}_{i,t-1}(j)\right]. \quad (8)$$

$$\widetilde{A}^H_{i,t-1}(j) \equiv \left\{\left[1-F\left(\overline{\varpi}^{H*}_{i,t}\right)\right]\overline{\varpi}^H_{i,t}\mathbb{E}_{t-1}\left[\widetilde{Q}^h_{i,t}T^h_{i,t}\right] + \int_0^{\overline{\varpi}^{H*}_{i,t}} \varpi^H_{i,t}dF\left(\varpi^H_{i,t}\right)\widetilde{Q}^h_{i,t}T^h_{i,t}\right\} \left(1-\chi^H_i\right)\left(1-\delta^D_i\right)\widetilde{D}_{i,t-1}(j) \quad (9)$$

In Equation 7 households' borrowing are denoted by $B^H_{i,t}(j)$ and the aggregate repayments of outstanding loans are given by $\widetilde{A}^H_{i,t-1}(j)$. As in the literature starting from Bernanke et al. [1999], the households' borrowing contract is collateralised by the housing stock. However, the collateral value of housing is subject to some idiosyncratic and i.i.d. shocks, $\varpi^H_{i,t}$, which realize when borrowings must be repayed.[20] Following Darracq Pariès et al. [2011], we assume that if the realized value of the housing (net of exemptions) is lower than the due repayments, then households will default on repayments and the bank can only seize households' collateral. Calling $\overline{\varpi}^{H*}_{i,t}$ the shock level at which an the households' collateral equals the debt repayment, households default when $\varpi^H_{i,t} < \overline{\varpi}^{H*}_{i,t}$. If households default, banks are only able to seize the collateral. The value of the collateral is $\varpi^H_{i,t}\left(1-\chi^H\right)\widetilde{Q}^h_{i,t}T^h_{i,t}\left(1-\delta^D_i\right)\widetilde{D}_{i,t-1}(j)$, but banks are able to seize only $\left(1-\mu^H\right)$ of the collateral value due to monitoring costs as in Bernanke et al. [1999], $\mu^H \in [0,1]$. Instead, if $\varpi^H_{i,t} > \overline{\varpi}^{H*}_{i,t}$ households repay their credit at a predetermined interest rate.

Lending in this economy is only possible through 1-period debt contracts with *predetermined* lending rates (see Darracq Pariès et al. [2011]) that require a constant repayment of $B^H_{i,t-1}IR^{H_L}_{i,t}$ independent of the realization of $\varpi^H_{i,t}$ and of the aggregate uncertainty, where $IR^{H_L}_{i,t}$ is the nominal predetermined lending rate. Differently from Bernanke et al. [1999], in this setting the contractual lending rate is predetermined and not state contingent, implying that aggregate shocks have an effect on banks' balance sheet. *Ex-ante* the borrower is indifferent between repaying and defaulting when the *expected* value of the collateral equals the future repayment costs. The *ex-ante* participation constraint to the credit contract of each household implies the following *ex-ante* shock threshold $\overline{\varpi}^H_{i,t}$:

$$IR^{H_L}_{i,t}B^H_{i,t-1}(j) = \overline{\varpi}^H_{i,t}\left(1-\chi^H_i\right)\mathbb{E}_{t-1}\left[\widetilde{Q}^h_{i,t}T^h_{i,t}\left(1+\pi_{i,t}\right)\right]\left(1-\delta^D_i\right)\widetilde{D}_{i,t-1}(j). \quad (10)$$

[20]The stochastic shock $\varpi^H_{i,t}$ has a lognormal distribution with PDF, $F'\left(\varpi^H_{i,t}\right) = f\left(\varpi^H_{i,t}\right)$, mean $E\left(\varpi^H_{i,t}\right) = 1$ and time-varying variance $\left(\sigma^H_i \exp\left(\varepsilon^{\sigma H}_{i,t}\right)\right)^2$, where $\varepsilon^{\sigma HH}_{i,t}$ is a AR(1) shock process.

However, when the shock $\varpi_{i,t}^{H}$ realizes at time t, the borrower is indifferent between repaying and defaulting only when the *realized* value of the collateral equals the already agreed repayment costs, implying the following threshold for the shock:

$$IR_{i,t}^{H_L} B_{i,t-1}^{H}(j) = \overline{\varpi}_{i,t}^{H*} \left(1-\chi_i^H\right) \widetilde{Q}_{i,t}^{h} T_{i,t}^{h} \left(1+\pi_{i,t}\right) \left(1-\delta_i^D\right) \widetilde{D}_{i,t-1}(j). \tag{11}$$

This implies that the banks will suffer unexpected losses when the aggregate shocks realize.

3.2 Labour Supply and Wage Setting

The labour market structure is modeled following Schmitt-Grohé and Uribe [2006]. Households of each type (patient, impatient) provide homogeneous labour services j, sold by labour unions to perfectly competitive labour packers who assemble them in a CES aggregator and sell the homogenous labour to firms.

We assume that in each sector $s \in \{C, D\}$ there are monopolistically competitive labour unions representing the patient and impatient households. Unions differentiate the homogeneous labour provided by households, $N_{i,t}^{s}(j)$ from savers and $\widetilde{N}_{i,t}^{s}(j)$ from borrowers, creating a continuum of labour services (indexed by $j \in [0,1]$) which are sold to labour packers. Then perfectly competitive labour packers buy the differentiated labour input and aggregate them through a CES technology into one labour input per sector and households type. Finally the labour inputs are further combined using a Cobb-Douglas technology to produce the aggregate labour resource $N_{i,t}^{C}$ and $\widetilde{N}_{i,t}^{s}$ that enter the production functions of entrepreneurs (see next section). The equilibrium is characterized by four different wages in each country, each corresponding to a specific worker type (patient, impatient) in a specific sector $s \in \{C, D\}$.

In a first stage, we suppose that a representative union is closely related to household $j \in [0,1]$. Unions set wages on a staggered basis *à la Calvo* Calvo [1983], so that there is a fraction of households $1-\theta_i^W$ allowed to re-negotiate its nominal wage while for the other share θ_i^W, its wage is indexed on inflation $\pi_{i,t}$ in a proportion ζ_i^w,

$$w_{i,t}^{s}(j) = \pi_{i,t}^{\zeta_i^w} \overline{\pi}_{i,t}^{1-\zeta_i^w} w_{i,t-1}^{s}(j) \text{ and } \widetilde{w}_{i,t}^{s}(j) = \pi_{i,t}^{\zeta_i^w} \overline{\pi}_{i,t}^{1-\zeta_i^w} \widetilde{w}_{i,t-1}^{s}(j) \tag{12}$$

Assuming that the trade union is able to modify its wage with a probability $1-\theta_i^W$, it chooses the optimal wage to maximize its expected sum of profits as described in the appendix.

In a second stage, perfectly competitive labour packers, in each country i, buy the differentiated labour inputs from each household j for each sector $s = \{C, D\}$ and aggregate them through a CES technology to supply labour services to firms. The aggregated demand of labour inputs for saving and borrowing households in each sector and in each country, respectively, can be expressed as

$$L_{i,t}^{s} = \left[\int_0^1 \left(L_{i,t}^{s}(j)\right)^{1/\mu_w} dj\right]^{\mu_w} \text{ and } \widetilde{L}_{i,t}^{s} = \left[\int_0^1 \left(\widetilde{L}_{i,t}^{s}(j)\, dj\right)^{1/\mu_w}\right]^{\mu_w}, \tag{13}$$

where $L_{i,t}^{s}$ (resp. $\widetilde{L}_{i,t}^{s}$) is the aggregate demand of packers of labour inputs from saving (borrowing) households in country i for sector s. In the same way, the aggregate nominal wage for each type of household in each country and for each sector is determined by,

$$w_{i,t}^{s}=\left[\int_{0}^{1}\left(w_{i,t}^{s}\left(j\right)\right)^{1/(1-\mu_{w})}dj\right]^{1-\mu_{w}}\text{ and }\widetilde{w}_{i,t}^{s}=\left[\int_{0}^{1}\left(\widetilde{w}_{i,t}^{s}\left(j\right)\right)^{1/(1-\mu_{w})}dj\right]^{1-\mu_{w}}\tag{14}$$

The demand functions associated with this problem are

$$L_{i,t}^{s}\left(j\right)=\left(\frac{w_{i,t}^{s}\left(j\right)}{w_{i,t}^{s}}\right)^{-\frac{\mu_{w}}{\mu_{w}-1}}L_{i,t}^{s}\text{ and }\widetilde{L}_{i,t}^{s}\left(j\right)=\left(\frac{\widetilde{w}_{i,t}^{s}\left(j\right)}{\tilde{w}_{i,t}^{s}}\right)^{-\frac{\mu_{w}}{\mu_{w}-1}}\tilde{L}_{i,t}^{s}\tag{15}$$

In this setting, $\mu_w=\frac{\varepsilon_w}{\varepsilon_w-1}$ is the markup implied by the monopolistic competition on this market, ε_w denotes the substitutability between different types of labour. Market clearing conditions between households' supply of homogeneous labour services and unions' differentiated labour services imply that the aggregate labour supply by each type of household in each sector equals the aggregated supply:

$$\omega_{i}\widetilde{N}_{i,t}^{s}=\int_{0}^{1}\widetilde{L}_{i,t}^{s}\left(j\right)dj=\widetilde{\Delta}_{i,t}^{w_{s}}\widetilde{L}_{i,t}^{s}\tag{16}$$

$$\left(1-\omega_{i}\right)N_{i,t}^{s}=\int_{0}^{1}L_{i,t}^{s}\left(j\right)dj=\Delta_{i,t}^{w_{s}}L_{i,t}^{s},\tag{17}$$

where $\Delta_{i,t}^{w_s}$ (resp. $\widetilde{\Delta}_{i,t}^{w_s}$) are the wage dispersions in each sector and for each type of household. *In the last stage*, we suppose that labour packers aggregate labour of borrowers and lenders according to a Cobb-Douglas technology,

$$L_{i,t}^{s}=\omega_{i}^{\omega_{i}}\left(1-\omega_{i}\right)^{1-\omega_{i}}\left(\frac{N_{i,t}^{s}}{\Delta_{i,t}^{w_{s}}}\right)^{\omega_{i}}\left(\frac{\widetilde{N}_{i,t}^{s}}{\widetilde{\Delta}_{i,t}^{w_{s}}}\right)^{1-\omega_{i}}\tag{18}$$

Cost minimization implies that aggregate wage in sector s writes:

$$\mathbb{W}_{i,t}^{s}=\left(\frac{w_{i,t}^{s}}{\omega_{i}}\right)^{\omega_{i}}\left(\frac{\widetilde{w}_{i,t}^{s}}{\left(1-\omega_{i}\right)}\right)^{1-\omega_{i}}\tag{19}$$

and inputs satisfy $\widetilde{\Delta}_{i,t}^{w_s}N_{i,t}^{s}w_{i,t}^{s}=\Delta_{i,t}^{w_s}\widetilde{N}_{i,t}^{s}\widetilde{w}_{i,t}^{s}$.

3.3 Non-Financial Corporate Sector

The non-financial corporate sector is composed of three types of firms. Firms producing intermediate residential and non-residential goods combine labour and capital inputs to produce intermediate goods. To conduct their activity, entrepreneurs might recur to credit from both domestic and foreign banks. Distribution companies trade non-residential goods across countries and bundle them together. Final goods producers operate in monopolistic competition and differentiate intermediate products into imperfect substitute final goods. While in the residential sector final goods producers purchase intermediate products directly from entrepreneurs, in the non-residential sector final goods producers acquire bundles of domestic and foreign intermediate goods from the distribution companies.

3.3.1 Entrepreneurs

Entrepreneurs are more impatient than patient households, but less impatient than impatient households and have a discount factor $\widetilde{\beta}_i < \widehat{\beta}_i < \beta_i$. They receive utility from their consumption of non-residential goods, $\widehat{C}_{i,t}^{E}$ and their preferences are subject to habit formation. They are in charge of the production of intermediate residential and non-residential goods, and operate in a perfectly competitive environment. Contrary to the standard framework of Bernanke et al. [1999], entrepreneurs do not supply labour services. The intertemporal utility function of the representative entrepreneur $e \in [0,1]$ is given by:

$$\mathcal{W}_{i,t}^{E}(e) = \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \widehat{\beta}_i^{\tau} \varepsilon_{i,t+\tau}^{U^e} \frac{\left(\widehat{C}_{i,t+\tau}(e) - h_c \widehat{C}_{i,t-1+\tau}(e)\right)^{1-\sigma_i^C}}{1-\sigma_i^C} \right], \tag{20}$$

where σ_i^C is the risk aversion parameter, h_c denotes the habit formation in consumption of non-residential goods and $\varepsilon_{i,t+\tau}^{U^e}$ is a preference shock. Each entrepreneur faces supply constraints when producing both intermediate goods $Z_{i,t}^{C}(e)$ and residential goods $Z_{i,t}^{D}(e)$:

$$\begin{aligned} Z_{i,t}^{C}(e) &= \exp\left(\varepsilon_{i,t}^{A^C}\right)\left(u_{i,t}^{C}(e) K_{i,t-1}^{C}(e)\right)^{\alpha_i^C} L_{i,t}^{C}(e)^{1-\alpha_i^C} - \Omega_i^C \\ Z_{i,t}^{D}(e) &= \exp\left(\varepsilon_{i,t}^{A^D}\right)\left(u_{i,t}^{D}(e) K_{i,t-1}^{D}(e)\right)^{\alpha_i^D} L_{i,t}^{D}(e)^{1-\alpha_i^D-\alpha_i^{\mathcal{L}}} \mathcal{L}_{i,t}(e)^{\alpha_i^{\mathcal{L}}} - \Omega_i^D \end{aligned} \tag{21}$$

where, for each sector $s = \{C, D\}$, $\varepsilon_{i,t}^{A^s}$ is an exogenous technology shock normally distributed, $K_{i,t}^{s}$ is the capital input, $L_{i,t}^{s}$ is the labour input and $\mathcal{L}_{i,t}(e)$ denotes the endowment of land. Capital is sector specific and is augmented by a variable capacity utilization rate $u_{i,t}^{s}$ for both sectors $s \in \{C,\ D\}$. Variables $MC_{i,t}^{C}$ and $MC_{i,t}^{D}$ denote the selling prices for intermediate non-residential and residential products.[21]

Entrepreneurs maximize their utility function under the following budget constraint:

$$\widehat{C}_{i,t}(e) + \sum_{s=C,D} \left[Q_{i,t}^{s} \widehat{I}_{i,t}^{s}(e) + W_{i,t}^{s} L_{i,t}^{s}(e) + \Phi\left(u_{i,t}^{s}(e)\right) K_{i,t-1}^{s} \right] + \tag{22}$$

$$p_{i,t}^{\mathcal{L}} \mathcal{L}_{i,t}(e) + A_{i,t-1}^{E}(e) \leq \sum_{s=C,D} MC_{i,t}^{s} Z_{i,t}^{s}(e) + B_{i,t}^{E}(e) \tag{23}$$

where

$$\widehat{I}_{i,t}^{s}(e) = K_{i,t}^{s}(e) - \left(1-\delta_i^K\right) Q_{i,t}^{s} K_{i,t-1}^{s}(e) \tag{24}$$

where $\Phi\left(u_{i,t}^{s}\right)$ denotes the capital utilization cost[22], $W_{i,t}^{s}$ is the real wage paid by entrepreneurs to households from producing goods in sector $s \in \{C,\ D\}$. Similarly to the budget constraint of the borrowing households, $A_{i,t-1}^{E}(e)$ is defined as the aggregate repayments of entrepreneurs' loans. As in Darracq Pariès et al. [2011], we incorporate a financial friction in the credit relationship between entrepreneurs and banks (see Bernanke

[21] In a perfectly competitive equilibrium, they also denotes the marginal cost of producing a new unit of good.

[22] For each sector $s \in \{C, D\}$, the capital utilization function is determined by $\Phi(u_{i,t}^{s}) = \bar{R}_i^k \frac{(1-\varphi_i)}{\varphi_i} \left[\exp\left(\frac{\varphi_i}{(1-\varphi_i)}\left(u_{i,t}^{s}-1\right)\right) - 1 \right]$, where parameter φ_i denotes the capital utilization elasticity. Following Smets and Wouters [2007], the cost of capacity utilization is zero when capacity is fully used ($\Phi(1) = 0$).

et al. [1999]). Each investment project is risky and each borrower is subject to an idiosyncratic shock $\varpi^E_{i,t}$ to the value of her capital stock, where $\varpi^E_{i,t}$ is distributed and has the same properties as $\varpi^H_{i,t}$ (see section 3.1.2). The capital value after depreciation and the shock realization is given by $\varpi^E_{i,t}(1-\chi^E_i)(1-\delta^K_i)\sum_{s=C,D} Q^s_{i,t}K^s_{i,t-1}(e))$ and is equivalent to the collateral that the bank can seize in case of default, with $Q^s_{i,t}K^s_{i,t-1}(e)$ being the total value of the investment project conducted by entrepreneur e in sector $s \in \{C,\ D\}$. However, banks pay monitoring costs $\mu^E_i \in [0,1]$ and can effectively seize $\left(1-\mu^E_i\right)$ of the value of the collateral.

As for the household sector, also credit to the non-financial corporation sector is given with one-period contracts and at predetermined lending rates. With predetermined lending rates, *ex-ante* each individual borrower is indifferent between defaulting and repaying if the expected value of the collateral equals the repayment of the credit:

$$IR^{E_L}_{i,t}B^E_{i,t-1}(e) = \overline{\varpi}^E_{i,t}(1-\chi^E_i)(1-\delta^K_i)\mathbb{E}_{t-1}\left[\sum_{s=C,D} Q^s_{i,t}K^s_{i,t-1}(e)(1+\pi_{i,t})\right]. \tag{25}$$

with $IR^{E_L}_{i,t}$ being the lending rate. However, when the shock realizes in t, the actual shock level at which the entrepreneur is indifferent between repaying an defaulting is determined by the following relation

$$IR^{E_L}_{i,t}B^E_{i,t-1}(e) = \overline{\varpi}^{E*}_{i,t}(1-\chi^E_i)(1-\delta^K_i)\sum_{s=C,D} Q^s_{i,t}K^s_{i,t-1}(e)(1+\pi_{i,t}). \tag{26}$$

For this reason, the entrepreneur's expected repayments of the credit at time t are then given by

$$\begin{aligned} A^E_{i,t} \;=\; & \left\{\left[1-F\left(\overline{\varpi}^{E*}_{i,t}\right)\right]\overline{\varpi}^E_{i,t}\mathbb{E}_{t-1}\left[\sum_{s=C,D} Q^s_{i,t}K^s_{i,t-1}(e)\right] + \int_0^{\overline{\varpi}^{E*}_{i,t}} \varpi^E_{i,t}dF\left(\varpi^E_{i,t}\right)\sum_{s=C,D} Q^s_{i,t}K^s_{i,t-1}(e)\right\} \\ & \left(1-\chi^E_i\right)\left(1-\delta^K_i\right) \end{aligned} \tag{27}$$

3.3.2 Capital and housing stock producers

The stock of housing and fixed capital is produced by a segment of perfectly competitive firms owned by patient households. At the beginning of each period t capital and housing stock producers buy at real prices the depreciated capital $(\left(1-\delta^K_i\right)K^s_{i,t-1})$ and housing stock $(\left(1-\delta^D_i\right)D_{i,t-1}$ and $(\left(1-\delta^D_i\right)\widetilde{D}_{i,t-1}))$ from both households types and both intermediate sector firms. Then they augment the capital and housing stocks using distributed goods and facing adjustment costs. The augmented stocks are sold back at the end of the period to households and entrepreneurs at the same prices. The maximization problem of capital stock producers can be written as:

$$\max_{K^s_{i,t},\mathcal{I}^{K_s}_{i,t}} \mathbb{E}_t\left[\sum_{\tau=0}^{\infty}\beta^\tau_i Q^{K_s}_{i,t+\tau}\left(K^s_{i,t+\tau}-\left(1-\delta^K_i\right)K^s_{i,t-1+\tau}-\mathcal{I}^{K_s}_{i,t+\tau}\right)\right] \tag{28}$$

$$s.t. \quad K^s_{i,t} = \left(1-\delta^K_i\right)K^s_{i,t-1} + \left[1-S\left(\frac{\mathcal{I}^{K_s}_{i,t}\varepsilon^I_t}{\mathcal{I}^{K_s}_{i,t-1}}\right)\right]\mathcal{I}^{K_s}_{i,t} \tag{29}$$

which implies the following FOC:

$$\mathcal{Q}_{i,t}^{K_s}\left[1-S\left(\frac{\mathcal{I}_{i,t}^{K_s}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{K_s}}\right)-\frac{\mathcal{I}_{i,t}^{K_s}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{K_s}}S'\left(\frac{\mathcal{I}_{i,t}^{K_s}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{K_s}}\right)\right]+\beta_i\mathbb{E}_t\left[\mathcal{Q}_{i,t+1}^{K_s}\left(\frac{\mathcal{I}_{i,t+1}^{K_s}\varepsilon_{t+1}^I}{\mathcal{I}_{i,t}^{K_s}}\right)^2 S'\left(\frac{\mathcal{I}_{i,t+1}^{K_s}\varepsilon_{t+1}^I}{\mathcal{I}_{i,t}^{K_s}}\right)\right]=1. \quad (30)$$

Similarly for the housing stock producers, they optimize the following preferences

$$\max_{D_{i,t},\mathcal{I}_{i,t}^D}\mathbb{E}_t\left[\sum_{\tau=0}^{\infty}\beta_i^\tau\mathcal{Q}_{i,t+\tau}^D\left(D_{i,t+\tau}-\left(1-\delta_i^D\right)D_{i,t-1+\tau}-\mathcal{I}_{i,t+\tau}^D\right)\right] \quad (31)$$

$$s.t. \quad D_{i,t}=\left(1-\delta_i^D\right)D_{i,t-1}+\left[1-S\left(\frac{\mathcal{I}_{i,t}^D\varepsilon_t^I}{\mathcal{I}_{i,t-1}^D}\right)\right]\mathcal{I}_{i,t}^D \quad (32)$$

$$\max_{\widetilde{D}_{i,t},\mathcal{I}_{i,t}^{\widetilde{D}}}\mathbb{E}_t\left[\sum_{\tau=0}^{\infty}\beta_i^\tau\mathcal{Q}_{i,t+\tau}^{\widetilde{D}}\left(\widetilde{D}_{i,t+\tau}-\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1+\tau}-\mathcal{I}_{i,t+\tau}^{\widetilde{D}}\right)\right] \quad (33)$$

$$s.t. \quad \widetilde{D}_{i,t}=\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1}+\left[1-S\left(\frac{\mathcal{I}_{i,t}^{\widetilde{D}}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{\widetilde{D}}}\right)\right]\mathcal{I}_{i,t}^{\widetilde{D}}$$

which give the following FOCs:

$$\mathcal{Q}_{i,t}^{D}\left[1-S\left(\frac{\mathcal{I}_{i,t}^{D}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{D}}\right)-\frac{\mathcal{I}_{i,t}^{D}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{D}}S'\left(\frac{\mathcal{I}_{i,t}^{D}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{D}}\right)\right]+\beta_i\mathbb{E}_t\left[\mathcal{Q}_{i,t+1}^{D}\left(\frac{\mathcal{I}_{i,t+1}^{D}\varepsilon_{t+1}^I}{\mathcal{I}_{i,t}^{D}}\right)^2 S'\left(\frac{\mathcal{I}_{i,t+1}^{D}\varepsilon_{t+1}^I}{\mathcal{I}_{i,t}^{D}}\right)\right]=1$$

$$\mathcal{Q}_{i,t}^{\widetilde{D}}\left[1-S\left(\frac{\mathcal{I}_{i,t}^{\widetilde{D}}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{\widetilde{D}}}\right)-\frac{\mathcal{I}_{i,t}^{\widetilde{D}}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{\widetilde{D}}}S'\left(\frac{\mathcal{I}_{i,t}^{\widetilde{D}}\varepsilon_t^I}{\mathcal{I}_{i,t-1}^{\widetilde{D}}}\right)\right]+\beta_i\mathbb{E}_t\left[\mathcal{Q}_{i,t+1}^{\widetilde{D}}\left(\frac{\mathcal{I}_{i,t+1}^{\widetilde{D}}\varepsilon_{t+1}^I}{\mathcal{I}_{i,t}^{\widetilde{D}}}\right)^2 S'\left(\frac{\mathcal{I}_{i,t+1}^{\widetilde{D}}\varepsilon_{t+1}^I}{\mathcal{I}_{i,t}^{\widetilde{D}}}\right)\right]=1 \quad (34)$$

(35)

3.3.3 Final goods producers

Final good producers differentiate the residential and non-residential goods produced by the entrepreneurs and operate under perfect competition. The elementary differentiated goods are imperfect substitutes with elasticity of substitution denoted $\mu_D/\left(\mu_D-1\right)$ and $\mu_C/\left(\mu_C-1\right)$ for the residential and the non-residential sectors, respectively.

In the residential sector, final goods producers maximize their profits $P_{i,t}^D Y_{i,t}^D - \int_0^1 P_{i,t}^D\left(e\right) Z_{i,t}^D\left(e\right)\mathrm{d}e$, subject to the production function $Y_{i,t}^D = (\int_0^1 Z_{i,t}^D\left(e\right)^{1/\mu_D}\mathrm{d}e)^{\mu_D}$. This implies that the intermediate demand function associated with this problem is $Z_{i,t}^D\left(e\right)=\left(P_{i,t}^D(e)/P_{i,t}^D\right)^{-\mu_D/(\mu_D-1)}Y_{i,t}^D$, $\forall e$, where $Y_{i,t}^D$ is the aggregate demand for residential goods.

Final goods producers of non-residential goods aggregate home and foreign intermediate products and maximize their profits. The maximization of the non-residential goods producers can be split up between the production of domestic goods for the domestic demand $Y^C_{i,i,t}$ and for the foreign demand $Y^C_{i,j,t}$ which are subindexes of the continuum of differentiated goods produced in each country. Final goods for domestic and foreign demand have the following production technologies:

$$Y^C_{i,i,t} = \left[\int_0^1 \left(Z^C_{i,i,t}(e)\right)^{1/\mu_C} de\right]^{\mu_C} \text{ and } Y^C_{i,j,t} = \left[\int_0^1 \left(Z^C_{i,j,t}(e)\right)^{1/\mu_C} (e)\, de\right]^{\mu_C}, \tag{36}$$

where $Z^C_{i,i,t}(e)$ (resp. $Z^C_{i,j,t}(e)$) denotes the domestically (non-domestically) produced intermediate product used in the production of final goods for the domestic demand. For each product e we denote with $P^C_{i,i,t}(e)$ the price on the domestic market and with $P^C_{i,j,t}(e)$ the price on the foreign import market. The demand-based price indices for domestic and imported goods are defined as:

$$P^C_{i,i,t} = \left[\int_0^1 \left(P^C_{i,i,t}(e)\right)^{1/(1-\mu_C)} de\right]^{1-\mu_C} \text{ and } P^C_{i,j,t} = \left[\int_0^1 \left(P^C_{i,j,t}(e)\right)^{1/(1-\mu_C)} de\right]^{1-\mu_C}, \tag{37}$$

respectively. Then the demand for domestic and foreign the intermediated goods can be expressed as a function of the domestic and foreign aggregated demands for final goods:

$$Z^C_{i,i,t}(e) = \left[\frac{P^C_{i,i,t}(e)}{P^C_{i,i,t}}\right]^{-\mu_C/(\mu_C-1)} Y^C_{i,i,t} \text{ and } Z^C_{i,j,t}(e) = \left[\frac{P^C_{i,j,t}(e)}{P^C_{i,j,t}}\right]^{-\mu_C/(\mu_C-1)} Y^C_{i,j,t}. \tag{38}$$

3.3.4 Distribution sector

Non-residential intermediate goods are traded across countries and are bundled into final products from the distribution sector companies and then sold to households (see Adjemian et al. [2008]). There is a continuum of distribution companies operating under perfect competition and mixing domestic and foreign products to create bundles of non-residential consumption goods to satisfy domestic demand. The aggregation technology for each distribution company $l \in [0, 1]$ operating in country i is given by:

$$Y^C_{i,t}(l) = \left[\left(\alpha_i^{Y^C} \varepsilon^{Y^C}_{i,t}\right)^{1/\nu_y} \left(Y^C_{i,i,t}(l)\right)^{(1-\nu_y)/\nu_y} + \left(1 - \alpha_i^{Y^C} \varepsilon^{Y^C}_{i,t}\right)^{1/\nu_y} \left(Y^C_{i,j,t}(l)\right)^{(1-\nu_y)/\nu_y}\right]^{\nu_y/(1-\nu_y)} \tag{39}$$

with ν_y denoting the elasticity of substitution between bundles of domestic goods consumed by domestic citizens $Y^C_{i,i,t}(l)$ and foreign non-residential goods consumed by domestic citizens $Y^C_{i,j,t}(l)$. As only the difference of openness rates enters the linearized aggregate equations in the absence of adjustment costs on imports, home bias shocks are given by $\varepsilon^Y_{i,t} = \widetilde{\varepsilon}_t$ for $i = h$ and $\varepsilon^Y_{i,t} = 1/\widetilde{\varepsilon}_t$ for $i = f$. In a similar way, the before tax distribution prices are given by the following aggregate price indices:

$$P^C_{i,t} = \left[\alpha_i^{Y^C} \varepsilon^Y_{i,t} \left(P^C_{i,i,t}\right)^{1-\nu_y} + \left(1 - \alpha_i^{Y^C} \varepsilon^Y_{i,t}\right) \left(P^C_{i,j,t}\right)^{1-\nu_y}\right]^{1/(1-\nu_y)} \tag{40}$$

where $P^C_{i,j,t}$ is the price index of goods imported in country i and $P^C_{i,i,t}$ is the price index domestic goods sold to domestic final goods firms (see next section). Cost minimization implies the following demand for domestic and foreign goods in each country:

$$Y^C_{i,i,t} = \alpha_i^{Y^C} \varepsilon_{i,t}^{Y^C} \left[\frac{P^C_{i,i,t}}{P^C_{i,t}} \right]^{-\nu_y} Y^C_{i,t} \text{ and } Y^C_{i,j,t} = \left(1 - \alpha_i^{Y^C} \varepsilon_{i,t}^{Y^C}\right) \left[\frac{P^C_{i,j,t}}{P^C_{i,t}} \right]^{-\nu_y} Y^C_{i,t}. \tag{41}$$

From Equation 41, the demand for imports depends on the relative price of imported goods and the average domestic prices.

3.4 The banking sector

The banking sector is structured in a way similar to Darracq Pariès et al. [2011] and Gerali et al. [2010]. It is composed of four branches: The retail deposit, the wholesale, the loan-book financing and the retail lending branches. In the two-country set-up considered in this paper, deposit branches receive deposits from domestic saving households and place allocate them on the money market. Wholesale branches are in perfect competition, they get financing in the money market and allocate their funds to the loan-book financing branches in the form of loans to households and non-financial corporations, internalizing the country specific regulatory requirements on capital and risk weights. The loan-book financing branches operate under monopolistic competition, receive funds from the domestic wholesale branches and allocate them to domestic and foreign retail lending branches, adding a mark-up on the interest rate. The retail lending branches are responsible for distributing the loans to domestic households and non-financial corporations under a perfect competition regime. Retail lending branches charge an additional risk-premium on the interest rates to cover their monitoring costs.

3.4.1 Retail Deposit Branch

Each deposit bank $p \in [0, 1]$ collects differentiated deposit services to patient households. These branches collect deposits $Dep_{i,t}$ from domestic households and place them on the money market at the policy rate $R_{i,t}$. The deposit banks offer differentiated services which are imperfect substitutes and have elasticity of substitution equal to $\mu_i^{Dep} / \left(\mu_i^{Dep} - 1\right)$ with $\mu_i^{Dep} \in [0, 1]$. For this reason, the aggregated deposit services provided by deposit banks resident in country i are determined by $Dep_{i,t} = \left[\int_0^1 Dep_{i,t}(p)\, d(p)\right]^{\mu_i^{Dep}}$ and the average interest rate paid on deposits is given by $R^{Dep}_{i,t} = \left[\int_0^1 R^{Dep}_{i,t}(p)^{1/\left(1-\mu_i^{Dep}\right)} d(p)\right]^{1-\mu_i^{Dep}}$. Deposit branches set interest rates on a staggered basis *à la Calvo* (1983) having in each period a probability $1 - \theta^{Dep}_{i,t}$ to be able to reset their interest rate to $\hat{R}^{Dep}_{i,t}$ and a probability $\theta^{Dep}_{i,t}$ to keep rates unchanged with respect to the previous period ($R^{Dep}_{i,t}(p) = R^{Dep}_{i,t-1}(p)$). The maximization of the profits of the deposit bank p can be written as:

$$\max_{R^{Dep}_{i,t}(p)} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \beta_i^\tau \theta^{Dep}_{i,t+\tau} \lambda^C_{i,t+\tau} \left(R_{i,t+\tau} Dep_{i,t+\tau}(p) - R^{Dep}_{i,t}(p)\, Dep_{i,t}(p) \right) \right] \tag{42}$$

where $\lambda^C_{i,t+\tau}$ is the marginal value of non-residential consumption for the saving households. A markup shock is introduced on the interest rate setting, by allowing μ_i^{Dep} to follow an AR(1) process with iid innovations. The maximization in Equation 42 leads to the following expression for the individual deposit services demand: $Dep_{i,t}(d) = \left[\frac{R^{Dep}_{i,t}(d)}{R^{Dep}_{i,t+\tau}}\right]^{\mu_i^{Dep}/\left(1-\mu_i^{Dep}\right)} Dep_{i,t+\tau}$.

3.4.2 Wholesale branch

The wholesale branch operates in perfect competition deciding about the allocation of credit between the household and the non-financial corporation sectors ($B^{H_B}_{i,t}$ and $B^{E_B}_{i,t}$, respectively) and on the amount of deposits collected $Dep^B_{i,t}$. In doing so, it has no influence on the capital issuance and on the ditribution of dividends, but takes them as given. Then each wholesale branch $b \in [0,1]$ takes interest rates as given and decides upon the credit to give to households and non-financial corporations maximizing the following profit function:

$$\Pi^B_{i,t}(b) = R^{H_B}_{i,t} B^{H_B}_{i,t}(b) + R^{E_B}_{i,t} B^{E_B}_{i,t}(b) - R_t Dep^B_{i,t}(b) - \frac{\Psi^B_i}{2}\left(\frac{BK_{i,t}(b)}{RWA_{i,t}(b)} - \overline{CR}_{i,t}\right)^2 BK_{i,t}(b) - \Omega^B_{i,t} \quad (43)$$

where $R^{E_B}_{i,t}$ and $R^{H_B}_{i,t}$ are the interest rates charged on the credit to the non-financial corporation and households sectors and R_t is the rate paid on the deposits (which corresponds to the monetary policy rate). Profits maximization is constrained by the individual's bank balance sheet identity:

$$B^{H_B}_{i,t}(b) + B^{E_B}_{i,t}(b) = Dep^B_{i,t}(b) + BK_{i,t}(b) \quad (44)$$

and the bank capital's law of motion

$$BK_{i,t}(b) = \exp\left(\varepsilon^{BK}_{i,t}\right)\left(1-\delta^B_i\right) BK_{i,t-1}(b) + \theta^B_i \Pi^B_{i,t}(b). \quad (45)$$

where $\varepsilon^{BK}_{i,t}$ is a shock to capital accumulation, which is normally distributed with mean zero. We assume that wholesale banks finance their lending activity with deposits provided by the deposit branches $Dep_{i,t}(b)$ and bank capital $BK_{i,t}(b)$ which depreciates at a rate $\delta^B_i \in (0,1)$ and each period is increased with non-distributed profits $\theta^B_i \Pi^B_{i,t}$, where $\theta^{WB}_i \in [0,1]$. With predetermined interest rates, banks can suffer unexpected losses $\Omega^B_{i,t}$ because the ex-post and ex-ante cut-off values of the shocks ϖ^s with $s \in \{H, E\}$ are different. Moreover, when wholesale banks maximize their profits, they are constrained by some adjustment cost on their leverage. The capital adjustment function is the squared distance between the leverage and some target capital ratio $\overline{CR}_{i,t}$. As discussed later, in section 7 we allow $\overline{CR}_{i,t}$ to vary according to a specific policy rule of the macroprudential authorities, otherwise it is assumed to be time-invariant. The leverage of banks is defined as the ratio between the bank capital and the risk-weighted assets, defined as in the Basel framework. More in detail, the risk-weighted asset formula which is used to compute risk weighted assets is given by:

$$RWA_{i,t}(b) = RW^H_{i,t}B^{H_B}_{i,t}(b) + RW^E_{i,t}B^{E_B}_{i,t}(b) \tag{46}$$

$$RW^s_{i,t} = \varepsilon^{RW_s}_{i,t} LGD^s \left\{ \Phi\left(\left(1-\tau^{RW_s}\right)^{-0.5} \left(\Phi^{-1}\left(PD^s_{i,t}\right) + \left(\tau^{RW_s}\right)^{0.5} \Phi^{-1}(0.999) \right) \right) - PD^s_{i,t} \right\} \tag{47}$$

$$\tau^{RW_s} = n^s_1 \left[\frac{1-\exp\left(-n^s_3 PD^s_{i,t}\right)}{1-\exp(-n^s_3)} \right] + n^s_2 \left[1 - \frac{1-\exp\left(-n^s_3 PD^s_{i,t}\right)}{1-\exp(-n^s_3)} \right], \qquad s = \{H, E\} \tag{48}$$

$$PD^s_{i,t} = 4\alpha^{PD} PD^s_{i,t-1} + 4(1-\alpha^{PD})F\left(\overline{\omega}^s_{i,t}\right) \tag{49}$$

where LGD^s stands for the loss-given-default on corporate and mortgages exposures and is calibrated using historical stress test data such that $LGD^H = 0.22$ and $LGD^H = 0.35$, $PD^s_{i,t}$ is the yearly probability of default and $\alpha = 0.95$ is the autoregressive coefficient of the PD process which was estimated using historical stress test data, τ^{RW_s} is the asset-value correlation and $\varepsilon^{RW_s}_{i,t}$ is a shock to the sectoral risk weights. The parameters $n_x, x = \{1, 2, 3\}$ are derived from the Basel III regulation[23] and are such that $n^H_1 = 0.15$, $n^H_2 = 0.15$ and $n^H_3 = 35$ for credit to the household sector, $n^E_1 = 0.12$, $n^E_2 = 0.24$ and $n^E_3 = 50$ for credit to the non-financial corporation sector.

Each bank takes as given the interest rates and the interbank lending and decides on the optimal amount of borrowing to households and to non-financial corporations, $B^{H_B}_{i,t}(b)$ and $B^{E_B}_{i,t}(b)$, respectively. This maximization leads to the following lending spreads for wholesale banks:

$$R^{S_B}_{i,t} = R_t - \Psi^B_i \left(\frac{BK_{i,t}(b)}{RWA_{i,t}(b)} - \overline{CR}_i \right) \left(\frac{BK_{i,t}(b)}{RWA_{i,t}(b)} \right)^2 RW^s_{i,t}, \qquad s = \{H, E\}. \tag{50}$$

3.4.3 Loan book financing branch

The loan book financing branches take funds from the wholesale branch and provide funds to the retail commercial branches having CES preferences over the services provided by the different loan book financing branches. The loan book branches operate under monopolistic competition and provide imperfectly substitutable services and, consequently, they can charge differentiated rates on loans. Each loan book branch is specialized in one segment of the credit sector (one borrowing and lending funds for the household sector and the other for the non-financial corporations). The aggregate loans to non-financial and mortgage sectors provided from the loan book branches resident in country $i \in \{h, f\}$ take the form $B^{S_B}_{i,t} = \left[\int_0^1 B^{S_B}_{i,t}(l)^{1/\mu^s_i}\, d\, l\right]^{\mu^s_i}$ and the corresponding average interest rate $R^{S_B}_{i,t} = \left[\int_0^1 R^{S_B}_{i,t}(l)^{1/(1-\mu^s_i)}\, d\, l\right]^{1-\mu^s_i}$ with $s \in \{H, E\}$. Each loan book financing branch maximizes its profits with respect to the rate charged on its loans. However, similarly to the deposit branches, only a fraction ζ^s in each period is able to change the rate. The maximization problem of a loan book financing branch $l \in [0, 1]$ writes:

[23] see *https : //www.bis.org/bcbs/irbriskweight.pdf*

$$\max_{R^S_{i,t}(l)} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \beta_i^{\tau} \zeta^s \lambda^C_{i,t+\tau} \left(R^S_{i,t}(l) B^S_{i,t}(l) - R^{S_B}_{i,t} B^S_{i,t}(l)\right)\right] \tag{51}$$

where $\lambda^C_{i,t+\tau}$ is the marginal value of non-residential consumption for the saving households. A markup shock is introduced on the interest rate setting, by allowing μ^s_i to follow an AR(1) process with iid innvoations. The maximization in Equation 42 leads to the following expression for the individual deposit services demand: $Dep_{i,t}(d) = \left[\frac{R^{Dep}_{i,t}(d)}{R^{Dep}_{i,t+\tau}}\right]^{\mu^{Dep}_i/(1-\mu^{Dep}_i)} Dep_{i,t+\tau}$.

3.4.4 Retail lending branch

Retail lending branches are distributing credit contracts either to domestic households or entrepreneurs. These branches are perfectly competitive and bundle together funds coming from domestic and foreign loan-book financing branches.

Retail lending branches distributing loans to both sectors have CES preferences over domestic and foreign funding,

$$B^S_{i,t}(j) = \left(\left(1-\alpha_i^{B^S}\right)^{1/\nu_S} B^S_{i,i,t}(j)^{(\nu_S-1)/\nu_S} + \left(\alpha_i^{B^S}\right)^{1/\nu_S} B^S_{i,j,t}(j)^{(\nu_S-1)/\nu_S}\right)^{\nu_S/(\nu_S-1)}, \; S=\{H,E\} \tag{52}$$

where parameter ν_S denotes the elasticity of substitution between domestic and foreign loans, $\alpha^S_{h,i}$ represents the percentage of cross-border loan flows between countries and $B^S_{i,i,t}(j)$ (resp. $B^S_{i,j,t}(j)$) the amount of domestic (resp. foreign) loans demanded by retail lending branches j in country i. The average total cost of loans, $IR^S_{i,t}$, is thus defined according to:

$$IR^S_{i,t} = \left(\left(1-\alpha_i^{B^S}\right)\left(R^S_{i,t}\right)^{1-\nu_S} + \alpha_i^{B^S}\left(R^S_{j,t}\right)^{1-\nu_S}\right)^{1/(1-\nu_S)}, \; S=\{H,E\} \tag{53}$$

where $R^S_{i,t}$(resp. $R^S_{j,t}$) is the cost of funds obtained from home (resp. foreign) loan-book financing branches for a retail lending branch operating in country i.

The decision to borrow from a domestic rather than from a foreign loan-book financing branch is undertaken on the basis of the relative national domestic average rate,

$$B^S_{i,i,t}(j) = \left(1-\alpha_i^{B^S}\right)\left[\frac{R^S_{i,t+1}}{IR^S_{i,t+1}}\right]^{-\nu_S} B^S_{i,t}(j) \text{ and } B^S_{i,j,t}(j) = \alpha_i^{B^S}\left[\frac{R^S_{j,t+1}}{IR^S_{i,t+1}}\right]^{-\nu_S} B^S_{i,t}(j), \; S=\{H,E\}. \tag{54}$$

Retail lending banks borrow at an average rate IR^S from domestic and foreign loan-book financing branches specialized in their lending segment and are in perfect competition. Therefore, the participation constraint for the retail lending branches is that the expected profits from the credit contracts to households and entrepreneurs are zero. This means the following conditions for retail lending branches specialized in lending to households:

$$IR^H_{i,t}B^H_{i,t-1}(j) = \widetilde{G}\left(\overline{\varpi}^H_{i,t}\right)\left(1-\chi^H_i\right)\mathbb{E}_{t-1}\left[\widetilde{Q}^h_{i,t}T^h_{i,t}\left(1+\pi_{i,t}\right)\right]\left(1-\delta^D_i\right)\widetilde{D}_{i,t-1}(j), \tag{55}$$

where

$$\widetilde{G}\left(\overline{\varpi}^H_{i,t}\right) \equiv \left[\left(1-F\left(\overline{\varpi}^H_{i,t}\right)\right)\overline{\varpi}^H_{i,t} + \left(1-\mu^H\right)\int_0^{\overline{\varpi}^H_{i,t}} \varpi^H_{i,t}dF\left(\varpi^H_{i,t}\right)\right]. \tag{56}$$

Instead, the participation constraint to credit contracts with entrepreneurs is given by:

$$IR^E_{i,t}B^E_{i,t-1}(e) = G\left(\overline{\varpi}^E_{i,t+\tau}\right)(1-\chi^E_i)(1-\delta^K_i)\mathbb{E}_{t-1}\left[\sum_{s=C,D} Q^s_{i,t}K^s_{i,t-1}(e)\left(1+\pi_{i,t}\right)\right], \tag{57}$$

where

$$G\left(\overline{\varpi}^E_{i,t}\right) \equiv \left[\left(1-F\left(\overline{\varpi}^E_{i,t}\right)\right)\overline{\varpi}^E_{i,t} + \left(1-\mu^E\right)\int_0^{\overline{\varpi}^E_{i,t}} \varpi^E_{i,t}dF\left(\varpi^E_{i,t}\right)\right]. \tag{58}$$

3.5 Fiscal, Monetary and macroprudential authorities

3.5.1 Fiscal authority

The fiscal authority redistributes resources among households:

$$\begin{aligned} TR_{i,t} + \widetilde{TR}_{i,t} &= \int_{\omega_i}^1 \tau^w_i \varepsilon^W_{i,t}\left(w^C_{i,t}N^C_{i,t}(j) + w^D_{i,t}N^D_{i,t}(j)\right)dj \\ &+ \int_0^{\omega_i} \tau^w_i \varepsilon^W_{i,t}\left(\widetilde{w}^C_{i,t}\widetilde{N}^C_{i,t}(j) + \widetilde{w}^D_{i,t}\widetilde{N}^D_{i,t}(j)\right)dj \end{aligned} \tag{59}$$

3.5.2 Monetary authority

The monetary policy authority is common to both countries and follows a Taylor rule targeting the weighted average of inflation, output and their first difference:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left(\rho_\pi \pi_{t-1}\rho_y y_{t-1}\right) + \rho_{\Delta_\pi}\Delta\pi_t + \rho_{\Delta_y}\Delta y_t + log\,(e) \tag{60}$$

where π_t stands for the monetary union inflation rate and y_t stands for the monetary union total output.

3.5.3 Macroprudential authority

Macroprudential policies are implemented in the model in two ways. First, we assume that macroprudential policy changes are exogenous shocks to key variables in the model. In this case, we allow three possible macroprudential policies:

- System-wide capital requirements, implemented as an exogenous shock to the capital ratio target $\overline{CR}_{i,t}$
- Sectoral capital requirements on lending to the households, implemented as an exogenous shock to the risk weights $\overline{RW}_{i,t}^{H}$
- Loan-to-value ratio caps, implemented as an exogenous shock to the housing exemption χ_i^H.

Second, in section 7 we allow system-wide capital requirements to react endogenously to the evolution of other variables in the model, adopting a very simple country-specific and counter-cyclical policy rule for the macroprudential authorities: the target capital ratio increases (decreases) in periods with high (low) credit–to–GDP gap. This enables us to derive some welfare implications of the interaction between macroprudential and monetary policies.

3.6 Market clearing

3.6.1 Residential and non-residential goods

The aggregate demand for the non-residential goods in country $i \in \{h,\ f\}$ can be written as follows:

$$Y_{i,t}^{C} = \hat{C}_{i,t} + \omega_i C_{i,t} + (1-\omega)\widetilde{C}_{i,t} + I_{i,t}^{C} + I_{i,t}^{D} + \omega_i TR_{i,t} + (1-\omega_i)\widetilde{TR}_{i,t} + \Phi\left(u_{i,t}^{C}\right)K_{i,t-1}^{C} + \Phi\left(u_{i,t}^{D}\right)K_{i,t-1}^{D}, \quad (61)$$

were $I_{i,t}^{s},\ \Phi\left(u_{i,t}^{s}\right),\ K_{i,t-1}^{s}$ with $s = \{C,\ D\}$ are the aggregate investments, total capacity utilization and total capital for both sectors in both countries. Market clearing condition on the non-residential goods market then implies that aggregate demand weighted by the price dispersion equals the total production:

$$\begin{aligned} Z_{i,t}^{C} &= Z_{i,i,t}^{C} + Z_{i,jt}^{C} \\ &= \int_0^1 Z_{i,i,t}^{C}(e)\,de + \int_0^1 Z_{i,j,t}^{C}(e)\,de \\ &= Y_{i,y}^{C}\left\{\alpha_i^{Y^C}\varepsilon_{i,t}^{Y^C}\Delta_{i,i,t}^{P^C}\left[\frac{P_{i,i,t}^{C}}{P_{i,t}^{C}}\right]^{-\nu_y} + \left(1-\alpha_i^{Y^C}\varepsilon_{i,t}^{Y^C}\right)\Delta_{i,j,t}^{P^C}\left[\frac{P_{i,j,t}^{C}}{P_{j,t}^{C}}\right]^{-\nu_y}\right\}. \end{aligned} \quad (62)$$

where $Z_{i,t}^{C}$ is the aggregate production of non-residential intermediate goods and $\Delta_{i,i,t}^{P_i^c}$ (resp.$\Delta_{i,j,t}^{P_i^c}$) is the non-residential good price dispersion for the domestic goods purchased by domestic (foreign) citizens. Instead, for the residential sector, the total demand is only given by the domestic increase in the stock of residential good of borrowing and saving households:

$$Y_{i,t}^{D} = (1-\omega_i)\,I_{i,t}^{h} + \omega_i \widetilde{I}_{i,t}^{h} \quad (63)$$

where n_i indicates the total population of country i. Then the market clearing condition in this market is given by

$$Z_{i,t}^{D} = \Delta_{i,t}^{Q_i^h} Y_{i,y}^{D}. \tag{64}$$

where $Z_{i,t}^{D}$ is the aggregate production of residential goods and $\Delta_{i,t}^{Q_i^h}$ is the residential good price dispersion.

Aggregate demand in both countries then given by:

$$Y_y = Y_h^C + Y_f^C + Y_h^D + Y_f^D. \tag{65}$$

3.6.2 Banking sector

Both deposit and loan book financing banks operate under monopolistic competition and aggregate respectively deposits and loans according to a CES. For this reason, the aggregate volume of credit to households and to entrepreneurs and the aggregate volume of deposits should be weighted by the respective rates' dispersions:

$$B_{i,t}^{H_B} = \Delta_{i,t}^{R^H} \left[(1-\omega_i) B_{i,i,t}^{H} + (1-\omega_j) B_{j,i,t}^{H} \right] \tag{66}$$

$$B_{i,t}^{E_B} = \Delta_{i,t}^{R^E} \left[B_{i,i,t}^{E} + B_{j,i,t}^{E} \right] \tag{67}$$

$$Dep_{i,t}^{B} = \omega_i \int_0^1 Dep_{i,t}(d)\, dd = \Delta_{i,t}^{R^{Dep}} Dep_{i,t} \tag{68}$$

where $\Delta_{i,t}^{R^{Dep}}$ is the dispersion of the deposit rate. which imply the following aggregate profit function:

$$\Pi_{i,t}^{B} = R_{i,t}^{H} \left[(1-\omega_i) B_{i,i,t}^{H} + (1-\omega_j) B_{j,i,t}^{H} \right] + R_{i,t}^{E} \left[B_{i,i,t}^{E} + B_{j,i,t}^{E} \right] - \omega_i R_{i,t}^{Dep} Dep_{i,t} - \frac{\Psi_i^B}{2} \left(\frac{BK_{i,t}}{RWA_{i,t}} - \overline{CR}_{i,t} \right)^2 BK_{i,t}. \tag{69}$$

4 Calibration strategy

To explore the potential benefits of tailoring macroprudential policies to national circumstances while taking account of the single monetary policy stance, the two-country model is calibrated four times to capture the banking system characteristics and macroeconomic features of each of the four largest euro area countries, against the rest of the euro area. The cross-country heterogeneity is reflected first through the degree of demand-side and supply-side credit frictions related to i) leverage and credit risk profile of households and firms, ii) the lending rate pass-through and iii) the bank capital channel. Then, countries differ through their size, trade openness and financial interconnectedness.

For the calibration of the banking sector, we use inter alia proprietary granular bank level data from the 2016 EU-wide stress test to set credit risk characteristics, the target capital ratio and the capital requirements for each sector (i.e. portfolio-specific probabilities of default, LGDs, risk weights and banks' CET1 ratio). We aggregate up individual bank information to country level indicators, also taking into account the geographical breakdown of banks' exposures and selecting only IRB portfolio data in order to calculate the credit risk parameters. From the stress test database we extract probabilities of default at very granular level by bank and by portfolio exposure (country and segment). The probabilities of default on household mortgages and on credit to non-financial corporations, respectively, were aggregated at country level and used in order to calibrate the mean of the idiosyncratic shocks to the collateral ($\omega^H_{i,t}$ and $\omega^E_{i,t}$, respectively). Granular data on risk-weighted assets and on non-defaulted exposures by bank and portfolio segments were used to calculate the steady state values of the risk weights on credit exposures to households and non-financial corporations at country level (i.e., the steady state values of $RW^{HH}_{i,t}$ and $RW^E_{i,t}$, respectively). The steady state capital ratios ($\overline{CR}_{i,t}$) were calibrated as the ratio of common equity tier1 to risk exposure amounts, aggregated at country level. Importantly, to be consistent with the model structure (encompassing only loans to households and entrepreneurs), when computing the target capital ratio we only considered the household and non-financial corporate exposures while leaving out less risky exposures (from a regulatory perspective), such as sovereign exposures. As a result our target capital ratio is higher than the observed total capital ratio.

Country-specific bank interest rate pass-through estimates were used to calibrate the degree of stickiness in retail interest rates across countries, which affects the strength with which shocks to bank balance sheets propagate to the real economy via the cost of bank financing (see Darracq Pariès et al. [2014]).

Household indebtedness is an important structural factor determining how the economy reacts to, for instance, house price shocks. For this purpose, country-specific historical averages of loan-to-GDP ratios for households (sources: ECB and Eurostat) were used to calibrate the degree of private indebtedness at country level.

An overview of the country specific steady state values and parameters used for the calibration of the banking sectors are reported in Table 1. It is notable that perhaps with the exception of the capital ratios (which are broadly similar across countries) banking sector characteristics differ considerably across the four euro area countries. For instance, credit risk appears more pronounced in Italy and Spain as reflected in higher risk weights and higher lending spreads. At the same time, the interest rate pass-through is much faster in Spain than in the other countries reflecting the prevalence of floating-rate loans in that jurisdiction. Also private sector indebtedness differs markedly, again being highest in Spain. All in all, these differences will result in country heterogeneity of the macroeconomic propagation and the amplication effects that the model's financial frictions produce.

Table 1: Parameters and steady state values for the calibration of the banking sector

Description	Germany	Spain	France	Italy
Mean of idiosyncratic shock to collateral of households, $\omega^H_{i,t}$	0.31	0.15	0.25	0.17
Mean of idiosyncratic shock to collateral of non-financial corporations, $\omega^E_{i,t}$	0.40	0.41	0.30	0.14
Risk weights - household credit, $RW^{HH}_{i,t}$	0.18	0.22	0.18	0.22
Risk weights - non-financial corporate credit, $RW^E_{i,t}$	0.42	0.61	0.48	0.57
Capital ratio, $\overline{CR}_{i,t}$	0.15	0.12	0.13	0.13
Lending spread - loans to households, $R^{HH_B}_{i,t} - R_t$	1.18	2.26	1.77	1.81
Lending spread - loans to non-financial corporations, $R^{E_B}_{i,t} - R_t$	1.30	1.64	1.10	1.50
Lending rate pass-through (after 1 year) - loans to households	0.78	0.95	0.6	0.78
Lending rate pass-through (after 1 year) - loans to non-financial corporations	0.7	0.99	0.82	0.85
Household indebtedness	0.65	0.70	0.45	0.43
Non-financial corporate indebtedness	0.69	1.13	1.08	0.87

In terms of trade and financial linkages, the countries' share of imports and exports to real GDP was used to proxy trade openness (source: Eurostat), while MFI data on intra-euro area cross-border credit to MFIs and non-MFIs was used to proxy financial openness (source: ECB). Stronger trade links and/or more pervasive cross-border credit linkages would tend to strengthen spillover effects of macroprudential policies from one country to another. A summary of the target values for the calibration of the cross-border linkages is provided in Table 2.

In the first two rows of Table 2, the values used to calibrate the trade openness and size of each country are reported. Given that these values are relatively stable over time, we used long-term averages (from 2000) to calibrate the steady state values. The size of each country was calibrated using the average share of real GDP of each country in the euro area. We calibrated the parameters determining the demand of imported goods ($\alpha_i^{Y^C}$) to match the trade openness of each country in the steady state, measured as the average share of imports and exports over real GDP.

Table 2 shows that in terms of trade Germany is the most open economy among the big-4 euro area countries with Italy being the least open. In terms of financial openness there are no discernible differences between the four countries; although Spain and to some extent France appear marginally more interlinked with the rest of the euro area. It is also notable that when accounting also for interbank credit flows financial openness of the big-4 euro area countries vis-a-vis the rest of the currency area is non-negligible and hence material cross-border spillover effects via financial transmission channels should be expected within our framework.

Table 2: Target values for the cross-border trade and financial linkages.

Description	Germany	Spain	France	Italy
Size, $\overline{Y}_{i,t}/\sum_j \overline{Y}_{j,t}$	0.29	0.11	0.22	0.19
Trade openness toward other EA countries	0.46	0.38	0.39	0.33
Financial openness of each of the big-4 countries toward other EA countries	0.21	0.25	0.20	0.17
Financial openness of other EA countries toward each of the big-4 countries	0.03	0.03	0.05	0.05

For the calibration of the cross-border financial linkages, we considered the sum of loans and debt securities given to both MFI and non-MFI counterparts, as the interbank market is the major channel of financial cross-border linkages rather than direct loans to foreign households and firms. To illustrate this point Table 3 and Table 4 display the importance of cross-border credit flows between the four biggest euro area countries distinguishing between interbank (MFI) and non-MFI credit. While there is a clear home bias in both cases, the cross-border credit flows between the four countries are materially larger for interbank lending (Table 3) than for direct cross-border credit to the non-financial sector (Table 4). By also accounting for cross-border credit flows to banks in the foreign country we aim at capturing the effective size of cross-border credit interlinkages, thus somewhat circumventing the deficiency of the theoretical model which does not explicitly model cross-border credit flows via domestic banks' foreign subsidiaries or branches. Specifically, we set the parameters affecting the financial openness of each country in a way that the share of credit issued to households and entrepreneurs of the foreign country from domestic banks corresponds to the exposure in terms of loans and debt securities of the banking sector of each country toward non-MFI and MFI institutions in the other country.

Table 3: Cross-border loans and debt securities provided by domestic MFIs to domestic and foreign MFIs as a share of the total. The row of the table indicates the country to which credit is granted, while the column indicates the location of the counterparts

	Spain	Germany	France	Italy
Spain	74	6	5	3
Germany	2	82	3	2
France	3	5	80	3
Italy	3	6	4	80

Table 4: Cross-border loans and debt securities provided by domestic MFIs to domestic and foreign non-MFIs as a share of the total. The row of the table indicates the country to which credit is granted, while the column indicates the location of the counterparts

	Spain	Germany	France	Italy
Spain	95	1	1	1
Germany	1	92	1	2
France	1	2	89	3
Italy	0	1	0	97

The remaining parameters used for the calibration of the model are reported in Table 5 and were estimated at euro area level in Darracq Pariès et al. [2011]. This implies that the cross-country heterogeneity observed in our results are only due to (i) different banking sector characteristics, (ii) differences in the trade and financial openness, (iii) differences in private sector indebtedness.

Table 5: Paramenters common to all calibrations.

Param	Value	Description	Param	Value	Description
Preferences parameters			*NK parameters*		
β_i	0.995	Saver's discount factor	$\zeta_i^{W^C}$	0.93	wages forwardness
$\widetilde{\beta}_i$	0.97	Borrower's discount factor	$\zeta_i^{W^D}$	0.92	wages forwardness
$\widehat{\beta}_i$	0.995	Entrepreneur's discount factor	ζ_i^{Y}	0.25	price forwardness
σ_i^X	1.5	Consumption risk aversion, households	$\zeta_i^{R^D}$	0.29	deposit rates backwardness
$\sigma_i^{L_C}$	2	Labor risk aversion, sector C	γ_i^W	0.17	wages degree of indexation
$\sigma_i^{L_D}$	2	Labor risk aversion, sector Cn	γ_i^Y	0	prices degree of indexation
σ_i^C	0.99	Consumption risk aversion, entrepreneurs			
h_c	0.7	Consumption habits			
ϵ	1.1	Substitutability CES durable/non-durable			
η_i^D	0.25	Share of durable goods in CES			
Production function parameters			*Banks parameters*		
α_i^C	0.3	Capital share, sector C	Ψ_i^B	20	Adjustment cost bank cap
α_i^D	0.3	Capital share, sector D	δ_i^B	0.05	Banks'capital depreciation
$\alpha_i^{\mathcal{L}}$	0.15	Land share, sector D	θ_i^{WB}	0.01	Share of retained earnings
δ^K	0.02	Capital depreciation			
δ^D	0.025	Housing depreciation			
ϕ_i	1/3	Adjustment cost investment			
Financial friction parameters			*Aggregate economy parameters*		
μ^E	0.2	Auditing costs entrepreneurs	$\bar{G}_i/\bar{Y}_i$	0.20	Public spending costs
μ^H	0.15	Auditing costs households			
χ_i^H	0.20	Collateralization technology			
χ_i^E	0.20	Collateralization technology			
Shock processes, autoregressive coefficients			*Shock processes, std*		
ρ^A	0.88	Technology shock, non-res	ρ^A	0.54	Technology shock, non-res
ρ^I	0.72	Investment shock	ρ^I	0.30	Investment shock
ρ^l	0.87	Wage shock	ρ^l	1.96	Wage shock
ρ^g	0.98	Public expenses shock	ρ^g	0.09	Public expenses shock
ρ^U	0.88	Preference shock	ρ^U	0.88	Preference shock
ρ^{A_D}	0.94	Technology shock, res	ρ^{A_D}	0.83	Technology shock, res
ρ^η	0.99	Preference durables	ρ^η	1.00	Preference durables
ρ^{R^D}	0.94	Mark-down shock	ρ^{R^D}	0.07	Mark-down shock
$\rho^{R^{\sigma HH}}$	0.95	Riskiness households shock	$\rho^{R^{\sigma HH}}$	0.08	Riskiness households shock
$\rho^{R^{\sigma E}}$	0.98	Riskiness firms shock	$\rho^{R^{\sigma E}}$	0.08	Riskiness firms shock

5 Cross-country transmission of shocks

As discussed in the previous section, the model has been calibrated in order to capture the specific characteristics of the banking system and macroeconomic features of each of the four largest euro area countries. This aspect is particularly relevant in order to have a correct and realistic estimation of the transmission mechanism of macroprudential policies through the banking sector to the economy. The exercises that we present in this and in the following sections abstract from the estimation of the shocks' stochastic processes and are rather focused in understanding the transmission mechanism of shocks and policies for a given calibration of the home country (i.e. France, Germany, Italy and Spain, respectively) and foreign countries (i.e. the rest of the euro area).

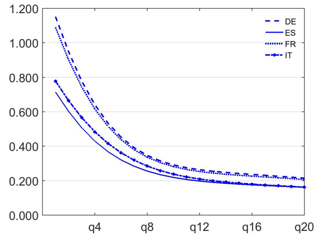
Before embarking on simulating the impact of various macroprudential policies, in this section we illustrate the importance of considering the cross-border dimension within a monetary union. The first illustrative example focuses on a negative shock to non-financial corporate credit risk to demonstrate the model mechanics and the relative importance of international trade and financial channels in transmitting shocks across borders. Figure 2 illustrate the responses of the main financial and macroeconomic variables to an increase in the probability of default of non-financial corporations,[24] for the four calibrations of the model.

Focusing first on the impact on the domestic economy, the increase in the riskiness of lending to non-financial corporations translates into higher risk weights on banks' corporate loan portfolio (see Figure 2).[25] This implies an increase in capital requirements, which in order to reestablish their target capital buffers induces banks to increase lending margins on loans to both their corporate borrowers and (to a lesser extent) their household borrowers. This in turn leads to a process of deleveraging, affecting non-financial corporate credit in particular. Tighter credit conditions for non-financial corporations lead to a significant drop in investment which is the main driver of the decline in GDP with respect to the steady state. Monetary policy endogenously reacts to the decline in consumption prices associated with the downturn in the economy. For the saving households, the monetary policy response increases disposable income and consequently avoids a significant fall in consumption of residential and non-residential goods. Instead, for borrowing households the effect of higher rates on mortgages would prevail and thus exerts downward pressure on consumption of residential and non-residential goods. The reduction of investment results in a decline of production and wages, which are the main factors driving the decline in consumption of non-residential goods over the second year.

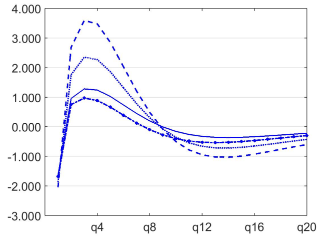
The macroeconomic propagation of the shock is qualitatively similar across the four countries but the magnitude differs depending on the countries' financial structures. In particular, one could observe a stronger reaction of domestic interest rates, which is then reflected in lending, investment and real GDP for Germany and France than Spain and Italy. This mainly reflects the lower steady state values of PDs and LGDs which imply a stronger elasticity of interest rates to shocks to non-financial corporate credit risk.

[24] This corresponds in the model to a 1% shock to the variance of the collateral value of credit to non-financial corporations.
[25] See Figure 2 and Appendix B for the full set of impulse responses under this simulation.

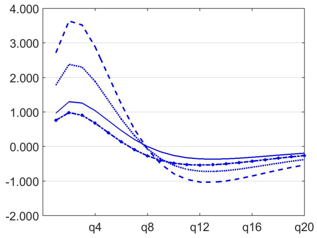
Figure 2: Average responses of domestic variables over the first five years. (Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy)



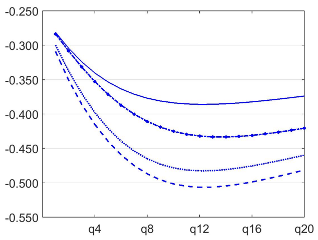
(a) Domestic risk weights (% deviation from the steady state level)



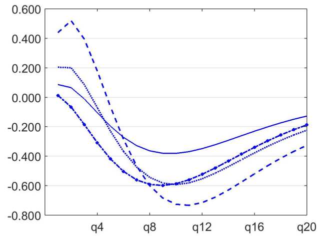
(b) Domestic effective lending rates (% bps difference from the steady state level)



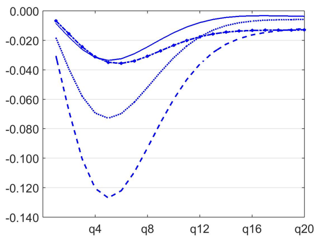
(c) Domestic lending rates on new credit to NFC (% bps difference from the steady state level)



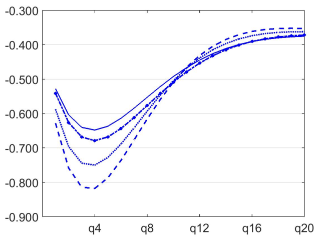
(d) Domestic credit to NFC (% deviation from the steady state level)



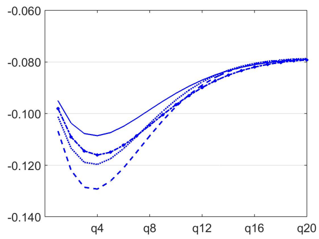
(e) Domestic lending rates on new credit to HH (% bps difference from the steady state level)



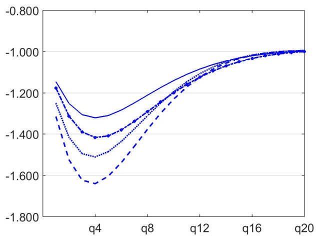
(f) Domestic credit to HH (% deviation from the steady state level)



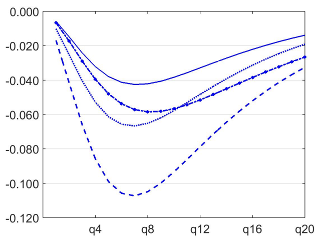
(g) Domestic Investments (% deviation from the steady state level)



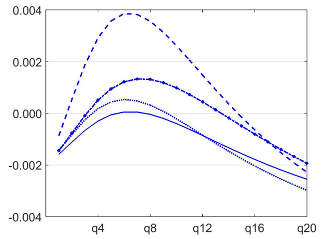
(h) Domestic GDP (% deviation from the steady state level)



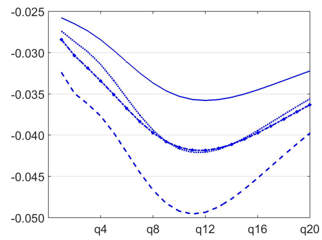
(i) Policy rate (% bps difference from the steady state level)



(j) Domestic consumption of residential goods from borrowing households (% deviation from the steady state level)



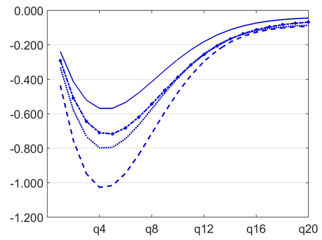
(k) Domestic consumption of residential goods from saving households



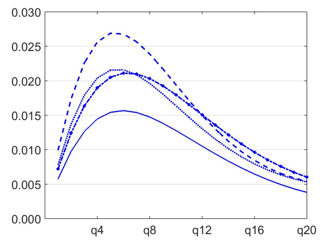
(l) Domestic consumption of non-residential goods from borrowing households (% deviation from the steady state level)

In terms of cross-border spillovers, the transmission of shocks hitting the domestic economy to the foreign country occurs through three main channels: trade, financial interlinkages and the common monetary policy. Negative spillovers to the foreign country arise directly from the reduction of imports from the domestic country and the decline in demand for credit from borrowers resident in the home country. However, in the first two years, these effects are counterbalanced by the accommodative monetary policy stance which is transmitted to borrowers via lower lending rates. Overall, lending to both sectors of the foreign economy increases, boosting investment and consumption of residential and non-residential goods for all households. But these positive spillover effects are not long lasting and, after one and a half years, consumption and GDP also decline in the foreign country.[26]

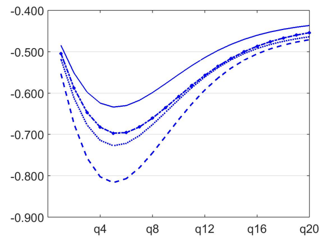
Figure 3: Average responses of foreign variables over the first five years. (Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy)



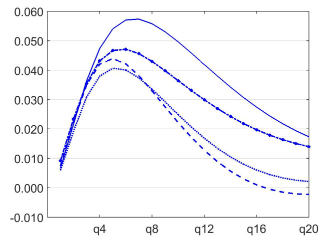
(a) Foreign lending rates on new credit to NFC (% bps difference from the steady state level)



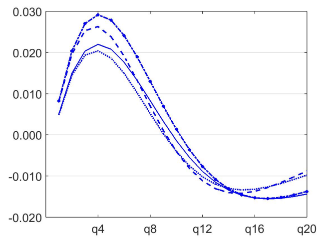
(b) Foreign credit to NFC (% deviation from the steady state level)



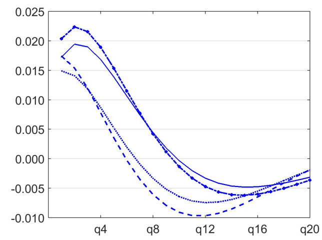
(c) Foreign lending rates on new credit to HH (% bps difference from the steady state level)



(d) Foreign credit to HH (% deviation from the steady state level)



(e) Foreign Investments (% deviation from the steady state level)



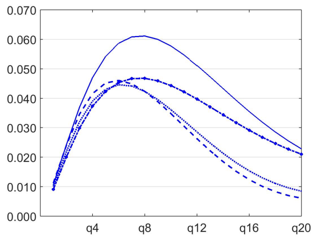
(f) Foreign GDP (% deviation from the steady state level)

The magnitude of the spillover effects on the other countries reflects both the relative response of domestic variables to the shock and also the size of the country. Namely, domestic shocks which have an effect on domestic demand and inflation will determine spillover effects on the foreign country proportionally to the weight that the domestic economy has in the interest rate rule. For these reason, Germany hast the strongest spillover effects on the foreign economy. In addition, while for Italy the shock has a less strong domestic

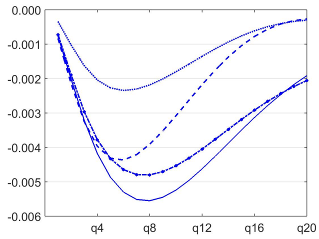
[26]The entire profiles of the impulse responses are illustrated in Figure 3 and Figure 4 in Appendix B.

impact than for Spain, the magnitude of the shock on the foreign economy is for Italy as it affects more the monetary policy response.

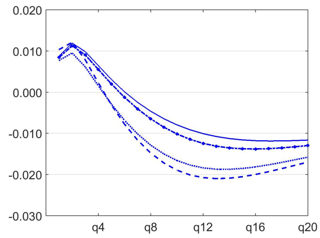
Figure 4: Average responses of foreign variables over the first five years. (Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy)



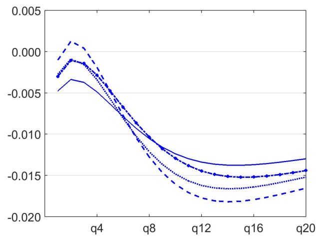
(a) Foreign consumption of residential goods from borrowing households (% deviation from the steady state level)



(b) Foreign consumption of residential goods from saving households (% deviation from the steady state level)



(c) Foreign consumption of non-residential goods from borrowing households (% deviation from the steady state level)



(d) Foreign consumption of non-residential goods from saving households (% deviation from the steady state level)

From the previous example, we could observe that the overall effect of an increase of non-financial corporate credit risk on the foreign economy's real GDP is positive over the first eight quarters for all countries (see ss). There are three main transmission channels in the model of domestic shocks to the foreign economy: trade, credit and monetary policy. In Figure 5 we disentangle the role played by each channel in the transmission of shocks. Given that we are interested in understanding the spillover effects of macroprudential policies, we analyse a tightening of system-wide capital requirements leading to a decline in loans to the household sector by about 1% at the end of the first year. For all countries we can observe that cross-border financial linkages determine negative spillover effects on foreign real GDP, as the tightening of capital requirements implies a deleveraging both on credit to domestic and foreign retail lenders. On the contrary, trade linkages and monetary policy have a positive impact on the foreign economy. While the decline of credit given by banks to the domestic borrowers imposes constrains the consumption of borrowing households and limits the investments of the non-financial corporate sector, demand of saving households increases in the first quarters after the policy implementation due to their higher purchasing power. For this reason, there are positive spillover effects on the foreign real GDP via the trade channel in the short-medium run.

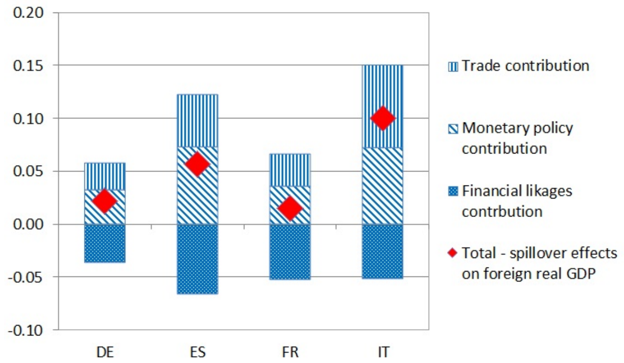


Figure 5: Contribution of trade, credit and monetary policy channels to the transmission of shocks to the foreign economy. Effect of tightening of system-wide cpaital measure

6 Macroprudential policy applications: System-wide capital requirements, Sectoral capital requirements and Loan-To-Value ratio caps

This section aims at comparing the effects of macroprudential policy both across countries and across different policy measures. Three macroprudential policy instruments are compared: (i) an increase of the system-wide capital requirements (such as the counter-cyclical capital buffer or the systemic risk buffer); (ii) an increase in the sectoral capital requirements for loans to households; (iii) tighter loan-to-value ratio caps.

Instruments targeting banks (sectoral capital requirements) increase their resilience and may also help in moderating the credit cycle. Capital requirements increase the resilience of the banking system as a whole by ensuring adequate buffers to cope with losses. Sectoral capital requirements make lending to certain classes of borrowers more costly and hence provide incentives for banks to reduce their activity in that segment.

Instruments targeting borrowers (i.e. LTV, LTI and DSTI limits) increase the resilience of both banks and borrowers. These instruments modify directly the terms and conditions of the loans by making the volume of credit granted dependent on the value of the underlying real estate (LTV limit) or on the debt servicing capacity of the borrower (LTI and DSTI limits).

Given the differences in their transmission channels and impact, the two instruments complement each other and there can be merit in having both types of instruments in place at the same time. Intuitively, for given strategic arrangements between macroprudential policies and monetary policy, two prescriptions would nonetheless hold with respect to the use of alternative macroprudential measures. First, from a domestic perspective, targeted instruments would be superior to non-targeted ones to address sector or financial-segment specific financial vulnerabilities. At the same time, broad-based signs of financial excesses or uncertainty on the main drivers of financial developments, would suggest exploiting instruments less intrusive in the asset composition of the banking system. Second, jurisdiction-specific macroprudential instruments may be better suited than the single monetary policy to address asymmetric country-wide developments within the monetary union.

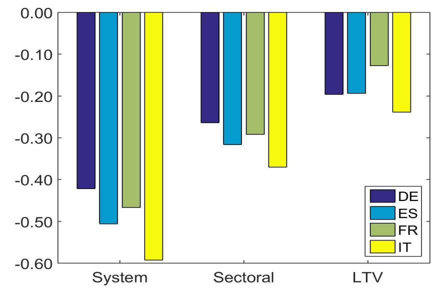
We find that the response of economic variables and the spillovers to other countries differs considerably across measures and countries where the policies are implemented. Overall, the effect on domestic GDP is stronger for system-wide capital measures rather than for targeted measures hitting either the demand (LTV ratio caps) or the supply (sectoral capital requirements) of credit. The spillovers to other countries depend on direct transmission channels such as the financial and trade openness of the country, but also on the interaction with the monetary policy response. The size of the country and the correlation of shocks across countries are two key factors affecting the interaction between monetary policy and macroprudential policies. The simulation exercises that follow aim at bringing some quantitative perspective on these aspects and elaborate further on the role of country characteristics, focusing on the four largest euro area members.

Figure 6 shows the impact of the above–mentioned macroprudential measures on the equilibrium allocations in the domestic economies for all country-specific calibrations (i.e. assuming in turn that Germany, Spain, France and Italy is the home country where the macroprudential measure is implemented). Specifically, we introduce macroprudential policy measures as exogenous shocks to the steady state capital ratio (system-wide capital requirements), to the risk weights (sectoral capital requirements) and to the borrowing constraints of impatient households (LTV ratio caps). Figure 6 compares the effect after one year on real GDP, inflation, lending rates on new loans and the policy rate. In order to make the different macroprudential policy measures comparable the size of the "policy shocks" (i.e. either total capital requirements, sectoral capital requirements or LTV ratio caps) is normalised so that the impact on loans to the household sector at the end of the first year is -1%.[27]

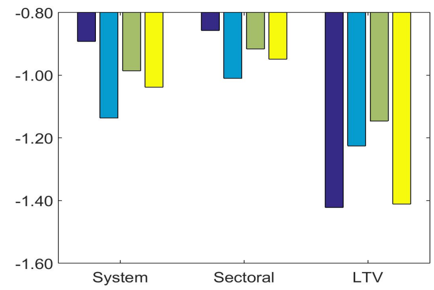
In response to higher regulatory system-wide (i.e. broad-based capital buffer requirements, such as a counter-cyclical capital buffer or a systemic risk buffer) and sectoral capital requirements, banks react by charging higher margins on new loans and curtailing the provision of credit symmetrically to domestic households and firms, albeit to different degrees. The reduction of credit to firms is higher in response to system-wide measures, as the risk weights are typically higher for this type of exposures (see Table 1). In the case of tighter loan-to-value ratio caps, lending to firms moderately increases reflecting banks' decision to reallocate part of the credit to firms. However, also in this case, total credit declines having a negative impact on investment. A notable difference in the transmission mechanism between borrower-based and lender-based macroprudential policies is observable in the lending rate responses: while caps on LTVs affect directly the households' demand for credit dampening the lending rates on new lending, the sectoral capital requirement causes an increase of mortgage lending rates.

[27]The entire profiles of the impulse responses are illustrated in Appendix C.

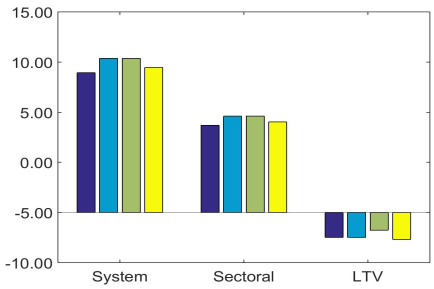
Figure 6: Average responses of domestic variables at the end of the first year. Each bar represents a particular calibration of the home country: (blue) Germany, (light blue) Spain, (green) France, (yellow) Italy.



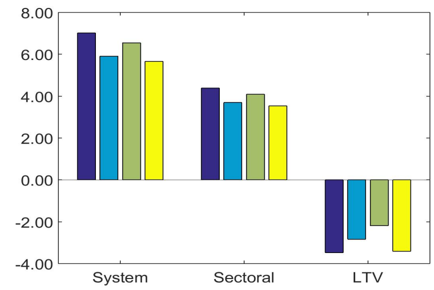
(a) Domestic real GDP (% deviation from the steady state level)



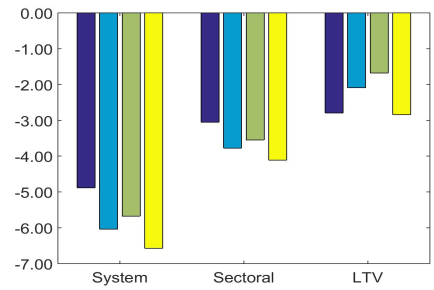
(b) Domestic inflation (bps difference from the steady state level)



(c) Domestic lending rates on new credit to the non-financial corporations sector (bps difference from the steady state level)



(d) Domestic lending rates on new credit to the household sector (bps difference from the steady state level)



(e) Policy rate (bps difference from the steady state level)

In all cases, the resulting contraction in both investment and private consumption depresses capital and house prices, which exacerbates the propagation effects through financial accelerator mechanisms (as the decline in collateral values tightens borrowing constraints). The impact on the economy of the macroprudential tightening is, however, mitigated by an accommodative response of monetary policy.

For all measures, we can observe dispersed macroeconomic effects across countries. This feature can be explained by the current high dispersion of default probabilities (PD), risk weights, LGDs and interest rate pass-through across euro area countries. In particular, the negative effect of curtailing credit to firms has most material effects on the real GDP of Italy and Spain which are characterised by the highest risk weights on corporate credit. For this reason, system-wide capital requirements have the strongest effect in these countries.

Letting the policy rate respond endogenously, the rate response is more accommodative when system-wide capital measures are applied. Moreover, the size of the monetary policy response is mainly driven by the country size and by the overall deleveraging in the country (which non-linearly depends on the steady state risk weights on each exposure). For this reason, the monetary policy response is largest in the case of Italy.

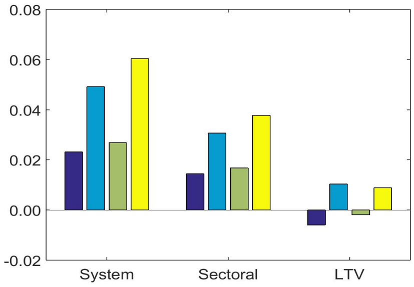
As shown in Figure 7, cross-country spillovers vary depending on the country implementing the policy and on the type of policy implemented. Overall, cross-country spillovers are largest for system-wide capital measures and depend on the amount of domestic deleveraging (which directly affects cross-country lending) and also on the size of the country (which affects both the exports of the foreign country and the reaction of monetary policy).

Overall, the positive effect on the foreign economy arising due to the pass-through of the downward shift in the common policy rate to retail rates in the foreign country appears to dominate negative effects from lower external demand for the foreign country's tradeable goods and from loan book deleveraging of domestic country banks. Some positive impulses on lending to households and entrepreneurs in the foreign country may also arise due to substitution effects, as domestic banks shift business away from domestic customers (that now are more capital intensive) to foreign customers. The net positive impact on the foreign real GDP is, however, quite small compared to the negative impact on domestic real GDP suggesting that cross-border spillover effects of national macroprudential policies are present though mostly of limited size.[28]

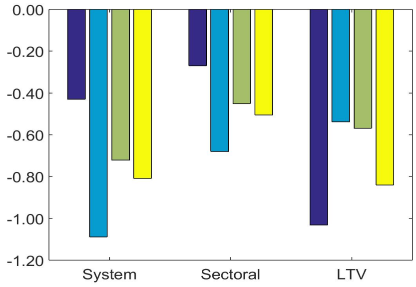
In line with the magnitude of the impact of the policy measures on the domestic economies, the spillover to the foreign country is strongest in the case of macroprudential measures implemented in Italy and Spain. Again, this is due to the relatively high PDs on especially corporate exposures in those two countries which results in a more pronounced macroeconomic propagation; in particular for capital-based measures.

[28] This is in line with the empirical literature on cross-border spillovers of macroprudential policies surveyed in section 2; see e.g. Buch and Goldberg [2017].

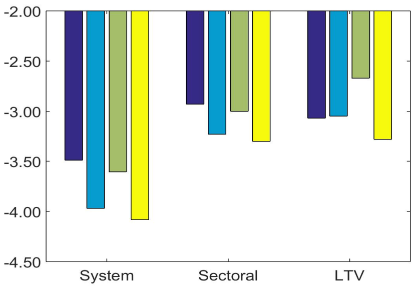
Figure 7: Average responses of foreign variables at the end of the first year. Each bar represents a particular calibration of the home country: (blue) Germany, (light blue) Spain, (green) France, (yellow) Italy.



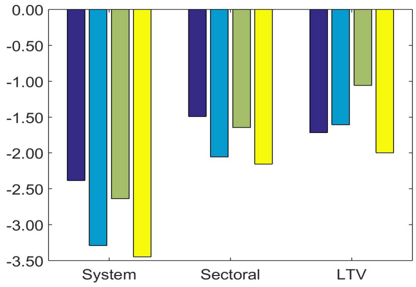
(a) Foreign real GDP (% deviation from the steady state level)



(b) Foreign inflation (bps difference from the steady state level)



(c) Foreign lending rates on new credit to the non-financial corporations sector (bps difference from the steady state level)



(d) Foreign lending rates on new credit to the household sector (bps difference from the steady state level)

7 Cross-country heterogeneity and the scope for macroprudential support to monetary policy conduct through the cycle

The potential interactions between monetary policy and macroprudential policies in a monetary union can also be illustrated with the two-country DSGE model. In the current euro area institutional set-up, the monetary policy authority responds to changes in the area-wide inflation and output gaps, while macroprudential policy authorities respond to country-specific financial stability shocks. A multi-country framework is therefore ideal to analyze the interaction between macroprudential and monetary policies, as it allows to correctly take account of both cross-country asymmetries and aggregate effects, thereby improving the understanding of the effects of these policies on individual economies and on the whole monetary union.

The following theoretical results are to some extent model-specific and should therefore be treated with caution. At the same time, they shed some light on the role of macroprudential policy through the cycle, also from the perspective of large and persistent cross-country heterogeneity within the monetary union.

Within the confines of this theoretical framework, the scope for macroprudential policies is evaluated through the joint optimization of an interest rate policy rule for the single monetary policy and counter-cyclical capital rules for the macroprudential authority:

$$\begin{aligned} r_t &= \rho_r r_{t-1} + (1-\rho)\left[\rho_{Y_{t-1}}\left(n_h Y_{h,t} + (1-n_h)Y_{f,t}\right) + \rho_{\pi_{t-1}}\left(n_h \pi_{h,t} + (1-n_h)\pi_{f,t}\right)\right] + \\ &\quad \rho_{\Delta\pi}\left(n_h \Delta\pi_{h,t} + (1-n_h)\Delta\pi_{f,t}\right) + \rho_{\Delta Y}\left(n_h \Delta Y_{h,t} + (1-n_h)\Delta Y_{f,t}\right) \end{aligned} \quad (70)$$

$$\overline{CR}_{i,t} = \overline{CR} + \rho_{\Delta CR}\Delta CreditGDP_{i,t} \quad (71)$$

where $\overline{CR}$ is the steady state capital ratio, $\overline{CR}_{i,t}$ is the target capital ratio set in each period by the macroprudential authority and $\Delta CreditGDP_{i,t}$ indicates the credit–to–GDP gap.

The monetary policy rule reflects the standard trade-off between inflation and output volatilities at union-wide level, while the macroprudential policy rules are country specific and counter-cyclical: the target capital ratio increases (decreases) in periods with high (low) credit–to–GDP gap.

In order to convey the stabilisation trade-offs, the results are presented in terms of efficiency policy frontiers reflecting the three target variables of the monetary and macroprudential policy authorities: inflation, output gap and credit–to–GDP gap volatilities. The efficiency policy frontier (EPF) portrays the surface where it is not possible to attain lower variance in one objective variable without increasing the one of the others. The EPF abstracts from the specific loss function and the strategic interaction between the monetary and macroprudential authorities and the 'best' allocation is given by the intersection with the EPF and the authorities loss function/s. We conducted four different simulations[29] using the three policy rules and in each case we optimized the policy rules in terms of the coefficient of the inflation gap ($\rho_{\Delta\pi}$), of the output gap ($\rho_{\Delta Y}$) and of the credit–to–GDP gap ($\rho_{\Delta CR}$). Four configurations are examined and in all cases we activate all possible macro-financial shocks in both countries.

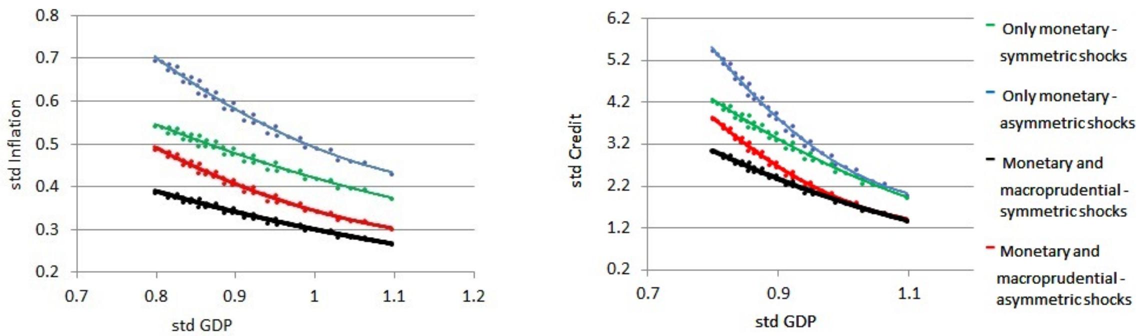
In the first two cases, we derive the efficiency policy frontier in the absence of macroprudential intervention ($\rho_{\Delta CR} = 0$) and activating symmetric or asymmetric shocks across countries. The resulting standard deviations for inflation, output gap and credit-to-GDP gap for each coefficient combination are illustrated in Figure 8a. In the case of symmetric shocks (red dots in Figure 8a), we considered a 1 std shock to all exogenous variables considered in both the home and the foreign countries, while in the asymmetric case (black dots in autoreffig EPF), we assumed perfectly uncorrelated shocks in both countries.

In the remaining two cases, counter-cyclical capital rules are introduced, reacting to the credit–to–GDP gap. In this case, there are two additional degrees of freedom in the optimization of the policy rules corresponding to the country specific coefficients of the macroprudential policy rules $\rho_{\Delta CR}$. As before, we assume two cases in which financial stability shocks occur symmetrically and asymmetrically (see Figure 8a, blue and green dots respectively).

[29]The simulations rely on a calibration of the model where the domestic country is Germany. We are currently working to replicate these results for all five calibrations and add further insights to this analysis.

Depending on the assumptions about the loss function/s of the monetary and macroprudential authorities and the strategic interaction between the authorities, we can select a different point on each efficiency policy frontier to be the best.

Figure 8: Representation of the efficiency policy frontier across three policy target variables: Inflation, credit-to-GDP, output (blue dots: monetary and macroprudential policies and symmetric shocks, red dots: only monetary policy and symmetric shocks, green dots: monetary and macroprudential policies and asymmetric shocks, black dots: only monetary policy and asymmetric shocks)



(a) Efficiency policy frontiers, inflation rate and GDP growth

(b) Efficiency policy frontiers, credit-to-GDP ratio and GDP growth

In Figure 8a and Figure 8b, we can observe that the two cases with asymmetric shocks are characterized (by construction) by overall higher volatility in equilibrium, despite the introduction of any sort of policy rule. We can derive some relevant policy conclusions from Figure 8a and Figure 8b even without being specific on the loss functions of the policy authorities and on the strategic interactions among the authorities. First, both under the assumption of symmetric or asymmetric shocks, the introduction of a counter-cyclical capital rule Pareto dominates the institutional configuration with only a monetary policy rule. This induces an inward shift in the efficiency frontier: macroprudential support to monetary policy enables to achieve superior performance in terms of macroeconomic stabilisation. Second, the welfare gains from the introduction of country-specific macroprudential policy rules are larger with asymmetric shocks. In the case of asymmetric shocks, the inward shift of the efficiency frontiers generated by the introduction of country specific macroprudential policy rules is larger than in the case of symmetric shocks. This holds particularly in terms of credit–to–GDP volatility indicating that country specific macroprudential policy rules allows for much larger gains in terms of reduction of the credit–to–GDP volatility than in the case of symmetric shocks.

8 Conclusions

The macroprudential policy framework in the euro area with its distinct role for national designated authorities, in conjunction with a central coordinating role for the ECB, should be conducive to designing targeted macroprudential policies, while also taking into account the single monetary policy stance. This set-up should also make it possible to address potential unintended side-effects on financial stability that may arise in a context of highly accommodative conventional and unconventional monetary policy.

In order to shed light on the transmission mechanism of macroprudential policies and their interaction with monetary policy within a monetary union, in this paper we develop the first structural two-country macro model with financial frictions and calibrated to individual euro area countries in the macroprudential policy iterature. We use the model to run various simulations that illustrate the importance of country-specific macroprudential policies, also incorporating cross-border spillovers, and how they may potentially complement and interact with the single monetary policy in the context of monetary union.

We illustrate that there are synergies and trade-offs between monetary and macroprudential policies and that these interactions may become even more pronounced in a monetary union where monetary policy, by definition, will be focusing on area-wide economic and financial conditions. In such circumstances, macroprudential policies targeting imbalances building up at the national level within the monetary union can help to achieve better policy outcomes in terms of price and financial stability.

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A Households

A.1 Savers

The Lagrangian of the saving households writes:

$$\begin{aligned}\mathcal{L}_{i,t}^{s}(j) &= \mathbb{E}_t\Bigg\{\sum_{\tau=0}^{\infty}\beta^{\tau}\Bigg\{\varepsilon_{i,t+\tau}^{U^s}\Bigg[\frac{X_{i,t+\tau}(j)^{1-\sigma_i^X}}{1-\sigma_i^X} - \frac{\varepsilon_{i,t+\tau}^{L}\chi_i^C}{1+\sigma_i^{L_C}}N_{i,t+\tau}^{C}(j)^{1+\sigma_i^{L_C}} - \frac{\varepsilon_{i,t+\tau}^{L}\chi_i^D}{1+\sigma_i^{L_D}}N_{i,t+\tau}^{D}(j)^{1+\sigma_i^{L_D}}\Bigg] - \\ &\lambda_{i,t+\tau}^{C}\Bigg[C_{i,t+\tau}(j) + T_{i,t+\tau}^{h}Q_{i,t+\tau}^{h}\Big(D_{i,t+\tau}(j) - \left(1-\delta_i^D\right)D_{i,t-1+\tau}(j)\Big) \\ &+Dep_{i,t+\tau}(j) - \frac{R_{i,t-1+\tau}^{Dep}}{1+\pi_{i,t+\tau}}Dep_{i,t-1+\tau}(j) - \Pi_{i,t+\tau}(j) - TR_{i,t+\tau}(j) - (1-\tau_i^w) \\ &\varepsilon_{i,t+\tau}^{W}\left(w_{i,t+\tau}^{C}N_{i,t+\tau}^{C}(j) + w_{i,t+\tau}^{D}N_{i,t+\tau}^{D}(j)\right)\Bigg]\Bigg\}\Bigg\}\end{aligned} \tag{72}$$

$$X_{i,t}(j) = \left[\left(1-\varepsilon_{i,t}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}\left(C_{i,t}(j) - h_i^C C_{i,t-1}(j)\right)^{\frac{\epsilon-1}{\epsilon}} + \left(\varepsilon_{i,t}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}D_{i,t}(j)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}. \tag{73}$$

Each saver maximizes his utility function with respect to $\Big\{C_{i,t}(j),\ D_{i,t}(j),\ N_{i,t}^{C}(j),\ N_{i,t}^{D}(j),\ Dep_{i,t}(j)\Big\}$, implying the following FOCs:

$$\begin{aligned}C_{i,t}(j) \ :\ &\varepsilon_{i,t}^{U^s}X_{i,t}^{-\sigma_i^X+1/\epsilon}\left[\left(1-\varepsilon_{i,t}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}\left(C_{i,t}(j) - h_i^C C_{i,t-1}(j)\right)^{-1/\epsilon}\right] - h_i^C\beta \\ &\mathbb{E}_t\Bigg\{\varepsilon_{i,t+1}^{U^s}X_{i,t+1}^{-\sigma_i^X+1/\epsilon}\Bigg[\left(1-\varepsilon_{i,t+1}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}\left(C_{i,t+1}(j) - h_i^C C_{i,t}(j)\right)^{-1/\epsilon}\Bigg]\Bigg\} \\ &-\lambda_{i,t}^{C} = 0\end{aligned} \tag{74}$$

$$\begin{aligned}D_{i,t}(j) \ :\ &\varepsilon_{i,t}^{U^s}X_{i,t}^{-\sigma_i^X+1/\epsilon}\left[\left(\varepsilon_{i,t}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}D_{i,t}^{-1/\epsilon}(j)\right] - T_{i,t}^{h}Q_{i,t}^{h}\lambda_{i,t}^{C} + \\ &\beta\mathbb{E}_t\left[\lambda_{i,t+1}^{C}T_{i,t+1}^{h}Q_{i,t+1}^{h}\left(1-\delta_i^D\right)\right] = 0\end{aligned} \tag{75}$$

$$Dep_{i,t}(j) \ :\ \lambda_{i,t}^{C} - \beta\mathbb{E}_t\left[\lambda_{i,t+1}^{C}\frac{R_{i,t}^{Dep}}{1+\pi_{i,t+1}}\right] = 0 \tag{76}$$

$$N_{i,t}^{C}(j) \quad : \quad -\varepsilon_{i,t}^{U^s}\varepsilon_{i,t}^{L}\chi^{C}\left(N_{i,t}^{C}(j)\right)^{\sigma_i^{L_C}} + \lambda_{i,t}^{C}\left(1-\tau_i^{w}\right)\varepsilon_{i,t}^{W}w_{i,t}^{C} = 0 \tag{77}$$

$$N_{i,t}^{D}(j) \quad : \quad -\varepsilon_{i,t}^{U^s}\varepsilon_{i,t}^{L}\chi^{D}\left(N_{i,t}^{D}(j)\right)^{\sigma_i^{L_D}} + \lambda_{i,t}^{C}\left(1-\tau_i^{w}\right)\varepsilon_{i,t}^{W}w_{i,t}^{D} = 0 \tag{78}$$

$$\begin{aligned}\lambda_{i,t}^{C}(j) \quad : \quad & C_{i,t}(j) + T_{i,t}^{h}Q_{i,t}^{h}\left(D_{i,t}(j) - \left(1-\delta_i^{D}\right)D_{i,t-1}(j)\right) + \\ & Dep_{i,t}(j) - \frac{R_{i,t-1}^{Dep}}{1+\pi_{i,t}}Dep_{i,t-1}(j) - \Pi_{i,t}(j) - TR_{i,t}(j) - \left(1-\tau_i^{w}\right)\varepsilon_{i,t}^{W} \\ & \left(w_{i,t}^{C}N_{i,t}^{C}(j) + w_{i,t}^{D}N_{i,t}^{D}(j)\right) = 0\end{aligned} \tag{79}$$

A.2 Borrowers

The Lagrangian of the borrowing households writes:

$$\begin{aligned}
\mathcal{L}_{i,t}^{b}(j) &= \mathbb{E}_t\Bigg\{\sum_{\tau=0}^{\infty}\widetilde{\beta}^{\tau}\Bigg\{\varepsilon_{i,t+\tau}^{U^b}\left[\frac{\widetilde{X}_{i,t+\tau}(j)^{1-\sigma_i^X}}{1-\sigma_i^X}-\frac{\varepsilon_{i,t+\tau}^{L}\chi_i^C}{1+\sigma_i^{L_C}}\widetilde{N}_{i,t+\tau}^{C}(j)^{1+\sigma_i^{L_C}}-\frac{\varepsilon_{i,t+\tau}^{L}\chi_i^D}{1+\sigma_i^{L_D}}\widetilde{N}_{i,t+\tau}^{D}(j)^{1+\sigma_i^{L_D}}\right]- \\
&\quad \widetilde{\lambda}_{i,t+\tau}^{C}(j)\Bigg[\widetilde{C}_{i,t+\tau}(j)+T_{i,t+\tau}^{h}\widetilde{Q}_{i,t+\tau}^{h}\left(\widetilde{D}_{i,t+\tau}(j)-\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1+\tau}(j)\right) \\
&\quad +\left[\left(1-F\left(\varpi_{i,t}^{H*}\right)\right)\varpi_{i,t}^{H}\frac{\mathbb{E}_{t-1+\tau}\left[\widetilde{Q}_{i,t}^{h}T_{i,t}^{h}\left(1+\pi_{i,t}\right)\right]}{1+\pi_{i,t}}+\int_0^{\varpi_{i,t}^{H*}}\varpi_{i,t}^{H}dF\left(\varpi_{i,t}^{H}\right)\widetilde{Q}_{i,t}^{h}T_{i,t}^{h}\right] \\
&\quad \left(1-\chi_i^H\right)\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1+\tau}(j)-B_{i,t+\tau}^{H}(j)-\widetilde{TR}_{i,t+\tau}(j)- \\
&\quad \left(1-\tau_i^w\right)\varepsilon_{i,t+\tau}^{W}\left(w_{i,t}^{C}\widetilde{N}_{i,t+\tau}^{C}(j)+w_{i,t+\tau}^{D}\widetilde{N}_{i,t+\tau}^{D}(j)\right)\Bigg]+ \\
&\quad \widetilde{\lambda}_{i,t-1+\tau}^{PB}(j)\Bigg[\frac{IR_{i,t+\tau}^{H}B_{i,t-1+\tau}^{H}(j)}{1+\pi_{i,t+\tau}}-\widetilde{G}\left(\varpi_{i,t+\tau}^{H}\right)\left(1-\chi_i^H\right)\mathbb{E}_{t-1+\tau}\left[\widetilde{Q}_{i,t+\tau}^{h}T_{i,t+\tau}^{h}\right] \\
&\quad \left(1-\delta_i^D\right)\widetilde{D}_{i,t-1+\tau}(j)\Bigg]\Bigg\}\Bigg\} \qquad (80)
\end{aligned}$$

where

$$\widetilde{X}_{i,t}(j) = \left[\left(1-\varepsilon_{i,t}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}\left(\widetilde{C}_{i,t}(j)-h_i^C\widetilde{C}_{i,t-1}(j)\right)^{\frac{\epsilon-1}{\epsilon}}+\left(\varepsilon_{i,t}^{D}\eta_i^D\right)^{\frac{1}{\epsilon}}\widetilde{D}_{i,t}(j)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \qquad (81)$$

$$\varpi_{i,t}^{H*} = \frac{IR_{i,t}^{H_L}B_{i,t-1}^{H}}{1+\pi_{i,t}}\left[\left(1-\chi_i^H\right)\widetilde{Q}_{i,t}^{h}T_{i,t}^{h}\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1}(j)\right]^{-1} \qquad (82)$$

In what follows we will use the following notation:

$$\widetilde{H}\left(\varpi_{i,t}^{H},\varpi_{i,t}^{H*}\right)\equiv\left(1-F\left(\varpi_{i,t}^{H*}\right)\right)\varpi_{i,t}^{H}+\int_0^{\varpi_{i,t}^{H*}}\varpi_{i,t}^{H}dF\left(\varpi_{i,t}^{H}\right) \qquad (83)$$

Each borrowers maximizes his utility with respect to

$\left\{\widetilde{C}_{i,t}(j),\ \widetilde{D}_{i,t}(j),\ \widetilde{N}_{i,t}^{C}(j),\ \widetilde{N}_{i,t}^{D}(j),\ B_{i,t}^{H}(j),\ \varpi_{i,t+1}^{H}\right\}$ implying the following FOCs:

$$\widetilde{C}_{i,t}(j) \quad : \quad \varepsilon_{i,t}^{U^b}\widetilde{X}_{i,t}^{-\sigma_i^X+1/\epsilon}(j)\left[\left(1-\varepsilon_{i,t}^D\eta_i^D\right)^{\frac{1}{\epsilon}}\left(\widetilde{C}_{it}(j)-h_i^C\widetilde{C}_{i,t-1}(j)\right)^{-1/\epsilon}\right]-h_i^C\widetilde{\beta}$$

$$\mathbb{E}_t\left\{\varepsilon_{i,t+1}^{U^b}\widetilde{X}_{i,t+1}^{-\sigma_i^X+1/\epsilon}(j)\left[\left(1-\varepsilon_{i,t+1}^D\eta_i^D\right)^{\frac{1}{\epsilon}}\left(\widetilde{C}_{i,t+1}(j)-h_i^C\widetilde{C}_{i,t}(j)\right)^{-1/\epsilon}\right]\right\}$$

$$-\widetilde{\lambda}_{i,t}^C(j)=0 \tag{84}$$

$$\widetilde{D}_{i,t}(j) \quad : \quad \varepsilon_{i,t}^{U^s}\widetilde{X}_{i,t}^{-\sigma_i^X+1/\epsilon}(j)\left[\left(\varepsilon_{i,t}^D\eta_i^D\right)^{\frac{1}{\epsilon}}\widetilde{D}_{i,t}^{-1/\epsilon}(j)\right]-T_{i,t}^h\widetilde{Q}_{i,t}^h\widetilde{\lambda}_{i,t}^C(j)+$$

$$\widetilde{\beta}\mathbb{E}_t\left\{\widetilde{\lambda}_{i,t+1}^C T_{i,t+1}^h\widetilde{Q}_{i,t+1}^h\left(1-\delta_i^D\right)-\left(1-\delta_i^D\right)\left(1-\chi_i^H\right)T_{i,t+1}^h\widetilde{Q}_{i,t+1}^h\right.$$

$$\left.\left[\widetilde{\lambda}_{i,t+1}^C\widetilde{H}\left(\overline{\varpi}_{i,t+1}^H,\overline{\varpi}_{i,t+1}^{H*}\right)-\widetilde{\lambda}_{i,t+1}^{PB}\widetilde{G}\left(\overline{\varpi}_{i,t}^H\right)\right]\right\}=0 \tag{85}$$

$$B_{i,t}^H(j) \quad : \quad \widetilde{\lambda}_{i,t}^C(j)-\widetilde{\beta}\mathbb{E}_t\left[\widetilde{\lambda}_{i,t}^{PB}(j)\frac{IR_{i,t+1}^H}{1+\pi_{i,t+1}}\right]=0 \tag{86}$$

$$\widetilde{N}_{i,t}^C(j) \quad : \quad -\varepsilon_{i,t}^{U^s}\varepsilon_{i,t}^L\chi^C\left(\widetilde{N}_{i,t}^C(j)\right)^{\sigma_i^{L_C}}+\widetilde{\lambda}_{i,t}^C\left(1-\tau_i^w\right)\varepsilon_{i,t}^W w_{i,t}^C=0 \tag{87}$$

$$\widetilde{N}_{i,t}^D(j) \quad : \quad -\varepsilon_{i,t}^{U^s}\varepsilon_{i,t}^L\chi^D\left(\widetilde{N}_{i,t}^D(j)\right)^{\sigma_i^{L_D}}+\widetilde{\lambda}_{i,t}^C\left(1-\tau_i^w\right)\varepsilon_{i,t}^W w_{i,t}^D=0 \tag{88}$$

$$\overline{\varpi}_{i,t+1}^H \quad : \quad \mathbb{E}_t\left[\widetilde{\lambda}_{i,t+1}^C\widetilde{H}'\left(\overline{\varpi}_{i,t+1}^H,\overline{\varpi}_{i,t+1}^{H*}\right)\widetilde{Q}_{i,t+1}^h T_{i,t+1}^h\right]-\mathbb{E}_t\left[\widetilde{\lambda}_{i,t+1}^{PB}\widetilde{G}'\left(\overline{\varpi}_{i,t+1}^H\right)\widetilde{Q}_{i,t+1}^h T_{i,t+1}^h\right]=0 \tag{89}$$

$$\widetilde{\lambda}_{i,t}^C(j) \quad : \quad \widetilde{C}_{i,t}(j)+T_{i,t}^h\widetilde{Q}_{i,t}^h\left(\widetilde{D}_{i,t}(j)-\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1}(j)\right)+\left[\left(1-F\left(\overline{\varpi}_{i,t}^{H*}\right)\right)\overline{\varpi}_{i,t}^H\mathbb{E}_{t-1}\left[\widetilde{Q}_{i,t}^h T_{i,t}^h\right]+\right.$$

$$\left.\int_0^{\overline{\varpi}_{i,t}^{H*}}\varpi_{i,t}^H dF\left(\varpi_{i,t}^H\right)\widetilde{Q}_{i,t}^h T_{i,t}^h\right]\left(1-\chi_i^H\right)\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1}(j)-$$

$$B_{i,t}^H(j)-\widetilde{TR}_{i,t}(j)-\left(1-\tau_i^w\right)\varepsilon_{i,t}^W\left(w_{i,t}^C\widetilde{N}_{i,t}^C(j)+w_{i,t}^D\widetilde{N}_{i,t}^D(j)\right)=0 \tag{90}$$

$$\widetilde{\lambda}_{i,t}^{PB} \quad : \quad \frac{IR_{i,t}^H B_{i,t-1}^H(j)}{1+\pi_{i,t}}-\widetilde{G}\left(\overline{\varpi}_{i,t}^H\right)\left(1-\chi_i^H\right)\mathbb{E}_{t-1}\left[\widetilde{Q}_{i,t}^h T_{i,t}^h\right]\left(1-\delta_i^D\right)\widetilde{D}_{i,t-1}(j)=0 \tag{91}$$

A.3 Entrepreneurs

The Lagrangian of the entrepreneurs writes:

$$
\begin{aligned}
\mathcal{L}_{i,t}^{e}(e) = \; & \mathbb{E}_t \Bigg\{ \sum_{\tau=0}^{\infty} \widehat{\beta}_i^{\tau} \Bigg\{ \varepsilon_{i,t+\tau}^{U^e} \frac{\widehat{C}_{i,t+\tau}^{1-\sigma_i^C}}{1-\sigma_i^C} - \widehat{\lambda}_{i,t+\tau}^{C}(e) \Bigg[\widehat{C}_{i,t+\tau}(e) + \sum_{s=C,D} \Bigg[Q_{i,t+\tau}^{s} I_{i,t+\tau}^{s}(e) \\
& + W_{i,t+\tau}^{s} L_{i,t+\tau}^{s}(e) + \Phi\left(u_{i,t+\tau}^{s}(e)\right) K_{i,t-1+\tau}^{s} \Bigg] + p_{i,t+\tau}^{\mathcal{L}} \mathcal{L}_{i,t+\tau}(e) + \\
& \Bigg[\Big(1 - F\left(\overline{\varpi}_{i,t+\tau}^{E*}\right)\Big) \overline{\varpi}_{i,t+\tau}^{E} \mathbb{E}_{t-1+\tau} \Bigg[\sum_{s=C,D} Q_{i,t+\tau}^{s} K_{i,t-1+\tau}^{s}(e) \Bigg] + \int_0^{\overline{\varpi}_{i,t+\tau}^{E*}} \varpi_{i,t+\tau}^{E} dF\left(\varpi_{i,t+\tau}^{E}\right) \\
& \sum_{s=C,D} Q_{i,t+\tau}^{s} K_{i,t-1+\tau}^{s}(e) \Bigg] - \sum_{s=C,D} MC_{i,t+\tau}^{s} Z_{i,t+\tau}^{s}(e) - B_{i,t+\tau}^{E}(e) \Bigg] - \widehat{\lambda}_{i,t+\tau}^{PB}(e) \\
& \Bigg[\frac{IR_{i,t+\tau}^{E} B_{i,t-1+\tau}^{E}(e)}{1+\pi_{i,t+\tau}} - \widehat{G}\left(\overline{\varpi}_{i,t+\tau}^{E}\right)(1-\chi_i^E)(1-\delta_i^K)\mathbb{E}_{t-1+\tau} \Bigg[\sum_{s=C,D} Q_{i,t}^{s} K_{i,t-1}^{s}(e) \Bigg] \Bigg] \Bigg\} \Bigg\} \qquad (92)
\end{aligned}
$$

$$
Z_{i,t}^{C}(e) = \exp\left(\varepsilon_{i,t}^{A^C}\right)\left(u_{i,t}^{C}(e) K_{i,t-1}^{C}(e)\right)^{\alpha_i^C} L_{i,t}^{C}(e)^{1-\alpha_i^C} - \Omega_i^C \qquad (93)
$$

$$
Z_{i,t}^{D}(e) = \exp\left(\varepsilon_{i,t}^{A^D}\right)\left(u_{i,t}^{D}(e) K_{i,t-1}^{D}(e)\right)^{\alpha_i^D} L_{i,t}^{D}(e)^{1-\alpha_i^D-\alpha_i^{\mathcal{L}}} \mathcal{L}_{i,t}(e)^{\alpha_i^{\mathcal{L}}} - \Omega_i^D \qquad (94)
$$

$$
\overline{\varpi}_{i,t}^{E*} = \frac{IR_{i,t}^{E_L} B_{i,t-1}^{E}}{1+\pi_{i,t}} \left[\left(1-\chi_i^E\right) \sum_{s=C,D} Q_{i,t}^{s} K_{i,t-1}^{s}(e) \left(1-\delta_i^K\right) \right]^{-1} \qquad (95)
$$

In what follows we will use the following notation:

$$
\widehat{H}\left(\overline{\varpi}_{i,t}^{E}, \overline{\varpi}_{i,t}^{E*}\right) \equiv \left(1 - F\left(\overline{\varpi}_{i,t}^{E*}\right)\right) \overline{\varpi}_{i,t}^{E} + \int_0^{\overline{\varpi}_{i,t}^{E*}} \varpi_{i,t}^{E} dF\left(\varpi_{i,t}^{E}\right) \qquad (96)
$$

Enterpreneurs maximize their utility function with respect to:

$\left\{ \widehat{C}_{i,t}(e),\ K_{i,t}^{C}(e),\ K_{i,t}^{D}(e),\ L_{i,t}^{C}(e),\ L_{i,t}^{D}(e),\ u_{i,t}^{C}(e),\ u_{i,t}^{D}(e),\ \mathcal{L}_{i,t}(e),\ B_{i,t}^{E}(e),\ \overline{\varpi}_{i,t+1}^{E} \right\}$. The FOCs of enterpreneurs'maximization problem are given by:

$$\widehat{C}_{i,t}(e) \quad : \quad \varepsilon_{i,t}^{U^e} \widehat{C}_{i,t}^{-\sigma_i^C}(e) - h_i^C \widehat{\beta} \mathbb{E}_t \left[\varepsilon_{i,t+1}^{U^e} \widehat{C}_{i,t+1}^{-\sigma_i^C}(e) \right] - \widehat{\lambda}_{i,t}^C(e) = 0 \tag{97}$$

$$u_{i,t}^C(e) \quad : \quad \Phi'\left(u_{i,t}^C(e)\right) - \alpha_i^C MC_{i,t}^C \exp\left(\varepsilon_{i,t}^{A^C}\right) \left(u_{i,t}^C(e) K_{i,t-1}^C(e)\right)^{\alpha_i^C - 1} L_{i,t}^C(e)^{1-\alpha_i^C} = 0 \tag{98}$$

$$u_{i,t}^D(e) \quad : \quad \Phi'\left(u_{i,t}^D(e)\right) - \alpha_i^D MC_{i,t}^D \exp\left(\varepsilon_{i,t}^{A^D}\right) \left(u_{i,t}^D(e) K_{i,t-1}^D(e)\right)^{\alpha_i^D - 1} L_{i,t}^D(e)^{1-\alpha_i^D-\alpha_i^{\mathcal{L}}} \mathcal{L}_{i,t}^{\alpha_i^{\mathcal{L}}} = 0 \tag{99}$$

$$L_{i,t}^C(e) \quad : \quad W_{i,t}^C - \left(1-\alpha_i^C\right) MC_{i,t}^C \exp\left(\varepsilon_{i,t}^{A^C}\right) \left(u_{i,t}^C(e) K_{i,t-1}^C(e)\right)^{\alpha_i^C} L_{i,t}^C(e)^{-\alpha_i^C} = 0 \tag{100}$$

$$L_{i,t}^D(e) \quad : \quad W_{i,t}^D - \left(1-\alpha_i^D-\alpha_i^{\mathcal{L}}\right) MC_{i,t}^D \exp\left(\varepsilon_{i,t}^{A^D}\right) \left(u_{i,t}^D(e) K_{i,t-1}^D(e)\right)^{\alpha_i^D} L_{i,t}^D(e)^{-\alpha_i^D-\alpha_i^{\mathcal{L}}} \mathcal{L}_{i,t}^{\alpha_i^{\mathcal{L}}} = 0 \tag{101}$$

$$\mathcal{L}_{i,t}(e) \quad : \quad p_{i,t}^{\mathcal{L}} - \alpha_i^{\mathcal{L}} \exp\left(\varepsilon_{i,t}^{A^D}\right) \left(u_{i,t}^D(e) K_{i,t-1}^D(e)\right)^{\alpha_i^D} L_{i,t}^D(e)^{1-\alpha_i^D-\alpha_i^{\mathcal{L}}} \mathcal{L}_{i,t}(e)^{\alpha_i^{\mathcal{L}}-1} = 0 \tag{102}$$

$$\begin{aligned}
K_{i,t}^C(e) \quad : \quad & -\widehat{\lambda}_{i,t}^C(e) Q_{t,i}^C + \widehat{\beta}\mathbb{E}_t \Bigg\{ \widehat{\lambda}_{i,t+1}^C(e) \Big[\left(1-\delta_i^K\right) Q_{i,t+1}^C - \Phi\left(u_{i,t}^C(e)\right) + \alpha_i^C MC_{i,t+1}^C \exp\left(\varepsilon_{i,t+1}^{A^C}\right) \\
& \left(u_{i,t+1}^C(e)\right)^{\alpha_i^C} \left(K_{i,t}^C(e)\right)^{\alpha_i^C-1} L_{i,t+1}^C(e)^{1-\alpha_i^C} - \left(1-\chi_i^E\right)\left(1-\delta_i^K\right) \widehat{H}\left(\overline{\varpi}_{i,t+1}^E, \overline{\varpi}_{i,t+1}^{E*}\right) Q_{t+1}^C \Big] + \\
& \widehat{\lambda}_{i,t+1}^{PB} \left[\widehat{G}\left(\overline{\varpi}_{i,t+1}^E\right)\left(1-\chi_i^E\right)\left(1-\delta_i^K\right) Q_{i,t+1}^C \right] \Bigg\} = \\
& -\widehat{\lambda}_{i,t}^C(e) Q_{t,i}^C + \widehat{\beta}\mathbb{E}_t \Bigg\{ \widehat{\lambda}_{i,t+1}^C(e) \Big[\left(1-\delta_i^K\right) Q_{i,t+1}^C - \Phi\left(u_{i,t}^C(e)\right) + \Phi'\left(u_{i,t}^D(e)\right) u_{i,t}^C(e) \\
& - \left(1-\chi_i^E\right)\left(1-\delta_i^K\right) \widehat{H}\left(\overline{\varpi}_{i,t+1}^E, \overline{\varpi}_{i,t+1}^{E*}\right) Q_{t+1}^C \Big] + \\
& \widehat{\lambda}_{i,t+1}^{PB} \left[\widehat{G}\left(\overline{\varpi}_{i,t+1}^E\right)\left(1-\chi_i^E\right)\left(1-\delta_i^K\right) Q_{i,t+1}^C \right] \Bigg\} = 0
\end{aligned} \tag{103}$$

$$\begin{aligned}
K_{i,t}^D(e) \quad : \quad & -\widehat{\lambda}_{i,t}^C Q_{t,i}^D + \widehat{\beta} \Bigg\{ \widehat{\lambda}_{i,t+1}^C \left[\left(1-\delta_i^K\right) Q_{i,t+1}^D - \Phi\left(u_{i,t}^D(e)\right) \right] + \alpha_i^D MC_{i,t+1}^D \exp\left(\varepsilon_{i,t+1}^{A^D}\right) \\
& \left(u_{i,t+1}^D(e)\right)^{\alpha_i^D} \left(K_{i,t}^D(e)\right)^{\alpha_i^D-1} L_{i,t+1}^D(e)^{1-\alpha_i^D-\alpha_i^{\mathcal{L}}} \mathcal{L}_{i,t}^{\alpha_i^{\mathcal{L}}} + \\
& \widehat{\lambda}_{i,t+1}^{PB} \left[\widehat{G}\left(\overline{\varpi}_{i,t+1}^E\right)\left(1-\chi_i^E\right)\left(1-\delta_i^K\right) Q_{i,t+1}^D \right] - \widehat{H}\left(\overline{\varpi}_{i,t+1}^E, \overline{\varpi}_{i,t+1}^{E*}\right) Q_{t+1}^D \Bigg\} = 0
\end{aligned} \tag{104}$$

$$\widehat{B}_{i,t}^E(e) \quad : \quad \widehat{\lambda}_{i,t}^C - \widehat{\beta}\mathbb{E}_t \left[\widehat{\lambda}_{i,t+1}^{PB} \frac{IR_{i,t}^E}{1+\pi_{i,t+1}} \right] = 0 \tag{105}$$

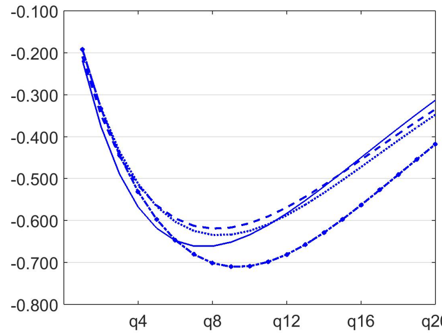
$$\begin{aligned}
\overline{\varpi}^{E}_{i,t+1} \quad &: \quad \mathbb{E}_t\left[\widehat{\lambda}^{C}_{i,t+1}\widehat{H}'\left(\overline{\varpi}^{E}_{i,t+1},\overline{\varpi}^{E*}_{i,t+1}\right)\sum_{s=C,D}Q^{s}_{i,t+1}K^{s}_{i,t}\right]- \\
&\mathbb{E}_t\left[\widehat{\lambda}^{PB}_{i,t+1}\widehat{G}'\left(\overline{\varpi}^{H}_{i,t+1}\right)\sum_{s=C,D}Q^{s}_{i,t+1}K^{s}_{i,t}\right]=0 \qquad (106)
\end{aligned}$$

$$\begin{aligned}
\widehat{\lambda}^{C}_{i,t}(e) \quad &: \quad \widehat{C}_{i,t}(e)+\sum_{s=C,D}\left[Q^{s}_{i,t}I^{s}_{i,t}(e)+W^{s}_{i,t}L^{s}_{i,t}(e)+\Phi\left(u^{s}_{i,t}\right)K^{s}_{i,t-1}\right]+ \\
&p^{\mathcal{L}}_{i,t}\mathcal{L}_{i,t}(e)\left[\left(1-F\left(\overline{\varpi}^{E*}_{i,t}\right)\right)\overline{\varpi}^{E}_{i,t}\mathbb{E}_{t-1}\left[\sum_{s=C,D}Q^{s}_{i,t}K^{s}_{i,t-1}(e)\right]+\int_0^{\overline{\varpi}^{E*}_{i,t}}\varpi^{E}_{i,t}dF\left(\varpi^{E}_{i,t}\right)\right. \\
&\left.\sum_{s=C,D}Q^{s}_{i,t}K^{s}_{i,t-1}(e)\right]-\sum_{s=C,D}MC^{s}_{i,t}Z^{s}_{i,t}(e)-B^{E}_{i,t}(e)=0 \qquad (107)
\end{aligned}$$

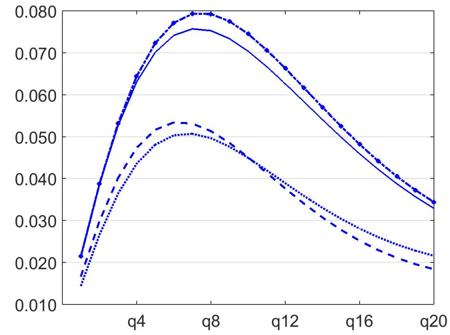
$$\widehat{\lambda}^{PB}_{i,t}(e) \quad : \quad \frac{IR^{E}_{i,t}B^{E}_{i,t-1}(e)}{1+\pi_{i,t}}-\widehat{G}\left(\overline{\varpi}^{E}_{i,t}\right)(1-\chi^{E}_{i})(1-\delta^{K}_{i})\mathbb{E}_{t-1}\left[\sum_{s=C,D}Q^{s}_{i,t}K^{s}_{i,t-1}(e)\right]=0 \qquad (108)$$

B Impulse responses: 1% Shock to system-wide capital requirements in the home country

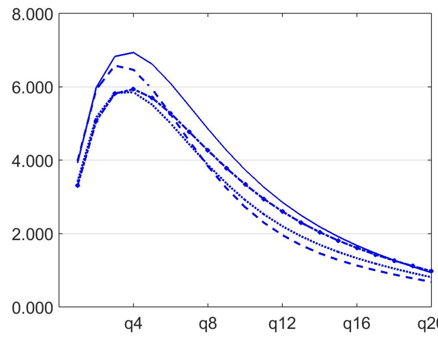
Figure 9: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



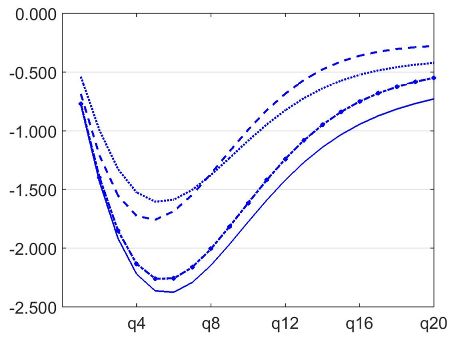
(a) Domestic credit to the NFC sector (% deviation from the steady state level)



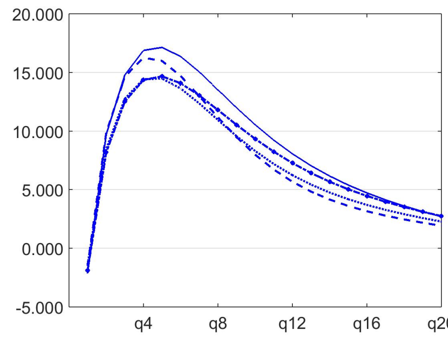
(b) Foreign credit to the NFC sector (% deviation fromthe steady state level)



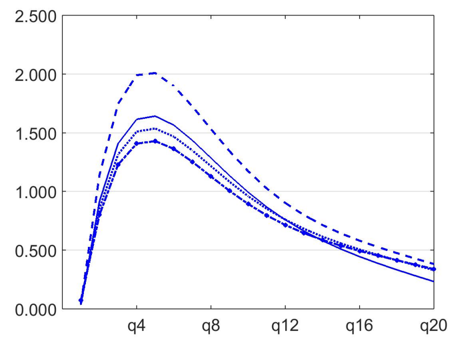
(c) Domestic lending rates on new credit to the NFC sector (bps difference from the steady state level)



(d) Foreign lending rates on new credit to the NFC sector (bps difference from the steady state level)

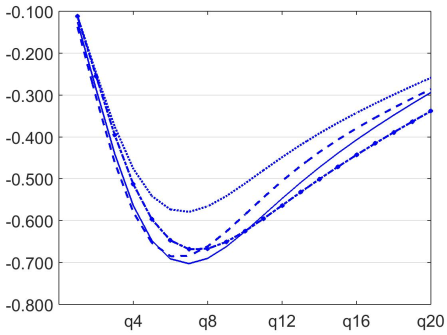


(e) Domestic effective lending rates on existent credit to the NFC sector (bps difference from the steady state level)

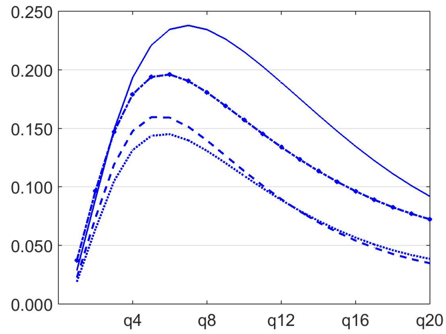


(f) Foreign effective lending rates on existent credit to the HH sector (bps difference from the steady state level)

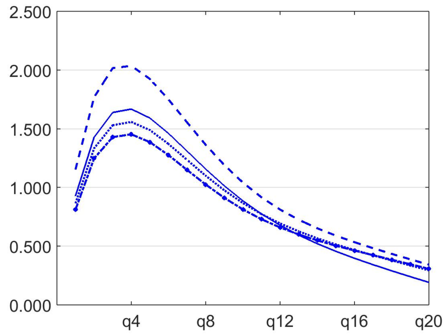
Figure 10: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



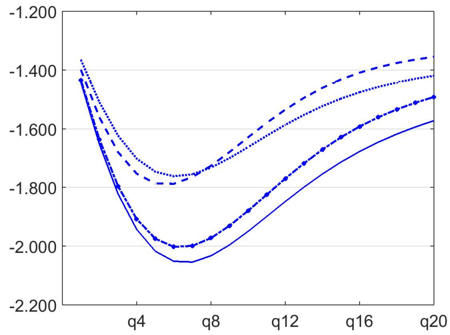
(a) Domestic credit to the HH sector (% deviation from the steady state level)



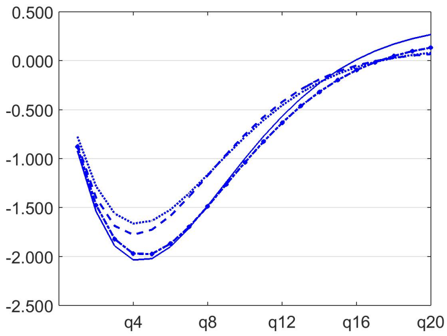
(b) Foreign credit to the HH sector (% deviation from the steady state level)



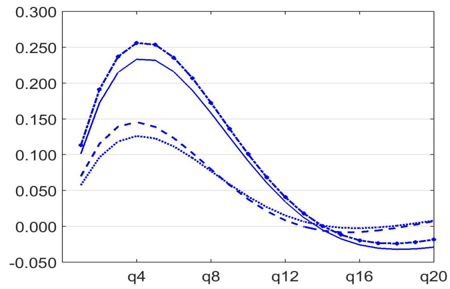
(c) Domestic lending rates on credit to the HH sector (bps difference from the steady state level)



(d) Foreign lending rates on credit to the HH sector (bps difference from the steady state level)

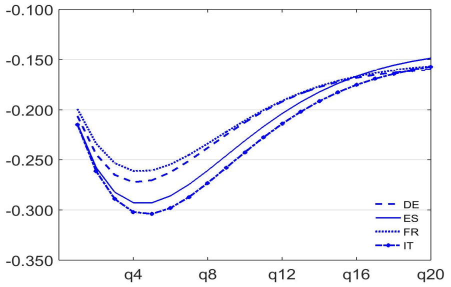


(e) Domestic investments (% deviation from the steady state level)

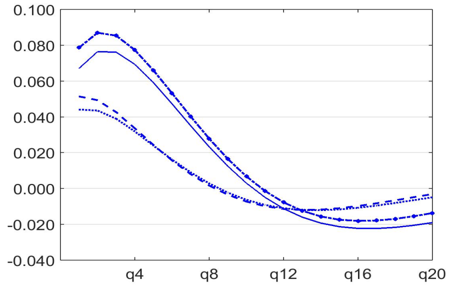


(f) Foreign investments (% deviation from the steady state level)

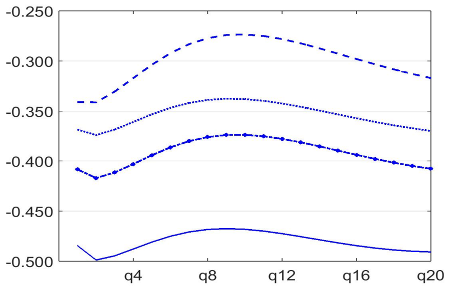
Figure 11: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



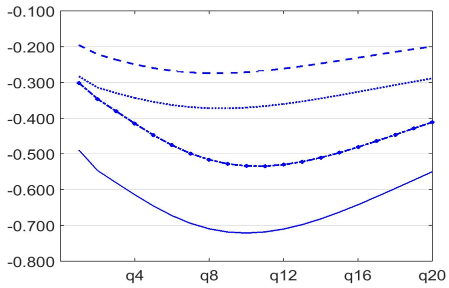
(a) Domestic real GDP (% deviation from the steady state level)



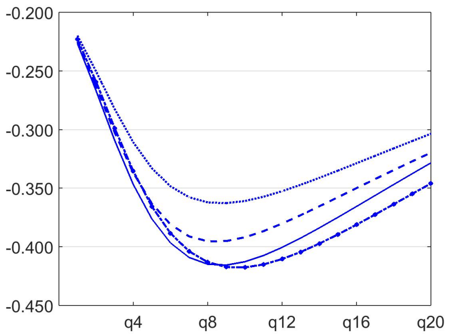
(b) Foreign real GDP (% deviation from the steady state level)



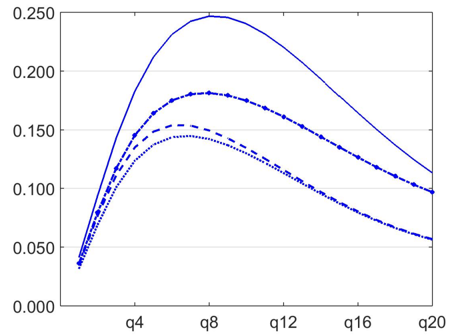
(c) Domestic inflation (bps difference from the steady state level)



(d) Foreign inflation (bps difference from the steady state level)

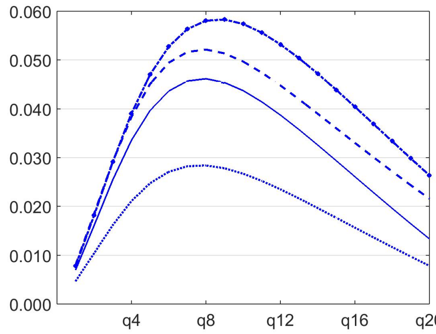


(e) Domestic consumption of residential goods, borrowing households (% deviation from the steady state level)

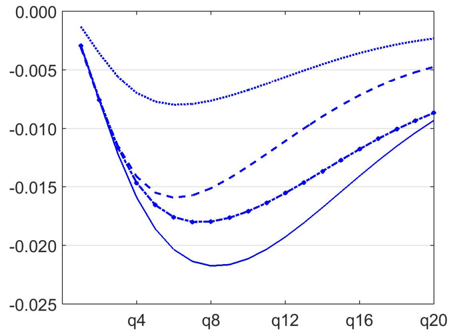


(f) Foreign consumption of residential goods, borrowing households (% deviation from the steady state level)

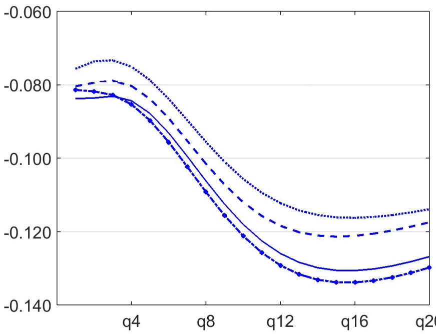
Figure 12: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



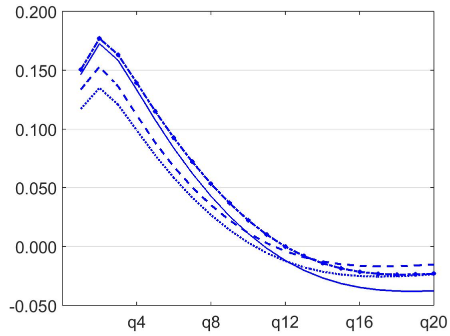
(a) Domestic consumption of residential goods, saving households (% deviation from the steady state level)



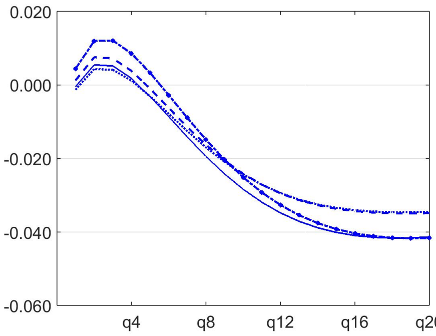
(b) Foreign consumption of residential goods, saving households (% deviation from the steady state level)



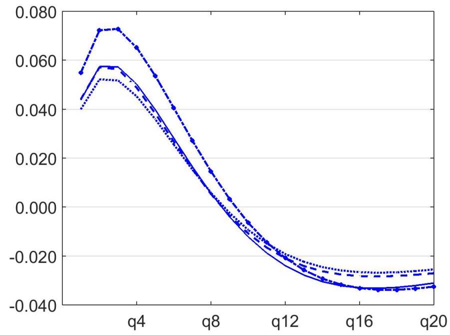
(c) Domestic consumption of non-residential goods, borrowing households (% deviation from the steady state level)



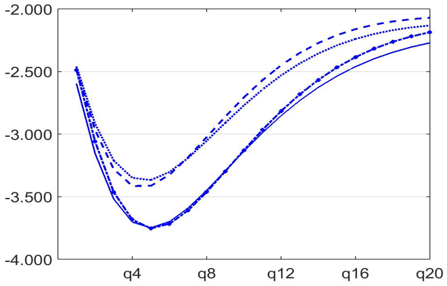
(d) Foreign consumption of non-residential goods, borrowing households (% deviation from the steady state level)



(e) Domestic consumption of non-residential goods, saving households (% deviation from the steady state level)



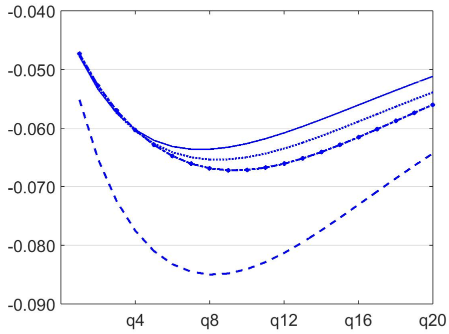
(f) Foreign consumption of non-residential goods, saving households (% deviation from the steady state level)



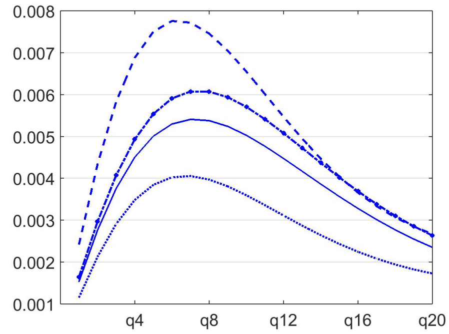
(a) Policy rate (bps difference from the steady state level)

C Impulse responses: 1% Shock to the risk weight of credit to the HH sector in the home country

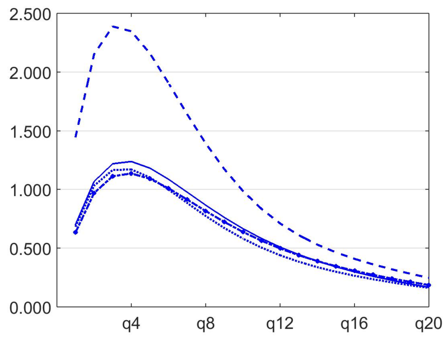
Figure 14: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



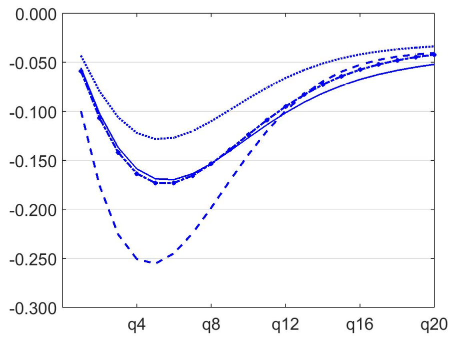
(a) Domestic credit to the NFC sector (% deviation from the steady state level)



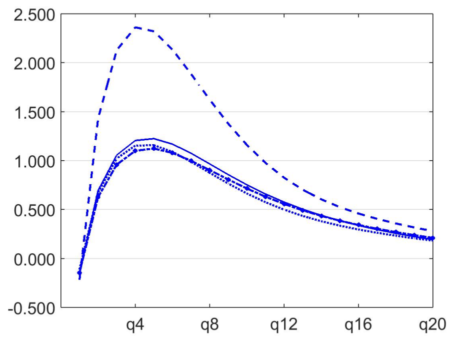
(b) Foreign credit to the NFC sector (% deviation from the steady state level)



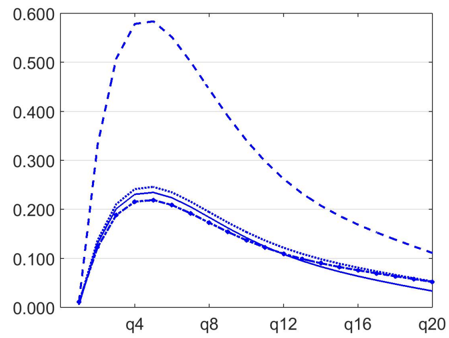
(c) Domestic lending rates on new credit to the NFC sector (bps difference from the steady state level)



(d) Foreign lending rates on new credit to the NFC sector (bps difference from the steady state level)

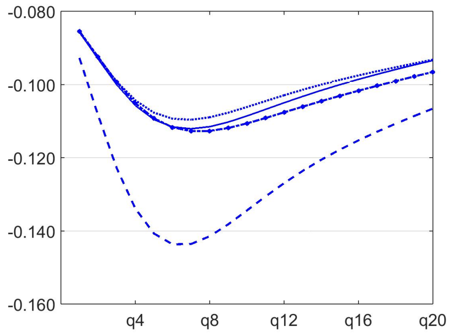


(e) Domestic effective lending rates on existent credit to the NFC sector (bps difference from the steady state level)

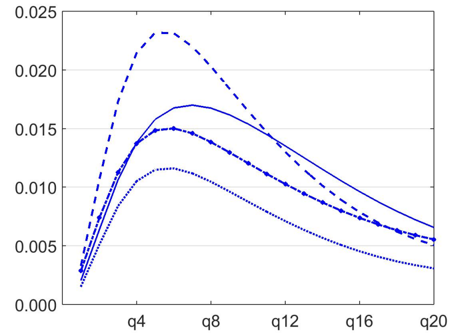


(f) Foreign effective lending rates on existent credit to the HH sector (bps difference from the steady state level)

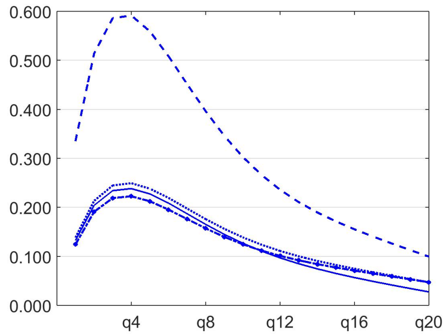
Figure 15: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



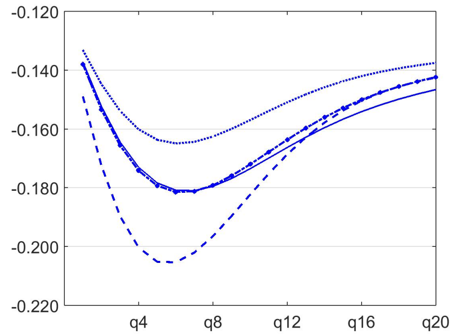
(a) Domestic credit to the HH sector (% deviation from the steady state level)



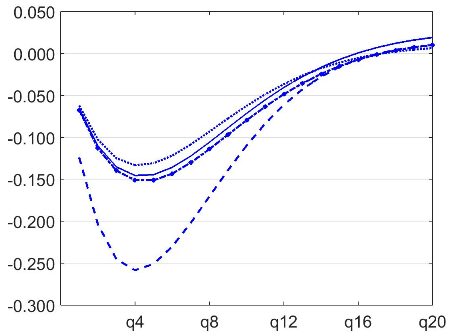
(b) Foreign credit to the HH sector (% deviation from the steady state level)



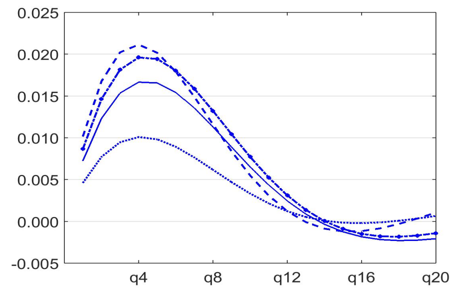
(c) Domestic lending rates on credit to the HH sector (bps difference from the steady state level)



(d) Foreign lending rates on credit to the HH sector (bps difference from the steady state level)

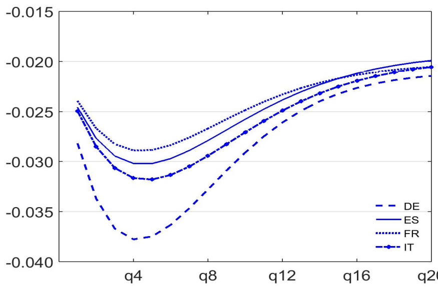


(e) Domestic investments (% deviation from the steady state level)

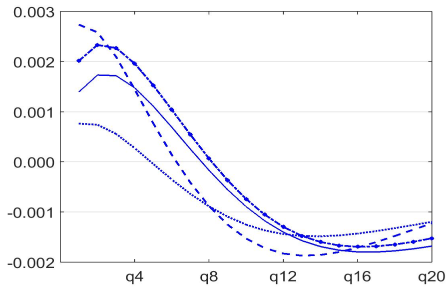


(f) Foreign investments (% deviation from the steady state level)

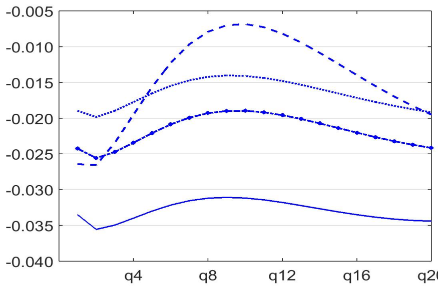
Figure 16: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



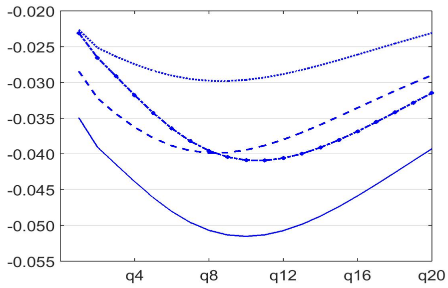
(a) Domestic real GDP (% deviation from the steady state level)



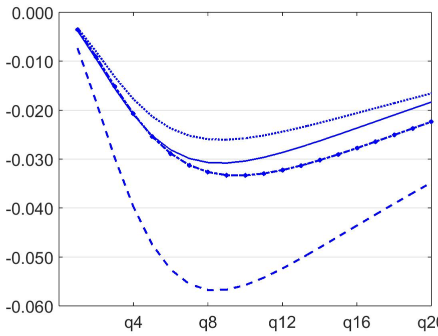
(b) Foreign real GDP (% deviation from the steady state level)



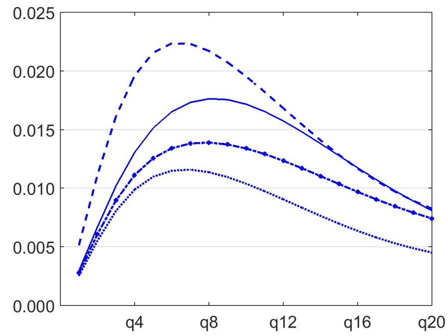
(c) Domestic inflation (bps difference from the steady state level)



(d) Foreign inflation (bps difference from the steady state level)

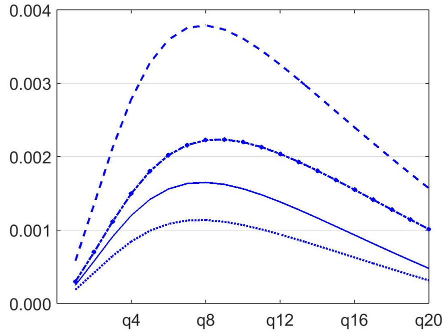


(e) Domestic consumption of residential goods, borrowing households (% deviation from the steady state level)

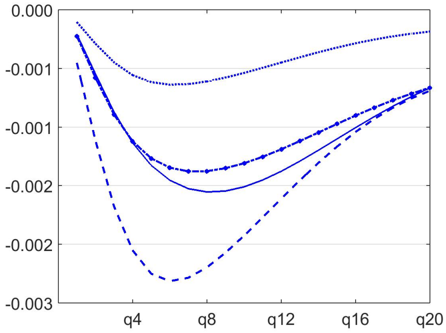


(f) Foreign consumption of residential goods, borrowing households (% deviation from the steady state level)

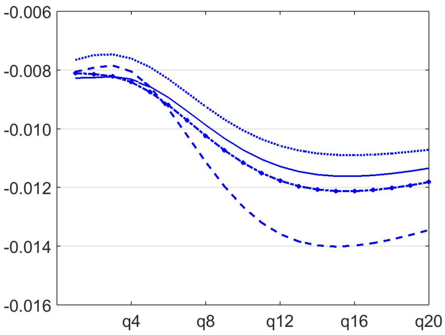
Figure 17: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



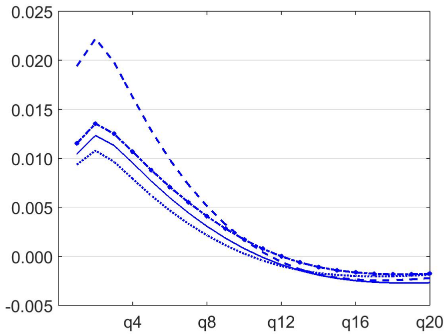
(a) Domestic consumption of residential goods, saving households (% deviation from the steady state level)



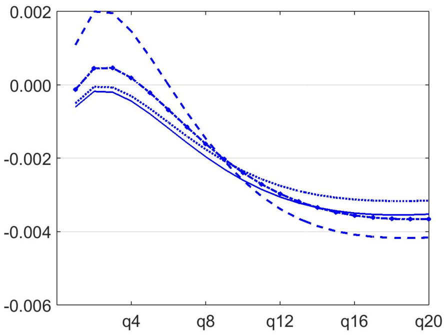
(b) Foreign consumption of residential goods, saving households (% deviation from the steady state level)



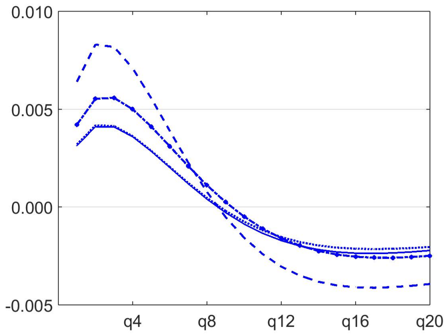
(c) Domestic consumption of non-residential goods, borrowing households (% deviation from the steady state level)



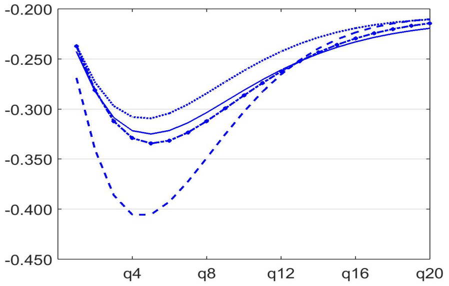
(d) Foreign consumption of non-residential goods, borrowing households (% deviation from the steady state level)



(e) Domestic consumption of non-residential goods, saving households (% deviation from the steady state level)



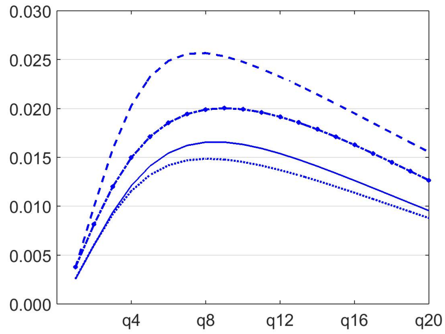
(f) Foreign consumption of non-residential goods, saving households (% deviation from the steady state level)



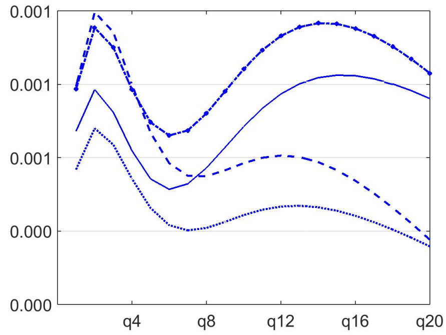
(a) Policy rate (bps difference from the steady state level)

D Impulse responses: 1% Shock to the Loan-to-Value ratio in the home country

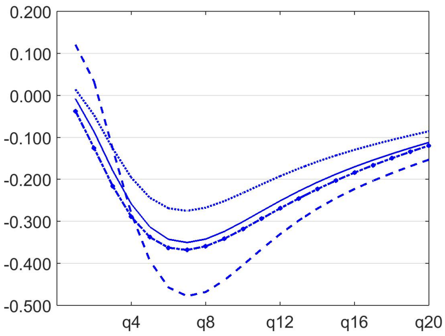
Figure 19: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



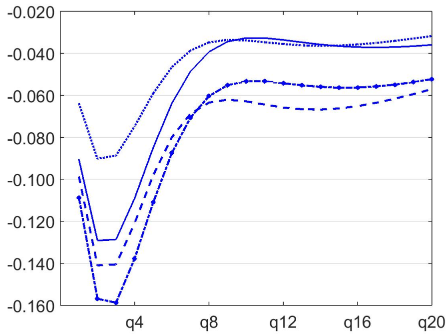
(a) Domestic credit to the NFC sector (% deviation from the steady state level)



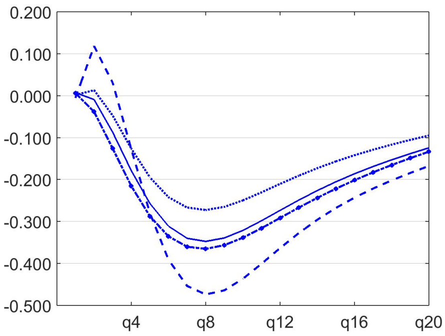
(b) Foreign credit to the NFC sector (% deviation from the steady state level)



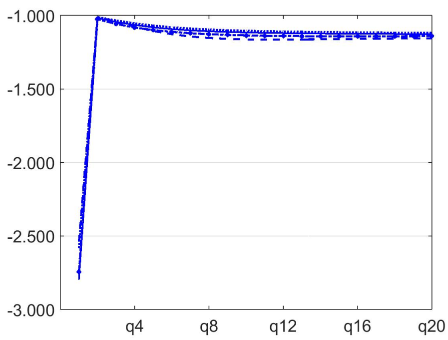
(c) Domestic lending rates on new credit to the NFC sector (bps difference from the steady state level)



(d) Foreign lending rates on new credit to the NFC sector (bps difference from the steady state level)

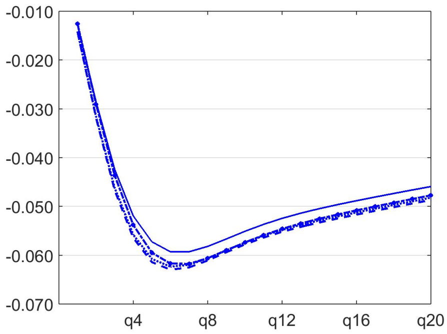


(e) Domestic effective lending rates on existent credit to the NFC sector (bps difference from the steady state level)

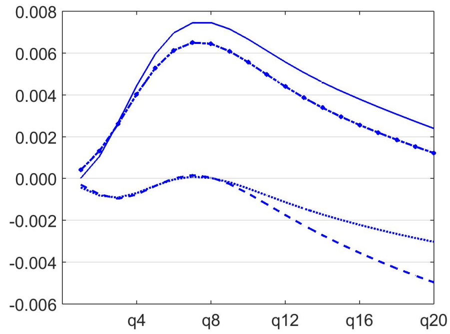


(f) Foreign effective lending rates on existent credit to the HH sector (bps difference from the steady state level)

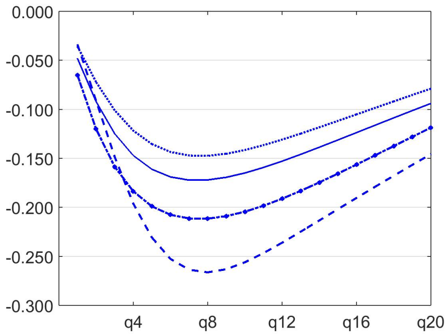
Figure 20: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



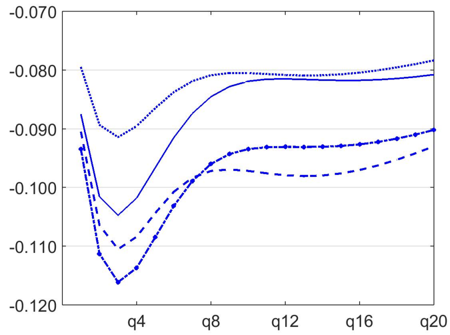
(a) Domestic credit to the HH sector (% deviation from the steady state level)



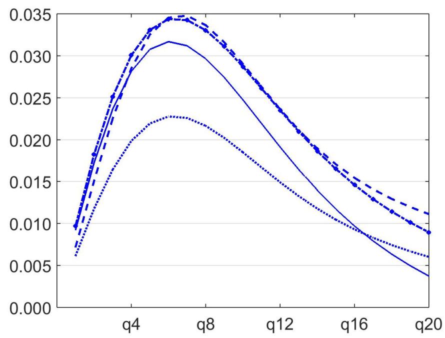
(b) Foreign credit to the HH sector (% deviation from the steady state level)



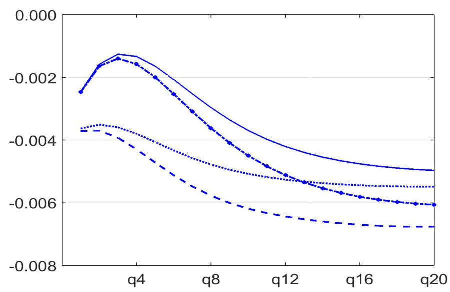
(c) Domestic lending rates on credit to the HH sector (bps difference from the steady state level)



(d) Foreign lending rates on credit to the HH sector (bps difference from the steady state level)

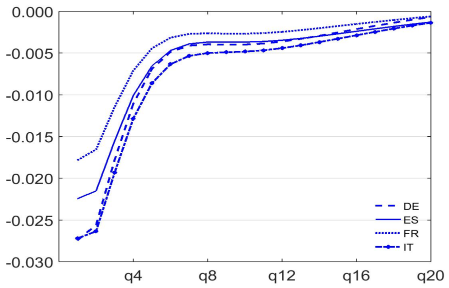


(e) Domestic investments (% deviation from the steady state level)

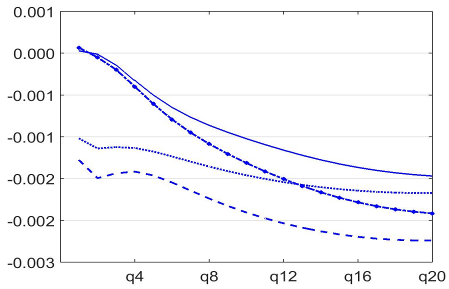


(f) Foreign investments (% deviation from the steady state level)

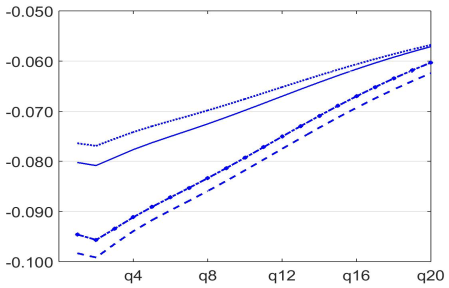
Figure 21: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



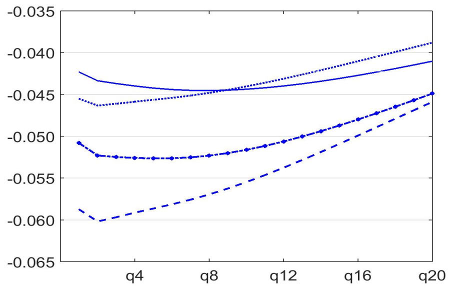
(a) Domestic real GDP (% deviation from the steady state level)



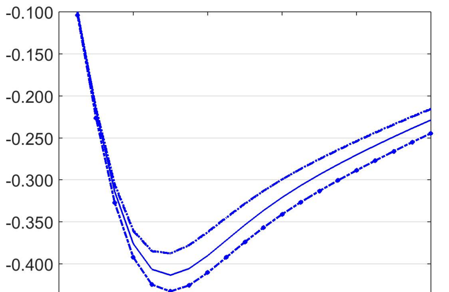
(b) Foreign real GDP (% deviation from the steady state level)



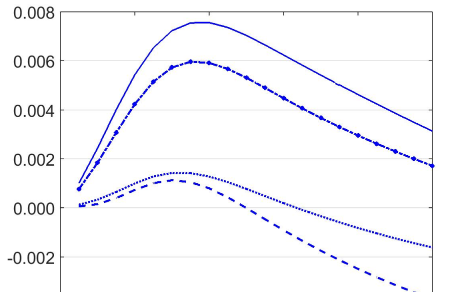
(c) Domestic inflation (bps difference from the steady state level)



(d) Foreign inflation (bps difference from the steady state level)

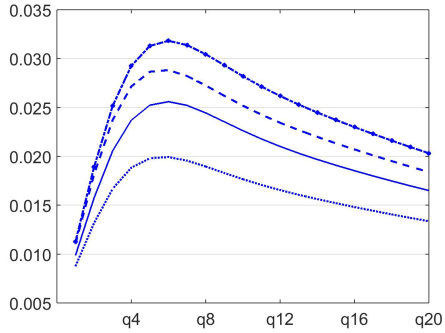


(e) Domestic consumption of residential goods, borrowing households (% deviation from the steady state level)

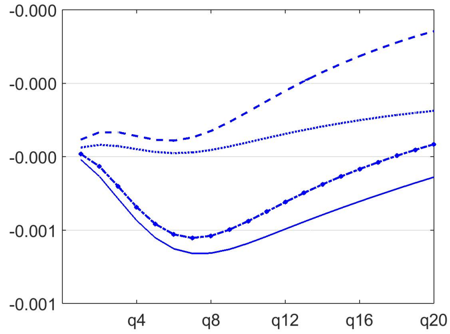


(f) Foreign consumption of residential goods, borrowing households (% deviation from the steady state level)

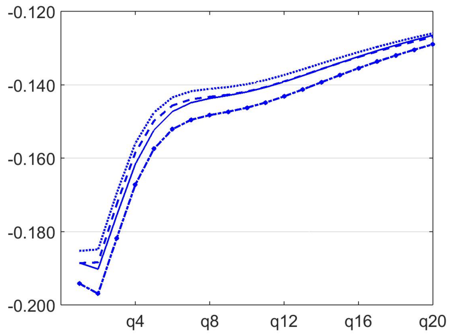
Figure 22: Each line represents a particular calibration of the home country: dashed line Germany, dotted line France, normal line Spain, line with a dot Italy



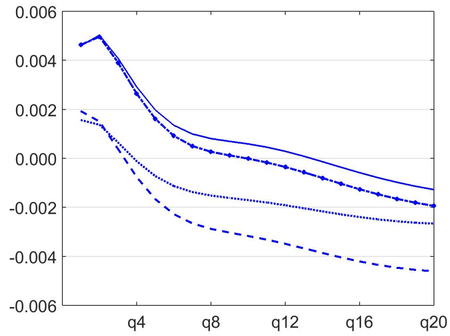
(a) Domestic consumption of residential goods, saving households (% deviation from the steady state level)



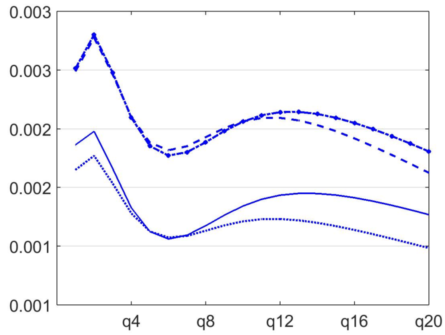
(b) Foreign consumption of residential goods, saving households (% deviation from the steady state level)



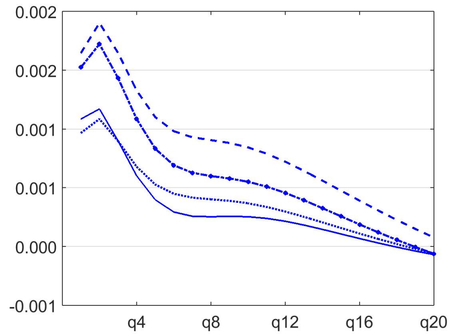
(c) Domestic consumption of non-residential goods, borrowing households (% deviation from the steady state level)



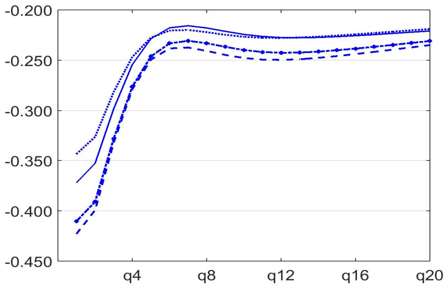
(d) Foreign consumption of non-residential goods, borrowing households (% deviation from the steady state level)



(e) Domestic consumption of non-residential goods, saving households (% deviation from the steady state level)



(f) Foreign consumption of non-residential goods, saving households (% deviation from the steady state level)



(a) Policy rate (bps difference from the steady state level)

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PDF ISBN 978-92-899-3522-7 ISSN 1725-2806 doi:10.2866/378688 QB-AR-19-041-EN-N