EUROPEAN CENTRAL BANK
EUROSYSTEM

Working Paper Series

Matthieu Darracq Pariès,
Pascal Jacquinot
and Niki Papadopoulou

Parsing financial fragmentation in the euro area: a multi-country DSGE perspective

No 1891 / April 2016

Abstract

The euro area experience during the financial crisis highlighted the importance of financial and sovereign risk factors in macroeconomic propagation, as well as the constraints that bank lending fragmentation would pose for monetary policy conduct in a currency union. We design a 6-region multi-country DSGE model which provides a structural interpretation of the salient features of these developments. The model spans the relevant "financial wedges" at play during the crisis, together with its cross-country heterogeneity within the euro area, focusing on Germany, France, Italy, Spain, and rest-of-euro area. We construct three stylised macro-financial scenarios as a synopsis of the euro area financial crisis and argue that the adverse interactions between sovereign, banking and corporate risk, can account to a large extent for the financial repression and poor economic performance observed in some parts of the euro area.

Keywords: DSGE models, banking, financial regulation, cross-country spillovers, bank lending rates.

JEL classification: E4, E5, F4.

Non-technical summary

Since the outbreak of the financial crisis in 2007-2008 and the euro area sovereign debt crisis, the transmission of monetary policy has been impaired by factors related to financial sector distress and its potential amplifying effects on the macroeconomic landscape. In particular, credit risk and risk perceptions, banks undercapitalisation and poor asset quality, or fragmentation in bank funding conditions, all contributed to asymmetric and pervasive credit constraints across member countries. In this context, the euro area experience constitutes an insightful laboratory for analysing the monetary policy challenges posed by financial disruptions in a large, diverse and financially-developed monetary union.

The main contribution of this paper is to design a multi-country dynamic stochastic general equilibrium (DSGE) model for the euro area which provides a structural interpretation of the salient features of the euro area bank lending fragmentation. Our specification choices are primarily inspired by the seminal contribution of Corsetti et al. (2013) which put the emphasis on the credit channels of sovereign tensions. We extend their work by introducing more granular financial and banking frictions, and by considering wider cross-country heterogeneity through a 6-region global model. The model features a reduced-form sovereign-bank nexus, risky banks acting in a monopolistic manner, financial frictions associated with corporate default and cross-border lending. It allows us to analyse the observed heterogeneity in bank lending rates observed across euro area countries and the role of sovereign and financial spillovers in the international propagation of shocks.

We develop macro-financial scenarios which give a meaningful synopsis of the various phases of the euro area financial crisis. The macroeconomic cost of financial fragmentation lies in the interplay between sovereign, banking and corporate credit risk. So the first experiment considers the transmission through credit channels, of the sovereign market tensions which are calibrated to reproduce the surge in sovereign spreads as observed from 2010 to 2013. This source of financial fragmentation is amplified by the observed contagion to bank funding conditions in jurisdictions less affected by the turbulence in sovereign segments. The macroeconomic multipliers are strong in countries under stress and spillovers within the euro area are sizeable. In itself, this counterfactual experiment would explain a large part of lending rate dispersion and poor economic performance in the euro area over the period.

The second experiment focuses on the vicious circle that was activated through the crisis, from rising corporate default, lower bank asset quality and higher credit constraints. We simulate a cross-country increase in corporate risk to match available evidence on default frequency and non-performing loans within the euro area. These conditions propagate more forcefully through the intermediation chain of jurisdictions where banks are under-capitalised and risk-averse. The scenario adequately portrays another important source of financial fragmentation and shows to which extent such real-financial feedback loops could contribute to impair the monetary policy transmission channel in countries like Spain and Italy.

The final experiment explores the potential for bank deleveraging process, on the back of unprecedented regulatory reform, to explain the pervasively high bank lending rates and the lacklustre credit dynamics in some countries, beyond the forces analysed in the previous two experiments.

Even if our experiments could potentially overlap, not least as their quantitative calibration is not based on structural estimations, they do reflect independent forces at play during the crisis. A face value reading of the simulations, taken all together, would imply dramatic effects on lending rate dispersion, potentially beyond what was observed in reality both for stressed and non-stressed countries. This should not be seen as questioning the plausibility of our experiments but instead, it implicitly points to mitigating factors which partially shielded some jurisdictions. A crucial one has been non-standard monetary policy measures.

1 Introduction

A well-functioning banking sector is fundamental in order to guarantee the effectiveness of the monetary policy transmission mechanism, especially in the euro area, where banks play a predominant role in providing external finance for the non-financial private sector. Traditionally, it was assumed that policy rates and market interest rates are the most direct determinants of retail bank lending rates, that there is no fragmentation in bank funding conditions and financial institutions are well capitalised and that there is healthy bank competition and low and stable level of risk. However, since the outbreak of the euro area crisis, financial factors severely altered bank lending conditions and impaired the credit channel of the single monetary policy: the crisis broke the relative homogeneity of financial systems within the euro area (EA) as observed in the early 2000s and brought back financial variables at the heart of the policy debate.

More specifically, lending rates appear to be symptomatic of the bank lending fragmentation hindering the transmission of monetary policy during the euro area financial crisis. From 2010 to 2013, lending rate differentials across euro area countries widened considerably, as shown in Figure 1, with Italian and Spanish rates creeping up and failing to respond to cuts in the monetary policy rates. The dispersion in the cost of bank lending across euro area countries is partly due to fragmentation in banks funding conditions on the back of sovereign debt tensions. In addition, the massive write-downs and losses that banks had to incur over this period significantly impaired their liquidity and capital positions, which in turn forced many banks to cut back on activities and to shed assets. This deleveraging process in the banking sector has been reinforced by unprecedented overhaul in the regulatory landscape. Consequently banks in some jurisdictions have considerably restricted the access to financing for some bank-dependent borrowers, which ultimately contributed the massive cutbacks in capital expenditures. From an institutional perspective, these salient features of the euro area crisis vindicated the need expressed in both academic and policy circle to revisit standard workhorse models which failed to predict (and now to explain) these developments.

Against this background, the objective of the paper will be twofold. First, we develop a global dynamic stochastic general equilibrium (DSGE) model with a detailed banking system and a rich set of financial frictions. Second, based on this model we propose a narrative of the crisis. The paper will pay a special attention on financial variables (in particular lending rates) and the international dimension of the crisis (financial heterogeneity across EA countries and financial spillovers). As such our contribution will be both methodological and empirical with an original interpretation of the turmoil through the lenses of the model.

The **first contribution** of this paper is to design a multi-country DSGE model for the euro area which provides a structural interpretation of the salient features of the euro area bank lending fragmentation. Our specification choices are primarily inspired by the seminal contribution of Corsetti et al. (2013) which put the emphasis on the credit channels of sovereign tensions. We extend their work by introducing more granular financial and banking frictions, and by considering wider cross-country heterogeneity through a 6-region global model.

Regarding the segmented banking specification, our DSGE model includes a set of financial frictions that could span the relevant typology of financial wedges, with sovereign risk and sovereign-banking nexus, risky banks facing capital constraints, oligopolistic retail banking segments, and risky debt contract to firms. Compared to the existing literature, our approach provides a synthesis of segmented banking features and proposes an original treatment of bank capital buffer and bank risk-taking incentives due to limited liability distortion. The granularity of financial frictions enables us to disentangle credit supply and demand factors in the impairments of the monetary policy transmission mechanism. It constitutes a relevant structural framework for interpreting the divergence in lending rates and bank lending policies due to fragmentation in bank funding conditions and sovereign debt tensions. We can also study the pro-cyclicality of the banking system in periods of lacklustre economic activity and fragile balance sheets in the corporate sector.

While the deeper understanding of the structural features underlying financial fragmentation in the euro area is a prerequisite for our analysis, the model also needs to account for the degree of cross-country heterogeneity in financial stress experienced during the euro area crisis. Indeed, the sovereign debt crisis spreads over the euro area in a very asymmetric manner, thereby posing serious challenges for monetary policy conduct. Besides, the balance sheet vulnerabilities within the corporate sector proved quite uneven across the largest euro area countries. This heterogeneity was also reflected in the timing, intensity and underlying sources of banking sector vulnerabilities. Consequently, our modelling strategy aims at introducing the segmented banking specification into a global economy model that could span the required set of countries within the euro area. Accordingly, the model covers six regions: Germany, France, Italy, Spain, rest of euro area (REA) and rest of the world. The largest four euro area countries are well-suited to evaluate the quantitative relevance of financial factors underlying cross-country developments during the crisis. This group of countries indeed displays different types of financial structure and frictions which can be reflected in our calibration exercise (sovereign spreads, probabilities of default, fund costs...).[1] Moreover, the euro area crisis manifested itself through very asymmetric financial shocks among these countries.

The cross-country dimension of our analysis calls for a review of the direct financial spillovers within the monetary union. For the sake of clarity and given the sophistication in the design of domestic financial frictions, we only considered one type of international financing flows between domestic wholesale banks and retail foreign entities which can be interpreted as direct cross-border lending. Finally, the model is calibrated which allows us to consider the state of the economy before and during the crisis.

Our **second contribution** exploits the granularity of the model with its detailed banking system and rich set of financial shocks to propose a narrative of the recent crisis. More precisely, we develop macro-financial scenarios which can give some meaningful synopsis of the various phases of the euro area financial crisis. The macroeconomic cost of financial fragmentation lies in the interplay between sovereign, banking and corporate credit risk. So the first experiment considers the transmission through credit channels, of the sovereign market tensions which are calibrated to reproduce the surge in sovereign spreads as observed from 2010 to 2013. This source of financial fragmentation is amplified by the observed contagion to bank funding conditions in jurisdictions less affected by the turbulence in sovereign segments. The macroeconomic multipliers are strong in countries under stress and spillovers within the euro area are sizeable. In itself, this counterfactual experiment would explain a large part of lending rate dispersion and poor economic performance in the euro area over

[1] But also on the real side. For example Germany and REA are more opened countries while the public sector is larger in France and REA. Regarding the country coverage, we did not consider the possible decomposition of the EA between core and periphery countries (followed by Guerrieri et al. (2012)) as it would blur the source of heterogeneity across these countries which is multi-dimensional (the size of multipliers depend both on the degree of openness and the size of financial frictions). Furthermore we do not choose to tackle the very specific case of Greece which is an interesting topic *per se* but out of the scope of this paper. It would require some ingredients (such as institutional and political aspects) we do not have in our model.

the period. The second experiment focuses on the vicious circle that was activated through the crisis, from rising corporate default, lower bank asset quality and higher credit constraints. We simulate a cross-country increase in corporate risk to match available evidence on default frequency and non-performing loans within the euro area. These conditions propagate more forcefully through the intermediation chain of jurisdictions where banks are under-capitalised and risk-averse. The scenario adequately portrays another important source of financial fragmentation and shows to which extent such real-financial feedback loops could contribute to impair the monetary policy transmission channel in countries like Spain and Italy. The final experiment explores the potential for bank deleveraging process, on the back of unprecedented regulatory reform, to explain the pervasively high bank lending rates and the lacklustre credit dynamics in some countries, beyond the forces analysed in the previous two experiments. Even if our experiments could potentially overlap, not least as their quantitative calibration is not based on structural estimation, they do reflect independent forces at play during the crisis. A face value reading of the simulations, taken all together, would imply dramatic effects on lending rate dispersion, potentially beyond what was observed in reality both for stressed and non-stressed countries. This should not be seen as questioning the plausibility of our experiments but instead, it implicitly points to mitigating factors which partially shielded some jurisdictions. A crucial one has been non-standard monetary policy measures. Dealing with the joint role of fragmentation drivers and monetary policy actions is however beyond the scope of the present paper and is left for future research.

The remainder of this paper is organized as follows. Section 2 lays out the main facts motivating our modeling choices and scenario design. Section 3 reviews the related literature while Section 4 describes the model. Section 5 discusses the calibration strategy and the parameterizing of the model. Section 6 shows the main financial wedges in the model. Subsequently, Section 7 is devoted to the synopsis of the euro area financial crisis, through the lenses of three macro-financial scenarios. Section 8 summarizes and concludes. Properties of the model and relevant simulations are presented in the Annex. Section B focuses on the importance of financial frictions on the transmission of monetary policy shock. Section C deals with sensitivity analysis to cross-country heterogeneity in financial frictions.

2 Stylised facts

Examining the pervasive cross-country lending rate dispersion through the lens of stylised loan pricing formulae provides a useful grid of lecture for any modelling framework which intends to provide structural underpinnings of euro area macroeconomic performance over this period. Indeed, Figures 2 and 3 present some accounting decomposition of lending rate into various pricing factors: lending rates are expected to be anchored to a market reference rate with the respective maturity, while subsequently charging to the borrower a number of spreads to recover the costs and risk-bearing activities involved in loan origination. These spreads, which could be loosely interpreted as financial wedges, correspond to *(i)* deposit spread, *(ii)* market-funding cost spread, *(iii)* bank capital charges, *(iv)* compensation for expected losses and *(v)* competitive wedge.

Starting with deposit funding, deposit spreads (against the maturity-equivalent money market rate) are negative on average over the pre-crisis period. Notably demand deposits provide liquidity services to households and firms, so that their remuneration can in principle fall below the average return on the money market. During the crisis, deposit spreads turned positive and increased by more in Spain and Italy. Fragmentation in banks' market-based financing conditions, in particular through the euro area sovereign debt crisis, is the second factor that may help to explain the divergence observed in MFI lending rates and bank lending policies. Third, banks need to recoup their cost of equity. When a loan is created and the regulatory risk weight is positive, the bank has to set aside some capital to back the loan. Bank capital has been depleted during the crisis in several countries as a result of valuation losses on securities holdings and loan losses. Fourth, there is a credit risk margin that banks charge for intermediation. That margin has to compensate the bank for a number of factors related to the riskiness of the borrower and generates net earnings from borrowing activity. Fifth, the pricing of bank retail products is influenced by banking sector competition. Decreasing competition in banking is expected to have an increase in lending rate determination as markups are higher.

The additional evidence put forward in this section aim at motivating the three counterfactual scenarios at the core of the paper. First of all, the financial stress shouldered by intermediaries from 2010 to 2013 is related to sovereign debt tensions as illustrated by the rise in sovereign spreads in Italy and Spain notably (see Figure 4, top-left panel). The sovereign debt crisis contributed to the increase in bank-bond spreads for domestic banking jurisdictions (see Figure 4, top-right panel) and beyond, as some contagion to other banking sectors in countries less affected by the sovereign tensions became apparent (in France or Belgium notably). The resulting funding difficulties for banks impaired the ability of intermediaries to provide credit in many countries, with adverse implications for bank lending rates. Second, corporate risk surged in some jurisdictions and led to mounting non-performing assets in the banking system (see Figure 4, bottom-left and bottom-right panel). Increasing credit risk, deteriorating asset quality and bank risk aversion can also help to explain divergences in lending rates in an environment of weak economic growth. Third, euro area banks sizeably frontloaded over a three to four-year period a tightening of capital requirements related to the Basel III reform. While phased-in arrangement would have given almost 10 years for banks to adjust, the monitoring exercise conducted by the European Banking Authority shows that from mid-2011 to end-2014, euro area banks had increased their common equity tier 1 capital ratio (CET1) under the full implementation of the Basel III package, by around 5 p.p. (see Figure 5), thereby meeting market expectations well in advance of the initially planned horizon. Such a frontloading reinforced the deleveraging forces in some countries, already facing adverse financial market turbulence. Indeed, banks have in principle many ways to gradually comply with the new regulatory requirements while shielding their loan portfolio and lending practices to firms and households. However, an *ad hoc* question of the euro area bank lending survey (BLS) suggests that Italian or Spanish banks faced the regulatory and supervisory pressures by cutting on credit origination while in France and Germany the bulk of the adjustment came from capital increases (see Figure 6).

In light of these stylised facts, the financial frictions in our model are inspired by the various pricing factors included in the accounting lending rate decompositions, and are designed to span the relevant "financial wedges" underlying developments within the monetary union. Besides, we put forward three originating factors to the euro area financial fragmentation and discuss the role of specific financial frictions in transmitting and amplifying them: *i*) the cross-country rise in sovereign spreads, together with the strength of the sovereign-bank nexus, *ii*) the cross-country rise in corporate risk and non-performing loans together with banks risk-aversion and capital position, *iii*) the frontloading of bank deleveraging needs together with the cost-benefits analysis of tighter regulatory requirements.

3 Related literature

The specification of the domestic financial frictions is related to various strands of modelling literature which consider both supply and demand-side credit frictions, introduce risky banks and sovereign default. The introduction of financial frictions in DSGE models is usually done through credit demand frictions, with the usual financial accelerator (Bernanke et al. (1999), hereafter BGG, Christiano et al. (2010) and Kumhof et al. (2010)) or borrowing constraints *à la* Iacoviello (2005). Other seminal contributions, like Gertler and Karadi (2011), focus on balance frictions within the financial system. Some models do bridge these perspectives. Gerali et al. (2010) introduce a segmented banking sector with a bank capital channel and monopolistic lending rate setting into a DSGE model with financial frictions like Iacoviello (2005). Darracq Pariès et al. (2011) propose a comprehensive representation of the banking system allowing frictions on both credit demand and supply with both firms and households default. More recent contributions also feature risky banks within segmented banking models. Clerc et al. (2015) considers a real model with three layers of borrower defaults where simultaneously impatient households borrow from banks through mortgages to finance housing purchases; entrepreneurs borrow from banks to finance capital accumulation and banks borrow from patient households through deposits. The IMF has recently proposed the MAPMOD model (Benes and Kumhof (2011); Benes et al. (2014b,a)) designed to study vulnerabilities associated with excessive credit expansions. The model depicts a small open economy with a financial sector consisting of a representative competitive bank where risky loan exposures can impair bank capital position. Banks respond to losses through higher spreads and rapid credit cutbacks, with adverse effects for the real economy. Finally, some papers analyse sovereign defaults in a DSGE models with financial frictions. Corsetti et al. (2013) propose a New Keynesian model of a two-region monetary union that introduces a sovereign risk channel to credit spread in the private sector. van der Kwaak and van Wijnbergen (2014) introduce sovereign default risk in the model of Gertler and Karadi (2013) and analyse the link between sovereign solvency and financial fragility. In our model, the sovereign-bank nexus is dealt with in reduced-form manner, albeit with more structure than Corsetti et al. (2013): risky banks do not directly hold government debt but are exposed to sovereign default risk through their funding costs. A more microfounded treatment of sovereign bank interactions in the spirit of van der Kwaak and van Wijnbergen (2014) is left for future research.

The most recent literature proposes multi-country DSGE models (generally in a two-country setup) allowing various international propagation channels based on global banks which are either lending internationally to the private sector (Fujiwara and Teranishi, 2010) or investing in foreign government bonds (Guerrieri et al. (2012)). Fujiwara and Teranishi (2010) incorporate staggered loan contracts into a two country model to study the dynamics of the real exchange rate. In their model, banks collect deposits from households and provide loans to firms to finance their factor expenditures in advance. However, there are two types of banks in each country: local banks intermediate between domestic households and domestic firms while international banks intermediate between domestic households and foreign firms. In a more stylized manner Kollmann et al. (2011) and Kalemli-Ozcan et al. (2012) are also considering a two-country environment with a global banking sector. When a shock erodes the capitalisation of global banks, it reduces credit supply and depresses economic activity in both countries.

Guerrieri et al. (2012) study the international propagation of sovereign debt default. They propose a two-block economy where capital constrained banks grant loans to firms and invest in bonds issued by the domestic and the foreign government. The model economy is calibrated to data from Europe, with the two blocks representing the Periphery (Greece, Italy, Portugal and Spain) and the Core, respectively. Interestingly, they find sizeable spillover effects of default from Periphery to the Core through a drop in the volume of credit extended by the banking sector. From a quite different perspective, Mendoza and Quadrini (2010) consider an open-economy model with a different degree of financial development in each country and investigate cross-country spillovers effects of shocks to bank capital. They show that financial integration leads to a sharp rise in net credit in the most financially developed country and to large asset price spillovers of country-specific shocks to bank capital. The impact of these shocks on asset prices are amplified by bank capital requirements based on mark-to-market.

Overall, our model is a global DSGE including a reduced-form sovereign-bank nexus, risky banks acting in a monopolistic manner, financial frictions *à la* BGG and cross-border lending. It provides an original set of financial frictions together with wide cross-country heterogeneity. This framework is well-suited to analyse the dispersion in bank lending rates observed across euro area countries. In doing so, we construct macro-financial scenarios evaluating the structural underpinnings of lending rate fragmentation and its macroeconomic spillovers.

4 The model

A multi-country DSGE model is developed in order to examine in depth the propagation of financial tensions to the broader economy that characterised the international financial crisis and the euro area sovereign debt crisis. On the non-financial side the general setup of the model is close to existing multi-country DSGE models like EAGLE (Gomes et al., 2012), the NAWM (Coenen et al., 2008), GEM (Laxton and Pesenti (2003) and Pesenti (2008)), GIMF (Kumhof et al., 2010) or QUEST (Ratto et al. (2009) and Kollmann et al. (2014)). And as such it shares with them a common theoretical framework based on the New Open Economy Macroeconomics paradigm and thus includes a rich set of nominal and real frictions. As our main objective is assessing cross-country heterogeneities within the euro area (EA), the country coverage has been decomposed in five regions, namely the big four and the rest of the euro area. The sixth block gathering most important non-EA countries closes the global model. All country-blocks are symmetric, feature eleven types of agents in a four sectoral economy and only differ by their calibration. Given its relatively large size the model is calibrated. As stressed before one of the stricking features of the crisis is the introduction of specific cross-country heterogeneities in the financial sector the EA. To evaluate their impacts on the transmission of shocks we have conisdered two sets of calibrations for the financial bloc: before the crisis when countries are relatively homogeneous and after.[2]

[2]In order to clearly isolate the specific impact of the financial transformation observed during the crisis on our results we decided to keep unchanged other parameters which are related to the real bloc. This amounts to implicitly making the assumption that structural parameters of the real economy were not affected although it is not completely true.

The next sections focus on the financial segments, which constitute the original part of the model. For the sake of clarity, we will present the associated decision problems in a closed economy setup, finally exposing the open economy dimension with cross-border lending. Beforehand, we start with a brief overview of the global economic environment (see also Figure 7 for the overall schematic representation), leaving the more detailed description of households, firms, capital producers and government features to the Appendix.

4.1 Global economic environment

Households are infinitely-lived agents and identified as Ricardian or non-Ricardian according to their access to financial markets. The former have access to financial markets while the latter do not. A fraction of Ricardian household's members are workers while the remaining is split into entrepreneurs and bankers. Furthermore, households supply differentiated labour services in monopolistically competitive markets where they act as setter of the nominal wage. It is assumed that wages are determined by staggered nominal contracts *à la* Calvo (Calvo (1983)). Ricardian households also gain utility from bank deposits over consumption due to the liquidity services bank debt provides them.

On the supply side, there are two types of firms, the intermediate and the final goods producing firms. The intermediate goods are consisting of internationally tradable and non-tradable goods for consumption and investment. The final-goods producing firms use all intermediate goods to produce the final goods which are non-traded and used for consumption and investment. Each firm in the intermediate goods sector sells its differentiated output under monopolistic competition. There is sluggish price adjustment due to staggered price contracts as *à la* Calvo.

Finally, the public authority includes the government and the central bank. Sovereign default may arise as a consequence of the government's inability to raise the funds necessary to honor its debt obligations. The monetary policy in each of the regions of the model (euro area and rest of the world) follows an interest rate rule of Taylor-type. In the case of the euro area, the equation holds for the single monetary authority.

Regarding the international dimension, cross-country spillovers can arise via two main channels: firstly, through cross border lending from domestic bankers to foreign retail lending branches and secondly through trade of intermediate consumption and investment. The different agents that interplay in our model and the respective sectors in the domestic or foreign economy where they operate on are illustrated in Figure 7 in a simplified schematic representation.

4.2 Financial intermediation and monetary policy transmission channel

The banking sector collects deposit from Ricardian households and provides funds to the retail deposit banks. Wholesale banks take deposits from the retail deposit banks and give loans to the retail lending branches. In doing so, they face capital requirements which are sensitive to the riskiness of the loan contract. In particular, it is clear that by introducing capital requirements that are sensitive to the state of the economy, the inherent cyclicality in banks' lending behaviour is likely to be reinforced, as shown in Darracq Pariès et al. (2011). *Ceteris paribus*, a risk-sensitive capital requirements regime (i.e. the Basel II or Basel III capital adequacy framework; see BIS (2004)) is expected to have pro-cyclical effects. Wholesale banks provide lending to the retail lending banks which subsequently through loan officers provide loan contracts to entrepreneurs. The presence of nominal stickiness generates imperfect pass-through of market rates to bank deposit and lending rates. Credit contracts are proposed by loan officers to entrepreneurs with predetermined lending rates. The latter buy capital stock from the capital producers. Due to asymmetric information and costly state verification through monitoring costs, there are external financing premia which depend indirectly on the borrower's leverage.

Overall, default can occur in the model in three layers. Firstly, sovereign default materialises whenever the government debt-to-GDP reaches the fiscal limit. Secondly, banks may default when their return on asset is not sufficient to cover the repayments due to deposits. Lastly, entrepreneurs default when their income that can be seized by the lender falls short of the agreed repayment of the loan. Additionally, the same schematic representation provides an illustrative way to the impairments in the transmission mechanism of monetary policy by decomposing final lending rate into the chain of financing costs faced by the different agents and the associated financial shocks.

4.2.1 Banking sector

Every period, a fraction $(1 - f_I)$ of the representative I-type household's members are workers while a fraction $f_I e_I$ are entrepreneurs and the remaining mass $f_I(1 - e_I)$ are bankers. Bankers face a probability ζ_b of staying banker over next period and a probability $(1 - \zeta_b)$ of becoming a worker again. When a banker exits, accumulated earnings are transferred to the respective I-type household while newly entering bankers receive initial funds from households. Overall, households transfer a real amount $\Psi_{B,t}$ to the bankers for each period t. In our setting, bankers' decisions are identical so we will expose the decision problem for a representative banker.

The banking sector is owned by the I-type households and is segmented in various parts. First, bankers get financing in the money market and fund to the retail lending branches, facing a regulatory penalty which forces bankers to hoard a sufficient level of equity and benefiting from limited liability under a deposit insurance scheme. Second deposit branches collects savings from the I-type households and place them in the money markets. Third retail lending branches receive funding from the bankers and allocate it to the loan officers. In the retail segment, banks operate under monopolistic competition and face nominal rigidity in their interest rate setting. The final segment of the banking group is formed loan officers which provide loan contracts to entrepreneurs.

4.2.2 Retail deposit branches

The deposits offered to I-type households are a CES aggregation of the differentiated deposits provided by the retail deposit branches

$$D_t = \left[\int_0^1 D_t(j)^{\frac{1}{\mu_D^R}} \mathrm{d}j \right]^{\mu_D^R} \tag{1}$$

expressed in real terms. Retail deposits are imperfect substitute with elasticity of substitution $\frac{\mu_D^R}{\mu_D^R - 1} < -1$. The corresponding average interest rate offered on deposits is

$$R_{D,t} = \left[\int_0^1 R_{D,t}(j)^{\frac{1}{1-\mu_D^R}} \mathrm{d}j \right]^{1-\mu_D^R}. \tag{2}$$

Retail deposit branches are monopolistic competitors which collect deposit from savers and place them in the money market.[3] Deposit branches set interest rates on a staggered basis *à la* Calvo, facing each period a constant probability $1-\xi_D^R$ of being able to re-optimize their nominal interest rate. When a retail deposit branch cannot re-optimize its interest rate, the interest rate is left at its previous period level

$$R_{D,t}(j) = R_{D,t-1}(j). \tag{3}$$

The retail deposit branch j chooses $\hat{R}_{D,t}(j)$ to maximize its intertemporal profit.

$$\mathbb{E}_t \left[\sum_{k=0}^{\infty} \left(\beta \xi_D^R\right)^k \frac{\Lambda_{I,t+k}}{\Lambda_{I,t}} \left(R_{BD,t+k} D_{t+k}(j) - \hat{R}_{t,D}(j) D_{t+k}(j) \right) \right] \tag{4}$$

where

$$D_{t+k}(j) = \left(\frac{\hat{R}_{D,t}(j)}{R_{D,t}} \right)^{-\frac{\mu_D^R}{\mu_D^R - 1}} \left(\frac{R_{D,t}}{R_{D,t+k}} \right)^{-\frac{\mu_D^R}{\mu_D^R - 1}} D_{t+k} \tag{5}$$

and $\Lambda_{I,t}$ is the marginal value of consumption for the Ricardian households.

A markup shock is introduced on the interest rate setting, by allowing μ_D^R to follow an AR(1) process with i.i.d. error term.

4.2.3 Bankers

Bankers operate in competitive markets providing loans to retail lending branches, $L_{BE,t}$. To finance their lending activity, bankers receive deposits, $D_{B,t}$, from the retail deposit branches, with a gross interest rate $\widetilde{R}_{BD,t}$ and accumulate net worth, $NW_{B,t}$. Their balance identity reads

$$L_{BE,t} = D_{B,t} + NW_{B,t} \tag{6}$$

Bankers' assets are subject to idiosyncratic shocks, $\omega_{b,t}$, independent and identically distributed across time and across bankers. $\omega_{b,t}$ follows a lognormal CDF $F_b(\omega_{b,t})$, with mean 1 and variance $\sigma_{b,t}$. One may rationalise this source of microeconomic risks as a lack of diversification in loan exposures at the bank level or any other source heterogeneity which leads to a distribution of asset returns across the banking system.

The operating profit of a banker for the period $t+1$, OP_{t+1}^b, results from the gross interest received from the loans to the retail lending bank, the lump-sum share of profits (and losses) coming from retail deposit, $\Pi_{D,t}^R$, retail lending and loan officers activity, $\Pi_{B,t}^R$, pro-rated according to each banker's net worth, minus the gross interest paid on deposits

$$OP_{t+1}^b \left(\omega_{b,t+1}\right) \equiv \omega_{b,t+1} R_{BLE,t} L_{BE,t} - \widetilde{R}_{BD,t} D_{B,t} + \Pi_{D,t}^R + \Pi_{B,t+1}^R. \tag{7}$$

where $R_{BLE,t}$ is the banker's financing rate while $\widetilde{R}_{BD,t}$ captures the funding cost of the bankers specified as follows

[3] Notice that in an open economy setup with incomplete markets, deposit branches are charged by an extra risk premium depending on the country intra-EA net foreign position. The risk premium is required for the existence of a well-defined steady state and stationarity of the net foreign asset position. See for example Schmitt-Grohe and Uribe (2003) and Quint and Rabanal (2014).

$$\widetilde{R}_{BD,t} = \Psi_t R_{BD,t} \tag{8}$$

with

$$\Psi_t = \Lambda_{\Psi,t} \left(RP_{G,t} - 1 \right) + 1 \tag{9}$$

being the funding cost spread related to sovereign risk. In a reduced-form manner, we set it as a linear function of the sovereign risk premium $RP_{G,t}$, with semi-elasticity $\Lambda_{\Psi,t}$.

Following Corsetti et al. (2013) we allow for sovereign default as a consequence of the government's inability to raise the funds necessary to honor its debt obligations. Subsequently sovereign risk premia respond to changes in the fiscal outlook of the country and the probability of sovereign default is closely and nonlinearly linked to the level of public debt. Overall this sovereign risk channel raises the cost of financial intermediation as described above. More specifically, sovereign default is operationalised with the notion of a fiscal limit in a manner similar to Corsetti et al. (2013) and Bi and Leeper (2010). Whenever the debt level rises above the fiscal limit, a default will occur. The fiscal limit is determined stochastically capturing the uncertainty that surrounds the political process in the context of sovereign default. Specifically, we assume that in each period the limit will be drawn from a normal distribution with parameters $B_Y^{\max}$ which is the maximum debt-to-GDP that a country can sustain and σ_{BY} the standard deviation of the probability distribution which captures the sensitivity of sovereign risk to debt-to-GDP. Beyond this limit the probability of default is certain. As a result, the *ex ante* probability of a default, $p_t^{\xi_G}$, at a certain level of sovereign indebtedness, $B_{Y,t+1}$, will be given by the normal cumulative distribution function $F_g(B_{Y,t+1})$, with mean $B_Y^{\max}$ and standard deviation σ_{B_Y}.

$$p_t^{\xi_G} \approx E_t \left\{ F_g \left[\frac{B_{Y,t+1} - B_Y^{\max}}{\sigma_{B_Y}} \right] \right\} \tag{10}$$

where $B_Y^{\max}$ denotes the upper range of the support for the debt level in terms of the debt-to-GDP. By assuming that the size of the haircut in case of a default is constant, the actual haircut in the economy is defined as

$$\begin{aligned} \xi_{G,t} &= \begin{cases} \xi_G^{\max}, & \text{with probability } p_t^{\xi_G} \\ 0, & \text{with probability } 1 - p_t^{\xi_G} \end{cases} \\ &= p_t^{\xi_G} \xi_G^{\max} \end{aligned} \tag{11}$$

Following the optimisation solution of the households problem, the sovereign risk premium can be defined as

$$RP_{G,t} = \frac{1}{1 - p_t^{\xi_G} \xi_G^{\max}} \tag{12}$$

We introduce two key assumptions in the decision problem of bankers: first, bankers enjoy *limited liability*, so their payoffs are always positive and second, regulators impose a *penalty* $\chi_b L_{BE,t}$ if the operating profit is less than a fraction ν_b of the risk weighted assets

$$rw_{e,t} \omega_{b,t+1} R_{BLE,t} L_{BE,t} \tag{13}$$

where $rw_{e,t}$ is the risk weight on corporate loans. Each banker takes the risk weight $rw_{e,t}$ as exogenous to their decisions.

In line with the Basel III capital adequacy framework, the risk weighted assets can be modelled as non-linear functions of the probability of default of the borrowers at a certain horizon.[4] Except if stated otherwise, we assume that the risk weight is constant and equal to 1. This assumption will be relaxed in the final sections of the paper.

Regarding limited liability, bankers default when their return on asset is not sufficient to cover the repayments due to deposits. This happens for draws of $\omega_{b,t+1}$ that fall below the threshold $\overline{\omega}_{b,t+1}$ given by

$$\overline{\omega}_{b,t+1} \equiv \frac{\widetilde{R}_{BD,t} D_{B,t} - \Pi^R_{D,t} - \Pi^R_{B,t+1}}{R_{BLE,t} L_{BE,t}}. \tag{17}$$

Bank leverage is denoted as $\kappa_{b,t} = \frac{L_{BE,t}}{NW_{B,t}}$ and the default cutoff point can be expressed as

$$\overline{\omega}_{b,t+1} \equiv \frac{\widetilde{R}_{BD,t}\left(\kappa_{b,t} - 1\right) - \frac{\Pi^R_{D,t}}{NW_{B,t}} - \frac{\Pi^R_{B,t+1}}{NW_{B,t}}}{\kappa_{b,t} R_{BLE,t}} \tag{18}$$

When bankers default occurs, the deposit insurance agency serves the depositors and takes over the loan portfolio of the failed banker subject to resolution costs (μ_b), expressed as a fraction of the banker's assets.

Turning to the penalty, if the banker does not default, it will be paid for realisations of $\omega_{b,t+1}$ below a second threshold $\overline{\omega}^{\nu}_{b,t+1}$ given by

$$\overline{\omega}^{\nu}_{b,t+1} = \frac{\overline{\omega}_{b,t+1}}{1 - \nu_b rw_{e,t+1}} > \overline{\omega}_{b,t+1} \tag{19}$$

where ν_b is the regulatory bank capital ratio. We assume that bankers are myopic and choose the volume of loans that maximizes the expected return on net worth one period ahead. Due to the assumption of limited liability, the period t objective of a banker is

$$\max_{\{\overline{\omega}^{\nu}_{b,t+1}, \overline{\omega}_{b,t+1}, \kappa_{b,t}\}} \mathbb{E}_t \left\{ \widetilde{E}\left[OP^b_{t+1}\left(\omega_{b,t+1}\right) \mid \omega_{b,t+1} \geq \overline{\omega}_{b,t+1}\right] - \widetilde{E}\left[\chi_b L_{BE,t} \mid \omega_{b,t+1} \leq \overline{\omega}^{\nu}_{b,t+1}\right] \right\} \tag{20}$$

[4] For more details on the Basel II formulas, see BIS (2004). For corporate exposures, the risk weights are given by

$$rw_{e,t} = \frac{\overline{LGD}_E}{\nu_b} \Phi\left[\left(1 - \tau^E_t\right)^{-0.5} \Phi^{-1}\left(PD^E_t\right) + \left(\frac{\tau^E_t}{1 - \tau^E_t}\right)^{0.5} \Phi^{-1}\left(0.999\right)\right] - \frac{\overline{LGD}_E}{\nu_b} PD^E_t \tag{14}$$

where PD^E_t and LGD^E_t refer to the one-year-ahead probability of default and loss-given-default on corporate exposures, respectively. Φ denotes the cumulative distribution function for a standard normal random variable. τ^E_t denotes the asset-value correlation which parameterizes cross-borrower dependencies and being a decreasing function of PD^E_t is equal to

$$\tau^E_t = 0.12\left[\frac{\left(1 - \exp\left(-50 PD^E_t\right)\right)}{\left(1 - \exp\left(-50\right)\right)}\right] + 0.24\left[1 - \frac{\left(1 - \exp\left(-50 PD^E_t\right)\right)}{\left(1 - \exp\left(-50\right)\right)}\right] \tag{15}$$

As we assume a fixed $\overline{LGD}_E$ (equal to 0.45), the only time-varying component in the risk weighting is the PD^E_t and the resulting risk curve has a concave nature. On the other hand, PD^E_t is related to entrepreneurs quarterly default probability according to

$$PD^E_t = \mathbb{E}_t\left\{\sum_{i=1}^{4}\left[\prod_{s=0}^{i-1}\left(1 - F_e\left(\overline{\omega}_{e,t+s}\right)\right)\right] F_e\left(\overline{\omega}_{e,t+i}\right)\right\} \tag{16}$$

where $\widetilde{E}$ is the conditional expectation operator for the cross-section distribution of idiosyncratic banker returns on private loans.

After some manipulations, this problem can be formulated as follows

$$\max_{\{\overline{\omega}^{\nu}_{b,t+1},\overline{\omega}_{b,t+1},\kappa_{b,t}\}} \mathbb{E}_t \left\{ R_{BLE,t}\kappa_{b,t}\left[1-\Gamma_b\left(\overline{\omega}_{b,t+1}\right)\right] - \chi_b\kappa_{b,t}\left(F\left(\overline{\omega}^{\nu}_{b,t+1}\right)-F\left(\overline{\omega}_{b,t+1}\right)\right)\right\} \tag{21}$$

subject to the balance sheet constraint (6) and the definition of cutoff idiosyncratic shocks (18) and (19) and where χ_b is the regulatory penalty, and $\Gamma_b(\overline{\omega})$ is defined as follows

$$\Gamma_b(\overline{\omega}) = (1-F_b(\overline{\omega}))\overline{\omega} + \int_0^{\overline{\omega}} \omega \mathrm{d}F_b(\omega) \tag{22}$$

The first order condition for the banker's decision problem, in the case of limited liability, after some manipulations, gives

$$R_{BLE,t}\left(1-\int_0^{\overline{\omega}_{b,t+1}} \omega \mathrm{d}F_b(\omega)\right) = \widetilde{R}_{BD,t}\left(1-F_b\left(\overline{\omega}_{b,t+1}\right)\right) \tag{23}$$

$$+\chi_b \left[\begin{array}{c} \left(F\left(\overline{\omega}^{\nu}_{b,t+1}\right)-F\left(\overline{\omega}_{b,t+1}\right)\right) \\ +\left(\mathrm{d}F_b\left(\overline{\omega}^{\nu}_{b,t+1}\right)/\left(1-\nu_b r w_{e,t+1}\right)-\mathrm{d}F_b\left(\overline{\omega}_{b,t+1}\right)\right)\left(\frac{\widetilde{R}_{BD,t}}{R_{BLE,t}}-\overline{\omega}_{b,t+1}\right)\end{array}\right]$$

In the absence of limited liability, the expected return on net worth would boil down to

$$\mathbb{E}_t\left[R_{BLE,t}\kappa_{b,t}\left(1-\overline{\omega}_{b,t+1}\right)-\chi_b\kappa_{b,t}F\left(\overline{\omega}^{\nu}_{b,t+1}\right)\right] \tag{24}$$

and the first order condition could be written as

$$R_{BLE,t} = \widetilde{R}_{BD,t} + \chi_b\left[F\left(\overline{\omega}^{\nu}_{b,t+1}\right)+\frac{\mathrm{d}F_b\left(\overline{\omega}^{\nu}_{b,t+1}\right)}{1-\nu_b r w_{e,t+1}}\left(\frac{\widetilde{R}_{BD,t}}{R_{BLE,t}}-\overline{\omega}_{b,t+1}\right)\right] \tag{25}$$

Finally, aggregating across bankers, a fraction ζ_b continues operating into the next period while the rest exits from the industry. The new bankers are endowed with starting net worth, proportional to the assets of the old bankers. Accordingly, the aggregate dynamics of bankers' net worth is given by

$$NW_{B,t} = \zeta_b\left\{R_{BLE,t-1}\kappa_{b,t-1}\left[1-\Gamma_b\left(\overline{\omega}_{b,t}\right)\right]-\chi_b\left(F\left(\overline{\omega}^{\nu}_{b,t}\right)-F\left(\overline{\omega}_{b,t}\right)\right)\right\}\frac{NW_{B,t-1}}{\Pi_{C,t}}+\Psi_{B,t} \tag{26}$$

Several shocks are introduced in the banker's problem. The first one is a bank capital shock, rationalised as a temporary decline in the bankers survival probability $\zeta_{b,t}$, the second one is a permanent or temporary increase in regulatory requirement ν_b, and the last one is a temporary increase in the idiosyncratic risk on bankers asset return $\sigma_{b,t}$. All variables are assumed for this purpose to follow an AR(1) process with i.i.d. error term.

4.2.4 Retail lending branches

A continuum of retail lending branches indexed by j, provide differentiated loans to loan officers. The total financing needs of loan officers follow a CES aggregation of differentiated loans

$$L_{E,t} = \left[\int_0^1 L_{E,t}(j)^{\frac{1}{\mu_E^R}} \mathrm{d}j \right]^{\mu_E^R} \tag{27}$$

Differentiated loans are imperfect substitute with elasticity of substitution $\frac{\mu_E^R}{\mu_E^R - 1} > 1$. The corresponding average return on loan is

$$R_{LE,t} = \left[\int_0^1 R_{LE,t}(j)^{\frac{1}{1-\mu_E^R}} \mathrm{d}j \right]^{1-\mu_E^R}. \tag{28}$$

Retail lending branches are monopolistic competitors which levy funds from bankers and set gross nominal interest rates on a staggered basis *à la* Calvo, facing each period a constant probability $1 - \xi_E^R$ of being able to re-optimize. As for deposits, the indexation rule in case a retail lending branch cannot re-optimize its interest rate is given by

$$R_{LE,t}(j) = R_{LE,t-1}(j) \tag{29}$$

The retail lending branch j chooses $\hat{R}_{LE,t}(j)$ to maximize its intertemporal profit

$$\mathbb{E}_t \left[\sum_{k=0}^{\infty} \left(\beta \xi_E^R\right)^k \frac{\Lambda_{I,t+k}}{\Lambda_{I,t}} \left(\hat{R}_{LE,t}(j) L_{E,t+k}(j) - R_{BLE,t+k}(j) L_{E,t+k}(j) \right) \right] \tag{30}$$

where the demand from the loan officers is given by

$$L_{E,t+k}(j) = \left(\frac{\hat{R}_{LE,t}(j)}{R_{LE,t}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} \left(\frac{R_{LE,t}}{R_{LE,t+k}} \right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} L_{LE,t+k} \tag{31}$$

The staggered lending rate setting acts in the model as maturity transformation in banking activity and leads to imperfect pass-through of market interest rates on bank lending rates. We add markup shocks to the staggered nominal interest rate setting, by allowing μ_E^R to follow an AR(1) process with i.i.d. error term.

4.2.5 Loan officers

Loan officers provide loan contracts to entrepreneurs. They operate in a perfectly competitive environment. They receive one-period loans from the retail lending branches which pay a gross nominal interest rate $R_{LE,t}$. The loan officers have no other source of funds so that the level of loan they provide to the entrepreneurs equals the level of financing they receive, $B_{E,t}$. Loan officers seek to maximise its discount intertemporal flow of income so that the first order condition of their decision problem gives

$$\mathbb{E}_t \left[\Xi_{t,t+1}^I \left(\frac{\widetilde{R}_{LE,t+1} - R_{LE,t}}{\Pi_{C,t+1}} \right) \right] = 0 \tag{32}$$

We denoted $\widetilde{R}_{LE,t+1}$ the state-contingent returns on the loan portfolio, whereas $\Xi_{t,t+1}^I = \beta \frac{\Lambda_{I,t+1}}{\Lambda_{I,t}}$ is the period t stochastic discount factor of the I-type households for nominal income streams at period $t + 1$.

The first order conditions (32) will serve as participation constraints in the decision problems of entrepreneurs (see Appendix).

4.2.6 Market clearing conditions

On the credit market, due to nominal rigidity in the setting of interest rate by retail banking branches, the following conditions holds

$$L_{BE,t} = \Delta^R_{E,t} L_{E,t} \quad (33)$$

$$D_{B,i} = \Delta^R_{D,t} D_t \quad (34)$$

where $\Delta^R_{i,t} = \int_0^1 \left(\frac{R_{i,t}(j)}{R_{i,t}}\right)^{-\frac{\mu_i^R}{\mu_i^R - 1}} \mathrm{d}j$ for $i \in \{E, D\}$ are dispersion indexes among retail bank interest rates.

In equilibrium

$$\Pi^R_{D,t} = (R_{BD,t} - R_{D,t}) D_{B,t} \quad (35)$$

$$\Pi^R_{B,t+1} = \left(\widetilde{R}_{LE,t+1} - R_{BLE,t}\right) L_{BE,t}. \quad (36)$$

Finally, the financing needs of the deposit insurance agency, which are assumed to be amount to be recouped out of government spending are defined as follows

$$\Omega_{b,t} \equiv \left[\overline{\omega}_{b,t} - \Gamma_b(\overline{\omega}_{b,t}) + \mu_b \int_0^{\overline{\omega}_{b,t+1}} \omega \mathrm{d}F_b(\omega)\right] R_{BLE,t} L_{BE,t}. \quad (37)$$

where μ_b is the resolution cost of the bankrupt bank.

4.2.7 Entrepreneurs

Every period, a fraction $f_I e_I$ are entrepreneurs. Each entrepreneur faces a probability ζ_e of staying entrepreneurs over next period and a probability $(1 - \zeta_e)$ of becoming a worker again. To keep the share of entrepreneurs constant, we assume that similar number of workers randomly becomes entrepreneur. When an entrepreneur exits, their accumulated earnings are transferred to the respective I-type household. At the same time, newly entering entrepreneurs receive initial funds from households. Overall, households transfer a real amount $\Psi_{E,t}$ to the entrepreneurs for each period t. Finally, as it will become clear later, entrepreneurs decisions for leverage and lending rate are independent from their net worth and therefore identical. Accordingly, we will expose the decision problem for a representative entrepreneur.

A segment of perfectly competitive capital producer firms, owned by the I-type households, produce the stock of fixed capital in the economy using tradable investment goods. At the end of the period t entrepreneurs buy the capital stock K_t from the capital producers at real price Q_t (expressed in terms of consumption goods). They transform it into an effective capital stock $u_{t+1} K_t$ by choosing the utilisation rate u_{t+1}. The adjustment of the capacity utilization rate entails some costs per unit of capital stock $\Gamma_u(u_{t+1})$. The effective capital stock can then be rented out to intermediate goods producers at a nominal rental rate of $r_{K,t+1}$. Finally, by the end of period $t+1$, entrepreneurs sell back the depreciated capital stock $(1 - \delta) K_t$ to capital producer at price Q_{t+1}.

The gross nominal rate of return on capital across from period t to $t+1$ is therefore given by

$$R_{KK,t+1} \equiv \frac{((1-\tau_{t+1}^{K})(r_{K,t+1}u_{t+1} - \Gamma_u(u_{t+1}))P_{I,t+1} + \tau_t^{K}\delta P_{I,t+1} + (1-\delta)Q_{t+1})}{Q_t \Pi_{C,t+1}} \quad (38)$$

where τ_t^K is tax rate to capital, $\Pi_{C,t+1}$ is CPI inflation and $P_{I,t+1}$ is the relative price of investment goods in terms of consumption goods.

Each entrepreneurs' return on capital is subject to multiplicative idiosyncratic shock $\omega_{e,t}$. These shocks are independent and identically distributed across time and across entrepreneurs. $\omega_{e,t}$ follows a lognormal CDF $F_e(\omega_{e,t})$, with mean 1 and variance $\sigma_{e,t}$. By the law of large number, the average across entrepreneurs (denoted with the operator $\widetilde{E}$) for expected return on capital is given by

$$\widetilde{E}\left[\mathbb{E}_t\left(\omega_{e,t+1}R_{KK,t+1}\right)\right] = \mathbb{E}_t\left(\int_0^{\infty} \omega_{e,t+1}\mathrm{d}F_{e,t}(\omega)\, R_{KK,t+1}\right) = \mathbb{E}_t\left(R_{KK,t+1}\right) \quad (39)$$

Entrepreneur's choice over capacity utilization is independent from the idiosyncratic shock and implies that $r_{K,t} = \Gamma'_u(u_t)$.

Entrepreneurs finance their purchase of capital stock with their net worth $NW_{E,t}$ and one-period loan $L_{E,t}$ from the commercial lending branches, where

$$Q_t K_t = NW_{E,t} + L_{E,t} \quad (40)$$

In the tradition of costly-state-verification frameworks, loan officers cannot observe the realisation of the idiosyncratic shock unless they pay a monitoring cost μ_e per unit of assets that can be transferred to the bank in case of default. We constrain the set of lending contracts available to entrepreneurs. They can only use debt contracts in which the lending rate $R_{LLE,t}$ is pre-determined at the previous time period. Default will occur when the entrepreneurial income that can be seized by the lender falls short of the agreed repayment of the loan. At period $t+1$, once aggregate shocks are realised, this will happen for draws of the idiosyncratic shock below a certain threshold $\overline{\omega}_{e,t}$, given by

$$\overline{\omega}_{e,t+1}\chi_e R_{KK,t+1}\kappa_{e,t} = \left(R_{LLE,t}+1\right)\left(\kappa_{e,t}-1\right) \quad (41)$$

where $R_{LLE,t}$ is the nominal lending rate determined at period t and $\kappa_{e,t}$ is the corporate leverage defined as

$$\kappa_{e,t} = \frac{Q_t K_t}{NW_{E,t}}. \quad (42)$$

χ_e represents the share entrepreneurs assets (gross of capital return) that banks can recover in case of default. When banks take over entrepreneur's assets, they have to pay the monitoring costs.

The *ex post* return to loan officers, denoted $\widetilde{R}_{LE,t}$, can then be expressed as

$$\widetilde{R}_{LE,t} = G(\overline{\omega}_{e,t})\chi_e R_{KK,t}\frac{\kappa_{e,t-1}}{\kappa_{e,t-1}-1} \quad (43)$$

where

$$G_e(\overline{\omega}) = (1 - F_e(\overline{\omega}))\overline{\omega} + (1-\mu_e)\int_0^{\overline{\omega}} \omega \mathrm{d}F_e(\omega)\,. \quad (44)$$

We assume that entrepreneurs are myopic and the end-of-period t contracting problem for entrepreneurs consists in maximising next period return on net worth for lending rate and leverage

$$\max_{\{R_{LLE,t},\kappa_{e,t}\}} \mathbb{E}_t \left[(1 - \chi_e \Gamma_e(\overline{\omega}_{e,t+1})) R_{KK,t+1} \kappa_{e,t} \right] \tag{45}$$

subject to the participation of constraint of the lender (32), the equation (41) for the default threshold $\overline{\omega}_{e,t+1}$, and where

$$\Gamma_e(\overline{\omega}) = (1 - F_e(\overline{\omega}))\overline{\omega} + \int_0^{\overline{\omega}} \omega \mathrm{d}F_e(\omega). \tag{46}$$

After some manipulations, the first order conditions for the lending rate and the leverage lead to

$$\mathbb{E}_t \left[(1 - \chi_e \Gamma_e(\overline{\omega}_{e,t+1})) R_{KK,t+1} \kappa_{e,t} \right] = \frac{\mathbb{E}_t \left[\chi_e \Gamma'_e(\overline{\omega}_{e,t+1}) \right]}{\mathbb{E}_t \left[\Xi^I_{t,t+1} G'_e(\overline{\omega}_{e,t+1}) \right]} \mathbb{E}_t \left[\Xi^I_{t,t+1} \right] R_{LE,t} \tag{47}$$

where

$$\Gamma'_e(\overline{\omega}) = (1 - F_e(\overline{\omega})) \tag{48}$$

$$G'_e(\overline{\omega}) = (1 - F_e(\overline{\omega})) - \mu_e \overline{\omega} \mathrm{d}F_e(\overline{\omega}). \tag{49}$$

As anticipated at the beginning of the section, the solution of the problem shows that all entrepreneurs choose the same leverage and lending rate. Moreover, the features of the contracting problem imply that the *ex post* return to the lender $\widetilde{R}_{LE,t}$ will defer from the *ex ante* return $R_{LE,t-1}$.[5]

The loan contract introduced in this section is different from the one of Bernanke et al. (1999) in two respects: first, we impose that the contractual lending rate is predetermined and second, we assume limited seizability of entrepreneurs assets in case of default. In BGG, it is the return to the lender that is predetermined[6] while the contractual lending rate is state contingent. This implies that from period t to $t+1$, the realisation of aggregate shocks has no impact of lender's balance sheet. The assumption of predetermined contractual lending rate relaxes this property and allows for innovations on the lender's return. Besides, the restrictions imposed on the contracting problem imply that it is not optimal in the sense of Carlstrom et al. (2013a,b).

Finally, the dynamic of net worth is given by

$$NW_{E,t} = \zeta_e (1 - \chi_e \Gamma_e(\overline{\omega}_{e,t})) R_{KK,t} \kappa_{e,t-1} \frac{NW_{E,t-1}}{\Pi_{C,t}} + \Psi_{E,t}. \tag{50}$$

It is assumed that the standard deviation σ_e which measures the risk to bankruptcy, is time-varying and follow and AR(1) process with i.i.d error terms.

4.2.8 Cross-border banking

Following the closed economy exposition of the various financial segments, we now introduce the open economy dimension which allows for the possibility of cross-border lending between domestic

[5] Log-linearising equation (47) and the participation constraint (32), one can show that innovations in the *ex post* return are notably driven by innovations in $R_{KK,t}$.

[6] If the lending rates offered by banks are not contingent on the *ex post* realization of aggregate uncertainty (i.e. pre-determined lending rates) shocks hitting the economy tend to have a more muted effect relative to the benchmark scenario. In this case, this reflects the less pronounced interactive effects between macroeconomic developments (e.g. the accelerator effects on borrower net worth) and the credit market. This mitigates somewhat the macroeconomic amplification implied by the existence of credit frictions observed in the benchmark case.

bankers and foreign retail lenders. Given the stylised description of the banking system in the model, such flows can be interpreted both as cross-border lending whereby a domestic bank provides direct loan contract to a foreign non-financial corporation, or intrabank lending to an affiliate which in turn provides financing to foreign non-financial corporations. We will discuss this point in more detail in the section on the model calibration.

To simplify the notations, the open economy specifications will be exposed in a symmetric two-country setup under monetary union, denoting by H the domestic country and by F the foreign one. In the following, we derive the modified decision problems for retail lending branches and bankers in country H.

Each retail lending branch receives funding domestic as well as foreign bankers through a CES aggregation technology

$$L_{E,t} = \left[v_{LE}^{\frac{1}{\xi_{LE}}} \left(L_{E,t}^{H} \right)^{\frac{\xi_{LE}-1}{\xi_{LE}}} + (1 - v_{LE})^{\frac{1}{\xi_{LE}}} \left(RER_t L_{E,t}^{H \leftarrow F} \right)^{\frac{\xi_{LE}-1}{\xi_{LE}}} \right]^{\frac{\xi_{LE}}{\xi_{LE}-1}} \tag{51}$$

where $L_{E,t}^{H}$ and $L_{E,t}^{H \leftarrow F}$ are domestic and foreign currency loans, expressed in real terms, and RER_t is the bilateral CPI-based real exchange rate.

Cost minimisation implies that the composite gross funding cost for the retail lending branches $\widehat{R}_{BLE,t}$ is given by

$$\left(\widehat{R}_{BLE,t} \right)^{1-\xi_{LE}} = v_{LE} \left(R_{BLE,t}^{H} \right)^{1-\xi_{LE}} + (1 - v_{LE}) \left(R_{BLE,t}^{F} \right)^{1-\xi_{LE}} . \tag{52}$$

In this context, the demand for domestic and foreign lending is

$$L_{E,t}^{H} = v_{LE} \left(\frac{R_{BLE,t}^{H}}{\widehat{R}_{BLE,t}} \right)^{-\xi_{LE}} L_{E,t} \tag{53}$$

$$RER_t L_{E,t}^{H \leftarrow F} = (1 - v_{LE}) \left(\frac{R_{BLE,t}^{F}}{\widehat{R}_{BLE,t}} \right)^{-\xi_{LE}} L_{E,t}. \tag{54}$$

In this open economy context, the market clearing condition of bank loans is modified as follows

$$L_{BE,t} = \Delta_{E,t}^{R} L_{E,t}^{H} + \Delta_{E,t}^{R*} L_{E,t}^{F \leftarrow H} \tag{55}$$

where $\Delta_{E,t}^{R}$ and $\Delta_{E,t}^{R*}$ are dispersion indexes among retail bank interest rates in the home economy and the foreign one, respectively.

4.3 Monetary policy

Given the variety of interest rates in the model, the monetary policy implementation deserves some discussion. We assume that the central bank aims at steering the money market rate, i.e. the credit-risk free interest rate that applies to bank funding instruments, $R_{BD,t}$. The asset structure of the model economy could in principle have allowed for another operational target, like the risk-free private bond (i.e. the CAPM interest rate) or the household deposit rate. Our specification is probably more realistic and consistent with the approach followed by most recent papers which consider segmented banking models.

The monetary policy in each of the regions of the model (rest-of-the-world or the euro area) follows an interest rate rule, of Taylor-type, defined as follows

$$R_{BD,t} = \phi_R \left(R_{BD,t-1}\right) + (1 - \phi_R) \left[\left(\overline{R}\right) + \phi_\Pi \left(\Pi_{C,t} - \overline{\Pi}\right)\right] + \phi_Y \left(\Delta Y_t - 1\right) \tag{56}$$

specified in terms of region-wide CPI inflation rate ($\Pi_{C,t}$ defined in deviation from the target $\overline{\Pi}$ and output growth ΔY_t). The intercept of the rule is the equilibrium interest rate $\overline{R}$.

5 Calibration

As our main objective is assessing cross-country heterogeneities within the euro area, we made a special effort on this part and allow for the euro area to be decomposed into five regions: namely the four largest countries which are Germany, France, Italy and Spain, and the rest of the euro area. The sixth region corresponds to the rest of the world, transforming the model to global DSGE. In order to derive macroeconomic simulations at the country level, the calibration of the model is fine-tuned to capture selected country-specific structural conditions. While cross-country heterogeneity may manifest itself in several dimensions, we make a special effort to consider the scope for asymmetric calibration regarding corporate and banking sector balance sheets as well as intermediation spreads. We also allow for international financial and trade linkages via detailed calibration of cross-border lending and trade of consumption and investment goods.

The calibration of the model's steady state is based on country-specific structural conditions, empirical evidence, historical data and on existing literature on DSGE models (e.g. EAGLE, GEM and NAWM). The calibration is summarised in annual terms in Tables 1 to 15. With respect to the non-financial variables, great ratios and import shares are computed using National Accounts over the 1999-2012 sample while tax rates are based on the 2000-2012 period. All tax rates are implicit using Eurostat with the exception of the tax on capital which is based on OECD data (see Table II.4 in OECD (2014)). The size of the regions is set to match their respective shares in terms of world GDP. Net foreign asset position of each economy is set to zero at the steady state. Structural parameters are mainly based on the NAWM and GEM.

As concerns the financial variables, we use data on loans and lending rates from the BSI and MIR statistics from the ECB. We also base the calibration on consolidated banking statistics for foreign exposures from BIS (2013), on the expected default probabilities from Moodys, and Basel II and III capital adequacy framework (see BIS (2004)). The calibration of financial block is broadly in line with existing literature, e.g. Jakab and Kumhof (2014), Benes and Kumhof (2011) and Cruces and Trebesch (2013).

5.1 Non-financial block

Table 1 shows the steady-state values of **main macro variables** in the model. Variables which are part of national accounts and represent the domestic demand and trade in the economies are reported as ratios to GDP. The endogenous variable investment to GDP ratio is calibrated in the steady state to much the respective ratio of each country. This is achieved through parameterizing accordingly the share of capital in the production of non-tradables intermediate goods. Government expenditure are set equal to their steady-state values. With respect to trade, the bilateral quasi shares of imports of consumption and investment goods are calibrated as such so that the corresponding shares are equal to the steady-state values. Lastly, the same table reports the share of each region to the world GDP.

Table 2 reports the calibration of the **monetary and fiscal authorities**. Regarding the monetary policy rule, the interest rate reacts to its lagged value as well as to quarterly inflation and to the quarterly output growth. It is calibrated non-symmetrically across countries as we allow for higher interest rate inertia and interest rate sensitivity to inflation gap in the rest of the world rather than in the euro area, while the sensitivity of output growth in the rest of the world is lower than in the euro area. The inflation target is set to 2% per year on all regions.

As concerns the fiscal authority, taxes are calibrated to be non-symmetric across regions. Steady-state tax rates on consumption τ_t^C, income τ_t^N, capital τ_t^K, dividend income τ_t^D, social security contributions by households $\tau_t^{W_h}$ and by firms $\tau_t^{W_f}$ differ across countries in order to capture country differences in the allocation of taxes imposed by the government. Finally, the lump-sum taxes sensitivity to debt-to-GDP ratio, which corresponds to the fiscal rule of the model, is calibrated symmetrically across all regions.

Table 3 reports the calibration of the Ricardian and non-Ricardian **households**. The discount factor, β, is set symmetrically across countries to 0.995. This implies that the equilibrium gross annual real interest rate, $(1/\beta)^4$, is approximately equal to 1.02. The parameters for the intertemporal elasticity of substitution, σ, and the inverse of the Frisch elasticity of labour, ζ, are also calibrated symmetrically and equal to 1 and 2. The habit persistence parameter, κ, is calibrated symmetrically to 0.9. The consumption transaction cost parameters, γ_{vi1} and γ_{vi2}, are also calibrated symmetrically and being equal to 0.029 and 0.153, respectively. Wage implied elasticities of substitution, η_I and η_J, are calibrated symmetrically across the two types of households but country specific across regions. They imply higher wage markups in the euro area around 30% compared to the rest of the world which is around 16%. Calvo wage parameters, ξ_I and ξ_J, are calibrated as well symmetrically across the two types of households and equal to 0.75. The indexation parameters, χ_I and χ_J, are calibrated symmetric across the two types of households and across regions and equal to 0.65.

As concerns only the Ricardian I-type households, whose share $1-\omega$, is set to 0.75 in all region, their deposit preferences, ζ_{db}, are consistent with an overall annual deposit spread of 40%, since households are ready to accept lower returns on deposits due to utility gains from services provided. The elasticity of substitution for deposits, η_{db}, is calibrated symmetrically and equal to 1.25. The international traded bonds transaction cost, γ_{B^*} is calibrated non-symmetrically, being equal to 0.01 for euro area countries and 0.2 for countries belonging to the rest of the world.

Table 4 reports the calibration of the **capital producers and firms** behaviour. With respect to the capital producers, the depreciation rate, δ, the investment adjustment cost parameter, γ_I, and the capital utilisation rate, γ_{u2}, are calibrated symmetrically across countries being equal to 2.5% (consistent with an annual depreciation rate of 10%), 6 and 7, respectively. In the intermediate goods sector, the bias towards capital is higher for tradable goods (α_T) than for nontradable goods (α_N). As for the final goods baskets, the degree of substitutability between domestic and imported tradables, μ_{TC}, is higher than that between tradables and nontradables, μ_C, consistent with existing literature (e.g. GEM or EAGLE). In particular, we set the elasticity of substitution between tradables and non-tradables to 0.5 while the elasticity between domestic and imported tradable goods to 3.5[7]. In

[7] These numbers are broadly in line with related literature, see Imbs and Méjean (2009), Imbs and Méjean (2010)

most countries, the bias towards the tradable bundle is higher in the investment basket than in the consumption baskets. The weight of domestic tradable goods in the consumption and investment tradable baskets is different across countries, to be coherent with multilateral import-to-GDP ratios.

Price markups in the two sectors are higher in the EA than in ROW. Specifically, the net price markup in the tradables sector ($\theta_T/(\theta_T - 1)$) is around 20% in the euro area and around 15% in the rest of the world. The markup in the nontradable good's sector ($\theta_N/(\theta_N - 1)$) is equal to 40% in the euro area and below 30% in ROW.[8] Calvo price parameters in the domestic tradables, ξ_H, and non-tradables, ξ_N, sectors are set to 0.90 ($1/(1 - \xi_H) = 10$ quarters) in the euro area, consistently with estimates by Christoffel et al. (2008) and Smets and Wouters (2003). Corresponding nominal rigidities outside the euro area are equal to 0.75, implying an average frequency of adjustment equal to 4 quarters, in line with Faruquee et al. (2007). Calvo price parameters in the export sector, χ_X, are equal to 0.75 in all the regions. The indexation parameters on prices, χ_H and χ_N, are both equal to 0.40.

5.2 Financial block

The financial block of the model involves sovereign risk associated with fiscal developments of each country, the banking sector which is represented by bankers and retail banking branches and entrepreneurs. There are three different calibration strategies for assigning parameter values. The first one involves the direct setting of parameters in the financial block based on information from existing literature or historical data. If that is not possible, then the second strategy uses information on endogenous variables which can shed light on the target parameters.[9] Lastly, when dealing with the dynamic model, we try to specify sensitivities and degrees of adjustments through the usage of information on elasticities or pass-through parameters or multipliers available from econometric studies. Irrespective of the above techniques, we calibrate the above sectors both symmetrically across regions and asymmetrically. The symmetric one aims at facilitating the interpretation of the qualitative properties of the model and could for some aspects be rationalised as a pre-crisis calibration (notably regarding bankers or entrepreneurs calibration) or correspond to very long-term structural features of the steady state (notably regarding symmetric government debt-to-GDP ratio). The asymmetric calibration allows for cross-country heterogeneity which helps quantifying the role of country-specific financial frictions in domestic propagation and international spillovers.

Starting with **sovereign risk**, we calibrate the parameters of the cumulative probability function which links debt-to-GDP developments to the probability of default of the government. Although in Corsetti et al. (2013) the *cdf* is represented with a *beta* distribution, in our case due to computational limitations,[10] we try to proxy the *beta* with a *Normal* distribution, in the range debt-to-GDP around 40-160% that we consider more plausible to materialise for the countries we focus our analysis on. In this respect, the *Normal* distribution $F_g(B_Y)$ is characterised by two parameters, the mean B_Y^{mean} and the standard deviation σ_{B_Y}. We calibrate both parameters by mapping them with two endogenous variables of the model. The first being the average level of sovereign risk premium

and Corbo and Osbat (2013) for details.

[8]The chosen values are consistent with estimates from Martins et al. (1996), suggesting that the degree of competition in the nontradable sector is lower than in the tradable sector. Also, these values are in line with other similar studies, such as Bayoumi et al. (2004), Faruquee et al. (2007) and Everaert and Schule (2008).

[9]We map an endogenous variable at the steady state with a parameter and adjust the later to match the target value for the former.

[10]The beta distribution is not available in Troll.

as observed from the five-year credit default swaps. The second is the sensitivity of the sovereign government bond spread to a 1% increase in the debt-to-GDP ratio. These elasticities are taken from available studies: Borgy et al. (2011) estimates the increase in five-year spreads of France, Italy and Spain against Germany following an expected increase in their debt-to-GDP ratio over the next year; the sensitivity for Germany is assumed to be similar to the US which is estimated in Laubach (2006).

The symmetric calibration of sovereign risk is shown in Table 5. Sovereign bond spreads are set at 0.8%, resulting in B_Y^{mean} equal to 119.5. The sovereign bond spread sensitivity to debt-to-GDP is set to 0.12%, a cross-country average following the above studies, implying that σ_{B_Y} is 20.4. Lastly, debt-to-GDP ratio is calibrated to be 67.5% which corresponds to the average value across time and countries in the pre-crisis period. The level of haircut, $\xi_G^{\max}$, in case of sovereign default, is calibrated symmetrically across countries to 0.37, which according to Cruces and Trebesch (2013) corresponds to the median haircut calculated from a sample of sovereign debt re-structuring between 1970 and 2010.

When allowing for cross-country heterogeneity, as reported in Table 6, we intend to capture country-specific features on the steady-state level of debt-to-GDP, on the probability of government default and its sensitivity to changes in government indebtedness. Sovereign spreads for Germany and France are calibrated below average, at 0.32% and 0.4%, respectively, while in Spain and Italy there are higher, at 1.2% and 1.12%, respectively. Furthermore, the sensitivity of sovereign spreads to 1% increase in debt-to-GDP is also calibrated to be heterogeneous across countries and consistent with the studies above: at 0.035% for Germany, 0.07% for France, 0.17% for Spain and 0.23% for Italy. Concerning steady-state debt levels, Spain has the lowest while Italy the highest. The rest-of-the-euro-area region remains calibrated as in the symmetric case. As mentioned before, our asymmetries are taken from (Borgy et al., 2011). The loss given default parameter $\xi_G^{\max}$ in case of sovereign default remains the same across countries. The fiscal rules are also kept unchanged.

Table 7 shows the calibration of the **bankers** in the symmetric case. We set the bankers funding cost sensitivity to sovereign bond spread, Λ_Ψ, to 0.6. This value is consistent to the average empirical evidence across euro area countries on the pass-through of sovereign yield to lending rates (see for example Darracq Pariès et al. (2014) or Altavilla et al. (2014)). Furthermore, we calibrate the standard deviation of the idiosyncratic shock σ_b so that the annual percentage of banks violating the minimum capital adequacy ratio is approximately equal to 15%, corresponding to a 4% per quarter as in Benes and Kumhof (2011). The bank resolution cost, μ_b, is calibrated to 0.3. The minimum capital requirements, ν_b, is set to 8% while the steady-state capital ratio of bankers is set approximately to 12%. A symmetric capital buffer of around 4-4.5% is consistent with available empirical evidence over the pre-crisis period. Furthermore, we calibrate regulatory penalty, χ_b, such that in the steady state, the bank capital wedge which is the spread over and above the funding cost is equal to 0.6%. The continuation probability of bankers, ζ_b, clears the net worth accumulation equation for given spreads and capital ratio. This calibration leads to a negligible steady-state probability of bankers defaulting. In this context, the limited liability distortions become almost irrelevant in the symmetric case.

In the non-symmetric case, as shown in Table 8 we generate cross-country heterogeneity through a non-symmetric calibration of the level of NFC loan indebtedness of each country which results in non-symmetric bank leverage for each country. Furthermore, cross-country heterogeneity emerges from the non-symmetric calibration of sovereign risk, which impacts in a non-symmetric manner the funding cost of the banking sector. Although the rest of the calibration in the benchmark case remains the same as in the symmetric case, in section E.2 we perform and show some sensitivity analysis around the above two cases where we allow for higher and asymmetric bank risk calibration and for limited liability to be active. The calibration of these exercises is not shown in the tables.

Table 9 shows the calibration of the **retail banking branches** in the symmetric case. The elasticity of substitution μ_D^R of the CES aggregation of differentiated deposits is parameterised to be 0.999, resulting in a negative deposit spread of 40%. Furthermore, the probability of not being able to re-optimise deposit rate, ξ_D^R, is set to 1%, resulting in almost perfect pass-through of market interest rate on to bank deposit rates. The elasticity of substitution μ_E^R of the CES aggregation of differentiated loans is calibrated as such so that the overall spread between the commercial lending rate is equal to 2.4%. Regarding staggered lending rate setting, the probability of not being able to re-optimise lending rates each quarter, ξ_E^R, is calibrated symmetrically at 40%. This value allows to reproduce the euro area wide average pass-through of short-term rate to composite bank lending rates (see notably the evidence provided by Darracq Pariès et al. (2014)).

When allowing for cross-country heterogeneity, as shown in Table 10, we assume that in Germany and France there is lower maturity transformation than in Spain and Italy. This is calibrated through higher probabilities of not re-optimising lending rates in Germany and France, up to 60% , and lower in Spain and Italy, down to 20%.

As shown in Table 11, we calibrate the standard deviation of the idiosyncratic shock in the **entrepreneurs** problem, σ_e, to match 2.8% of corporate default probability. This value is very close to the one used by Jakab and Kumhof (2014). The monitoring cost μ_e of the costly-state-verification set-up is set so that the commercial lending rates are 0.6% higher than the retail bank returns. The recovery ratio in case of default, χ_e, is calibrated to 100%. On this basis, the steady-state level of corporate leverage, κ_e, is symmetric across countries at around 1.6. The entrepreneurs debt-to-GDP ratio is however country-specific as it also depends on asymmetric features from the non-financial block. The level of private sector indebtedness in the steady state is broadly consistent with an interpretation of bank intermediation which would cover both firms and household borrowing. In this sense, the productive capital stock of the model should also account for commercial and residential housing stock. At the same time, the recovery ratio, χ_e, constitutes an additional degree of freedom to target lower levels of corporate indebtedness, everything else being equal. The continuation probability of bankers, ζ_e, clears the net worth accumulation equation for given spreads.

In the non-symmetric case, as indicated in Table 12, we intend to account for cross-country differences in steady-state probabilities of default, private sector indebtedness and external finance premium. This is done firstly by setting lower default probabilities for Germany and France but higher for Spain and Italy, in line with corresponding evidence from Moody's Expected Default Frequency.[11] Furthermore, we target steady-state values for entrepreneurs debt-to-GDP ratio to match historical data on country-specific indebtedness ratio for the non-financial private sector. The deep parameters that are adjusted are the monitoring cost, μ_e, and the volatility of idiosyncratic shocks, σ_e. The external finance premium and the entrepreneurs leverage are determined endogenously.

Finally, Table 13 shows the calibration of the **cross-border lending** matrix which allows for

[11] The probabilities of default are calculated based on the Moodys Expected Default Frequency (EDF). The EDFs corresponds to the expected probability of default 1-year ahead.

international financial linkages. The calibration of the matrix is based on consolidated banking statistics on foreign exposures from (BIS, 2013). Similarly to the calibration of the trade matrix, the quasi-shares of the CES function aggregating financing flows from euro area countries to domestic loan officers are calibrated to match the structure of cross-border loans as a share of total financing (endogenous in the model). In the symmetric case, it is assumed that there is no cross-border lending and therefore no direct financial spillovers arising from the banking sector. In the asymmetric case, we would like to focus on exposures among euro area countries, therefore ignore cross-border flows between the euro area and the rest of the world. The BIS data suggest that Germany, Italy and rest-of-euro area are the most exposed countries with loans granded by foreign banks accounting to around 35% of total private credit. The largest bilateral exposure is observed between Italy and France as around 19% of Italian corporate loans are granted by French banks. Financial bilateral spillovers among other euro area countries are also significant but to a lesser extent. For example, around 20% of German NFC loans are granded by Italian and rest-of-euro area banks. In addition, around 17% of Italian NFC loans are granted by French banks. Lastly, around 11% of rest-of-euro area NFC loans are intermediated also by French banks.

Tables 13 and 14 attempts to show an accounting decomposition of lending rates in order to identify the major source of risks in the determination of lending rates. The former table corresponds to the symmetric case, while the latter in the non-symmetric case. As shown in Tables 10 and 14, cross border lending has an impact on the determination of the final commercial lending rate, allowing for risk shifting within euro area countries. For example, we observe that in jurisdictions with higher risk (e.g. sovereign and banking) like Italy and Spain, the more open is the banking sector the more it helps in alleviating some of the factors that has an upward push in commercial lending rates. The vice versa is almost true. In jurisdictions with less riskiness, the more open the banking sector, the more the increase in commercial lending rates. In the symmetric case where we do not allow for cross border lending, this factor is zero.

In the dynamic setup of the model the AR(1) processes of the exogenous shocks have an autocorrelation parameter equal to 0.9-0.95 and the errors are i.i.d with zero mean and standard deviation equal to 1.

6 Financial wedges

Focusing specifically on the credit intermediation process, sources of impairments in the monetary policy transmission mechanism can arise from four distinct segments of the model, related both to the demand and the supply of credit. These intermediation wedges constitute specific typologies of financial frictions and can independently represent the epicenter of specific financial disturbances. The financial wedge shocks display propagation features which have the potential for strongly counteracting the monetary impulse (see Appendix B for a detailed exposition of the corresponding impulse response functions).

An illustrative way to think about impairments in the transmission mechanism of monetary policy is to decompose the final lending rate into the chain of financing costs faced by the different agents and the associated financial shocks.

(i) The first financing segment relates to the bankers funding cost, $\Lambda_{\Psi,t} R_{BD,t}$, which corresponds to the monetary policy rate augmented for the sovereign risk compensation. This source of financial friction approximates in a reduced-form manner the spillovers from domestic sovereign tensions to bank funding conditions. A shock on the loss given default of the government, $\xi^{max}_{G,t}$, increases the haircuts on sovereign bonds, implying higher sovereign yield and diffuses through the intermediation chain via higher funding cost of the bank. This amplification mechanism which arises due to the presence of sovereign default, becomes more relevant as the level of debt-to-GDP reaches the fiscal limit, operationalised in our framework as in Corsetti et al. (2013) and Bi and Leeper (2010).

(ii) Secondly, the bankers decision problem features financial frictions associated with bank-specific vulnerabilities in the form of weak capital positions and funding constraints. Several shocks could be introduced to illustrate this source of impairment, and are primarily affecting the intermediation chain through the bankers financing rate $R_{BLE,t}$, everything else being equal. In particular, bank capital shock can be rationalised as a temporary decline in the bankers survival probability $\zeta_{b,t}$.

(iii) The third segment of the financial intermediation focuses on the monopolistic margins in lending rate setting by retail branches. Operating under some degree of market power, monopolistically competitive retail branches set staggered nominal lending rates, which are subject to exogenous markup shocks. Similarly retail lending branches receive funding from bankers and allocate them to loan portfolio officers. The monopolistic wedge introduced by lending branches in their required loan returns for loan officers, $R_{LE,t}$, may act as a specific financial disturbance. the corresponding shock would affect the lending rate markup $\mu^R_{E,t}$.

(iv) The fourth segment relates to the last stage of the financial intermediation implying credit risk compensation in the provision of loans to entrepreneurs. The possibility of firms to default on their loans creates a motive for loan officers to charge higher lending rates to cover for expected losses. This type of real-financial interaction is commonly formalised in macroeconomic models through the financial accelerator mechanism. Intuitively, a negative shock hitting a firm's net worth constrains the firm's ability to borrow due to its adverse impact on creditworthiness and a higher external finance premium. The resulting adverse impact on investment leads, in turn, to a further deterioration in the firm's net worth and thus to a more severe impact on economic activity. While default rates vary endogenously in the model as a result of fluctuations in asset prices, the time-varying nature of the idiosyncratic riskiness of borrowers may constitute a specific source of shocks. At the same time, this triggers time variation in the credit risk premium and hence in commercial lending rates applied to entrepreneurs, $R_{LLE,t}$. To target this particular financial wedge, a temporary increase in the volatility of the idiosyncratic shock on entrepreneurs return on capital, $\sigma_{e,t}$, could be considered.

These four segments can be seen as the basic ingredients of the crisis. As such they will be appropriately calibrated and combined to propose an original interpretation of the recent period through the lenses of the model. Indeed, the role of the various wedges in the financial fragmentation of the euro area is relatively undisputed but their relative quantitative contributions remain an empirical question, to which we intend to shed some light through the following scenarios.

7 Synopsis of the financial crisis

The narrative of the euro area financial crisis that our model aims at disentangling, lies in the interplay of credit risk in the sovereign, banking and corporate sectors. The phases of the euro area crisis that we concentrate on, abstract from the first recession in 2008-2009 when the global demand and uncertainty constituted common contractionary factors for all euro area countries. Conversely, the subsequent years, from 2011 to 2013, witnessed successive episodes of financial stress whose emblematic symptoms could be portrayed by bank lending rate dispersion. The size of the model leaves any direct estimation strategy computationally challenging. Therefore, we do not intend in this paper to reach formal statistical inference on the most likely sources of financial fragmentation over this period. Instead, we develop three scenarios which illustrate the structural underpinnings of three salient features of the crisis: ***(i)* the macroeconomic spillovers of sovereign market tensions through risky banks, *(ii)* the adverse real-financial feedback loop from rising corporate default to weak banks and credit supply constraints, *(iii)* bank deleveraging process at times of unprecedented regulatory overhaul.** Those three dimensions are certainly not mutually exclusive but give some meaningful synopsis of the various phases of the euro area financial crisis.

To construct our counterfactual experiments we proceed in two steps. First, we derive suitable country-specific instruments to proxy the source of financial fragmentation under scrutiny (from sovereign tensions to corporate rate risk and bank deleveraging needs). Second, we consider amplification or dampening forces that could operate across the euro area economies. The benchmark model used in the scenarios allows for asymmetric calibration in sovereign risk (as in section C.1), monopolistic lending rate setting (as in section C.3), corporate risk (as in section C.4) and cross-border lending (as in section C.5). The symmetric calibration of section B is also used to help disentangling the role of asymmetric shocks and non-financial block calibration in the cross-country features of the scenarios.

We will also assume that monetary policy is temporarily constrained in responding to the financial disturbance. In doing so, we want to reflect the conditions in which the central bank rapidly exhausted its room of maneuver regarding its standard monetary policy instrument. Treating the lower bound on interest rate more explicitly is beyond the scope of the present paper. Similarly, we would not consider the role of non-standard monetary policy actions in mitigating the adverse consequences of the various scenarios. This evaluation is also left for further research. Nonetheless, the macroeconomic multipliers of financial factors that we illustrate thereafter are plausible assessment lines that central banks may consider *ex ante* when deciding and calibrating non-standard measures.

As explained in subsection 5.2, we could consider either symmetric or asymmetric calibration of the financial block. In order to better assess the role played by the cross-country heterogeneity in our model, we start first by evaluating each scenarios in the symmetric case. This symmetry concerns both the steady-state features as well as the strength of the financial frictions which are intimately related in our micro-foundations and calibration strategy. To some extent, it could also be seen as a pre-crisis calibration, when the financial spreads across the monetary union appeared relatively close to each other. The specific financial frictions and structural inefficiencies within each financial jurisdiction could be reflected in the calibration strategy. This is all the more important as it comes to evaluating bank lending fragmentation in the euro area crisis. Indeed the deep parameters of the financial block have implications both for the steady-state features and the dynamic properties of the model.

7.1 Euro area financial fragmentation and the sovereign debt crisis

The first scenario takes as its main driving force, the emergence of tensions in sovereign markets from 2010 to 2012. The surge in sovereign spreads for Italy and Spain due to re-appraisal of solvency risk as well as global uncertainty around the future of the euro area can be seen as the main originating factor for our experiment. Another dimension to consider is the financial contagion from domestic sovereign tensions to foreign banks. In particular, market-based funding costs increased significantly in countries less affected by the sovereign stress, like France or Belgium. Therefore, we will set exogenous shocks on government bond yield risk premium in Spain, Italy and the rest-of-euro area, and supplement this with a funding shock on bankers in France. Germany and the rest-of-the-world are not hit by any specific disturbance. For the sake of isolating the credit channels of the euro area sovereign debt tensions, we nonetheless ignore two important aspects of the economic narrative: first, we do not account for a global uncertainty shock and its fallouts on global growth, which undoubtedly accompanied the euro area crisis. Second, the fiscal rules in the stressed countries are left unchanged even if the deteriorating fiscal positions would otherwise call for additional fiscal consolidation as governments unconvincingly attempt to address markets' concern about the sustainability of the public finances.

The magnitude of the sovereign shocks, $\xi_{G,t}^{max}$, is guided such that the increases in sovereign bond yields simulated with the symmetric calibration, are qualitatively similar to the observed developments during the 2010-2012 period. In reality, the rise in sovereign spreads is driven by series of risk factors, like "risk-free" term premium, fundamental solvency risk, liquidity premium, global uncertainty and what has been labelled "redenomination risk" (see De Santis (2015)). Such premia can be considered exogenous in our model and proxied by $\xi_{G,t}^{max}$ shocks, with the exception of fundamental solvency risk. Consequently, the counterfactual experiment could have been calibrated *ex ante* on the basis of the changes in sovereign spreads that cannot be attributed to fundamental solvency risk. The regression analysis of De Santis (2015) may provide a basis to do so and would imply smaller shocks. At the same time, since we do not directly account in the scenario for the observed increase in public indebtedness and solvency risk, this strategy would understate the contribution of the sovereign-bank feedback loop over the period.

Figure 8 first shows the outcome of higher government spreads for three years in Italy, Spain and rest of euro area, based on the symmetric calibration of the model. The sovereign yield shocks propagate through the intermediation chain of the vulnerable countries, ultimately driving up commercial lending rates by approximately 150 bps in Spain, 125 bps in Italy and 100 bps in the rest-of-euro area. The tightening of credit supply conditions is particularly adverse in Italy and Spain, with around 10% decline in investment, around 2% output loss and 6% credit contraction. For Germany and France, the financial conditions remain broadly unchanged (also given that in the symmetric calibration cross-border lending is absent) and the adverse effects on economic activity come from trade and exchange rate channels. Overall, the disinflationary pressures peak at -0.2 p.p. for all euro area countries. The homogenous responses on the nominal side contrasts with the asymmetric impact on economic activity: as noticed in the analysis of financial wedge shocks transmission, this can be explained by the "cost channel" of financial tensions which raises up the output sacrifice ratio of disinflation in the countries most affected by sovereign tensions.

Figure 9 repeats the same scenario, adding contagion to French banks and using the benchmark asymmetric calibration. The *ex ante* funding shock on bankers in France is calibrated at 40% of the sovereign shock in Italy, in line with the high frequency dynamic correlation measured over the crisis period 2010-2012. The benchmark calibration implies stronger transmission of the sovereign shocks on the cost-of-financing chain in Italy and Spain and now, commercial lending rates in France also move up by almost 100 bps. Through cross-border lending, financing conditions in Germany tighten, albeit marginally. Turning to the real-side, investment falls significantly more than in the symmetric calibration and the output loss reaches around 3% in Italy and Spain and 1.5% in France while Germany is not significantly affected.

7.2 Real-financial amplification through weak bank balance sheets

Protracted periods of weak economic conditions and continued uncertainty regarding the duration of the sovereign debt crisis have weighed on the profitability and the financial buffers of non-financial corporations. Successive recessionary episodes left the corporate sectors in part of the euro area with fragile balance sheet conditions, impaired debt-servicing capacity and higher probability of default. As a result, banks would tend to charge higher lending rates and tighten credit conditions for borrowers. The pro-cyclical behaviour of financial intermediaries may also be aggravated by weak bank capital position, excessive risk concentration or mounting legacy assets. In these conditions, lenders can be expected to recoup more than the expected losses due to rising default rates, building up capital buffers, de-risking their asset composition and even outright deleveraging.

Our second scenario imports such a rationale and portrays real-financial feedback loops by considering the propagation of corporate credit risk shocks through risk-averse bankers which respond to increasing expected losses on their loan portfolio by hoarding more capital. This mechanism is introduced in the model through risk-sensitive capital requirements: bankers extrapolate the unexpected increase in corporate default probability into higher regulatory risk weights for corporate exposures. This assumption shares some similarities with the model of bank credit supply exposed in Adrian et al. (2012) and Adrian and Shin (2014), where intermediaries adjust their leverage through the cycle and crisis time, in order to stabilise their value-at-risk (VaR). In our model, we account for this pattern through the risk-weights formulae of the Basel Committee for Banking Supervision, which actually proxy a VaR constraint from the credit risk model of Vasicek (2002). As shown in the description of bankers decision problem of section 4.2.3, risk weights are a non-linear functions of regulatory probability of default, the later being some "through the cycle" average of borrowers default risk (see equations (14) to (16)): $rw_{e,t} = g\left(PD_t^E\right)$ with $PD_t^E = \mathbb{E}_t\left\{h\left(..., F_e\left(\overline{\omega}_{e,t+i}\right), ...\right)\right\}$. The tightness of the additional "VaR constraint" will therefore depend on the link between PD_t^E and the shorter term actual default probabilites of entrepreneurs $F_e\left(\overline{\omega}_{e,t+i}\right)$. To illustrate the mechanism, we postulate the following relation

$$PD_t^E = \alpha_{PD}\left\{F_e\left(\overline{\omega}_{e,t}\right)\right\}^{annual} + \left(1-\alpha_{PD}\right)\mathbb{E}_t PD_{t+1}^E \qquad (57)$$

setting α_{PD} equal to 0.05. Accordingly, the regulatory probability of default will respond to the corporate risk shocks of the scenario, reflecting the medium-term average of expected default probabilities of entrepreneurs.

The exogenous disturbances for this scenario are the standard deviations of idiosyncratic shocks,

$\sigma_{e,t}$, affecting entrepreneurs return on capital. The scenario is calibrated so that the simulated credit risk compensation in lending rate setting under the symmetric calibration, reaches the level of expected losses and capital charges observed from the mechanical lending rate decomposition of Figure 2 for Spain, Italy and France. Over a two-year horizon, commercial lending rates gradually increase to 150 bps in Spain, 100 bps in Italy and 50 bps in France, following a sequence of unexpected corporate risk shocks.

Figure 10 reports on the scenario outcome under the symmetric calibration, assuming that risk-weights are not responding to the temporary rise in corporate default risk. We focus the description of the scenario on peak effects. The repeated upside surprises on corporate default probabilities trigger loan losses for bankers due to pre-determined lending rates in loan contracts offered to entrepreneurs. In turn, bankers decrease their financing rate, by around 30-40 bps depending on the country. The tightening in cost of financing conditions leads to investment cutbacks of approximately 13% in Spain, 8% in Italy and 3% France. The corresponding output losses amount to 2% in Spain, 1% in Italy and 0.6% in France while the associated credit contractions are roughly four times bigger. The trade spillovers to Germany and the rest-of-euro area bring economic activity are quite limited. Overall, annual inflation falls by 0.2 p.p. below baseline across euro area countries. Similarly to the previous sovereign tension scenario, the disinflation pressures are quite homogenous across countries despite the asymmetric corporate risk shocks: this is partly explained by the "cost channel" of financial frictions in stressed countries which the lack of monetary policy accommodation reinforces the disinflationary dynamics in the other countries.

Figure 11 reproduces the scenario of Figure 10 using the benchmark asymmetric calibration. Riskier sovereign and corporate sectors in Italy and Spain, and to a lesser extent in France, significantly amplify the real-financial propagation of corporate risk shocks. Commercial lending rates now rise up to 150 bps in Spain and 125 bps in Italy. The transmission of corporate vulnerabilities to sovereign risk is particularly pronounced in Italy and to a lesser extent Spain, leading to stronger and pervasive fragmentation in bankers funding rate through the sovereign-bank nexus. For Italy the decline in capital expenditures and economic activity is then twice stronger than in the symmetric case (with 2% instead of 1% output losses).

In Figure 12, the same scenario is conducted but now banks in Italy and Spain adjust their risk weights along with the rise in entrepreneurs default probabilities. This creates an additional accelerator mechanism, this time on the supply side of credit markets. Commercial lending rates now rise up to almost 250 bps in Spain and 200 bps in Italy. The more stringent regulatory requirements in Spain and Italy constrain bankers in those jurisdictions to reduce their leverage and increase their loan-deposit margins, which is noticeable in the stronger adjustment of bankers refinancing rates, as compared to the constant risk-weight simulations. Overall, the decline in investment is more pronounced in Spain and in Italy. We set for these simulations quite low response of regulatory default probability to actual ones, and it did generate significant amplification. Higher and more protracted pick-up in risk-weights would trigger dramatic deleveraging patterns and credit supply constraints.

7.3 Bank deleveraging process and regulatory pressures

The third scenario explores the potential for bank deleveraging needs, on the back of unprecedented regulatory reform, to explain the pervasively high bank lending rates and the lacklustre credit dynamics in some countries, beyond the forces analysed in the previous two experiments. In principle, the new regulatory requirements for banks initiated since 2010 would constitute a common shock across euro area countries. Its phase-in arrangements would ensure that the transitory costs are contained and its credible implementation would allow the long-term benefits to even materialise earlier. Our model has potentially a lot to say about both macroeconomic costs and benefits of regulatory changes: higher capital requirements lead to a temporary tightening of loan supply conditions which is gradually compensated by lower bank default probability, the mitigation of risk-shifting behaviour and lower fiscal cost of deposit insurance. A fully-fledged analysis along those lines is not the focus of the present paper and as such, would have limited relevance for the assessment of euro area financial fragmentation. Indeed, euro area banks have met the new regulatory requirements much ahead of the envisaged timeline, against the backdrop of adverse financial market conditions. Such a frontloading of bank balance sheet adjustment is the main subject of this section.

Transitory costs and long-term benefits of higher regulatory requirements: some illustrative simulations

Beforehand, we nonetheless expose the trade-offs between transitory costs versus potential long-term benefits of regulatory changes within our modelling framework. Certainly, the long-term macroeconomic benefits of tighter regulatory requirements are stronger when banks are risky and weakly capitalised and when phase-in arrangements cover an extended period of time. In order to illustrate this, as in Clerc et al. (2015), we first postulate the following relation on the funding cost of bankers

$$\widetilde{R}_{BD,t} = \Psi_{1,t}\Psi_{2,t}R_{BD,t} \tag{58}$$

with

$$\Psi_{1,t} = \Lambda_{\Psi_1,t}\left(RP_{G,t} - 1\right) + 1 \tag{59}$$

being the funding cost spread related to sovereign risk, as described in section 4.2.3, while $\Psi_{2,t}$ captures the cost depositors incur in case of bank default. The later is defined as

$$\Psi_{2,t} = \frac{1}{1 - \Lambda_{\Psi_2,t}\Gamma_b\left(\overline{\omega}_{b,t+1}\right)} \tag{60}$$

with $\Lambda_{\Psi_2,t}$ being the semi-elasticity to bank default probability. This cost should not be thought as being related to any loss on deposits since the presence of the deposit insurance agency guarantees that its financing needs are fully recouped out of government spending. It should rather be thought as a transaction cost associated with bank restructuring in the case of default.

On the one hand, this assumption provides a channel for higher capital requirements, and thereby lower probability of bank default, to ease in the long-run the financing conditions of bankers. An additional steady-state macroeconomic benefits stems from the lower fiscal cost of deposit insurance, $\Omega_{b,t}$ from equation (37), which is assumed to be recouped out of public spending. On the other hand, higher capital requirements have a detrimental effect on steady-state lending conditions through the bank capital channel and the regulatory penalty.

In order to evaluate these trade-offs both in the steady state and through the transitional dynamics, the model is calibrated symmetrically across countries with high bank risk, and significant risk-shifting distortions within the banking system. Similarly to the calibration strategy explained in section 5.2, bankers in each country have now an annual probability of default of 2%, a capital buffer of 3 p.p. and a financing rate spread of 0.6% (in annual terms). We also vary the depositor cost of bank default $\Lambda_{\Psi_2,t}$, from 0.1 to 0.2.

The first exercise focuses on *steady-state comparative statics*. We illustrate the sensitivity of the steady-state allocation to higher capital requirements, for different assumptions on the depositor cost of bank capital or the fiscal cost of deposit insurance. Figure 13 shows the steady-state level of euro area GDP and lending rate spreads for various levels of ν_b, starting from 8% to 15%. Results are expressed in deviation from the initial steady state (with ν_b at 8%). The blue and green lines correspond to the simulations with $\Lambda_{\Psi_2,t} = 0.1$ and $\Lambda_{\Psi_2,t} = 0.2$ respectively, assuming that the fiscal cost of deposit insurance is constant. The red line keeps $\Lambda_{\Psi_2,t} = 0.2$ and let the fiscal cost of deposit insurance decline with lower bank probability of default. As anticipated, output and intermediation spread tend to display hump-shaped patterns, which are all the more pronounced as the depositor and fiscal costs channels of bank default are active. Capital requirements is costly for banks and as the increase in capital requirements becomes larger, this effect dominates. For milder regulatory tightening however, the benefits from safer banks outweigh the costs, by deterring incentives for risk-shifting, and lowering the costs for depositors and governments. Quantitatively, with high depositor cost of bank default and endogenous fiscal cost of deposit insurance, the steady-state output improves and lending rate spread compresses till capital requirements reach around 10-11% (see red lines in Figure 13). Keeping the fiscal cost of deposit insurance constant limits the output gains but leaves the narrowing of spreads unchanged. Dampening the depositor cost channel dramatically mutes the scope for net benefits, with output declining below and spreads ending up above the initial steady state for capital requirements higher then 10% (see blue line in Figure 13).

We turn now to *the transitional dynamics*. We consider a scenario of 25% more stringent capital requirements (i.e. from 8% to 10%) phased-in over 5 years. In addition, the regulatory reform is announced 5 years before it gradually enters into play and we assume that it is fully anticipated by economic agents. The scenario is then run for two calibrations of the model. The first one corresponds to the high bank risk calibration as in Figure 13, with high depositor cost of bank default and endogenous fiscal cost. In this case, the 2 p.p. increase in capital ratio almost maximises the long-term output benefits. The second one is the symmetric calibration of section 5.2 which ignores the economic benefits channels given the very low probability of bank defaults in the steady state. The two simulations will therefore give polar illustrations for the transition to meaningful long-term benefits in the former case, and to mild long-term cost in the later case. Figure 14 displays the euro area output and lending rate spread responses for both calibrations, in percentage deviations from the initial steady state. With the high bank risk calibration (red line), the macroeconomic allocation is broadly unchanged over the anticipation period. When the capital requirements start increasing, the lending rate spread tightens somewhat for two years before gradually decreasing towards its long-term level at 0.25% below the initial steady state. This generates a mild temporary contraction in output, peaking at less than 0.2 p.p., 3 years after the new requirements are phased-in. Thereafter, the macroeconomic benefits gradually materialise amounting to 0.9 p.p. of output in the long run. By contrast, with the symmetric calibration (blue line), the output transitional costs appear sooner, also through the announcement period as banks and firms start deleveraging in anticipation of future tightening of capital requirements. Output then reaches its new steady-state level already after 10 years. Lending rate spreads temporarily overshoot their long-term increase in the first 3 years of the implementation period, peaking at 0.35%, and narrow somewhat afterwards to end at around 0.25% above the initial steady state after 15 years.

Overall, this section has shown that, within the confines of our theoretical framework, higher regulatory requirements can lead to sizeable long-term net benefits and mild transitional costs when *i*) banks engaged in excessive risk-taking and are weakly capitalised, and *ii*) the new requirements are credibly announced and gradually phased-in. It is also worth noticing that the macroeconomic costs measured under the symmetric calibration, both for the short-to-medium term and in the long-run, are quite close to the main DSGE-based evaluation of the FSB-BCBS Macroeconomic Assessment Group and the long-term economic impact studies from the BCBS (see BIS (2010b) and BIS (2010a)). However the preceding simulations showed that our model can go beyond the costs and quantify the sources of macroeconomic benefits related to the lower riskiness of banking system. More quantitative analysis in this respect is left for future research.

Bank deleveraging and frontloading of regulatory adjustments

Conditions prevailing through the euro area financial crisis were certainly not conducive to the relatively benign evaluation of the regulatory reform illustrated previously. Instead, some euro area jurisdictions faced strong deleveraging pressures against adverse financial market developments. In this context, banks frontloaded the needed adjustments as an attempt to bring back market confidence. To some extent, the financial turbulences made the regulatory changes pro-cyclical, adding deleveraging pressures at times of weak economic fundamentals, tight lending conditions, disruptions in funding markets and low bank profitability.

The previous two scenarios, on sovereign tensions and corporate losses, precisely put banks in Italy and Spain, and to a lesser extent France, in a challenging position to strengthen their capital base, due to funding strains and loan losses. To recall, with the benchmark model calibration, the combination of both scenarios would imply a peak bank capital shortfall for these countries between 0.4 p.p. and 0.8 p.p. of total assets over the first 5 years of the simulations. At the same time, the peak decline in loans over the same horizon reaches 7% in Italy and Spain, and 4% in France, while GDP falls below baseline by 5% and 3.5% respectively.

Against the backdrop of unfolding sovereign and corporate risk scenarios, the frontloadling of capital requirements would be consistent, notably for banking jurisdictions already struggling to consolidate their balance sheets against such adverse headwinds. The evidence presented in section 2 on stylised facts also suggest that while most of euro area banks met the new requirements much ahead of the envisaged final implementation, the shedding of assets and the more adverse spillovers to the macroeconomy, would have been most acute in Italy and Spain.

This notwithstanding, we start by simulating for all euro area countries a symmetric higher capital requirements, by 4 percent in a period of 3 to 4 years. Figures 15 reports the outcome of the scenario, under the benchmark calibration of the model. As in the symmetric calibration used before, we ignore here the economic benefits channels from depositor cost of bank default and endogenous fiscal cost of the deposit insurance scheme, also given the very low probability of bank defaults in the steady state. Higher capital requirements will lead to an immediate increase in bank risk of exhausting its capital buffer. Bankers are therefore pushing up their financing rate in order to boost net interest income and retained earnings. Cross-country heterogeneity already appears at this stage with higher rate in Italy, mainly due to the stronger sensitivity of sovereign spreads, and thereby bankers funding cost, to deteriorating fiscal position. Subsequently, the higher capital requirements impact entrepreneurs as commercial lending rates increase with even more cross-country dispersion. Asymmetric nominal rigidities in lending rate setting together with different degree of corporate riskiness drive the stronger increase observed for Italy and Spain, compared with France and Germany: commercial lending rates peak at 50 bps in Italy, 40 bps in Spain and around 35 bps in France, Germany and rest-of-euro area. before returning to a new higher equilibrium. The overall capital ratio of banks gradually increase, by almost three percentage points after 5 years. Given the 4 p.p. higher capital requirements, it implies a compression of the long-run capital buffer: by consolidating their capital base and raising their net interest rate margin (even in the steady state as shown in Figure 14, blue line), bankers can cushion part of the tighter requirements through lower excess capital.

Turning to broader economic conditions, investment expenditures are significantly cut back, declining by 7% at the peak for Italy, around 6% for Germany, 5% for Spain and France, and a bit less for rest-of-the euro area. This cross-country heterogeneity extends to output responses, with peak effects ranging from around 1.2% in Germany and Italy to less than 1% in France and rest-of-the euro area.

As discussed before, such a frontloading of capital requirements which affects adversely euro area countries in a symmetric manner may not be fully plausible, as some jurisdictions had much easier access to capital markets and might have coped with the new regulatory framework in ways that shielded their core retail exposures. In order get a sense of an asymmetric distribution of bank deleveraging needs across the monetary union, we reproduced the previous scenario only considering the frontloading of capital requirements in Spain and Italy. The corresponding simulations are displayed in Figure 16. Now, the deterioration of economic situation in Spain and Italy is slightly stronger, with output declining by more than 1.5% and investment by almost 10%. The degradation is explained by a less favourable evolution of real interest rates compared to previous case (higher nominal interest rates − only part of the EA is affected − are not fully compensated by higher inflation). All in all, the interest rate channel dominate here clearly the trade channel which brings positive gains from the countries which did not adjust. This also contributes to more pronounced increase in commercial lending rates in Italy notably. All in all, for the non-affected euro area countries, output is hardly responding.

7.4 Holistic perspective on the financial scenarios in the presence of the lower bound on interest rate

One salient feature of the crisis, which has not been explicitly discussed yet, is the lower bound on interest rate (ZLB) faced by the monetary authority. The severity of the financial crisis has exhausted the room of manoeuvre of standard monetary policy easing. Actually, the ZLB constraint has prevented the central bank from being as accommodative as necessary, according to available estimates of the Taylor rule for the euro area. Certainly, non-standard monetary policy actions have complemented the cuts in policy rates and in some cases, have been directly targeted to address financial fragmentation and impairments in the transmission channel of monetary policy. Modelling non-standard measures and assessing their effectiveness is beyond the scope of the present paper. Instead, we focus here on the propagation of financial tensions in the presence of the lower bound of interest rate.

For the sake of illustration, we consider the macroeconomic impact of the combined three crisis scenarios and evaluate the amplification that the ZLB may generate in this context. The literature has long emphasized the large impact on macroeconomic multipliers that restriction on monetary policy rates could have (see for example Gomes et al. (2015)). Therefore, we complement our scenario analysis by adding a ZLB constraint to the model (where $\underline{R}$ is the lower bound). This is implemented in the following way

$$
\begin{aligned}
R_{BD,t} &= max\left(\underline{R}, R^{*}_{BD,t}\right) && (61)\\
R^{*}_{BD,t} &= \phi_R\left(R^{*}_{BD,t-1}\right) + (1-\phi_R)\left[\left(\overline{R}\right) + \phi_\Pi\left(\Pi_{C,t} - \overline{\Pi}\right)\right] + \phi_Y\left(\Delta Y_t - 1\right). && (62)
\end{aligned}
$$

This specification enables the length of time for which the ZLB is binding to become endogenously determined.

Considering the shocks of the scenarios exposed in the previous sections, two sets of simulations are conducted, with and without ZLB. Let us consider first the cumulative impact of the financial crisis without the ZLB, as shown in Figure 17. The overall scenario clearly implies much more severe consequences for Italy and Spain where GDP declines by around -6% while for other euro area countries output losses range between -1% in Germany and -3% in France. The same hierarchy across countries applies to investment which drops in cumulated terms by -35% in Italy and -30% in Spain. On the nominal side, inflation moderates by -0.7/-0.8 p.p. The rise in government debt to GDP ratio is particularly pronounced in Italy (6 p.p.) and to a lower extent in Spain (2 p.p.). As a consequence, sovereign risk premia increase in these countries and spillover to banks funding costs. Overall commercial lending rates surge in the most affected countries with a peak of 300 bps in Italy and Spain and around 100 bps for France. Altogether, the various financial scenarios lead to a significant loosening of the single monetary policy stance, despite the uneven cross-country distribution of the financial stress. In line with the Taylor rule, the policy rate is cut by around 150 bps over the first three years of the simulation.

Now, we assume that the short-term interest can not decline by more than 110 bps, which broadly corresponds to the fall in the EONIA observed from 2011 to 2015. Figure 19 presents the corresponding results and Figure 18 show them in deviation from the no-ZLB case. Once hit by the set of shocks needed to mimic the financial crisis, the model generates a ZLB period of around four years, starting 6 quarters after the beginning of the scenario. Restricting the monetary policy rate during the crisis hurts significantly the euro area as a whole and more specifically Italy with peak effects reached the fourth year of the simulation for all countries (when the gap between the notional interest rate and the lower bound is the largest, by around 30 bps). This translates into extra losses of output ranging from -1 p.p. in Italy to -0.7 p.p. in REA. Investment follows more or less the same pattern although in a more pronounced way with almost -4 p.p. for Italy and between -2 p.p. and -1 p.p. for the other countries. It is also during the fourth year that inflation decreases the more and the sovereign debt ratio increases the more: up to 2 p.p. for Italy. The more unsecured economic environment brought by the crisis and exacerbated by the ZLB ultimately incites banks to increase their lending rates: from 30 bps for France and Germany to 75 bps for Italy (and around 40 bps for Spain and REA).

8 Conclusion

The main objective and contribution of this paper is to design a multi-country dynamic stochastic general equilibrium (DSGE) model for the euro area which can provide structural interpretation of the salient features of the euro area bank lending fragmentation. It includes a reduced-form sovereign-banking nexus, risky banks acting in a monopolistic manner, financial frictions associated with corporate default and cross-border lending. This framework is well-suited to analyse the dispersion in bank lending rates observed across euro area countries. In doing so, propose three macro-financial scenarios to interpret the structural underpinnings of lending rate fragmentation and its macroeconomic spillovers.

In order to account for the range of financial disturbances and impairments which can stand in the way of monetary policy actions, we segment final lending rate spreads into a chain of four distinct "financial wedges" related both to the demand and the supply of credit. Taken in isolation, each wedge can be seen as a specific source of financial disturbances, related either to *i)* sovereign-banking nexus and funding access of banks, to *ii)* bank-specific vulnerabilities and capital constraints, to *iii)* monopolistic margins and staggered lending rate setting, or to *iv)* credit risk compensation in the provision of loans.

Besides, we allow for the euro area to be decomposed into five regions, namely the four largest countries which are Germany, France, Italy and Spain and the rest of the euro area. The sixth region captures the rest of the world, transforming the model to a global DSGE. The international financial and trade linkages are accounted for via detailed calibration of cross-border lending and trade in consumption and investment goods.

Finally, we evaluate specific financial frictions and structural inefficiencies within each financial jurisdiction. By considering both symmetric and asymmetric calibration of the financial block across euro area countries, we show the micro-structure of financial frictions have meaningful implications both for the steady-state features and the dynamic properties of the model.

Turning now to scenario analysis, we provide some stylised synopsis of the various phases of the euro area financial crisis from 2010 to 2013. The first experiment considers the transmission through credit channels of the sovereign market tensions which are calibrated to reproduce the surge in sovereign spreads, amplified by the observed contagion to bank funding conditions in jurisdictions less affected by the turbulence in sovereign segments. The second experiment focuses on the vicious circle that was activated through the crisis, from rising corporate default, lower bank asset quality and higher credit constraints. It is calibrated based on a cross-country increase in corporate risk to match available evidence on default frequency and non-performing loans within the euro area. The final experiment explores the potential for bank deleveraging process on the back of unprecedented regulatory reform.

The macroeconomic multipliers of those scenario are strong in countries under stress and spillovers within the euro area are sizeable. In itself, the sovereign stress scenario would go a long way in explaining lending rate dispersion and poor economic performance in parts of the euro area over the period. These conditions propagate more forcefully through the intermediation chain of jurisdictions where banks are under-capitalised and risk-averse. The second scenario adequately portrays another important source of financial fragmentation and shows to which extent such real-financial feedback loops could contribute to impair the monetary policy transmission channel in a lasting manner, as vulnerable corporations operate with risk-averse and weakly capitalised banks. The last experiment argues that the frontloading of new capital requirements triggered a bank deleveraging process which adversely constrained the provision of credit in some jurisdictions. This would partly explain the pervasively high bank lending rates in some jurisdictions, beyond the forces analysed in the previous two experiments.

Even if our experiments could potentially overlap, not least as their quantitative calibration is not based on structural estimations, they do reflect independent forces at play during the crisis. A face value reading of the simulations, taken all together, would imply dramatic effects on lending rate dispersion, potentially beyond what was observed in reality both for stressed and non-stressed countries. This should not be seen as questioning the plausibility of our experiments but instead, it implicitly points to mitigating factors which partially shielded some jurisdictions. A crucial one has been non-standard monetary policy measures. Dealing with the joint role of fragmentation drivers and monetary policy actions is promising avenue for future research.

Moreover, our model can go beyond the quantification of the costs of the euro area financial crisis and shed light on the macroeconomic benefits related to lower riskiness of banking system on the back of regulatory reforms, and the role for macro-prudential policies in a global general equilibrium set-up. This analysis will be considered in future research.

References

Adrian, T., P. Colla, and H. S. Shin (2012). Which Financial Frictions? Parsing the Evidence from the Financial Crisis of 2007-9. In D. Acemoglu, J. Parker, and M. Woodford (Eds.), *NBER Macroeconomics Annual*, Volume 27 of *NBER Macroeconomics Annual*, pp. 159 – 214.

Adrian, T. and H. S. Shin (2014). Procyclical Leverage and Value-at-Risk. *Review of Financial Studies 27*(2), 373–403.

Altavilla, C., D. Giannone, and M. Lenza (2014). The Financial and Macroeconomic Effects of OMT Announcements. Working Paper Series 1707, European Central Bank.

Bayoumi, T., D. Laxton, and P. Pesenti (2004). Benefits and Spillovers of Greater Competition in Europe: A Macroeconomic Assessment. International Finance Discussion Paper 803, Board of Governors of the Federal Reserve System.

Begenau, J. (2015). Capital Requirements, Risk Choice, and Liquidity Provision in a Business Cycle Model. Working paper 15-072, Harvard Business School.

Benes, J. and M. Kumhof (2011). Risky Bank Lending and Capital Adequacy Regulation. Working Paper 130, International Monetary Fund.

Benes, J., M. Kumhof, and D. Laxton (2014a). Financial Crises in DSGE Models: A Prototype Model. Working Paper 57, International Monetary Fund.

Benes, J., M. Kumhof, and D. Laxton (2014b). Financial Crises in DSGE Models: Selected Applications of MAPMOD. Working Paper 56, International Monetary Fund.

Bernanke, B., M. Gertler, and S. Gilchrist (1999). The Financial Accelerator in a Quantitative Business Cycle Framework. In J. B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Volume 1 of *New York: Cambridge University Press*, pp. 1341–1393.

Bi, H. and E. M. Leeper (2010). Sovereign Debt Risk Premia and Fiscal Policy in Sweden. Working Paper 15810, National Bureau of Economic Research.

BIS (2004, June). Basel II: International Convergence of Capital Measurement and Capital Standards - A Revised Framework. Standards, Bank for International Settlements.

BIS (2010a, August). An Assessment of the Long-Term Economic Impact of Stronger Capital and Liquidity Requirements. Technical report, Bank for International Settlements.

BIS (2010b, December). Assessing the Macroeconomic Impact of the Transition to Stronger Capital and Liquidity Requirements. Macroeconomic Assessment Group Report, Bank for International Settlements.

BIS (2013, March). Guidelines for Reporting the BIS International Banking Statistics. Monetary and Economic Department Publication, Bank for International Settlements.

Borgy, V., T. Laubach, J.-S. Mesonnier, and J.-P. Renne (2011). Fiscal Sustainability, Default Risk and Euro Area Sovereign Bond Spreads Markets. Document de Travail 350, Banque de France.

Calvo, G. (1983). Staggered Prices in a Utility Maximizing Framework. *Journal of Monetary Economics 12*, 383–398.

Carlstrom, C., T. S. Fuerst, and M. Paustian (2013a). Optimal Contracts, Aggregate Risk, and the Financial Accelerator. Working Paper 1420, Federal Reserve Bank of Cleveland.

Carlstrom, C., T. S. Fuerst, and M. Paustian (2013b). Privately Optimal Contracts and Suboptimal Outcomes in a Model of Agency Costs. Working Paper 1239, Federal Reserve Bank of Cleveland.

Christiano, L., R. Motto, and M. Rostagno (2010). Financial Factors in Economic Fluctuations. Working Paper 1192, European Central Bank.

Christoffel, K., G. Coenen, and A. Warne (2008). The New Area-Wide Model of the Euro Area: A Micro-Founded Open-Economy Model for Forecasting and Policy Analysis. Working Paper 944, European Central Bank.

Clerc, L., A. Derviz, C. Mendicino, S. Moyen, K. Nikolov, L. Stracca, J. Suarez, and A. P. Vardoulakis (2015). Capital Regulation in a Macroeconomic Model with Three Layers of Default. *International Journal of Central Banking 11*(3), 9–63.

Coenen, G., P. McAdam, and R. Straub (2008). Tax Reform and Labour-Market Performance in the Euro Area: A Simulation-Based Analysis Using the New Area-Wide Model. *Journal of Economic Dynamics and Control 32*, 2543–2583.

Corbo, V. and C. Osbat (2013). Trade Adjustment in the European Union - A Structural Estimation Approach. Working Paper 1535, European Central Bank.

Corsetti, G., K. Kuester, A. Meier, and G. J. Muller (2013). Sovereign Risk, Fiscal Policy, and Macroeconomic Stability. *Economic Journal, Royal Economic Society 123*(566), F99–F132.

Cruces, J. J. and C. Trebesch (2013). Sovereign Defaults: The Price of Haircuts. *American Economic Journal: Macroeconomics 5*(3), 85–117.

Darracq Pariès, M. and R. A. De Santis (2015). A Non-Standard Monetary Policy Shock: The ECB's 3-year LTROs and the Shift in Credit Supply. *Journal of International Money and Finance 54*, 1–34.

Darracq Pariès, M., C. Kok, and D. Rodriguez Palenzuela (2011). Macroeconomic Propagation under Different Regulatory Regimes: Evidence from an Estimated DSGE Model for the Euro Area. *International Journal of Central Banking 7*(4), 49–113.

Darracq Pariès, M., D. N. Moccero, E. Krylova, and C. Marchini (2014). The Retail Bank Interest Rate Pass-Through: The Case of the Euro Area during the Financial and Sovereign Debt Crisis. Occasional paper 155, European Central Bank.

De Santis, R. A. (2015). A Measure of Redenomination Risk. Working Paper 1785, European Central Bank.

EBA (2015, September). CRD IV-CRR/Basel III Monitoring Exercise Report. Basel III Monitoring Reports, European Banking Authority.

Everaert, L. and W. Schule (2008). Why it Pays to Sychronize Structural Reforms in the Euro Area Across Markets and Countries. Staff Papers 55, IMF.

Faruquee, H., D. Laxton, and D. Muir (2007). *Smooth Landing or Crash? Model-Based Scenarios of Global Current Account Rebalancing.* in R. Clarida (ed.) G7 Current Account Imbalances: Sustainability and Adjustment. Chicago, IL: University of Chicago Press.

Fujiwara, I. and Y. Teranishi (2010). Real Exchange Rate Dynamics Revisited: A Case with Financial Market Imperfections. Working Paper 62, Globalization and Monetary Policy Institute, Federal Reserve Bank of Dallas.

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

Gertler, M. and P. Karadi (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics 58*, 17–34.

Gertler, M. and P. Karadi (2013). QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool. *International Journal of Central Banking 9*(1), 5–53.

Gomes, S., P. Jacquinot, R. Mestre, and J. Sousa (2015). Global Policy at the Zero Lower Bound in a Large-Scale DSGE Model. *Journal of International Money and Finance, Elsevier 50(C)*, 134–153.

Gomes, S., P. Jacquinot, and M. Pisani (2012). The EAGLE. A Model for Policy Analysis of Macroeconomic Interdependence in the Euro Area. *Economic Modelling, Elsevier 29*(5), 1686–1714.

Guerrieri, L., M. Iacoviello, F. Covas, J. Driscoll, M. Kiley, M. Jahan-Parvar, A. Queralto, and J. Sim (2015). Macroeconomic Effects of Banking Sector Losses across Structural Models. Finance and Economics Discussion Series 2015-44, Federal Reserve Board.

Guerrieri, L., M. Iacoviello, and R. Minetti (2012). Banks, Sovereign Debt and the International Transmission of Business Cycles. NBER International Seminar on Macroeconomics 1, National Bureau of Economic Reseach.

Iacoviello, M. (2005). House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle. *American Economic Review 95*(3), 739–764.

Iacoviello, M. (2015). Financial Business Cycles. *Review of Economic Dynamics 18*(1), 140–163.

Illes, A., M. Lombardi, and P. Mizen (2015). Why did Bank Lending Rates Diverge from Policy Rates after the Financial Crisis. BIS Working Paper Series 486, Bank for International Settlements.

Imbs, J. and I. Méjean (2009). Elasticities Optimism. Discussion Paper 7177, Centre for Economic Policy Research.

Imbs, J. and I. Méjean (2010). Trade Elasticities. A Final Report for the European Commission. Economic Papers 432, European Commission.

Jakab, Z. and M. Kumhof (2014). Models of Banking: Loanable Funds or Loans that Create Funds. Unpublished, International Monetary Fund.

Kalemli-Ozcan, S., E. Papaioannou, and F. Perri (2012). Global Banks and Crisis Transmission. Working Paper 18209, National Bureau of Economic Research.

Kiley, M. T. and J. W. Sim (2014, June). Bank Capital and the Macroeconomy: Policy Considerations. *Journal of Economic Dynamics and Control 43*, 175–198.

Kollmann, R., Z. Enders, and G. Muller (2011). Global Banking and International Business Cycles. *European Economic Review 55*, 407–426.

Kollmann, R., M. Ratto, W. Roeger, J. in 't Veld, and L. Vogel (2014). What Drives the German Current Account? And how does it Affect Other EU Member States? Economic Papers 516, European Commission.

Kumhof, M., D. Laxton, D. Muir, and S. Mursula (2010). The Global Integrated Monetary and Fiscal Model (GIMF); Theoretical Structure. IMF Working Papers 34, International Monetary Fund.

Laubach, T. (2006). New Evidence on the Interest Rate Effects of Budget Deficits and Debt. *Journal of the European Economic Association 7*(4), 858–885.

Laxton, D. and P. Pesenti (2003). Monetary Policy Rules for Small, Open, Emerging Economies. *Journal of Monetary Economics 50*, 1109–1146.

Martins, J. O., S. Scarpetta, and D. Pilat (1996). Mark-Up Pricing, Market Structure and the Business Cycle. Economic Studies 27, OECD.

Mendoza, E. and V. Quadrini (2010). Financial Globalization, Financial Crisis and Contagion. *Journal of Monetary Economics 57*, 24–39.

OECD (2014). Revenue Statistics 2014. Tax database, OECD.

Pesenti, P. (2008). The Global Economy Model (GEM): Theoretical Framework. Staff Papers 55(2), IMF.

Quint, D. and P. Rabanal (2014). Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. *International Journal of Central Banking 10*(2), 169–236.

Ratto, M., W. Roeger, and J. in 't Veld (2009). QUEST III: An Estimated Open-Economy DSGE Model of the Euro Area with Fiscal and Monetary Policy. *Economic Modelling 26*, 222–233.

Schmitt-Grohe, S. and M. Uribe (2003). Closing Small Open Economy Models. *Journal of International Economics 54*(6), 1702–1725.

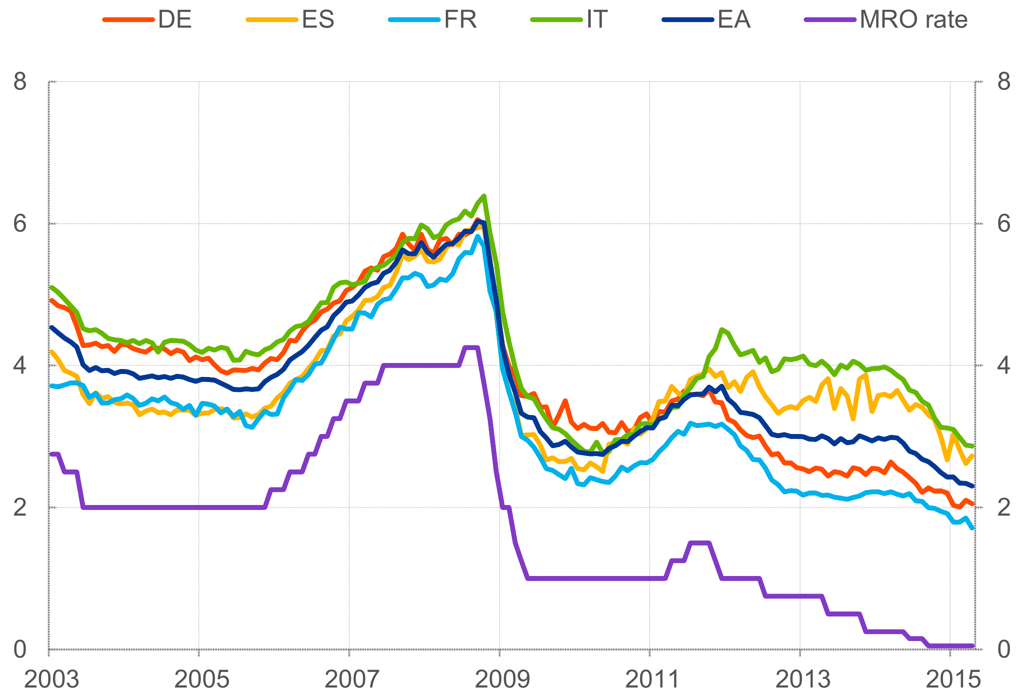
Smets, F. and R. Wouters (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association 1*(5), 1123–1175.

van der Kwaak, C. and S. van Wijnbergen (2014). Financial Fragility, Sovereign Default Risk and the Limits to Commercial Bank Bail-Outs. *Journal of Economic Dynamics and Control 43*(C), 218–240.

Vasicek, O. (2002, December). Loan Portfolio Value. *RISK*, 160–162.

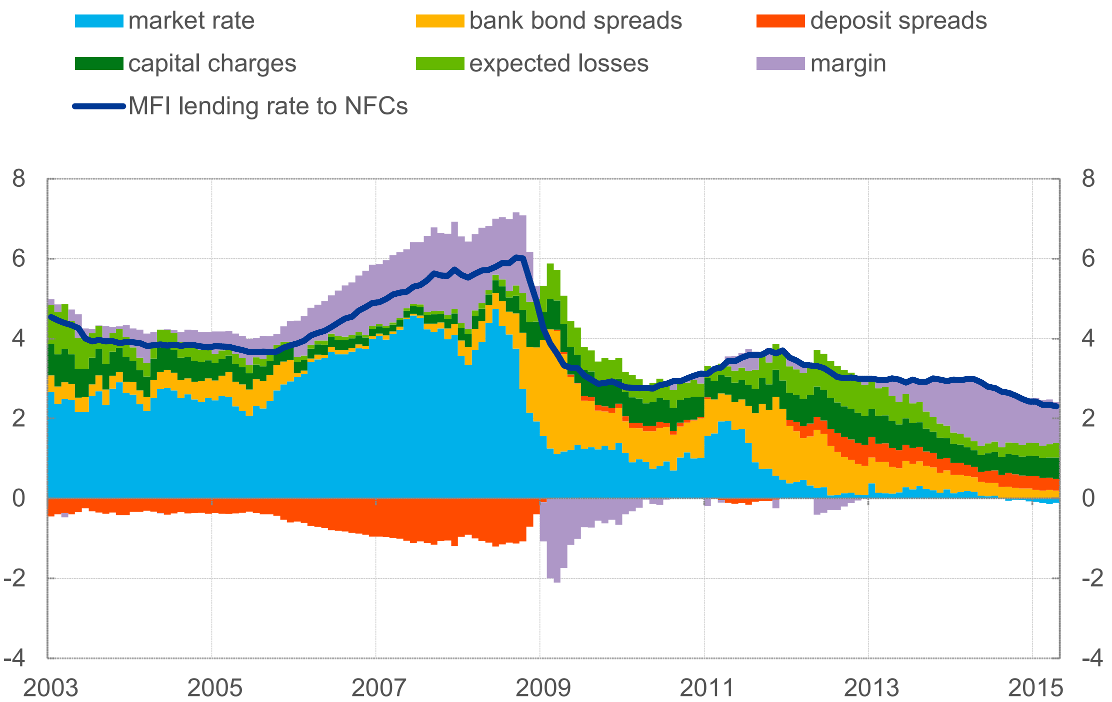
9 Stylised facts

Figure 1: Cost of borrowing indicators for non-financial corporations (percentages per annum)



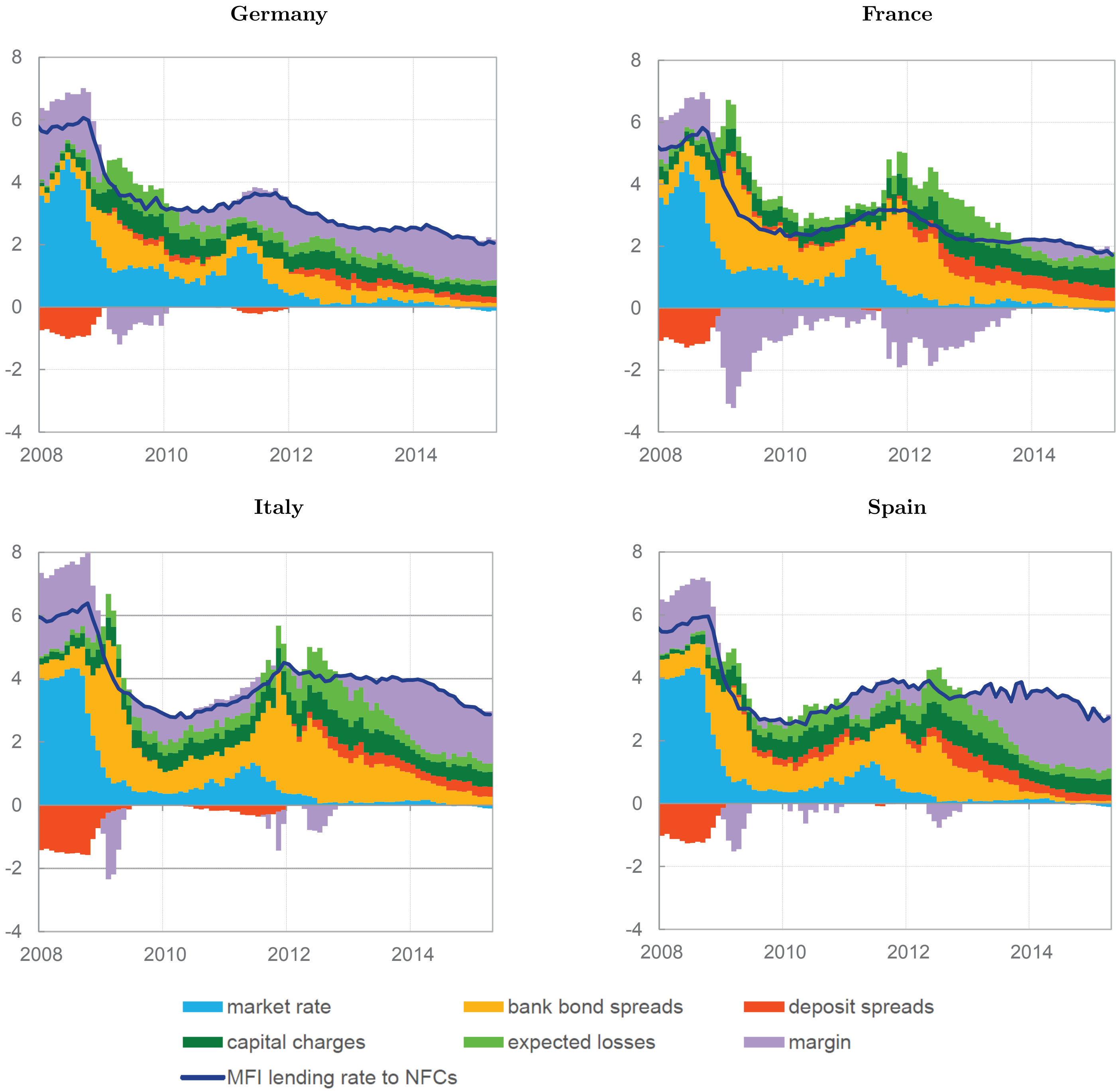
Source: ECB and ECB calculations.
Notes: The indicator for the cost of borrowing is calculated by aggregating short and long-term rates using a 24-month moving average of new business volumes.

Figure 2: Accounting decomposition of euro area composite cost of borrowing for NFCs (percentages per annum)



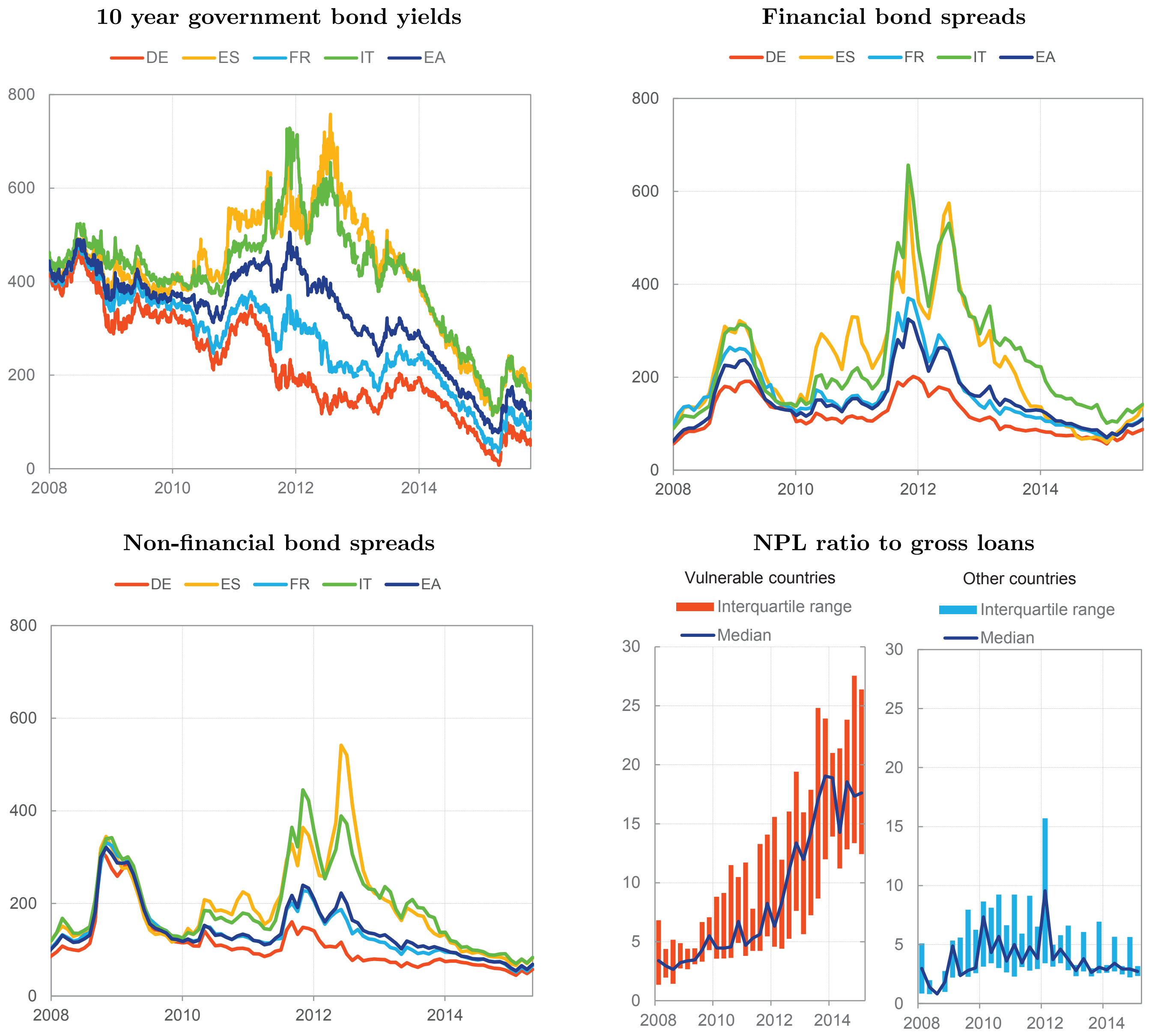
Sources: ECB, Moody's and Merrill Lynch Global Index.
Notes: **Market rate:** 3-month and 2-year OIS. **Deposit rate spreads:** deposit rates are computed as a weighted average between overnight deposits, deposits with agreed maturity and deposits redeemable at notice, with their corresponding new business volumes. Whenever new business volumes are not available, they have been derived by assuming that the differences in the mean and in the variability between net flows and the available new business series can be applied to derive estimates of new business series from available net flows. The spreads are then calculated vis-*à*-vis the EURIBOR rates of the closest maturity. The share of deposits: vis-*à*-vis total new business retail deposits and gross issuance of long-term debt securities by MFIs (EA = 92% in Dec13). **Bank bond spreads:** bank bond yields are taken from the Merrill Lynch Global Financial Index and aggregated on the basis of their corresponding outstanding amounts. The spreads are then calculated vis-*à*-vis the swap rate of the closest maturity. The share of long-term debt securities: vis-*à*-vis total new business retail deposits and gross issuance of long-term debt securities by MFIs (EA = 8% in Dec13), or long-term debt securities by MFIs and total Eurosystem borrowing netted by banks' claims on the Eurosystem (EA = 6% in Dec13). **Capital charges:** cost of the capital required by Basel II regulations. **Expected losses:** LGD*PD where PD (Probability of Default) is the EDF computed by Moody's, and LGD (Loss Given Default) is fixed at 0.45 100%. **Margin:** constructed as the residual between lending rates and all of the above components.

Figure 3: Accounting decomposition of composite cost of borrowing for NFCs (percentages per annum)



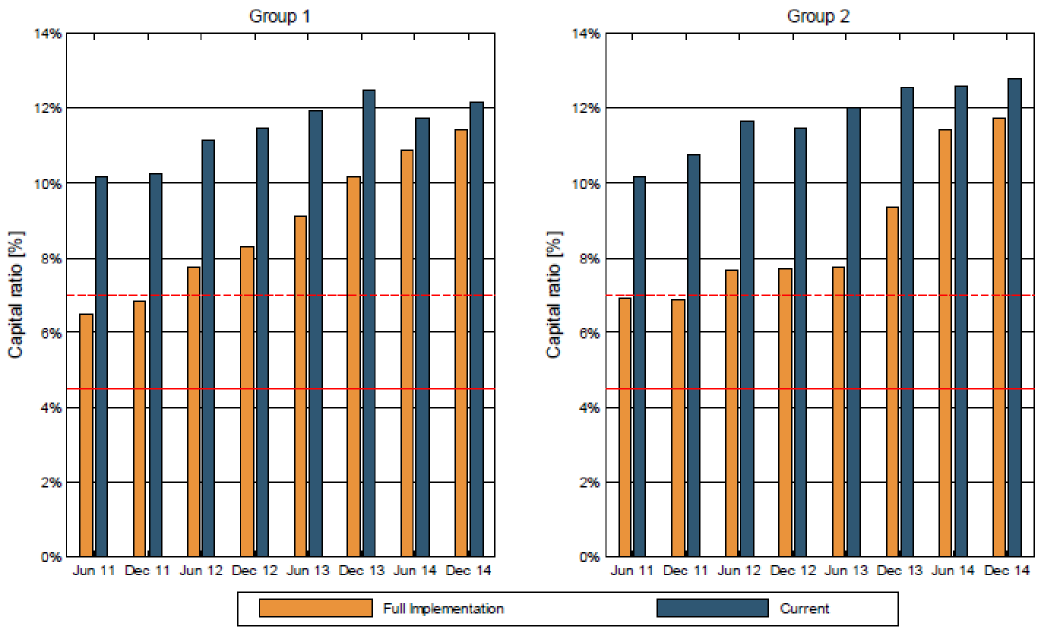
Notes: See footnote of Figure 2.

Figure 4: Evidence of financial stress since 2008



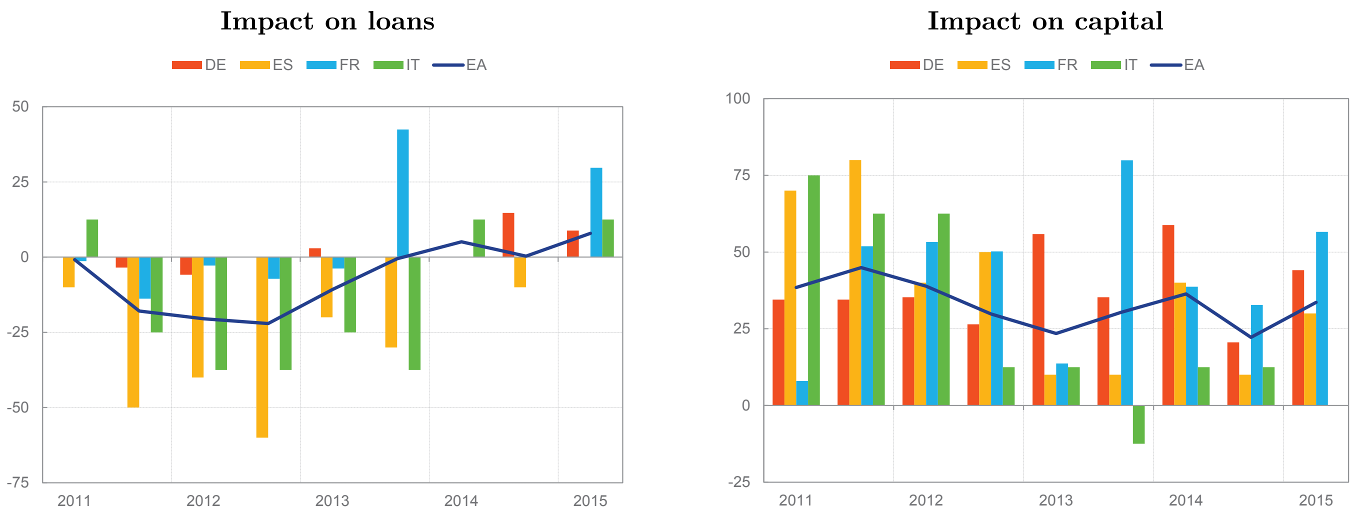
Sources: ECB, ECB calculations, Merrill Lynch and SNL Financial.
Notes: **Top-left panel**: 10-year Government Benchmark bond yield for euro area is GDP weighted. Latest observation: 23rd October 2015. **Top-right and bottom-left panels**: Maturity matched bond spreads. Indicators by country of risk excluding bonds which embed options such as asset-backed, callable, putable, floating rate, perpetual or sinking funds. **Bottom-right panel**: LHS - based on an unbalanced sample of up to 52 euro area banks which report at a quarterly frequency. RHS - based on a balanced sample of 12 euro area banks that have already reported the ratio of impaired loans to risk-weighted assets for 2015 Q1. Latest observation: 20145 Q1.

Figure 5: Evolution of CET1 ratios over time



Source: EBA (2015)
Notes: Group 1 banks are defined as banks with Tier 1 capital in excess of EUR 3 billion which are internationally active. All other banks are classified in Group 2. Comparison between capital ratios under the current level of implementation with the capital ratios that banks would exhibit where the set of rules in the CRD IV package fully implemented at the reference date.

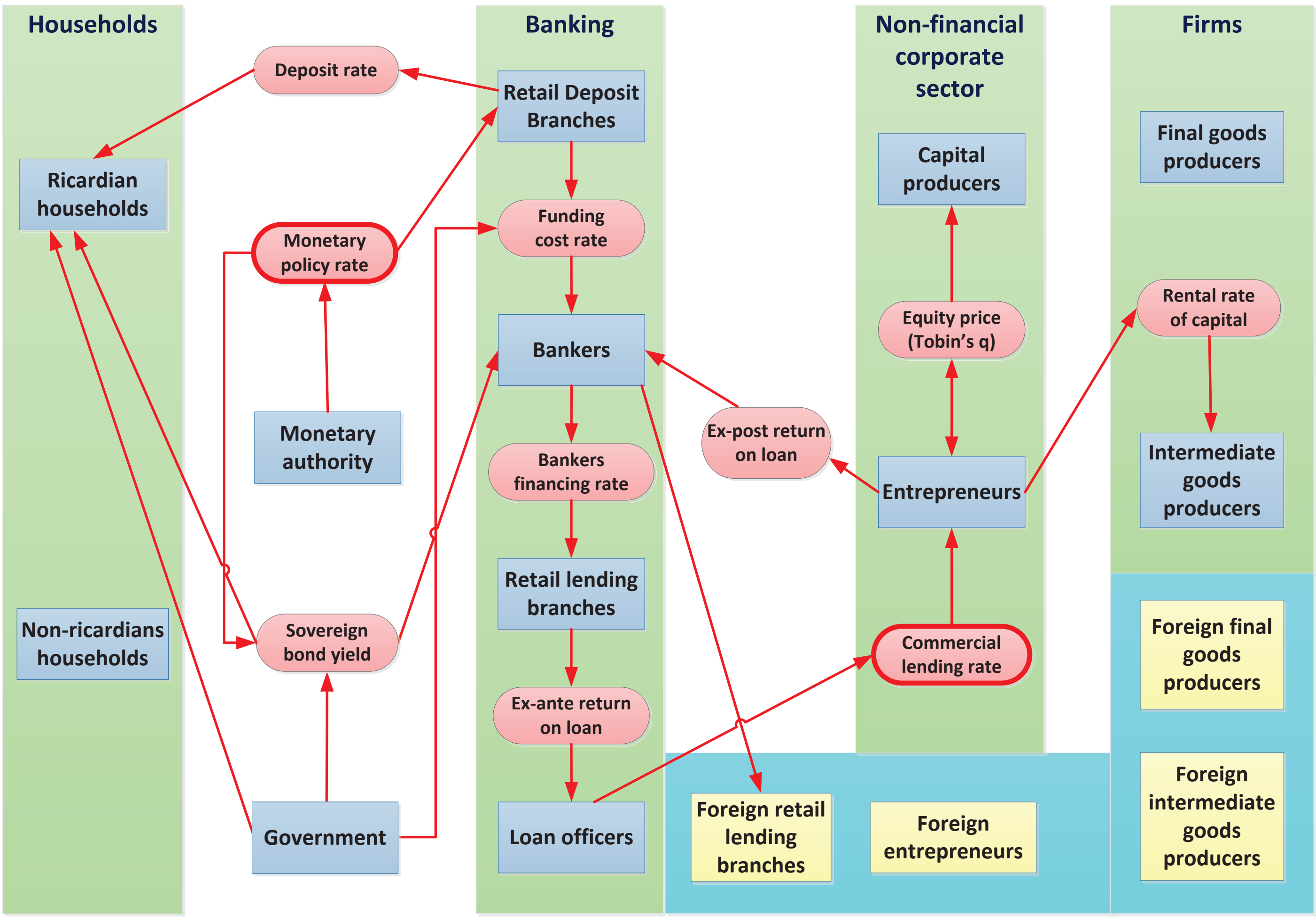
Figure 6: Impact of regulatory or supervisory actions (net percentages)



Source: ECB (Bank Lending Survey).
Notes: Net percentages are defined as the difference between the sum of the percentages for *increase considerably* and *increase somewhat* and the sum of the percentages for *decreased somewhat* and *decreased considerably*.

10 Schematic representation

Figure 7: Schematic representation of the model with cross border lending



11 Calibration

Table 1: Main macro variables

Variable		DE	FR	SP	IT	REA	ROW
Domestic demand (ratio to GDP)							
Private consuption	C/Y	0.626	0.568	0.554	0.600	0.580	0.602
Private investment	I/Y	0.210	0.220	0.250	0.210	0.210	0.220
Public consumption	G/Y	0.164	0.212	0.196	0.190	0.210	0.178
Trade (ratio to GDP)							
Total imports	M/Y	0.371	0.272	0.306	0.265	0.492	0.050
Imports of consumption goods	M_C/Y	0.253	0.196	0.225	0.198	0.351	0.032
Imported from DE		–	0.015	0.010	0.015	0.061	0.152
FR		0.026	–	0.015	0.016	0.037	0.102
SP		0.027	0.030	–	0.014	0.032	0.122
IT		0.025	0.020	0.010	–	0.034	0.110
REA		0.065	0.031	0.016	0.017	–	0.222
ROW		0.010	0.005	0.002	0.004	0.011	–
Imports of investment goods	M_I/Y	0.118	0.077	0.081	0.067	0.141	0.018
Imported from DE		–	0.013	0.002	0.005	0.020	0.078
FR		0.016	–	0.003	0.006	0.011	0.040
SP		0.013	0.010	–	0.009	0.010	0.039
IT		0.013	0.006	0.002	–	0.011	0.036
REA		0.029	0.008	0.004	0.006	–	0.094
ROW		0.008	0.003	0.001	0.002	0.005	–
Share of world GDP		0.060	0.040	0.015	0.033	0.044	0.808

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 2: Monetary and fiscal authorities

Parameter		DE	FR	SP	IT	REA	ROW
Monetary authority							
Annual inflation target (percent)	$\overline{\Pi}^4 - 1$	2.000	2.000	2.000	2.000	2.000	2.000
Interest rate inertia	ϕ_R	0.750	0.750	0.750	0.750	0.750	0.820
Interest rate sensitivity to inflation gap	ϕ_Π	1.500	1.500	1.500	1.500	1.500	1.830
Interest rate sensitivity to output growth	ϕ_Y	0.150	0.150	0.150	0.150	0.150	0.060
Fiscal authority							
Consumption tax rate	τ^C	0.178	0.196	0.169	0.203	0.201	0.101
Divident tax rate	τ^D	0.066	0.128	0.079	0.128	0.115	0.102
Capital income tax rate	τ^K	0.372	0.352	0.331	0.321	0.286	0.398
Labor income tax rate	τ^N	0.174	0.102	0.109	0.150	0.127	0.127
Rate of social security contr. by firms	τ^{W_f}	0.168	0.303	0.233	0.246	0.174	0.094
Rate of social security contr. by hhs	τ^{W_h}	0.174	0.095	0.059	0.070	0.120	0.073
Lump-sum taxes sens. to debt-to-GDP ratio	ϕ_{B_Y}	0.500	0.500	0.500	0.500	0.500	0.500

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 3: Households

Parameter		DE	FR	SP	IT	REA	ROW
Preferences I & J-type							
Discount factor	β	0.995	0.995	0.995	0.995	0.995	0.995
Intertemporal elasticity of substitution	σ	1.000	1.000	1.000	1.000	1.000	1.000
Inverse of the Frisch elasticity of labour	ζ	2.000	2.000	2.000	2.000	2.000	2.000
Habit persistence	κ	0.900	0.900	0.900	0.900	0.900	0.900
Share of J-type households	ω	0.250	0.250	0.250	0.250	0.250	0.250
Preferences I-type							
Deposit to consumption preferences	ζ_{db}	0.004	0.005	0.006	0.004	0.004	0.005
Elasticity of substitution for deposits	η_{db}	1.250	1.250	1.250	1.250	1.250	1.250
Transaction costs							
Transaction cost function param. I & J-type	γ_{vi1}	0.029	0.029	0.029	0.029	0.029	0.029
Transaction cost function param. I & J-type	γ_{vi2}	0.154	0.154	0.154	0.154	0.154	0.154
Internationally traded bonds transaction cost I-type	γ_{B^*}	0.010	0.010	0.010	0.010	0.010	0.200
Wage mark-ups							
Household I-type	$\eta_I/(\eta_I-1)$	1.303	1.303	1.303	1.303	1.303	1.159
Household J-type	$\eta_J/(\eta_J-1)$	1.303	1.303	1.303	1.303	1.303	1.159
Wage implied elasticities of substitution							
Household I-type	η_I	4.300	4.300	4.300	4.300	4.300	7.300
Household J-type	η_J	4.300	4.300	4.300	4.300	4.300	7.300
Wage calvo parameters							
Household I-type	ξ_I	0.750	0.750	0.750	0.750	0.750	0.750
Household J-type	ξ_J	0.750	0.750	0.750	0.750	0.750	0.750
Wage degree of indexation							
Household I-type	χ_I	0.650	0.650	0.650	0.650	0.650	0.650
Household J-type	χ_J	0.650	0.650	0.650	0.650	0.650	0.650

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world; I-type = Ricardian households; J-type = Non-Ricardian households. In annualised terms.

Table 4: Capital producers and firms

Parameter		DE	FR	SP	IT	REA	ROW
Capital producers							
Depreciation rate (percent)	δ	10.00	10.00	10.00	10.00	10.00	10.00
Investment adjustment cost parameter	γ_I	6.000	6.000	6.000	6.000	6.000	6.000
Capital utilization rate	γ_{u2}	7.000	7.000	7.000	7.000	7.000	7.000
Intermediate-good firms							
Bias towards capital, tradable goods	α_T	0.400	0.400	0.450	0.400	0.400	0.400
Bias towards capital, nontradable goods	α_N	0.388	0.415	0.463	0.365	0.333	0.434
Share of nontradables		0.414	0.527	0.517	0.543	0.407	0.649
Final consumption-good firms							
Subst. btw. domestic and imported trad. cons. goods	μ_{TC}	3.500	3.500	3.500	3.500	3.500	3.500
Bias towards domestic trad. cons. goods	υ_{TC}	0.645	0.548	0.111	0.527	0.235	0.707
Substitution btw. trad. and nontrad. cons. goods	μ_C	0.500	0.500	0.500	0.500	0.500	0.500
Bias towards trad. cons. goods	υ_C	0.737	0.624	0.560	0.596	0.789	0.390
Final investment-good firms							
Subst. btw. domestic and imported trad. inv. goods	μ_{TI}	3.500	3.500	3.500	3.500	3.500	3.500
Bias towards domestic trad. inv. goods	υ_{TI}	0.386	0.516	0.168	0.575	0.132	0.628
Substitution btw. trad. and nontrad. inv. goods	μ_I	0.500	0.500	0.500	0.500	0.500	0.500
Bias towards trad. inv. goods	υ_I	0.746	0.622	0.564	0.641	0.790	0.485
Price markups							
Tradables	$\theta_T/(\theta_T-1)$	1.213	1.213	1.213	1.213	1.213	1.150
Nontradables	$\theta_N/(\theta_N-1)$	1.400	1.400	1.400	1.400	1.400	1.279
Implied elasticities of substitution							
Tradables	θ_T	5.700	5.700	5.700	5.700	5.700	7.670
Nontradables	θ_N	3.500	3.500	3.500	3.500	3.500	4.580
Adjustment costs							
Imports of consumption goods	γ_{MC}	2.000	2.000	2.000	2.000	2.000	2.000
Imports of investment goods	γ_{MI}	1.000	1.000	1.000	1.000	1.000	1.000
Calvo parameters							
Prices - domestic tradables	ξ_H	0.900	0.900	0.900	0.900	0.900	0.900
Prices - domestic nontradables	ξ_N	0.900	0.900	0.900	0.900	0.900	0.900
Prices - exports	ξ_X	0.750	0.750	0.750	0.750	0.750	0.750
Degree of indexation							
Prices - domestic tradables	χ_H	0.400	0.400	0.400	0.400	0.400	0.400
Prices - domestic nontradables	χ_N	0.400	0.400	0.400	0.400	0.400	0.400
Prices - exports	χ_X	0.500	0.500	0.500	0.500	0.500	0.500
Degree of indexation							
Substitution btw. consumption good imports	μ_{MC}	3.500	3.500	3.500	3.500	3.500	3.500
Substitution btw. investment good imports	μ_{MI}	3.500	3.500	3.500	3.500	3.500	3.500

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 5: Sovereign risk (symmetric)

Parameter		DE	FR	SP	IT	REA	ROW
Government debt-to-annual GDP ratio (percent)	$\overline{B_Y}$	67.5	67.5	67.5	67.5	67.5	67.5
Mean of distribution	B_Y^{mean}	119.5	119.5	119.5	119.5	119.5	119.5
Std. dev. of prob. of default distribution	σ_{B_Y}	20.40	20.40	20.40	20.40	20.40	20.40
Loss given default (percent)	ξ_G	37.00	37.00	37.00	37.00	37.00	37.00
Variable							
Sov. bond spread sens. to debt-to-GDP (percent)	$\Lambda_{B_{GY}}$	0.120	0.120	0.120	0.120	0.120	0.120
Sovereign bond spread (percent)	$4(R_G/R_{BD}-1)$	0.800	0.800	0.800	0.800	0.800	0.800

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 6: Sovereign risk (cross-country heterogeneity)

Parameter		DE	FR	SP	IT	REA	ROW
Government debt-to-annual GDP ratio (percent)	$\overline{B_Y}$	63.7	61.8	49.3	106.5	61.8	60.3
Mean of distribution	B_Y^{mean}	149.9	114.5	98.7	142.1	113.8	199.8
Std. dev. of prob. of default distribution	σ_{B_Y}	30.20	18.98	20.55	14.65	20.40	54.73
Loss given default (percent)	ξ_G	37.00	37.00	37.00	37.00	37.00	37.00
Variable							
Sov. bond spread sens. to debt-to-GDP (percent)	$\Lambda_{B_{GY}}$	0.035	0.070	0.170	0.230	0.120	0.043
Sovereign bond spread (percent)	$4(R_G/R_{BD}-1)$	0.320	0.400	1.200	1.120	0.800	0.800

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 7: Bankers (symmetric)

Parameter		DE	FR	SP	IT	REA	ROW
Sensitivity of funding cost to sov. spread	Λ_ψ	0.600	0.600	0.600	0.600	0.600	0.600
St.dev. of idiosyncratic shock	σ_b	0.028	0.028	0.028	0.028	0.028	0.028
Bank resolution cost	μ_b	0.300	0.300	0.300	0.300	0.300	0.300
Regulatory bank capital ratio (percent)	ν_b	8.000	8.000	8.000	8.000	8.000	8.000
Bank capital ratio (percent)		12.00	12.00	12.00	12.00	12.00	12.00
Regulatory penalty	χ_b	0.003	0.003	0.003	0.003	0.003	0.003
Continuation probability of bankers	ζ_b	0.962	0.962	0.962	0.962	0.962	0.962
Variable							
Prob. of violating regulatory req. (percent)	$1-(1-F(\varpi_b^\nu))^4$	15.07	15.07	15.07	15.07	15.07	15.07
Prob. of default (percent)	$1-(1-F(\varpi_b))^4$	0.000	0.000	0.000	0.000	0.000	0.000
Bank NFC loans to GDP (percent)	$L_{BE}/(4Y)$	82.3	86.2	98.0	82.3	82.3	86.2
Bank leverage	κ_b	8.335	8.335	8.335	8.335	8.335	8.335
Funding cost spread (percent)	$4(\Psi-1)$	0.480	0.480	0.480	0.480	0.480	0.480
Bank capital wedge (percent)	$4(R_{BLE}/\widetilde{R}_{BD}-1)$	0.600	0.600	0.600	0.600	0.600	0.600

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 8: Bankers (cross-country heterogeneity)

Parameter		DE	FR	SP	IT	REA	ROW
Sensitivity of funding cost to sov. spread	Λ_ψ	0.600	0.600	0.600	0.600	0.600	0.600
St.dev. of idiosyncratic shock	σ_b	0.028	0.028	0.027	0.027	0.028	0.028
Bank resolution cost	μ_b	0.300	0.300	0.300	0.300	0.300	0.300
Regulatory bank capital ratio (percent)	ν_b	8.000	8.000	8.000	8.000	8.000	8.000
Bank capital ratio (percent)		11.93	11.97	12.02	12.00	11.99	12.00
Regulatory penalty	χ_b	0.003	0.003	0.003	0.003	0.003	0.003
Continuation probability of bankers	ζ_b	0.952	0.956	0.967	0.965	0.961	0.962
Variable							
Prob. of violating regulatory req. (percent)	$1-(1-F(\varpi_b^\nu))^4$	15.07	15.07	15.07	15.07	15.07	15.07
Prob. of default (percent)	$1-(1-F(\varpi_b))^4$	0.000	0.000	0.000	0.000	0.000	0.000
Bank NFC loans to GDP (percent)	$L_{BE}/(4Y)$	80.0	100.0	120.0	100.0	77.1	80.4
Bank leverage	κ_b	8.382	8.353	8.317	8.334	8.339	8.331
Funding cost spread (percent)	$4(\Psi-1)$	0.192	0.240	0.720	0.672	0.480	0.480
Bank capital wedge (percent)	$4(R_{BLE}/\widetilde{R}_{BD}-1)$	0.600	0.600	0.600	0.600	0.600	0.600

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 9: Retail banking branches (symmetric)

Parameter		DE	FR	SP	IT	REA	ROW
Retail deposit branches							
Elasticity of substitution of dif. deposits	μ_D^R	0.999	0.999	0.999	0.999	0.999	0.999
Prob. of not re-opt. deposit rates (percent)	ξ_D^R	1.000	1.000	1.000	1.000	1.000	1.000
Retail lending branch							
Elasticity of substitution of dif. loans	μ_E^R	1.002	1.002	1.002	1.002	1.002	1.002
Prob. of not re-opt. lending rates (percent)	ξ_E^R	40.00	40.00	40.00	40.00	40.00	40.00
Variable							
Retail deposit branches							
Deposit spread (percent)	$4(R_D/R_{BD}-1)$	-0.396	-0.396	-0.396	-0.396	-0.396	-0.396
Retail lending branch							
Cross border impact (percent)	$4(\widehat{R}_{BLE}/R_{BLE}-1)$	0.000	0.000	0.000	0.000	0.000	0.000
Monopolistic wedge (percent)	$4(R_{LE}/\widehat{R}_{BLE}-1)$	0.715	0.715	0.715	0.715	0.715	0.715

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 10: Retail banking branches (cross-country heterogeneity)

Parameter		DE	FR	SP	IT	REA	ROW
Retail deposit branches							
Elasticity of substitution of dif. deposits	μ_D^R	0.999	0.999	0.999	0.999	0.999	0.999
Prob. of not re-opt. deposit rates (percent)	ξ_D^R	1.000	1.000	1.000	1.000	1.000	1.000
Retail lending branch							
Elasticity of substitution of dif. loans	μ_E^R	1.003	1.003	1.001	1.001	1.002	1.002
Prob. of not re-opt. lending rates (percent)	ξ_E^R	60.00	60.00	20.00	20.00	40.00	40.00
Variable							
Retail deposit branches							
Deposit spread (percent)	$4(R_D/R_{BD}-1)$	-0.396	-0.396	-0.396	-0.396	-0.396	-0.396
Retail lending branch							
Cross border impact (percent)	$4(\widehat{R}_{BLE}/R_{BLE}-1)$	0.095	0.022	-0.014	-0.108	-0.028	0.000
Monopolistic wedge (percent)	$4(R_{LE}/\widehat{R}_{BLE}-1)$	1.174	1.018	0.368	0.581	0.710	0.690

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 11: Entrepreneurs (symmetric)

Parameter		DE	FR	SP	IT	REA	ROW
St.dev. of idiosyncratic shock	σ_e	0.357	0.357	0.357	0.357	0.357	0.357
Monitoring cost	μ_e	0.122	0.122	0.122	0.122	0.122	0.122
Continuation probability of entrepreneurs	ζ_e	0.984	0.984	0.984	0.984	0.984	0.984
Recovery ratio in case of default (percent)	χ_e	100.0	100.0	100.0	100.0	100.0	100.0
Variable							
Prob. of default (percent)	$1-(1-F(\overline{\omega}_e))^4$	2.771	2.771	2.771	2.771	2.771	2.771
Leverage	κ_e	1.644	1.644	1.644	1.644	1.644	1.644
Indebtedness to annual GDP (percent)	$L_E/(4Y)$	82.3	86.2	98.0	82.3	82.3	86.2
External financing premium (percent)	$4(R_{KK})/R_{LE}-1)$	1.760	1.760	1.760	1.760	1.760	1.760
Credit risk compensation (percent)	$4(1+R_{LLE})/R_{LE}-1)$	0.600	0.600	0.600	0.600	0.600	0.600
Total commercial lending spread (percent)	$4(1+R_{LLE})/R_{BD}-1)$	2.400	2.400	2.400	2.400	2.400	2.400

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 12: Entrepreneurs (cross-country heterogeneity)

Parameter		DE	FR	SP	IT	REA	ROW
St.dev. of idiosyncratic shock	σ_e	0.262	0.383	0.368	0.277	0.389	0.381
Monitoring cost	μ_e	0.221	0.166	0.100	0.083	0.126	0.125
Continuation probability of entrepreneurs	ζ_e	0.982	0.984	0.984	0.983	0.984	0.984
Recovery ratio in case of default (percent)	χ_e	100.0	100.0	100.0	100.0	100.0	100.0
Variable							
Prob. of default (percent)	$1-(1-F(\overline{\omega}_e))^4$	1.195	1.985	3.552	3.940	2.771	2.771
Leverage	κ_e	1.894	1.532	1.645	2.025	1.556	1.576
Indebtedness to annual GDP (percent)	$L_E/(4Y)$	99.1	76.4	98.1	106.3	75.0	80.4
External financing premium (percent)	$4(R_{KK})/R_{LE}-1)$	1.760	1.760	1.760	1.760	1.760	1.760
Credit risk compensation (percent)	$4(1+R_{LLE})/R_{LE}-1)$	0.334	0.515	0.720	0.651	0.633	0.625
Total commercial lending spread (percent)	$4(1+R_{LLE})/R_{BD}-1)$	2.400	2.400	2.400	2.400	2.400	2.400

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Table 13: Cross border lending

Variable	DE	FR	SP	IT	REA	ROW
Share of NFC loans in percent granted by:						
DE banks	69.91	7.48	1.03	4.03	8.00	0.00
FR banks	7.22	84.70	1.22	16.77	11.16	0.00
SP banks	2.29	1.48	96.72	1.27	4.70	0.00
IT banks	10.67	1.77	0.13	68.89	5.64	0.00
REA banks	9.91	4.57	0.90	9.04	70.50	0.00
ROW banks	0.01	0.00	0.00	0.00	0.00	100.00

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world.

Table 14: Lending rate decomposition (symmetric)

Variable (in percent)		DE	FR	SP	IT	REA	ROW
Deposit spread[a]	$4(R_D/R_{BD}-1)$	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40
Sovereign bond spread[b]	$4(R_G/R_{BD}-1)$	0.80	0.80	0.80	0.80	0.80	0.80
Funding cost spread[c]	$4(\Psi-1)$	0.48	0.48	0.48	0.48	0.48	0.48
Bank capital wedge[d]	$4(R_{BLE}/\widetilde{R}_{BD}-1)$	0.60	0.60	0.60	0.60	0.60	0.60
Cross border impact[e]	$4(\widehat{R}_{BLE}/R_{BLE}-1)$	0.00	0.00	0.00	0.00	0.00	0.00
Monopolistic wedge[f]	$4(R_{LE}/\widehat{R}_{BLE}-1)$	0.71	0.71	0.71	0.71	0.71	0.71
External financing premium[g]	$4(R_{KK})/R_{LE}-1)$	1.76	1.76	1.76	1.76	1.76	1.76
Credit risk compensation[h]	$4(1+R_{LLE})/R_{LE}-1)$	0.60	0.60	0.60	0.60	0.60	0.60
Commercial lending spread$^{i\approx c+d+e+f+h}$	$4(1+R_{LLE})/R_{BD}-1)$	2.40	2.40	2.40	2.40	2.40	2.40

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

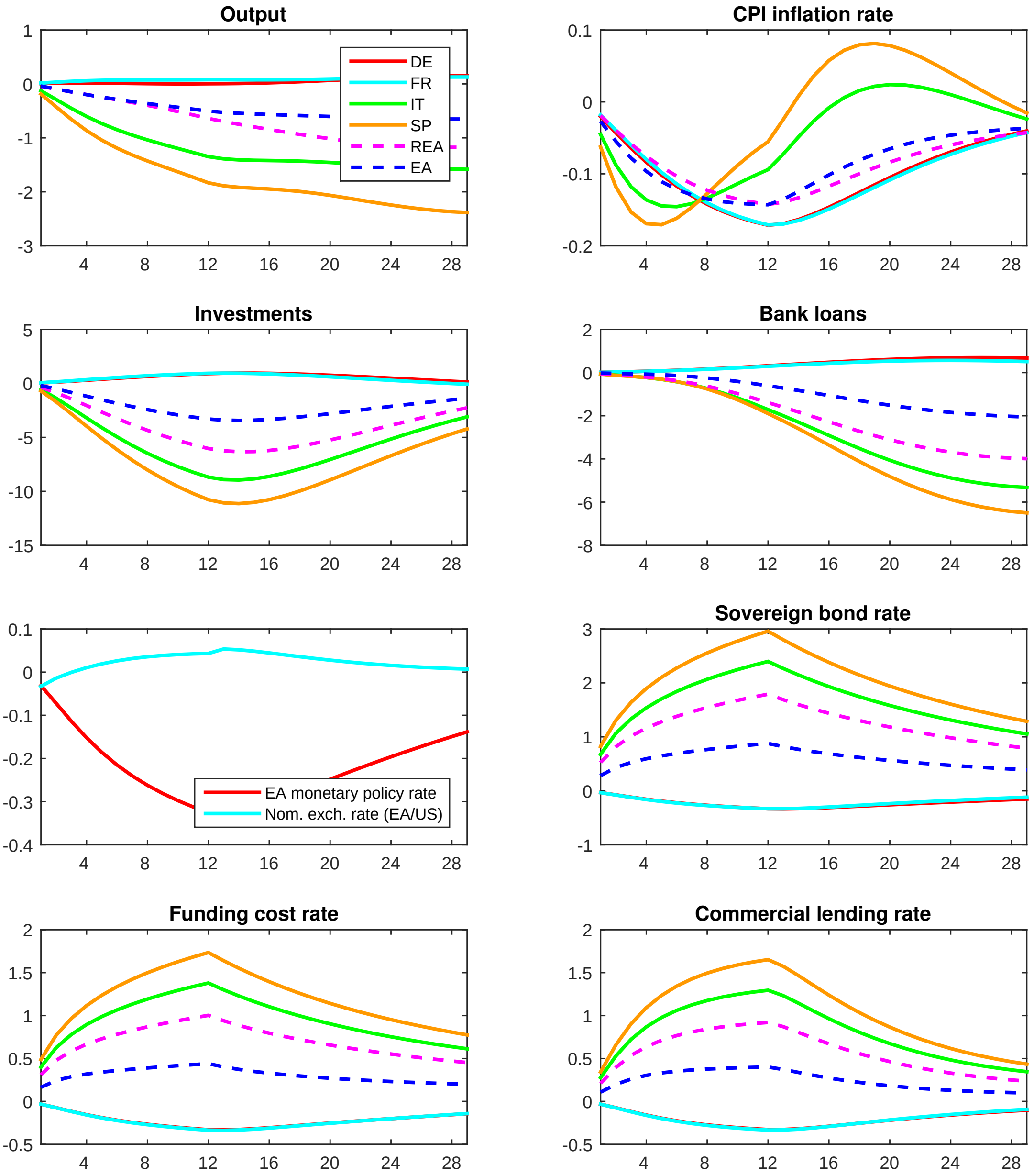
Table 15: Lending rate decomposition (cross-country heterogeneity)

Variable (in percent)		DE	FR	SP	IT	REA	ROW
Deposit spread[a]	$4(R_D/R_{BD}-1)$	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40
Sovereign bond spread[b]	$4(R_G/R_{BD}-1)$	0.32	0.40	1.20	1.12	0.80	0.80
Funding cost spread[c]	$4(\Psi-1)$	0.19	0.24	0.72	0.67	0.48	0.48
Bank capital wedge[d]	$4(R_{BLE}/\widetilde{R}_{BD}-1)$	0.60	0.60	0.60	0.60	0.60	0.60
Cross border impact[e]	$4(\widehat{R}_{BLE}/R_{BLE}-1)$	0.10	0.02	-0.01	-0.11	-0.03	0.00
Monopolistic wedge[f]	$4(R_{LE}/\widehat{R}_{BLE}-1)$	1.17	1.02	0.37	0.58	0.71	0.69
External financing premium[g]	$4(R_{KK})/R_{LE}-1)$	1.76	1.76	1.76	1.76	1.76	1.76
Credit risk compensation[h]	$4(1+R_{LLE})/R_{LE}-1)$	0.33	0.51	0.72	0.65	0.63	0.62
Commercial lending spread$^{i\approx c+d+e+f+h}$	$4(1+R_{LLE})/R_{BD}-1)$	2.40	2.40	2.40	2.40	2.40	2.40

Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

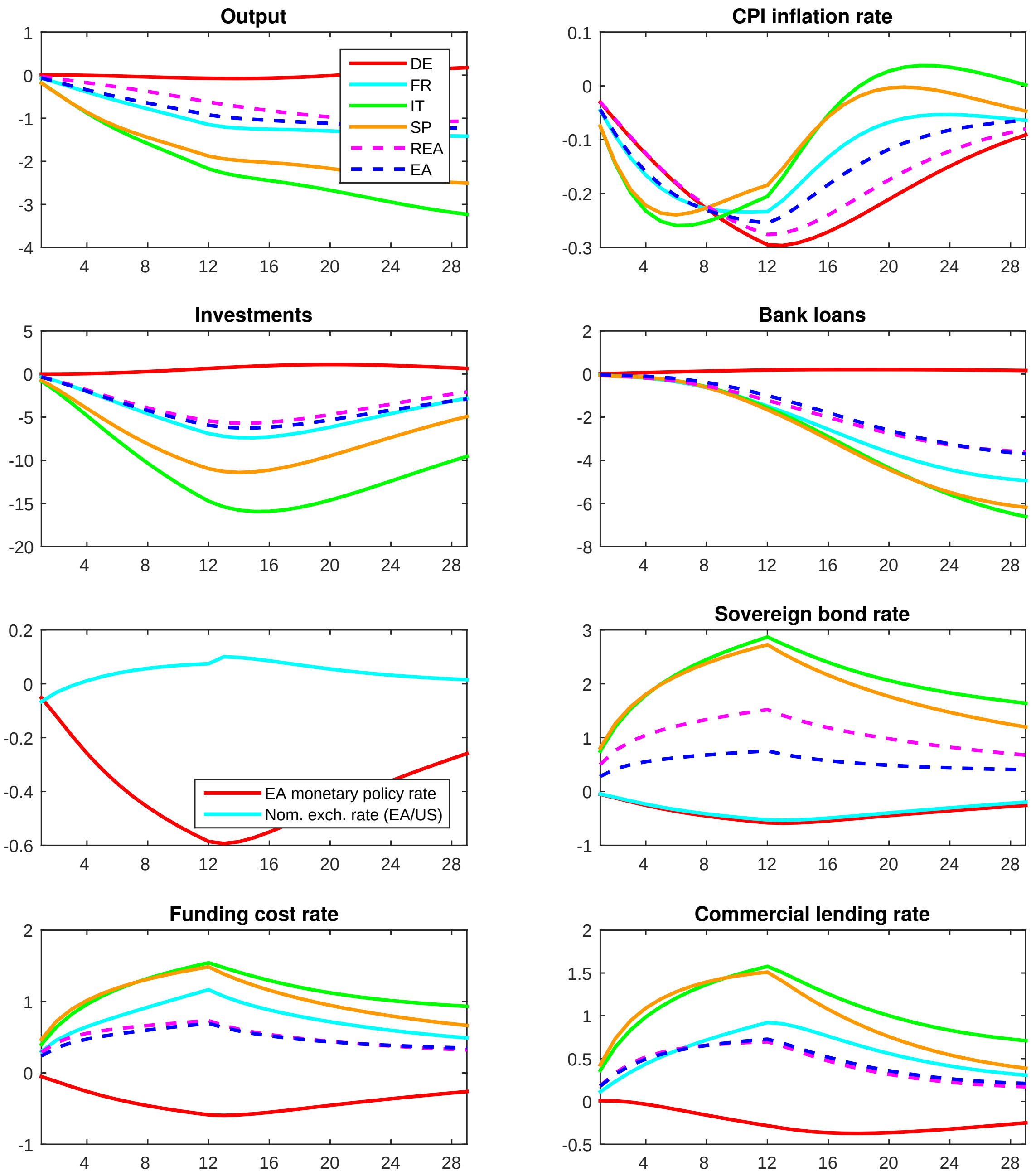
12 Synopsis of the financial crisis

Figure 8: Increase in **sovereign spreads in Italy, Spain and rest of euro area** - Symmetric calibration



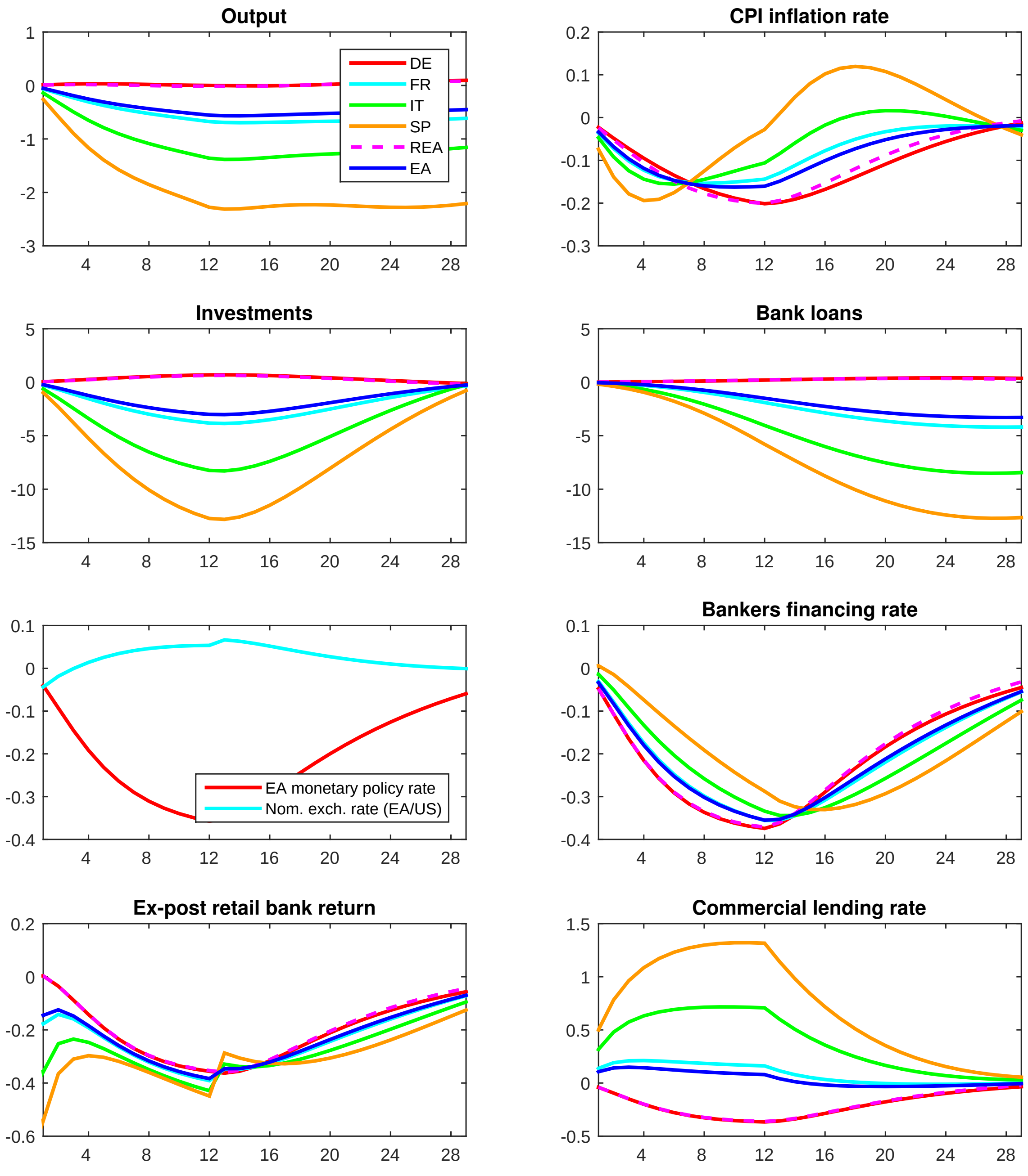
Notes: increase of the loss given default, $\xi_G^{\max}$, in Italy, Spain and rest of euro area, so that sovereign bond yields increase to crisis levels for three years; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.95. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 9: Increase in **sovereign spreads in Italy, Spain and rest of euro area** and **bank funding cost in France** - Benchmark calibration



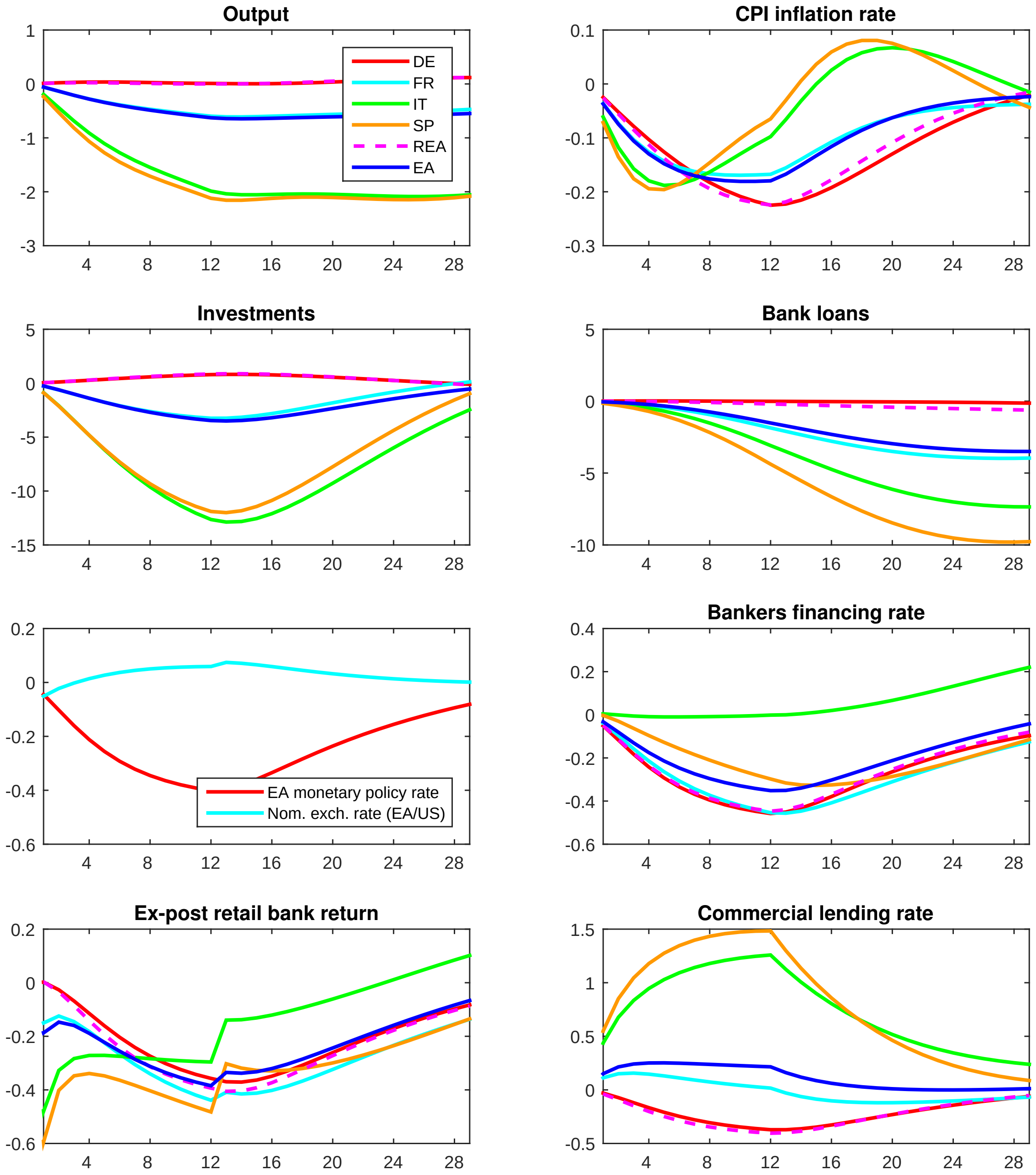
Notes: increase of the loss given default, $\xi_G^{\max}$, in Italy, Spain and rest of euro area and funding cost in France, so that sovereign bond yields and funding cost increase to crisis levels for three years; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.95. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 10: Increase in **entrepreneurs riskiness in France, Italy and Spain** - Symmetric calibration



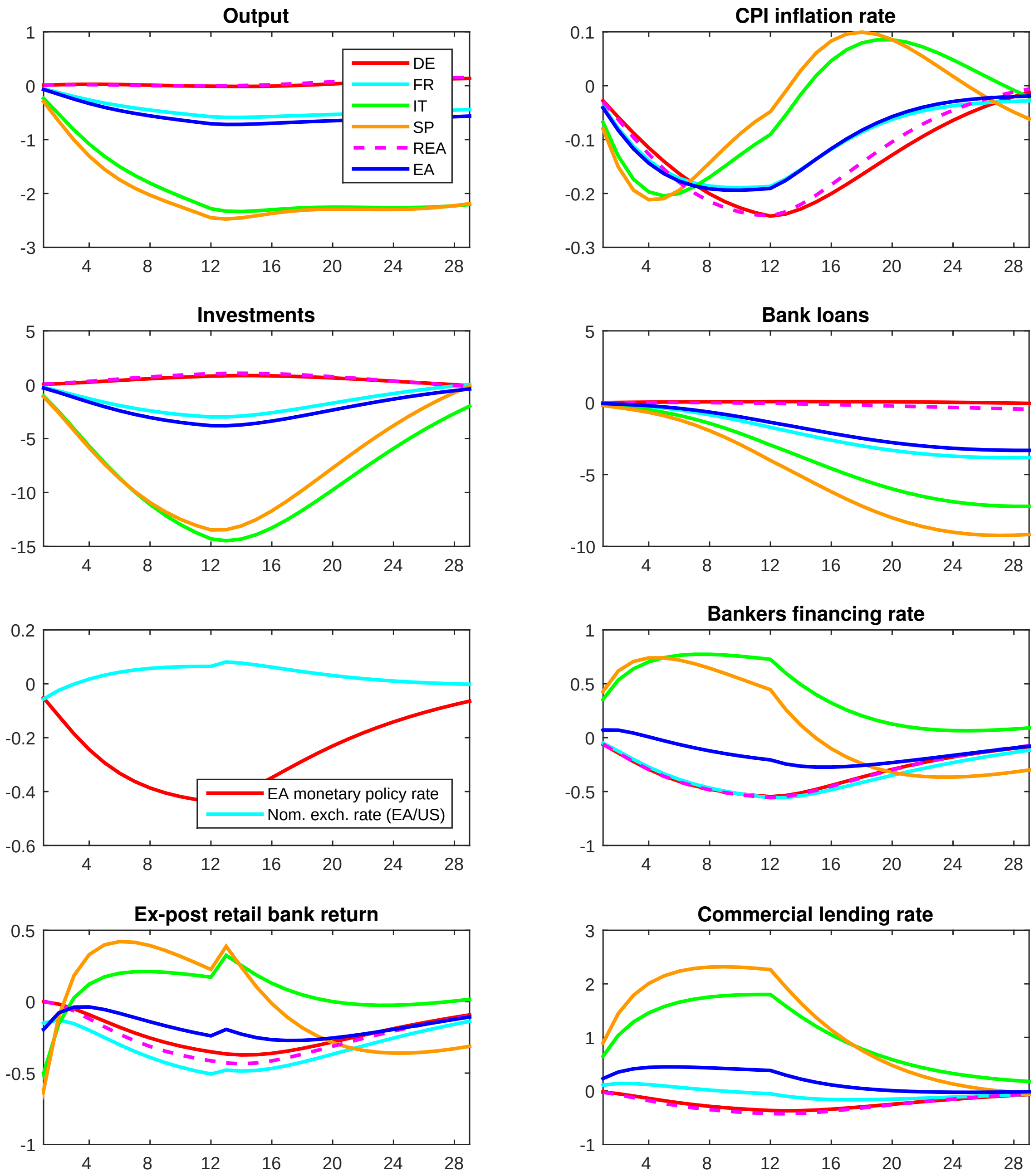
Notes: increase of the standard deviation of the multiplicative idiosyncratic shock of entrepreneurs, σ_e, in France, Italy and Spain for three years, so that the contribution of entrepreneurs expected losses to commercial lending rates increase to crisis levels for three years; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.95. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 11: Increase in **entrepreneurs riskiness shock in France, Italy and Spain** - Benchmark calibration



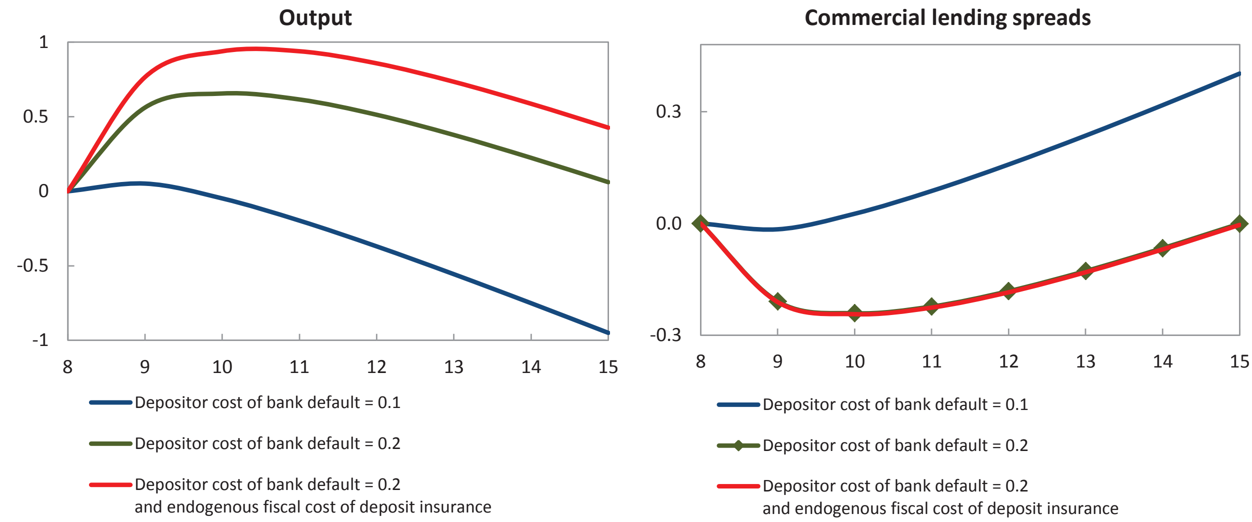
Notes: increase of the standard deviation of the multiplicative idiosyncratic shock of entrepreneurs, σ_e, in France, Italy and Spain for three years, so that the contribution of entrepreneurs expected losses to commercial lending rates increase to crisis levels for two years; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.95. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 12: Increase in **entrepreneurs riskiness shock in France, Italy and Spain** - Benchmark calibration with dynamic risk weights



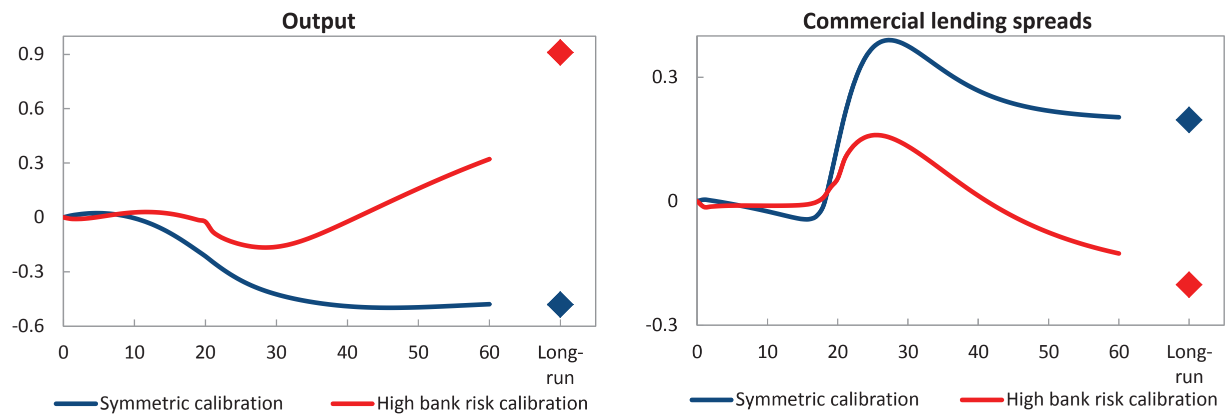
Notes: increase of the standard deviation of the multiplicative idiosyncratic shock of entrepreneurs, σ_e, in France, Italy and Spain for three years, so that the contribution of entrepreneurs expected losses to commercial lending rates increase to crisis levels for three years; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.95. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 13: Steady-state sensitivity to capital requirements - High bank risk calibration



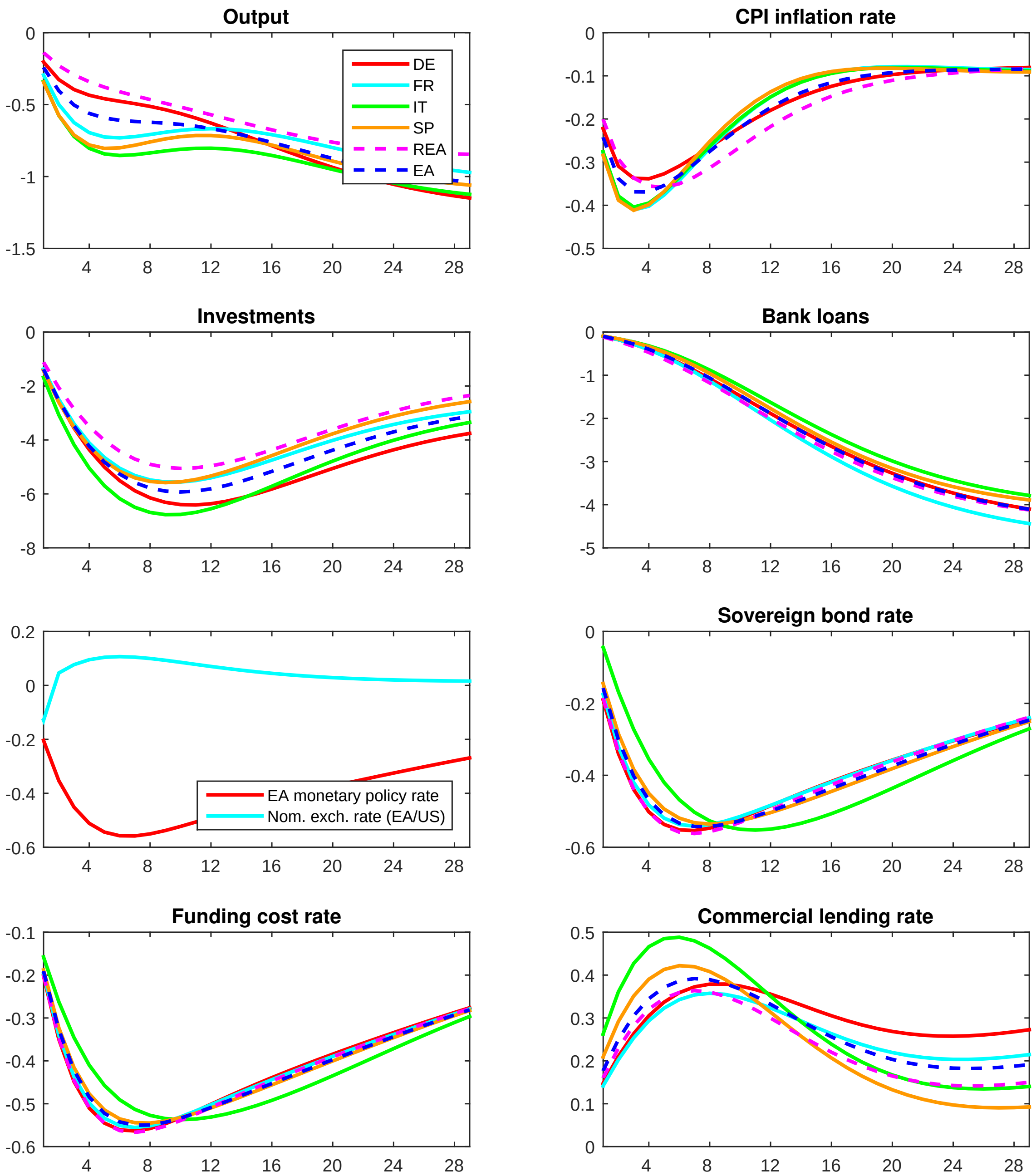
Notes: Incremental increase of capital requirements in the steady state, from 8 to 15 percent. Horizontal axes: Capital requirements in percent. Vertical access: **euro area output** expressed as percentage deviation from initial steady state, and **euro area commercial lending rate spread** (annualised), both expressed percentage deviations from initial steady state. Initial steady state corresponds to capital requirements of 8 percent.

Figure 14: Dynamic adjustment to higher capital requirements



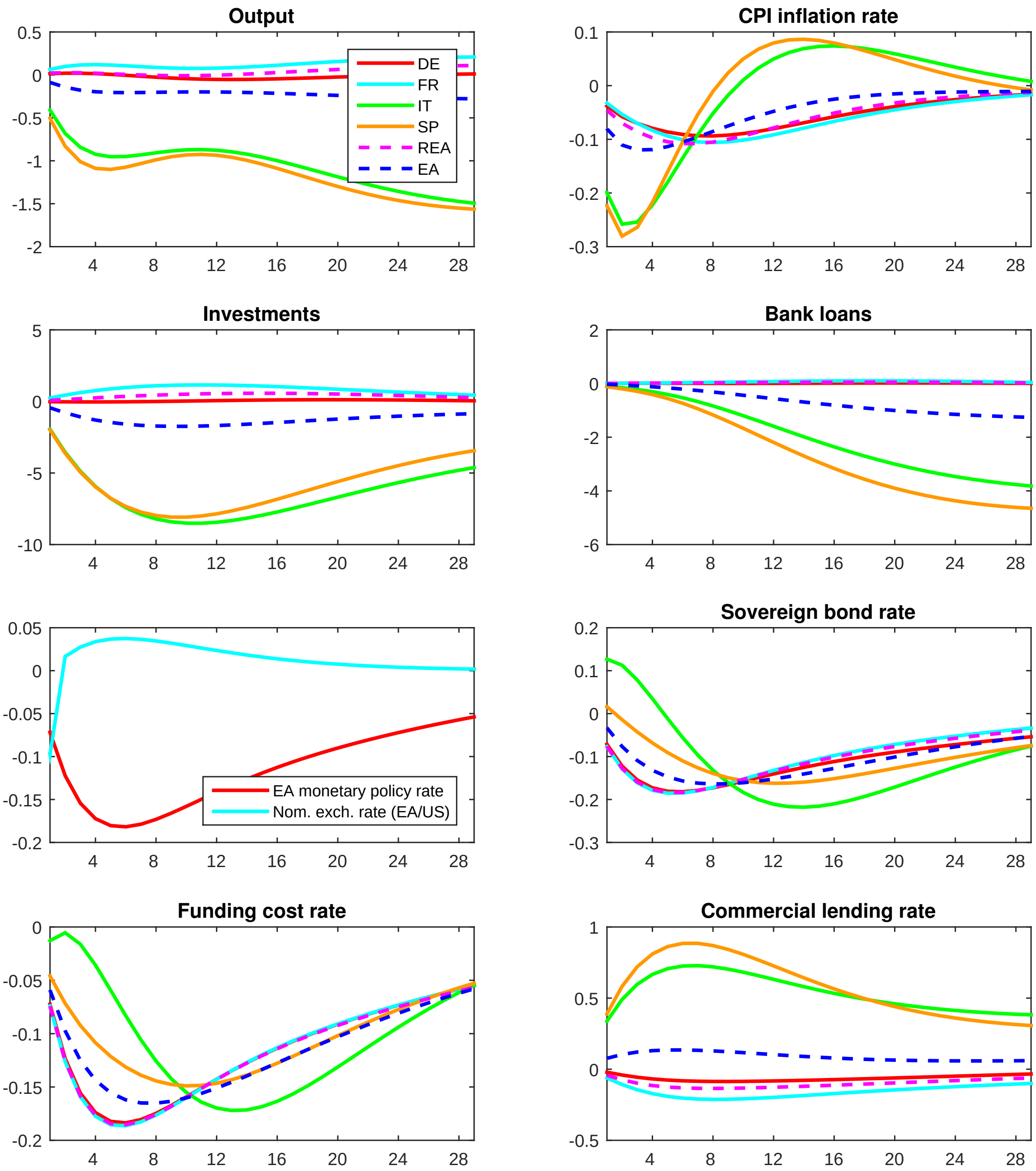
Notes: Anticipated increase in five years of capital requirements by 25 percent, with five years gradual phase-in arrangements. Horizontal axes: quarters. Vertical access: **euro area output** expressed as percentage deviation from initial steady state, and **euro area commercial lending rate spread** (annualised), both expressed percentage deviations from initial steady state. High bank risk calibration corresponds to a depositor cost of bank default of 0.2 and endogenous fiscal cost of deposit insurance.

Figure 15: Increase in **regulatory requirements** - Benchmark calibration



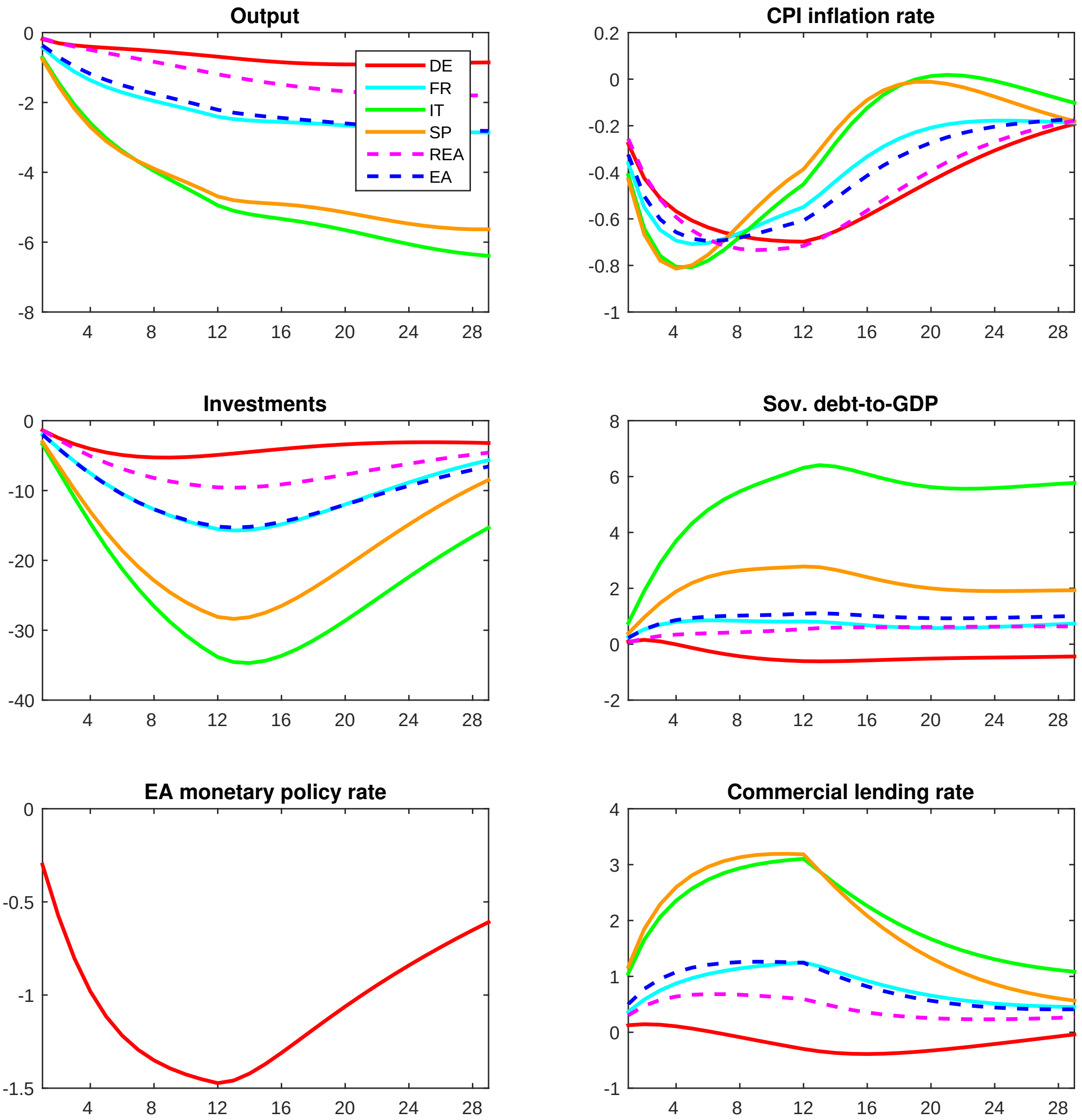
Notes: increase of euro area regulatory requirements by 4 percentage points; policy is permanent and gradually implemented within approximately a three-year horizon. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 16: Increase in **regulatory requirements** only for **Italy and Spain** - Benchmark calibration



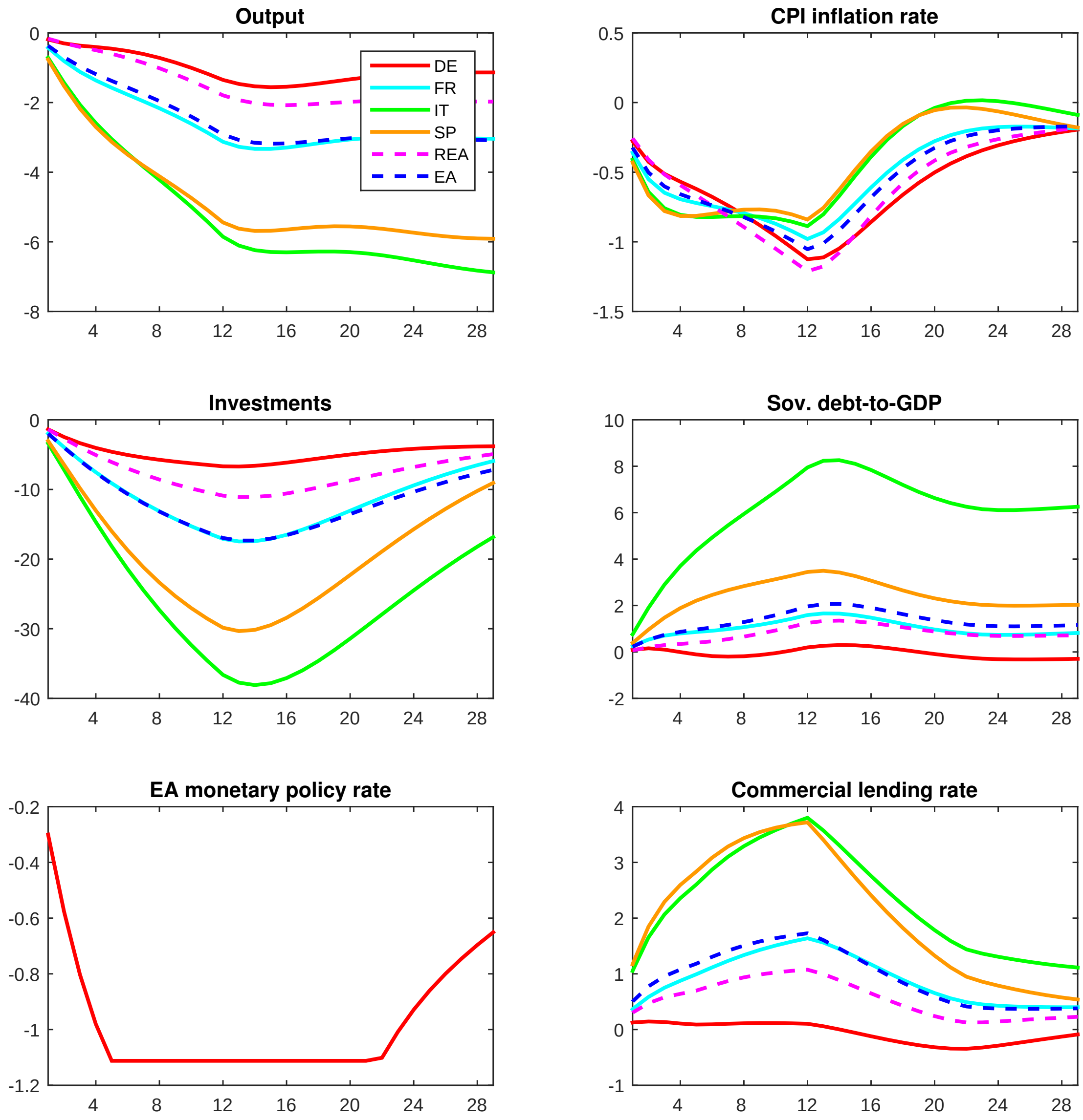
Notes: increase of regulatory requirements by 4 percentage points in Italy and Spain; policy is permanent and gradually implemented within approximately a three-year horizon. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation and interest rates which are expressed as annual percentage-point deviations. GDP, its components and bank loans are reported in real terms.

Figure 17: **Cumulative impact of the financial crisis** - Benchmark calibration



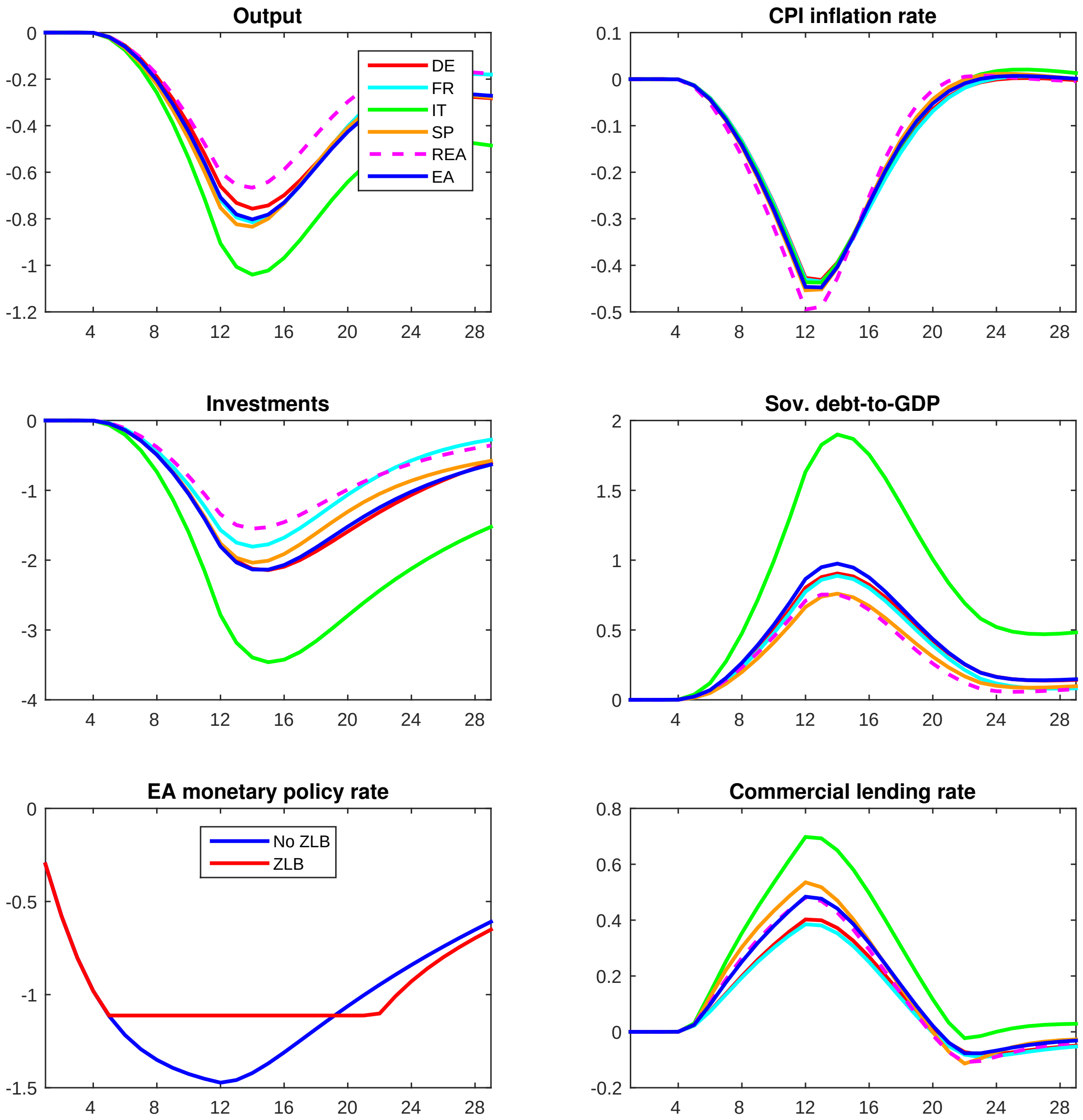
Notes: increase of the loss given default, $\xi_G^{\max}$, in Italy, Spain and rest of euro area, increase of the funding cost in France, so that sovereign bond yields and funding cost increase to crisis levels for three years; increase of the standard deviation of the multiplicative idiosyncratic shock of entrepreneurs, σ_e, in France, Italy and Spain for three years, so that the contribution of entrepreneurs expected losses to commercial lending rates increase to crisis levels for three years; increase of euro area regulatory requirements by 4 percentage points; policy is permanent and gradually implemented within approximately a three-year horizon. Shocks are persistent, i.e. follows an AR(1) process with autocorrelation being 0.95, except regulatory requirements which is permanent. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation, interest rates and debt-to-GDP ratio which are expressed as annual percentage-point deviations. GDP and its components are reported in real terms.

Figure 18: **Cumulative impact of the financial crisis subject to the zero lower bound -** Benchmark calibration



Notes: increase of the loss given default, $\xi_G^{\max}$, in Italy, Spain and rest of euro area, increase of the funding cost in France, so that sovereign bond yields and funding cost increase to crisis levels for three years; increase of the standard deviation of the multiplicative idiosyncratic shock of entrepreneurs, σ_e, in France, Italy and Spain for three years, so that the contribution of entrepreneurs expected losses to commercial lending rates increase to crisis levels for three years; increase of euro area regulatory requirements by 4 percentage points; policy is permanent and gradually implemented within approximately a three-year horizon. Shocks are persistent, i.e. follows an AR(1) process with autocorrelation being 0.95, except regulatory requirements which is permanent. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation, interest rates and debt-to-GDP ratio which are expressed as annual percentage-point deviations. GDP and its components are reported in real terms.

Figure 19: **Cumulative impact of the zero lower bound** - Benchmark calibration



Notes: increase of the loss given default, $\xi_G^{\max}$, in Italy, Spain and rest of euro area, increase of the funding cost in France, so that sovereign bond yields and funding cost increase to crisis levels for three years; increase of the standard deviation of the multiplicative idiosyncratic shock of entrepreneurs, σ_e, in France, Italy and Spain for three years, so that the contribution of entrepreneurs expected losses to commercial lending rates increase to crisis levels for three years; increase of euro area regulatory requirements by 4 percentage points; policy is permanent and gradually implemented within approximately a three-year horizon. Shocks are persistent, i.e. follows an AR(1) process with autocorrelation being 0.95, except regulatory requirements which is permanent. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for inflation, interest rates and debt-to-GDP ratio which are expressed as annual percentage-point deviations. GDP and its components are reported in real terms.

A Global economic environment

In the Appendix we provide details on the other sectors not covered in the main part: households, firms, capital producers and the government.

A.1 Households

There are two types of households, I and J, indexed by $i \in \left[0, s^H(1-\omega)\right]$ and $j \in \left[s^H(1-\omega), s^H\right]$, respectively. I-type households have access to financial markets, where they hold deposits to financial intermediaries, buy and sell domestic government and private bonds and internationally traded bonds. On the other hand, J-type households cannot trade in financial markets. Both types of households can smooth out consumption by adjusting their holdings of money for transaction purposes and can supply differentiated labor services and act as wage setters in monopolistically competitive markets.

A.1.1 I-type households

The representative I-type household enters period t with $\mathcal{M}_{I,t-1}$ units of money, $P_{C,t-1}D_{t-1}$ stock of nominal deposits plus interest, domestic government $B_{G,t-1}$ plus interest and net of a possible government haircut of $\xi_{G,t}$ percent due to sovereign risk, private bonds B_{t-1} plus interest and internationally traded bonds B^*_{t-1} denominated in the foreign currency. $P_{C,t}$ denotes the price of a unit of the private consumption good, $R_{D,t}$ is the gross nominal deposit rate, $R_{G,t}$ is the gross government bond interest rate, R_t is the gross private bond interest rate and $S_t^{H,ROW}$ denotes the exchange rate between euro and the foreign currency. Domestically traded bond are denominated in domestic currency.

During period t, I-type households purchases $C_{I,t}$ consumption goods which are subject to a proportional transaction cost defined as follows

$$\Gamma_v\left(v_{I,t}\right) \equiv \gamma_{v,1} v_{I,t} + \gamma_{v,2} v_{I,t}^{-1} - 2\sqrt{\gamma_{v,1}\gamma_{v,2}} \tag{63}$$

and is depended on the consumption-based velocity specified as $v_{I,t} = \frac{P_{C,t}C_{I,t}}{M_{I,t}}$. They also decide on the amount of their deposit holdings to the financial intermediaries $P_{C,t}D_t$ which will pays interest $R_{D,t}$ in the following period. They also choose on the amount of domestic government $B_{G,t}$ and private bonds B_t. The household also buys internationally traded bonds B^*_t where their gross interest rate R^*_t is adjusted for a financial intermediation premium that the household must pay when taking a position in the international bond market and is defined as

$$\Gamma_{B^*}\left(\frac{S_t^{H,ROW}B^*_{t+1}}{P_{Y,t}Y_t}; RP_t\right) \equiv \gamma_{B^*}\left(exp\left(\frac{S_t^{H,ROW}B^*_{t+1}}{P_{Y,t}Y_t} - \overline{B^*_Y}\right) - 1\right) - RP_t \tag{64}$$

where $\gamma_{B^*} > 0$ is a parameter, $\overline{B^*_Y}$ is the long-run (steady-state) net foreign asset position, RP_t is a risk premium shock, $P_{Y,t}$ is the gross domestic product deflator and Y_t is the GDP in real terms.

Finally, during period t, the household collects income from labour services and dividends. The fiscal authority levies taxes on the household's gross income and spending. In particular, τ_t^C denotes the consumption tax rate levied on consumption purchases, τ_t^N represents the tax rates levied on wage income and $\tau_t^{W_h}$ denotes the additional wage income tax rate that represents the household contribution to social security. τ_t^D represents the tax rate on dividends from firms ownership. $TR_{I,t}$ and $T_{I,t}$ represent lump-sum transfers and taxes received from or pay to the government, respectively.

I-type households also hold state-contingent securities, $\Phi_{I,t}$, which are traded amongst I-type households and provide insurance against individual income risk. This guarantees that the marginal utility of consumption out of wage income is identical across individual households and consequently all households choose identical allocations in equilibrium.

At the end of period t, I-type households collect after tax dividends $(1-\tau_t^D)DV_{I,t}$ paid by intermediate goods-producing firms nominal profits (which are owned by I-type households), the incurred premium Ξ_t when taking a position in the international bond market which is rebated in a lump-sum manner to domestic I-type households, profits from the financial intermediaries and non-financial corporations $\Pi_{BE,t}$ that are owned by I-type households and $\Xi_{G,t}$ from the government which is given independently from transfers in order to compensate for the loss from a haircut.

The household then carries $\mathcal{M}_{I,t}$ units of money into period $t+1$ and faces the following budget constraint in nominal terms

$$\begin{aligned}
&\mathcal{M}_{I,t-1} + R_{D,t-1}P_{C,t-1}D_{t-1} + R_{G,t-1}(1-\xi_{G,t})P_{C,t-1}B_{GH,t-1} + R_{t-1}P_{C,t-1}B_{t-1} \\
&+ (1-\Gamma_{B^*})\, R^*_{t-1}S_t^{H,ROW}P^*_{C,t-1}B^*_{t-1} + \left(1-\tau_t^N-\tau_t^{W_h}\right)W_{I,t}N_{I,t} + (1-\tau_t^D)DV_{I,t} \\
&+TR_{I,t} + \Phi_{I,t} + \Xi_t + \Xi_{G,t} + \Pi_{BE,t} \\
&= (1+\tau_t^C + \Gamma_v\left(V_{I,t}\right))P_{C,t}C_{I,t} + P_{C,t}D_t + P_{C,t}B_{G,t} + P_{C,t}B_t \\
&+S_t^{H,ROW}P^*_{C,t}B^*_t + T_{I,t} + \mathcal{M}_{I,t}
\end{aligned} \tag{65}$$

Households of type I care about consumption $C_{I,t}$ following external habits. In particular, the utility depends positively on the difference between the current level of individual consumption, $C_{I,t}$, and the lagged average consumption level of households of type I, $\overline{C}_{I,t}$. Furthermore, following Begenau (2015) households have preference for liquidity in the form of bank liabilities over consumption $\frac{D_t}{C_{I,t}}$ similar to the money in the utility specification. These preferences capture the benefits from money-like-securities which service households with liquidity.[12] Due to the utility gained from deposit households in this respect will be willing to accept lower interest rate than saving in other type of assets, e.g. private bonds. Its inverse is defined as $VD_{I,t} = \frac{C_{I,t}}{D_t}$.

Lastly, households gain disutility from working $N_{I,t}$. Hence, household I lifetime utility function is defined as follows

$$\begin{aligned}
\max_{\{C_{I,t},D_t,\mathcal{M}_{I,t},B_{G,t},B_t,B_t^*\}} &\left\{\mathbb{E}_t\left[\sum_{k=0}^{\infty}\beta^k\zeta_c\frac{(1-\kappa)}{1-\sigma}\left(\frac{C_{I,t+k}-\kappa\overline{C}_{I,t+k-1}}{1-\kappa}\right)^{1-\sigma}\right.\right. \\
&\left.\left.+\frac{\zeta_{db}}{1-\eta_b}\left(\frac{D_{t+k}}{C_{I,t+k}}\right)^{1-\eta_b} - \frac{1}{1+\zeta_n}\left(N_{I,t+k}\right)^{1+\zeta_n}\right]\right\}
\end{aligned} \tag{66}$$

where $0<\beta<1$ is the discount rate, $\sigma>0$ the inverse of the intertemporal elasticity of substitution, ζ_c is a parameter that captures consumption preferences, which resembles a shock to the IS curve in more traditional Keynesian analysis, $0\leq\kappa\leq1$ is the degree of habit persistence, where ζ_{db} is the

[12]We allow for two types of liquid assets, money and deposits, which can be approximated with M1 and M2 aggregates respectively.

utility weight on deposits D_t and η_b governs the curvature of the deposit-to-consumption ratio in the utility function and $\zeta_n > 0$ is the inverse of the elasticity of work effort with respect to the real wage (Frisch elasticity). The deposit in the utility function specification ensures that more consumption raises the marginal utility of liquidity.

The household, therefore, chooses $\{C_{I,t}, D_t, \mathcal{M}_{I,t}, B_{G,t}, B_t, B_t^*\}$ for all t to maximize its expected lifetime utility function, subject to the constraints imposed by (A.1.1) for all t. $\Lambda_{I,t}$ is defined to denote the Lagrange multiplier on the budget constraint (in real terms). The household's first-order conditions which are different from the original EAGLE or the NAMW are the following:

$$\zeta_c \left(\frac{C_{I,t} - \kappa \overline{C}_{I,t-1}}{1-\kappa}\right)^{-\sigma} - \frac{\zeta_{db}}{C_{I,t}} \left(VD_{I,t}\right)^{\eta_b - 1} = \Lambda_{I,t}\left(1 + \tau_t^C + \Gamma_v\left(v_{I,t}\right) + \Gamma_v'\left(v_{I,t}\right) v_{I,t}\right) \tag{67}$$

$$\beta E_t \left[\frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} \Pi_{C,t+1}^{-1}\right] R_{D,t} = 1 - \frac{\zeta_{db}\left(VD_{I,t}\right)^{\eta_b - 1}}{\Lambda_{I,t} D_t} \tag{68}$$

$$\beta E_t \left[\frac{\Lambda_{I,t+1}}{\Lambda_{I,t}} \Pi_{C,t+1}^{-1} (1 - \xi_{G,t+1})\right] R_{G,t} = 1 \tag{69}$$

A.1.2 J-type households

Households of type J care about consumption $C_{J,t}$ following external habits, where $\overline{C}_{J,t}$ denotes the average consumption level of households of type J. They also gain disutility from working $N_{J,t}$ with the inverse of the elasticity of work effort with respect to the real wage (Frisch elasticity) being defined as ζ_n ($\zeta_n > 0$).

Hence, J-type household faces the following budget constraint in nominal terms

$$\mathcal{M}_{J,t-1} + \left(1 - \tau_t^N - \tau_t^{W_h}\right) W_{J,t} N_{J,t} + TR_{J,t} + \Phi_{J,t} = (1 + \tau_t^C + \Gamma_v\left(V_{J,t}\right)) P_{C,t} C_{J,t} + T_{I,t} + \mathcal{M}_{I,t} \tag{70}$$

and their lifetime utility function is defined as follows

$$\max_{\{C_{J,t}, M_{J,t}\}} \left\{ \mathbb{E}_t \left[\sum_{k=0}^{\infty} \beta^k \left(\frac{1-\kappa}{1-\sigma} \left(\frac{C_{J,t+k} - \kappa C_{J,t+k-1}}{1-\kappa} \right)^{1-\sigma} - \frac{1}{1+\zeta_n} \left(N_{J,t+k}\right)^{1+\zeta_n} \right) \right] \right\} \tag{71}$$

The household chooses $\{C_{J,t}, \mathcal{M}_{J,t}\}$ for all t to maximize its expected lifetime utility function, subject to the constraints imposed by (70) for all t. The household's first-order conditions are standard and not reported.

A.2 Firms

There are two types of firms in the model, the intermediate and the final goods producing firms. The intermediate goods consist of internationally tradable and nontradable goods for consumption and investments. The final-goods producing firms use all intermediate goods to produce the final goods which are nontraded and used for consumption and investment.

A.2.1 Final goods production

Firms producing final nontradable goods are symmetric, act under perfect competition and use nontradable, domestic and imported tradable intermediate goods as inputs. The intermediate goods are assembled according to a constant elasticity of substitution (CES) technology. Final goods can be used for private consumption and investment.

Each firm indexed by x ($x \epsilon \left[0, s^H\right]$) produces a final good $\mathcal{Y}(x)_t$ using a CES technology

$$\mathcal{Y}_t(x) = \left[\upsilon^{\frac{1}{\mu}} \left(\left[\upsilon_T^{\frac{1}{\mu_T}} T_t(x)^{\frac{\mu_T - 1}{\mu_T}} + (1-\upsilon_T)^{\frac{1}{\mu_T}} M_t(x)^{\frac{\mu_T - 1}{\mu_T}} \right]^{\frac{\mu_T}{\mu_T - 1}} \right) + (1-\upsilon)^{\frac{1}{\mu}} NT_t(x)^{\frac{\mu - 1}{\mu}} \right]^{\frac{\mu}{\mu - 1}} \tag{72}$$

Three intermediate inputs are used in the production of this good. A basket NT_t of nontradable goods, a basket (T_t) of domestic goods and a basket (M_t) imported goods. The parameter $\mu > 0$ denotes the intratemporal elasticity of substitution between tradable and nontradable goods, while υ $(0 \leq \upsilon \leq 1)$ measures the weight of the tradable bundle in the production of the consumption good, the parameter $\mu_T > 0$ denotes the intratemporal elasticity of substitution between the bundles of domestic and foreign tradable intermediate goods and υ_T $(0 \leq \upsilon_T \leq 1$ $)$ measures the weight of domestic tradable intermediate goods. Imports $M_t(x)$ are a CES function of basket of goods imported from other countries, denoted as

$$M_t(x) = \left[\sum_{J \neq I} \left(\upsilon_M^{I,J} \right)^{\frac{1}{\mu_M}} \left(M_t^J(x) \left(1 - \Gamma_M^{I,J}(x) \right) \right)^{\frac{\mu_M - 1}{\mu_M}} \right]^{\frac{\mu_M}{\mu_M - 1}} \tag{73}$$

where $\mu_M > 0$ and the coefficients $\upsilon_M^{H,CO}$ are such that: $0 \leq \upsilon_{MC}^{I,J} \leq 1$, $\sum_{J \neq H} \upsilon_M^{I,J} = 1$. The term $\Gamma_M^{I,J}(x)$ represents adjustment costs on bilateral consumption imports of country I from country J (M_t^J):

$$\Gamma_M^{I,J}(x) \equiv \frac{\gamma_M}{2} \left(\frac{M_t^J(x) / Q_t(x)}{M_{t-1}^J / Q_{t-1}} - 1 \right)^2, \gamma_M \geq 0 \tag{74}$$

By assumption, each firm x takes the previous period (sector-wide) import share, M_{t-1}^J/Q_{t-1}, and the current demand for its output, $Q_t(x)$, as given. The adjustment costs lower the short-run price elasticity of imports.

Firm x chooses the combination of the tradable and nontradable bundles T_t, M_t and NT_t that minimizes the expenditure $P_{T,t}T_t + P_{M,t}M_t + P_{NT,t}NT_t$ subject to technology constraints (72) given the input price indexes $P_{T,t}$, $P_{M,t}$ and $P_{NT,t}$.

In the case of the basket NT_t, the following CES technology is exploited by final firms x:

$$NT_t(x) = \left[\left(\frac{1}{s^H} \right)^{\frac{1}{\theta_N}} \int_0^{s^H} NT_t(x,n)^{\frac{\theta_N - 1}{\theta_N}} dn \right]^{\frac{\theta_N}{\theta_N - 1}} \tag{75}$$

where $NT_t(x,n)$ defines the use of the nontradable intermediate goods n by the firm x and $\theta_N > 1$ is the intratemporal elasticity of substitution between the differentiated goods.

The firm x takes the prices of the nontradable goods $P_t(n)$ as given and chooses the optimal use of each differentiated intermediate good n by minimizing the expenditure $\int_0^{s^H} P_t(n) NT_t(x,n) dn$ subject to the production function. This yields the following demand for each nontradable intermediate good n:

$$NT_t(x,n) = \frac{1}{s^H}\left(\frac{P_t(n)}{P_{NT,t}}\right)^{-\theta_N} NT_t(x) \tag{76}$$

where $P_{NT,t}$ is the cost-minimizing price of one unit of the nontradable basket:

$$P_{NT,t} = \left[\frac{1}{s^H}\int_0^{s^H} P_t(n)^{1-\theta_N}\, dn\right]^{\frac{1}{1-\theta_N}} \tag{77}$$

A.2.2 Supply of intermediate goods

There are firms producing tradable and nontradable intermediate goods (brands) under monopolistic competition regime. Each tradable brand is produced by a firm h belonging to the continuum of mass s^H ($h \in [0, s^H]$). Similarly, each nontradable brand is produced by a firm n, also defined over the continuum of mass s^H ($n \in [0, s^H]$). We will focus this section on the nontradable sector.

Nontradable intermediate goods (n) are produced using a Cobb-Douglas technology

$$Y^S_{N,t}(n) = \max\{z_{N,t} K^D_t(n)^{\alpha_N} N^D_t(n)^{1-\alpha_N} - \psi_N, 0\} \tag{78}$$

The inputs are homogenous capital services, $K^D_t(n)$ and an index of differentiated labor services, $N^D_t(n)$. Capital and labor services are supplied by domestic households under perfect competition and monopolistic competition, respectively. $z_{N,t}$ is a sector-specific productivity shocks.

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

$$N^D_t(n) = \left[(1-\omega)^{\frac{1}{\eta}} N^D_{I,t}(n)^{\frac{\eta-1}{\eta}} + \omega^{\frac{1}{\eta}} N^D_{J,t}(n)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{79}$$

where $\eta > 0$ denotes the elasticity of substitution between the two household-specific bundles of labor services I and J. The household-specific labor bundles are

$$N^D_{I,t}(n) = \left[\left(\frac{1}{s^H(1-\omega)}\right)^{\frac{1}{\eta_I}} \int_0^{s^H(1-\omega)} N^D_t(n,i)^{\frac{\eta_I-1}{\eta_I}}\, di\right]^{\frac{\eta_I}{\eta_I-1}} \tag{80}$$

$$N^D_{J,t}(n) = \left[\left(\frac{1}{s^H\omega}\right)^{\frac{1}{\eta_J}} \int_{s^H(1-\omega)}^{s^H} N^D_t(n,j)^{\frac{\eta_J-1}{\eta_J}}\, dj\right]^{\frac{\eta_J}{\eta_J-1}} \tag{81}$$

where η_I, $\eta_J > 1$ are the elasticities of substitution between the differentiated services of labor varieties i and j, respectively. Similar equations hold for the firms producing tradables, h.

Given rental cost of capital R^K_t and the aggregate wage index W_t, firms minimize the cost $R^K_t K^D_t(n) + \left(1+\tau^{W_f}_t\right) W_t N^D_t(n)$ subject to the production function (78) where $\tau^{W_f}_t$ is the payroll tax rate.

Nominal wage contracts for differentiated labor services i and j are set in monopolistic competitive markets by I-type and J-type households, respectively. Each firm takes wages as given and chooses the optimal input of each variety i and j by minimizing the cost of forming household-specific labor bundles subject to the aggregation constraints (80) and (81), respectively. This setup yields the following demand functions for varieties i and j by the generic firm n

$$N_t^D(n,i) = \frac{1}{s^H}\left(\frac{W_t(i)}{W_{I,t}}\right)^{-\eta_I}\left(\frac{W_{I,t}}{W_t}\right)^{-\eta} N_t^D(n) \tag{82}$$

$$N_t^D(n,j) = \frac{1}{s^H}\left(\frac{W_t(j)}{W_{J,t}}\right)^{-\eta_J}\left(\frac{W_{J,t}}{W_t}\right)^{-\eta} N_t^D(n) \tag{83}$$

where:

$$W_{I,t} = \left[\frac{1}{s^H(1-\omega)}\int_0^{s^H(1-\omega)} W_t(i)^{1-\eta_I}\,di\right]^{\frac{1}{1-\eta_I}} \tag{84}$$

$$W_{J,t} = \left[\frac{1}{s^H\omega}\int_{s^H(1-\omega)}^{s^H} W_t(j)^{1-\eta_J}\,dj\right]^{\frac{1}{1-\eta_J}} \tag{85}$$

$$W_t = \left[(1-\omega)(W_{I,t})^{1-\eta} + \omega (W_{J,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{86}$$

Similar considerations hold for the generic firm in the tradable sector.

A.3 Capital producers

At the beginning of period t, those firms buy back the depreciated capital stocks $(1-\delta)K_{t-1}$ at real prices (in terms of consumption goods) Q_t. Then using distributed goods they augment the various stocks through the following capital law of motion

$$K_t = (1-\delta)K_{t-1} + \left[1-\Gamma_I\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{87}$$

where Γ_I represents a non-negative quadratic adjustment cost function formulated in terms of the gross rate of change in investment and it is defined as follows

$$\Gamma_I\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\gamma_I}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 \tag{88}$$

The augmented stocks are sold back to entrepreneurs at the end of the period t at the same prices. Hence, capital producer choose $\{K_t, I_t\}$ to maximise intertemporal profits for all t. $\Lambda_{I,t}$ is defined to denote the Lagrange multiplier on the budget constraint (in real terms). Therefore, the decision problem of capital stock producers is given by

$$\max_{\{K_t,I_t\}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \frac{\Lambda_{I,t+k}}{\Lambda_{I,t}} \{Q_{t+k}(K_{t+k}-(1-\delta)K_{t+k-1}) - P_{I,t+k}I_{t+k}\} \tag{89}$$

subject to the capital law of motion. When substituting (87) into (89), the resulting first order condition is the following

$$P_{I,t} = Q_t\left[1-\Gamma_I\left(\frac{I_t}{I_{t-1}}\right) - \Gamma_I'\left(\frac{I_t}{I_{t-1}}\right) I_t\right] + \beta\mathbb{E}_t\left[Q_{t+1}\frac{\Lambda_{I,t+1}}{\Lambda_{I,t}}\left(\frac{I_{t+1}}{I_t}\right)^2 \Gamma_I'\left(\frac{I_t}{I_{t-1}}\right)\right] \tag{90}$$

where

$$\Gamma_I'\left(\frac{I_t}{I_{t-1}}\right) \equiv \gamma_I\left(\frac{I_t}{I_{t-1}}-1\right)\frac{1}{I_{t-1}} \tag{91}$$

A.4 Government

In each country the fiscal authority's revenues consist of a set of taxes being imposed to households (both Ricardian and non-Ricardian) and firms. More specifically, τ_t^C, τ_t^N, τ_t^K, τ_t^D, corresponds to consumption, income, capital and dividend income tax rates. Total revenues of the government increase further via social security contributions, by households $\tau_t^{W_h}$ and by firms $\tau_t^{W_f}$. In addition, the fiscal authority earns seignorage on outstanding money holdings, which consist only by cash holdings by households (both Ricardians and non-Ricardians) and not deposits to financial intermediaries. Furthermore, the government receive lump-sum taxes from households as a fraction of steady-state nominal output $T_t \equiv t_t\overline{P_Y Y}$, where they are adjusted according to the following rule in order to make public debt stable across time:

$$t_t \equiv \phi_{B_Y}\left(\frac{B_t}{\overline{P_Y Y}}-\overline{B_Y}\right) \tag{92}$$

where $\frac{B_t}{\overline{P_Y Y}}$ is the fiscal authority's target for the ratio of government debt to output and $\phi_{B_Y}>0$ is a parameter. Distortionary tax rates $\tau_t^C, \tau_t^D, \tau_t^K, \tau_t^N, \tau_t^{W_h}, \tau_t^{W_f}$ are assumed to follow an AR(1) process. The government uses its revenues to finance government purchases G_t, a final good which is a composite of non-tradable intermediate good only, and transfer payments to households TR_t, which are both defined as a fraction of steady-state nominal output $P_{NT,t}G_t \equiv g_t\overline{P_Y Y}$ and $TR_t \equiv tr_t\overline{P_Y Y}$, respectively, that follow the following AR(1) process.

In the end, fiscal authority every period issues government bonds B_{t+1} on a discount to refinance its debt and neutralise its budget, with $(R_{G,t})$ being the gross government bond interest rate and $\Omega_{b,t}$ is the financing needs of the deposit insurance agency, which are recouped out of government spending. Therefore, the fiscal authority's budget constraint is as follows

$$\begin{aligned} P_{NT,t}\left(G_t+\Omega_{b,t}\right)+TR_t+\mathcal{M}_{I,t-1}+\mathcal{M}_{J,t-1}+R_{G,t}P_{C,t-1}B_{t-1} \\ =\tau_t^C P_{C,t}C_t+\left(\tau_t^N+\tau_t^{W_h}+\tau_t^{W_f}\right)W_tN_t \\ \tau_t^K\left(R_{k,t}u_t-\left(\Gamma_u\left(u_t\right)+\delta\right)P_{I,t}\right)K_t+\tau_t^D DV_t+T_t+P_{C,t}B_t+\mathcal{M}_{I,t}+\mathcal{M}_{J,t}. \end{aligned} \tag{93}$$

A.5 Financial intermediation: additional derivation

A.5.1 Retail deposit branches

The first order conditions of the retail deposit branches profit maximization implies the following recursive formulation for the average deposit rate $R_{D,t}$ dynamics:

$$\mathcal{Z}_{D1,t}^R=\frac{R_{BD,t}}{R_{D,t}}\Lambda_{I,t}D_t+\xi_D^R\beta\mathbb{E}_t\left[\left(\frac{R_{D,t+1}}{R_{D,t}}\right)^{\frac{\mu_D^R}{\mu_D^R-1}+1}\mathcal{Z}_{D1,t+1}^R\right] \tag{94}$$

$$\mathcal{Z}_{D2,t}^R=\Lambda_{I,t}D_t+\xi_D^R\beta\mathbb{E}_t\left[\left(\frac{R_{D,t+1}}{R_{D,t}}\right)^{\frac{\mu_D^R}{\mu_D^R-1}}\mathcal{Z}_{D2,t+1}^R\right] \tag{95}$$

$$1 = \xi_D^R \left(\frac{R_{D,t}}{R_{D,t-1}}\right)^{\frac{1}{\mu_D^R - 1}} + \left(1 - \xi_D^R\right) \left(\mu_D^R \frac{\mathcal{Z}_{D1,t}^R}{\mathcal{Z}_{D2,t}^R}\right)^{\frac{1}{1-\mu_D^R}} \tag{96}$$

. Deposit rate dispersion index is given by

$$\Delta_{D,t}^R = \left(1 - \xi_D^R\right) \left(\mu_D^R \frac{\mathcal{Z}_{D1,t}^R}{\mathcal{Z}_{D2,t}^R}\right)^{-\frac{\mu_D^R}{\mu_D^R - 1}} + \xi_D^R \Delta_{D,t-1}^R \left(\frac{R_t^D}{R_{t-1}^D}\right)^{\frac{\mu_D^R}{\mu_D^R - 1}} \tag{97}$$

A.5.2 Retail lending branches

The first order condition of the retail lending branches profit maximisation can be rearranged into the following recursive formulation which determines the aggregate gross financing rate for the loan officers R_{LE}:

$$\mathcal{Z}_{E1,t}^R = \frac{R_{BLE,t}}{R_{LE,t}} \Lambda_{I,t} L_{E,t} + \xi_E^R \beta \mathbb{E}_t \left[\left(\frac{R_{LE,t+1}}{R_{LE,t}}\right)^{\frac{\mu_E^R}{\mu_E^R - 1} + 1} \mathcal{Z}_{E1,t+1}^R\right] \tag{98}$$

$$\mathcal{Z}_{E2,t}^R = \Lambda_{I,t} L_{E,t} + \xi_E^R \beta \mathbb{E}_t \left[\left(\frac{R_{LE,t+1}}{R_{LE,t}}\right)^{\frac{\mu_E^R}{\mu_E^R - 1}} \mathcal{Z}_{E2,t+1}^R\right] \tag{99}$$

$$1 = \xi_E^R \left(\frac{R_{LE,t}}{R_{LE,t-1}}\right)^{\frac{1}{\mu_E^R - 1}} + \left(1 - \xi_E^R\right) \left(\mu_E^R \frac{\mathcal{Z}_{E1,t}^R}{\mathcal{Z}_{E2,t}^R}\right)^{\frac{1}{1-\mu_E^R}} . \tag{100}$$

Lending rate dispersion indexes are then given by

$$\Delta_{E,t}^R = \left(1 - \xi_E^R\right) \left(\mu_E^R \frac{\mathcal{Z}_{E1,t}^R}{\mathcal{Z}_{E2,t}^R}\right)^{-\frac{\mu_E^R}{\mu_E^R - 1}} + \xi_E^R \Delta_{E,t-1}^R \left(\frac{R_{LE,t}}{R_{LE,t-1}}\right)^{\frac{\mu_E^R}{\mu_E^R - 1}} . \tag{101}$$

B Shocks on financial wedges

In this section, we review the impulse response functions (IRFs) of the main set of financial shocks. Starting from the macroeconomic propagation of an unexpected easing of monetary policy, we analyse the sequence of financial disturbances which can stand in the way of monetary policy action. The IRFs are reported for selected variables which illustrate best the propagation of the various shocks through the banking system. With the view of enhancing the comparability of the experiments, we normalise the shocks on the financial wedges so that the response of the representative interest rate is similar across exercises. We also evaluate the macroeconomic propagation of the shocks on the various financial wedges in the symmetric case which could be rationalised as the very long-term features of the monetary union and as such constitute a useful benchmark.

B.1 Monetary policy shock

In order to gauge the strength of impairments related to the various financial wegdes, we start analysing the implications of an easing monetary policy shock in the euro area. The shock is such that there is an initial decline in the (annualized) short-term nominal interest rate of about 100 basis points and the corresponding IRFs are plotted in Figures 20 and 21.

In our model, the unexpected cut in monetary policy rate impacts the household deposit rates in a symmetric way across euro area countries. The transmission to sovereign bond yields is amplified due to mitigation of sovereign risk: the expansionary monetary policy shock leads to lower debt-to-GDP ratios and accordingly lower sovereign default probability. The mild compression of sovereign spreads also spills over to bankers funding costs which decline by more than the deposit rates.

Everything else being equal, the bank funding cost relief engineered by the monetary policy easing supports bank profitability, weakens the regulatory capital constraint, reduces bank default risk and ultimately gives scope for increasing asset origination. This propagation mechanism operates in our model and explains why the bankers financing rates decrease significantly more than the respective funding costs.

The easing of financing conditions finally transmits to commercial lending rates for entrepreneurs. Improving economic conditions and higher price of capital loosens the financial constraints on the corporate sector, with lower corporate default rates and external financing premium. Such a financial accelerator mechanism implies that the commercial lending rates decrease more than the *ex ante* return on loans and that the unexpected improvements on loan losses also contribute to support bankers capital position: indeed, the *ex post* return on loans improves on impact before declining in line with the other financing costs. Overall, the pass-through to commercial lending rates of an unexpected and temporary decline of the monetary policy rate by 100 bps is around 60 bps. This feature is broadly in line with euro area wide evidence.

Beyond the interest rate channel predominantly acting on Ricardian household consumption, the favourable credit conditions stimulate investment and credit. Bank loans are demand driven and depend on the capacity of entrepreneurs to finance their investment projects from their net worth or debt. In the case of stimulating monetary policy, net worth increases, alleviating the borrowing constraint of entrepreneurs, resulting in lower demand for loans. Labour demand and real wages pick up and further support the consumption dynamics of Ricardian households. Overall, domestic inflationary pressures emerge and are reinforced by the initial nominal exchange rate depreciation.

Given our symmetric calibration of the financial block, the cross-country heterogeneity in the transmission channel of monetary policy is very limited notably for the response of the various financial wedges. On output, consumption and investment, the monetary impulse appears marginally weaker in Germany and in the rest of the euro area than in Italy, Spain or France. Those differences and mainly driven by the asymmetries stemming from the trade block.

B.2 Sovereign risk premium shock

Figures 22 and 23 present the IRFs from symmetric $\xi_{G,t}^{max}$ shocks for all euro area countries so that government bond yields increase by 100 bps (in annual terms) on impact. The unexpected increase in the sovereign spreads spills over to bankers funding costs which weakens bankers profitability. This tightens the regulatory capital constraint and pushes bankers to charge higher financing rates. The general equilibrium effects of this transmission also imply higher corporate default and unexpected loan losses which exert further pressure on bankers capital position. The decline in money market rates stemming from the monetary policy accommodation offsets only partially the funding strains of bankers.

The pass-through of the sovereign risk shock to commercial lending rates reaches 45 bps, of which less than 10 bps are due to real-financial amplification through higher credit risk compensation and capital shortfalls. This magnitude is comparable to the findings of Altavilla et al. (2014) regarding the propagation of the ECB Open Market Transaction announcement, interpreted as a sovereign risk premium shocks on financial conditions.

The increase in financing costs for entrepreneurs weights on investment and credit dynamics while the monetary policy response dampens somewhat these adverse effects both through the supportive interest rate channel on household consumption and to a lesser extent through the favourable expenditure switching effects triggered by the initial nominal exchange rate depreciation. Compared with the transmission of the accommodative monetary policy shock, the negative effects of the sovereign tensions are relatively more pronounced on activity than on inflation. While the 100 bps cut in the policy rate generated peak response of 0.7% and 0.5% on euro area output and annual CPI inflation respectively, the 100 bps surge in bond yields leads to 0.2% lower output for only 0.07% less inflation. The cost-push nature of financial wedge shocks is a constant feature of our model, as it will become clear in the following simulations.

Regarding cross-country heterogeneity, the transmission of the shock to economic activity is less pronounced and slower in Germany or in the rest of the euro area. This is partially related to investment and consumption responses and is mainly driven by asymmetric trade channels.

B.3 Bank capital shock

Figures 24 and 25 present the IRFs from common bank capital shocks across euro area countries, scaled such that the maximum increase in the bankers financial rate is 100 bps (in annual terms) after 12 quarters. This can be rationalised as the recent financial crisis led banks to incur substantial losses on their trading and loan books, which in turn put severe pressure on their capital positions. In order to return to a more stable capital situation and possibly responding to pressures from regulators and market participants to operate with more solid capital buffers, banks have been faced with a trade-off of either raising new capital or adjusting their asset side, or (more likely) a combination of the two. Our model specification can be used to assess the macroeconomic implications of such shocks to bank capital.

The bank capital shock results in excessive bank leverage and higher risk of breaching the minimum capital requirements. In order for banks to replenish their capital buffer, bankers persistently increase their loan-deposit margins. The tightening of financing conditions finally reaches out to entrepreneurs through higher commercial lending rates. In the first quarters of the simulation, commercial lending rates increase significantly more than the required return on loans as contracting output and depreciating asset values imply higher credit risk compensation. This phenomenon reverses through the simulation horizon as corporate indebtedness and default rates recede, giving scope for the credit risk compensation to normalise. Actually, the bank capital shock has two types of "second round" financial effects in our model. The first one relates to corporate balance sheet channels through loan losses and credit risk, as mentioned before. The second one is associated with government indebtedness and sovereign risk: weak banks tightened financing conditions, investment and output contract, government debt-to-GDP increases along with the sovereign spreads which exerts additional constrains on bank funding. This amplification channel is noticeable in the more moderate decline of sovereign bond yields than deposit rates. This feedback loop would be stronger if financial sector rescue program were considered.

For the euro area as a whole, the tightening of loan supply conditions driven by the bankers deleveraging process, leads to more than 7% cumulated decline of loans and weights strongly on capital expenditures, with investment contracting by more than 10%. The corresponding fall in output amounts to less than 2%. In line with the empirical literature on credit supply, the response of credit lags the adjustment of output and is from 3 to 5 times larger (see Darracq Pariès and De Santis (2015) for example).

Monetary policy responds counter-cyclically and the policy rate decreases by almost 100 bps after two years. The monetary policy accommodation facilitates somewhat the bankers deleveraging process through substantial funding cost relief. In addition, it stimulates consumption expenditures from the Ricardian households. Should the central bank fail the respond to such banking system vulnerabilities (either due to the lower bound on interest rate or due to the localised nature of the shock in a monetary union), the macroeconomic multipliers would be compounded.

The model comparison exercise of Guerrieri et al. (2015) focuses on the macroeconomic propagation of financial shock similar in nature to the bank capital shock considered in this section. The macroeconomic impact in our model turns out to be very close to the simulations based on Kiley and Sim (2014) and qualitatively similar to the ones of Iacoviello (2015).

Turning to cross-country features of the IRFs, the heterogeneity through the intermediation chain is small but stronger than in the shocks of the previous sections. In this simulation, some asymmetric responses across countries are somewhat amplified via the sovereign-bank nexus. As in the previous simulation, the output contraction in Germany and the rest of the euro area is smaller during the first years. This results in relatively less pronounced increase in government indebtedness which translated into relatively lower bond yields and bankers funding costs.

B.4 Lending rate markup shock

Figures 26 and 27 present the IRFs from common retail lending markup shocks for all euro area countries such that the maximum increase in the *ex ante* bank return on loans is 100 bps.

The typology of this financial wedge shock is akin to an inefficient increase to the external financing premium but it also entails some mitigation of the bank capital friction. Indeed, by temporarily raising "pure" profits in the retail bank segment, the lump-sum transfers to bankers improve, which facilitates their capital accumulation process and loosens the regulatory constraint. This mechanism is noticeable in the significant decline in bank leverage through out the simulation together with the long lasting moderation in bank risk which leads to a sizeable compression of bankers intermediation spread (between bankers financing rate and their funding costs).

These counterbalancing effects explain the relatively less adverse macroeconomic multipliers on investment and output than in the other financial wedge shocks (also see next subsection). Actually, the protracted decline in the bankers financing rate, driven by persistent "excess capital" position of bankers, enables loans to recover rapidly after the shock and investment to go back to baseline after three years. Similarly, the mild disinflationary pressures dissipate quickly. By comparison, the sovereign risk shocks considered previously have similar peak effects on output and investment (albeit with more persistence) with only 30 bps increase in the bankers refinancing rate.

As in the previous case, some asymmetric responses across countries are marginally amplified via the sovereign-bank nexus, with the government yield declining somewhat more in Germany than in the other large euro area economies.

This simulation illustrates well some second-best configurations in banking frictions, whereby "pure" rents could even support broad macroeconomic performance at times of weak bank balance sheet conditions. Conversely, the long-term macroeconomic benefits of fostering competitive pressures within the banking system crucially hinge on the strength of bank capital position and on the effectiveness of regulation in deterring excessive risk taking.

B.5 Corporate risk shock

Figures 28 and 29 show the IRFs from common corporate risk shocks among euro area countries, scaled such that the commercial lending rates increase by 100 bps. This typology of financial wedge shock triggers a financial accelerator mechanism, whereby changes in borrower creditworthiness are propagated throughout the economy in the presence of demand-side credit market frictions. Higher borrower riskiness raises default probabilities, reduces lending to and spending by the corporate sector.

In our model, the surge in loan losses also reinforces the real-financial feedback loop through the erosion of bankers capital buffer and the subsequent tightening of credit supply conditions. More specifically, the loan contracts offered to entrepreneurs feature pre-determined lending rates which are set to cover for expected losses. Once next period uncertainty is realised, actual losses defer from the expected ones. This gap is particularly strong after an idiosyncratic corporate risk shock as considered in these IRFs, and it is noticeable from the relative response of the *ex ante* and the *ex post* retail bank return of Figure 29. The write-downs on loan exposures also explain the sharp rise in bank leverage and bank risk on impact. Note that the regulatory risk-weights are kept constant, in line with the assumption of through-the-cycle measurement of probability of default. We will review this assumption and explore its implications later on.

The cost of financing shock of this section turns out to have a strong and protracted effect on loan provision due to the compounded effects of both borrowers and lenders balance sheet vulnerabilities. Accordingly, cutbacks in capital expenditures are the main contributor to output contraction as in the previous financial wedge shocks. In this simulation, the peak output effect of the 100 bps exogenous increase in the commercial lending rate is twice stronger than in the simulations with comparable raise in either retail lending rates, following markup shocks, or government bond yields, after sovereign risk shocks.

As in the previous cases, monetary policy accommodates the negative effects on output and inflation. The easing of the monetary stance is imperfectly passed through to bankers financing rate. Two factors stand in the way of monetary policy conduct. First, the rise in sovereign risk pushes up government bond yield spreads and spills over to bankers funding cost. Second, weaker bankers capital position contributes to higher loan deposit margins at this stage of the transmission mechanism.

C Sensitivity to cross-country heterogeneity in financial frictions

C.1 Sovereign-banking nexus

First, we focus on the cross-country asymmetries in sovereign risk calibration, which governs the strength of the sovereign-banking nexus in each euro area country. Two sets of shocks are considered. The first one is a public debt shock where we assume that all euro area countries face the same *ex ante* increase of their debt stock, everything else being equal. This shock has no sound structural foundation as such events would normally imply some transfer to another sector of the economy, but it enables to activate the precise mechanism that we want to isolate. The second shock is the same bank capital shocks that we studied in the previous section and is well-suited to show how the asymmetric calibration affect the sovereign-banking feedback loop across the euro area.

Figure 30 shows the IRFs corresponding to the common sovereign debt shock, which is calibrated *ex ante* to increase by 10 p.p. the annual debt-to-GDP ratio. The response of sovereign yields is dramatically stronger in Italy and to a lesser extent in Spain, reaching more than 300 bps and 200 bps respectively over the first quarters. By comparison, yields in France barely increase to 50 bps, and even less in Germany. Such diverse developments diffuse thereafter through the intermediation chain with commercial lending rates peaking at around 175 bps in Italy, 100 bps in Spain, less than 25 bps in France and negligible levels in Germany. The same picture also extends to credit and activity multipliers, with peak effects ranging from a maximum in Italy at 1% for GDP and 3% for loans, to marginal impacts in Germany. Despite such real-side asymmetries, the responses are more similar on inflation. In particular the decline in Germany is significant. Several factors explain this. The most acute propagation of sovereign stress in Italy or Spain also entails a cost channel on price formation through higher rental rate of capital which mutes the fall in inflation due to weak economic activity. By contrast, the macroeconomic spillovers to countries like Germany mainly reflect trade channels and translate more directly into downward price pressures.

Turning to the transmission of bank capital shocks, Figure 31 report the corresponding IRFs, in deviation from the symmetric case of section B.3. The asymmetric credit risk calibration implies significantly more tightening of financing conditions in Italy, by 20 bps more on average over the intermediation chain. Given the higher level of sovereign debt and spreads and spreads sensitivity, the credit-supply driven economic slowdown has stronger impact on debt dynamics and the associated increase in bond yields. For France and Germany, the sovereign risk channel is somewhat muted compared to the symmetric case, while for Spain, the IRFs on the financing costs are broadly unchanged as the lower steady-state public debt level compensates the stronger sovereign spread elasticity. Through trade spillovers however, the macroeconomic amplification on output also affect France and Germany. The most affected country remains Italy which faces almost 0.6 further output loss compared to the benchmark case.

C.2 Bank capital frictions

The bankers decision problem is mainly driven by two parameters: χ_b, which determines the regulatory penalty, and σ_b, the standard deviation of the idiosyncratic risk on bankers asset returns. The association of these parameters to key features of euro area heterogeneity in banking systems is empirically challenging. Nonetheless, we consider an asymmetric calibration whereby steady-state bank risk would be higher in Italy and Spain, which to some extent could correspond to conditions prevailing in the run-up to the crisis. Besides, we analyse asymmetrically higher regulatory penalties in Italy and Spain, keeping σ_b unchanged. This configuration may reflect the different regulatory pressures exerted on the various euro area jurisdictions during the crisis. But more than the empirical validation of such calibrations, we are interested in the sensitivity analysis of the propagation mechanism to parameters of the bankers decision problem, which plausibly contributed to financial imbalances in the pre-crisis period, and to financial fragmentation through the crisis.

Starting with the higher bank risk calibration, we review the IRFs of monetary policy and bank capital shock, in deviation from the symmetric case of section B. From virtually zero, the steady-state probability of bank default increases to 1% annually in Italy and Spain. In this case, two main changes are noticeable compared to the symmetric calibration. First, bankers financing rate becomes less responsive to funding or profitability shocks and their balance sheet adjustments take much longer. Second, higher probability of default activates the limited liability distortion in bankers decision problem. Risk-shifting behaviour enters into play so that weaker capital position for example, would incentive bankers to originate more credit than otherwise, in order to benefit from the implicit subsidy of the deposit insurance. This second channel also reinforces the first one and can be isolated by comparing to similar IRFs without the limited liability distortion (see section 4.2.1 of the model description).

Looking first at the monetary policy shock in Figure 32, bankers refinancing rates and financing costs through the intermediation chain do not decline as much as in the symmetric case for Italy and Spain during the first quarters. But later on, financing conditions ease by more, for a protracted period of time. Actually, the monetary impulse on activity ends up being longer lasting in these countries, with higher bankers leverage and risk in the medium term. After the bank capital shocks, whose IRFs are shown in Figure 33, the responses of bankers financing rates in Italy and Spain are significantly below the symmetric case, and actually fall below steady state: risk-shifting implies that bankers ease their lending standards in absolute terms, and persistently operates with excess leverage when confronted with capital buffer erosion. This channel is evident in comparison with the simulations without limited liability distortion. As shown in Figure 34, bankers refinancing rates still respond more sluggishly in Italy and Spain than in the symmetric case but gradually increase in deviation from the baseline.

Strengthening the regulatory penalty amplifies the bank capital channel in our model. Bankers are pushed to recoup more forcefully any capital shortfall through higher loan-deposit margins. Regulatory pressures have also the benefits of mitigating the limited liability distortions and therefore deterring risk-shifting behaviour. Accordingly, we will not present here the comparison with the no-limited liability case, as this distortion is almost inoperative in the benchmark calibration. Figure 35 displays the corresponding IRFs after bank capital shocks. As expected, lower capital buffers lead to stronger increase in bankers financing rates and more pronounced deleveraging pattern than in the symmetric case, for Italian and Spanish banks. This leads to more adverse credit supply conditions in those countries, curtailing loan origination, investment dynamics and economic activity.

Overall, our model shows that loose monetary policy, lenient regulatory framework and excessive risk-taking behaviour have the potential to explain the build-up of vulnerabilities before the crisis. Conversely, the tightening of regulatory requirements together with delayed and protracted adjustment of bank balance sheets occurred during crisis in some jurisdictions, and constitute distinct features that our model can reproduce. More realistic scenarios along those lines are analysed in the final section.

C.3 Monopolistic competition in banking

In our model, the magnitude and speed of bank lending rate pass-through are also affected by the degree of imperfect competition in retail lending branches and the presence of nominal rigidities. These frictions prevent retail bankers from reacting on a regular basis to changes in their refinancing rates, which *inter alia* reflect funding conditions and the cost of capital of bankers.

The nominal rigidities introduced in the retail branch segment and the asymmetric calibration presented in subsection 5.2 qualitatively reflect the available empirical evidence on lending rate pass-through within the monetary union. Across euro area countries, the heterogeneity in bank lending rate setting is characterised by higher sensitivity of Italian and Spanish lending rates to short-term market rates while the lending rates in France and Germany respond to longer-term market interest rate. In all cases, the changes in respective market rates are passed only gradually to the final borrowers. Recent empirical studies document the apparent breakdown of pass-through regularities during the euro area crisis and show that once controlling for specific financial shocks, the pass-through of risk free rates into lending rates remain operative (see Darracq Pariès et al. (2014) and Illes et al. (2015) for example). Our specification of the segmented banking sector enables to consistently reproduce these features: the staggered setting of lending rates in the retail branches should be interpreted as a "summary" friction accounting for the maturity transformation in banking, the indexation of loan contracts in some jurisdictions (for example, floating mortgage loans in Italy or Spain), and the infrequent re-setting of expected asset returns in response to group-wide capital or funding position.

To illustrate the implication of asymmetric lending rate setting on macroeconomic propagation, we focus on monetary policy and sovereign risk shocks which are displayed in Figures 36 and 37, respectively. The IRFs are presented in deviation form the symmetric cases of section B.

After a monetary policy shock (Figure 36), the relative strength of the bank capital channel comes from the differences in nominal rigidities in lending rate setting: bank profitability in countries with low lending rate pass-through increase more than in countries with high lending rate pass-through. The decline in the *ex ante* loan returns is stronger in Italy and Spain than in France and Germany, which limits the increase in net interest rate margins of bankers and the leveraging capacity in these countries. This also explains why the bankers refinancing rates decline relatively less in Italy and Spain as to recoup their capital buffer erosion. Consequently the monetary policy impulse on investment and economic activity is temporarily amplified in France and Germany as their capital position is relatively more favourable. Notice however that the heterogeneity generated by the asymmetric staggered lending rate setting is quantitatively small beyond the financial block.

Turning to sovereign risk shocks (Figure37), the heterogeneity now operates on the opposite way for the "shorter-term" lending countries. The sovereign tensions lead to higher bankers funding costs which are more rapidly passed over to *ex ante* loan returns in the case of Italy and Spain, thereby shielding somewhat bankers interest rate margins. Consequently, the erosion of bankers capital buffers is milder in those countries than in Germany and France. This generates lower deleveraging needs and attenuates the adverse real-financial feedback loop. As for the previous shocks, the asymmetric calibration delivers marginal changes in propagation to output and inflation, but significantly affect the cyclicality of bank profits and capital structure.

C.4 Corporate balance sheet frictions

Introducing cross-country heterogeneity in demand-side credit frictions also affect the transmission of monetary policy and financial wedge shocks. As explained in the section on calibration, private sector indebtedness and credit risk could reflect country-specific conditions, leading notably to higher steady-state external finance premium in Spain and Italy, as well as more leveraged entrepreneurs in Spain, Italy and France. The rest of the euro area is left unchanged compared with the symmetric case. Accordingly, the traditional financial-accelerator mechanism will be weaker in Germany and the rest-of-the-euro-area than in the other euro area countries.

To quantify this, we simulated the same monetary policy shock and bank capital shocks as in section B. Figure 38 show the corresponding IRFs, in deviation form the ones of the symmetric case. After an accommodative monetary policy shock, credit risk improves and commercial lending rate compresses further in Italy and Spain. This spurs more capital expenditures and output. The impact on economic activity is also stronger in France due to higher corporate indebtedness (despite relatively less risky borrowers). The amplification remains moderate though in those countries and amount to less than 10% of the peak output. When considering the bank capital shock, the real-financial feedback loop across euro area countries is relatively more influenced by our asymmetric calibration (and this would also hold for the other financial wedge shocks). As Figure 39 shows, indeed, the output contraction is simulated to around 0.5 p.p. stronger than in the symmetric case for Italy and Spain. Due to higher debt stock and corporate risk, the bank deleveraging process takes marginally more time as bankers have to weather more losses on their loan exposures.

To sum up, our model has the ability to contemplate euro area financial fragmentation through the lens of adverse real-financial feedback loops in some jurisdictions, where overly indebted corporations contaminate the banking system or where undercapitalized banks tighten credit conditions and put at the risk the ability of the corporate sector to cope with persistent fall in demand. These considerations will be exploited in the last section of the paper.

C.5 Cross-border financial linkages

The model can explicitly allow for financial spillovers across the euro area. In a stylized way, we introduced cross-border lending between bankers and retail branches in other countries. The composition of cross-border flows for each country is determined by a CES technology. In principle, such a specification could be strictly interpreted as covering credit transactions between a domestically regulated financial intermediary and a foreign non-financial agent. The calibration presented in section 5.2 was conducted accordingly. In this way, a large part of bank cross-border exposures is excluded and the degree of financial openness is quite low for some jurisdictions. We could instead have considered the sum of loans and debt securities given to both foreign banks and non-banks, as interbank claims is the major channel of financial cross-border linkages, rather than direct loans to foreign households and firms. This would be less consistent with our micro-foundations but would capture the effective size of cross-border spillover across countries. In the following simulations we keep the narrow interpretation of cross-border lending, bearing in mind that it may understate the magnitude of direct financial spillovers. Accounting for interbank lending would require additional modelling efforts that we leave for further research.

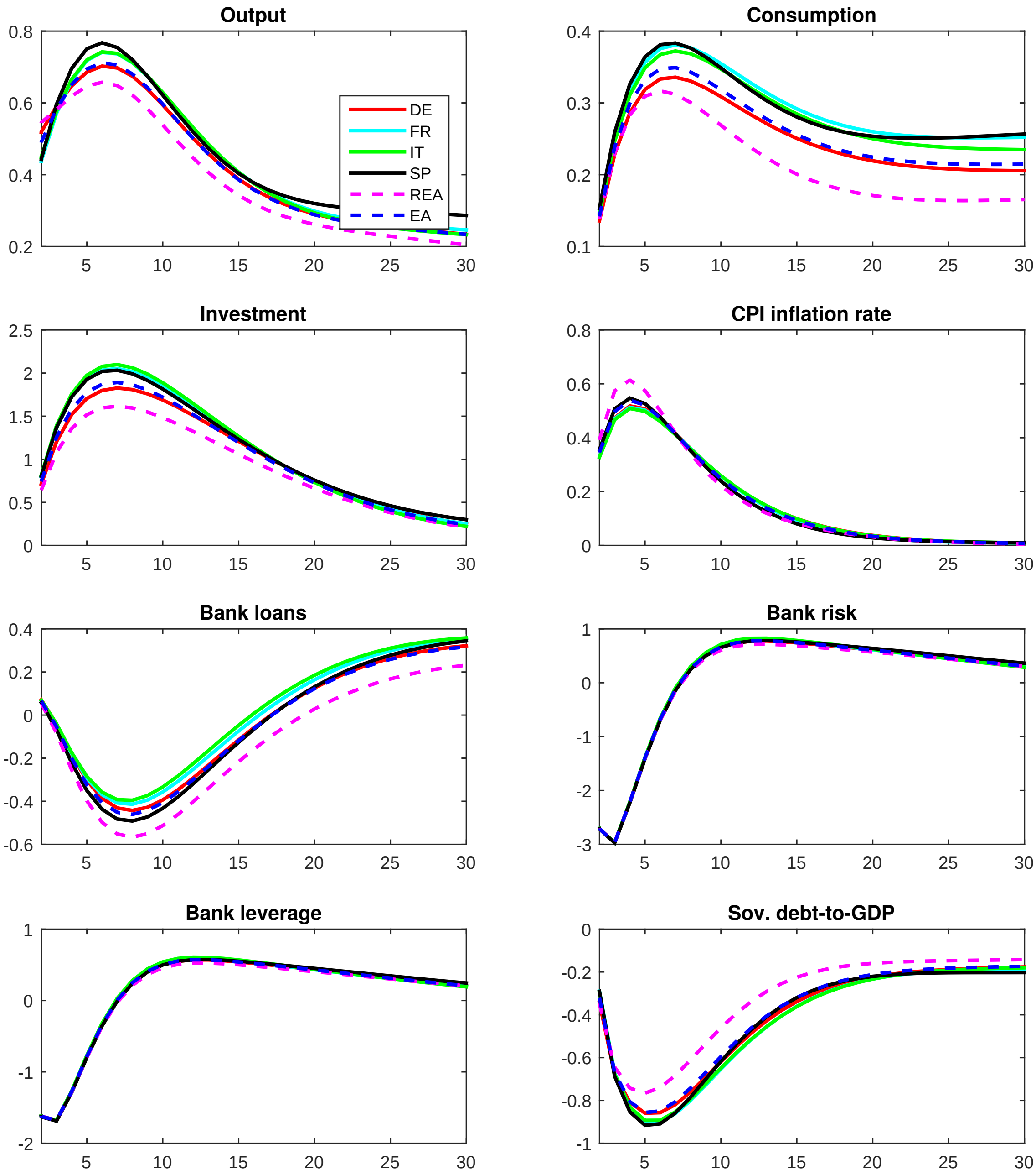
To illustrate the cross-border lending channels, we simulate country-specific capital shocks within the euro area. Figures 40 and 41 present the matrix of impacts for two variables, the *ex ante* return on loans and output, comparing the IRFs with and without cross-border lending. Cross-border lending takes place at the stage of retail branches so that the relative responses of the required return imposed on loan officers provide a good summary of direct financial spillovers in our model. After a bank deleveraging shock, the domestic banking vulnerabilities are passed over to the foreign jurisdictions which are most funding dependent on them. As explained in section 5.2, Germany, Italy and rest-of-euro area are receiving more cross-border flows. Conversely, Spain appears relatively close to inflows and mainly finances the rest-of-euro area.

Let us focus on the propagation of a shock on Italian banks and compare the IRFs in the absence of cross-border flows. The rise of loan returns in Italy is a contractionary shock that monetary policy would accommodate, thereby leading to an easing in financing conditions in other countries. However, the transmission of monetary policy is hampered in jurisdictions most dependent on funding from Italian banks: this is true for Germany, and to a lesser extent rest-of-euro area, where the return on loans fails to ease as it would be the case in the absence of cross-border lending. In the other countries, further monetary policy accommodation in equilibrium and consequently lowers the return on loans, notably in France. Turning to the impact on economic activity and considering again the shock on Italian banks, cross-border exposures change the sign of the transmission to Germany and imply a negative effect on output. All these features extend in particular to the transmission of shocks in France to Italian and rest-of-euro area banks, or shocks in rest-of-euro area to Italian banks.

As explained before, our interpretation of cross-border exposures is quite restrictive and ignores claims between banking jurisdictions within the monetary union. Besides, the model does not formalize any type of financial market contagion between sovereign or banking segments. At this stage such dimensions are left for future research.

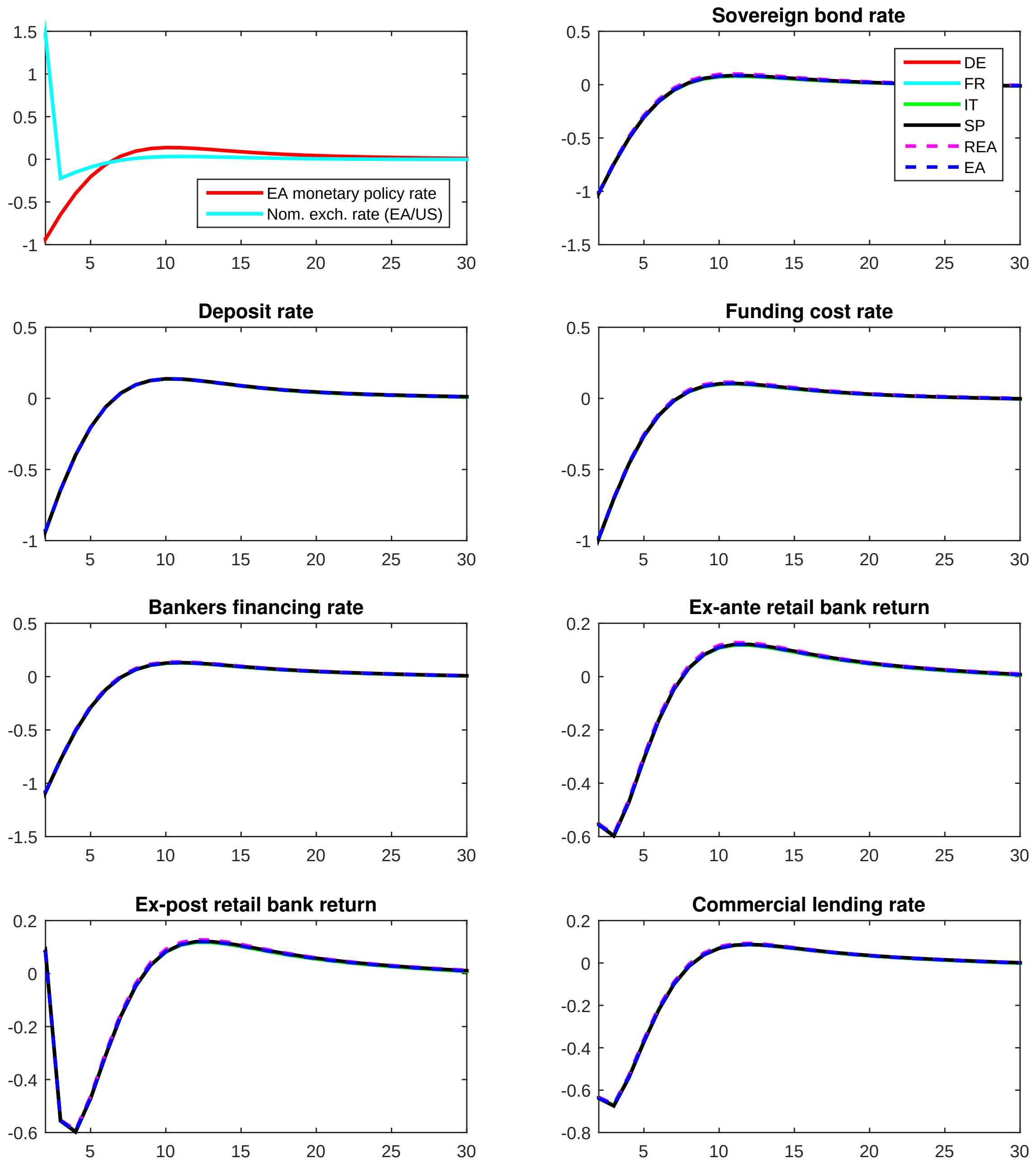
D Shocks on financial wedges

Figure 20: Reduction in the euro area **monetary policy rate** - Symmetric calibration



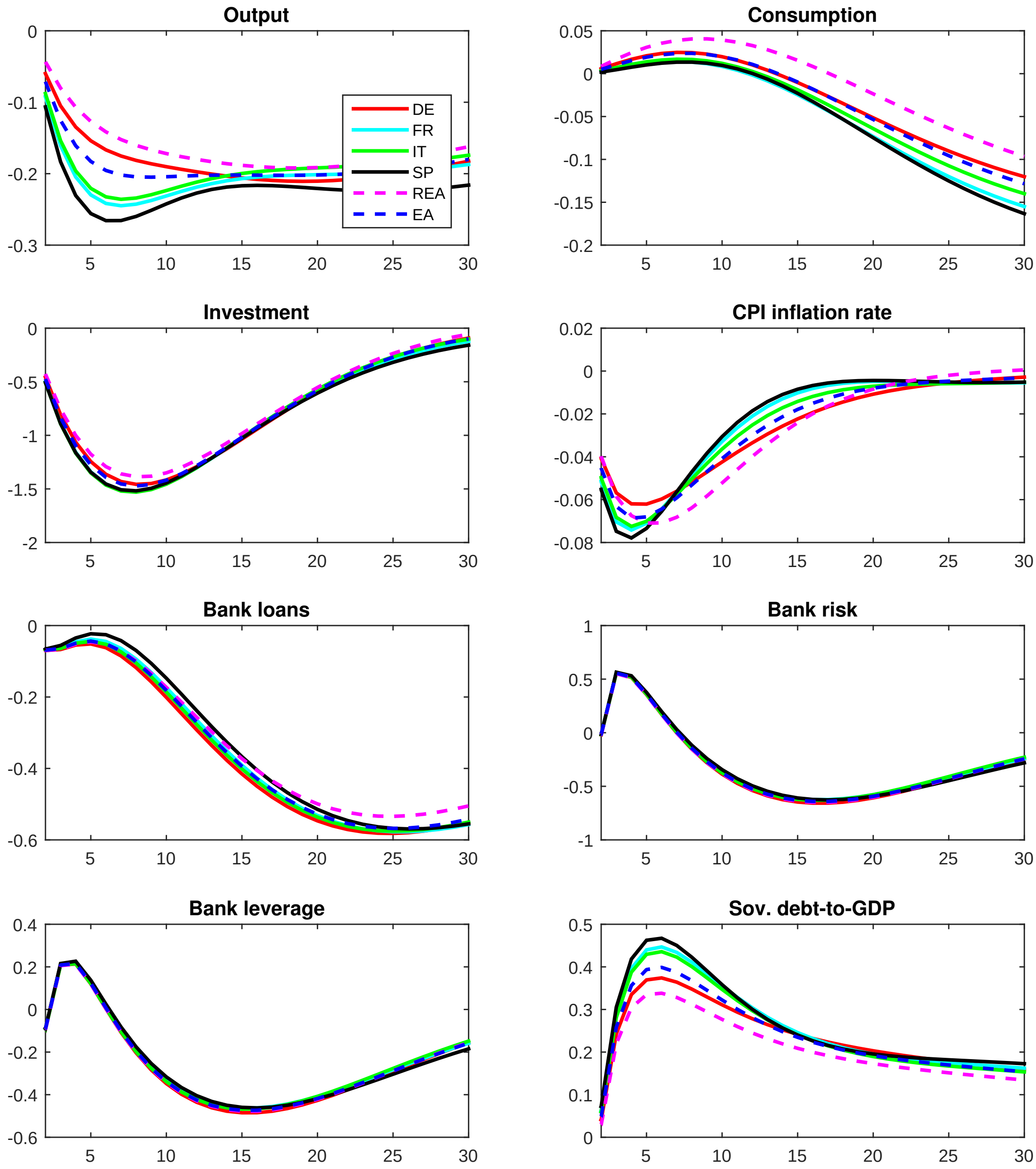
Notes: decrease of euro area monetary policy rate $\varepsilon_{R,t}$ by 1 percent in annual terms in the first period. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed as a quarterly percentage-point deviation and except for inflation and debt-to-GDP which are expressed as annual percentage-point deviations. GDP, its components, bank loans and bank leverage are reported in real terms.

Figure 21: Reduction in the euro area **monetary policy rate** - Symmetric calibration



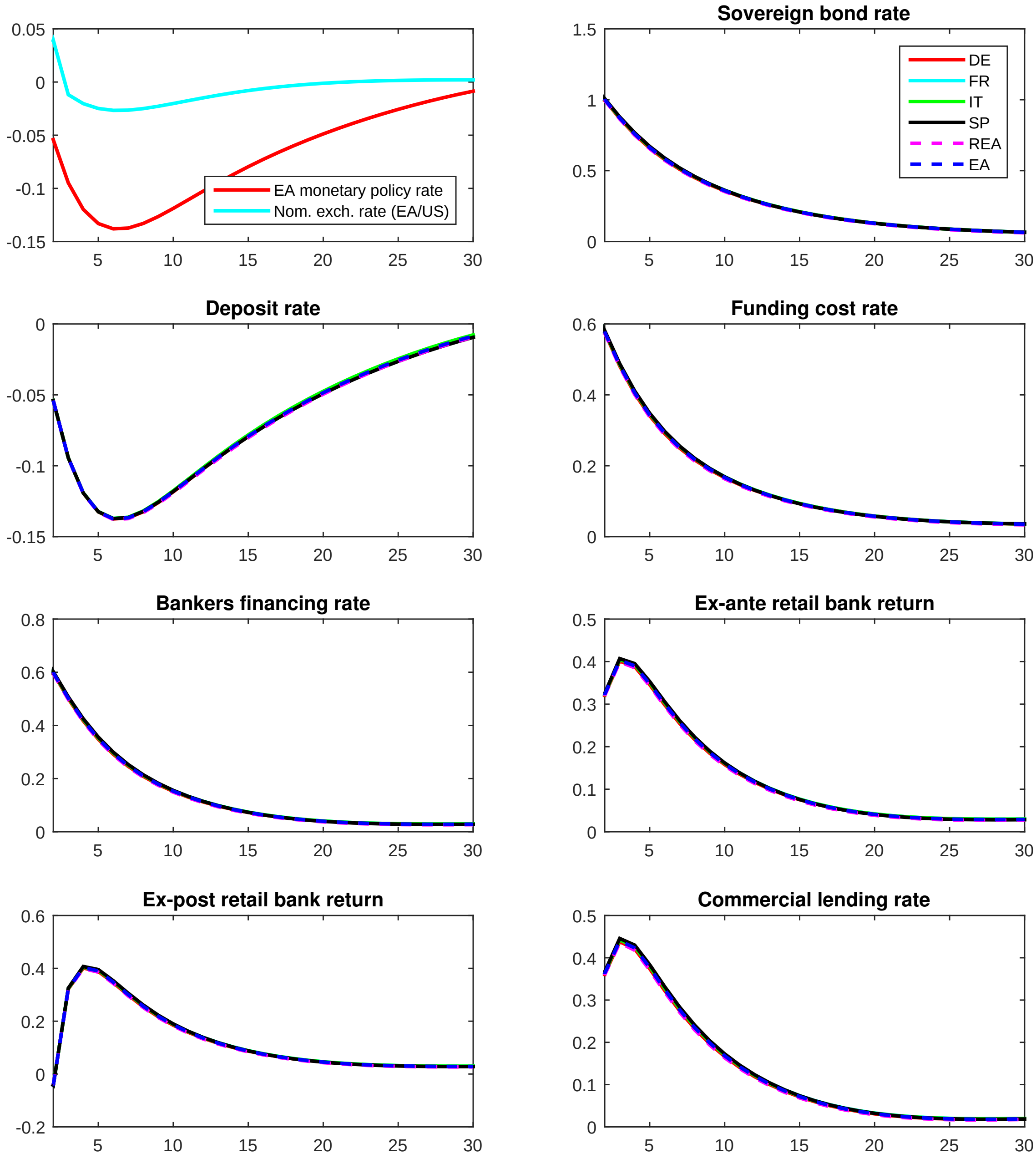
Notes: decrease of euro area monetary policy rate $\varepsilon_{R,t}$ by 1 percent in annual terms in the first period. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 22: Increase euro area **sovereign risk premium** - Symmetric calibration



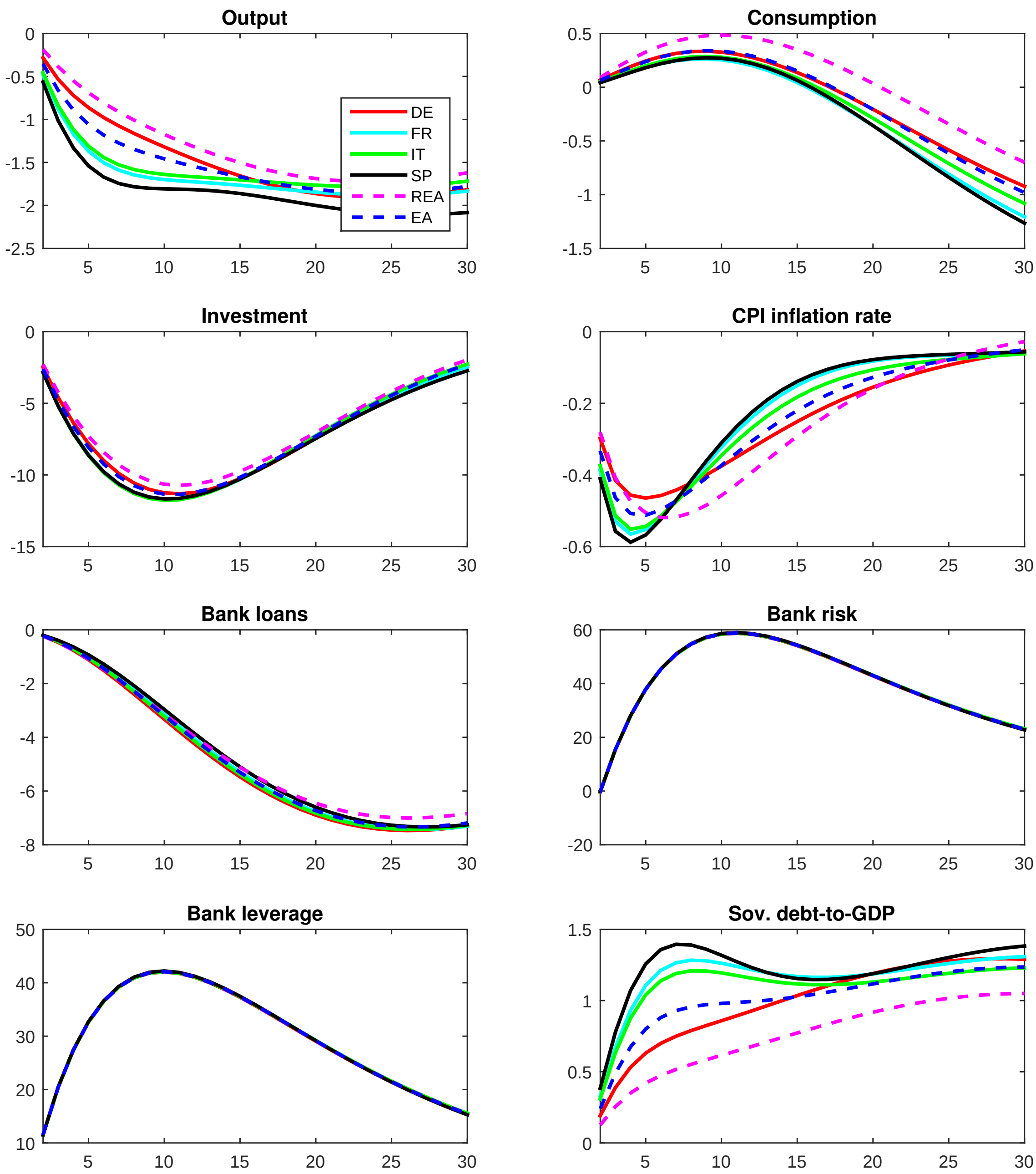
Notes: increase of the euro area loss given default so that sovereign bond yields increase approximately by 1 percent in the first period; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed as a quarterly percentage-point deviation and except for inflation and debt-to-GDP which are expressed as annual percentage-point deviations. GDP, its components, bank loans and bank leverage are reported in real terms.

Figure 23: Increase euro area **sovereign risk premium** - Symmetric calibration



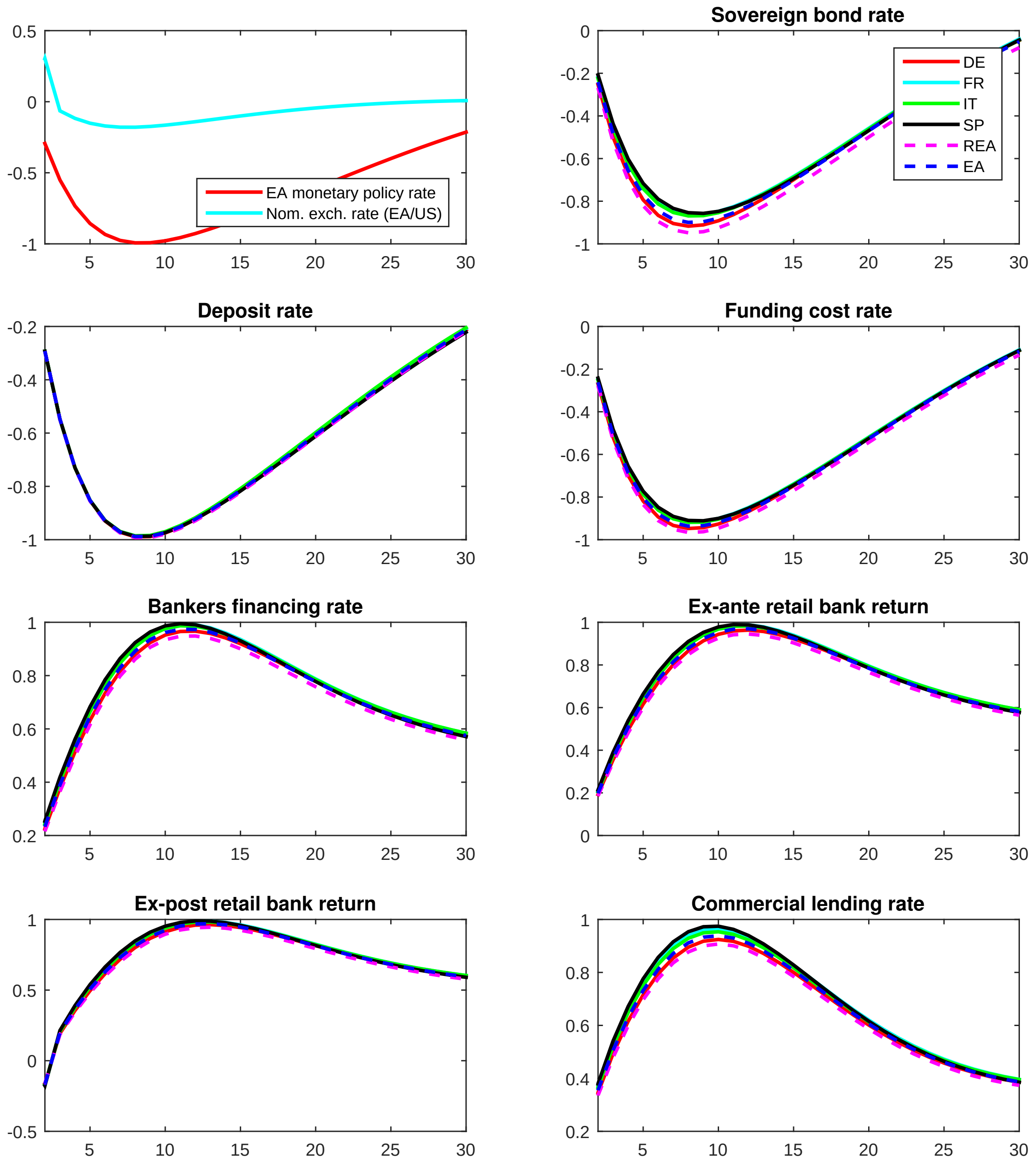
Notes: increase of the euro area loss given default so that sovereign bond yields increase approximately by 1 percent in the first period; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 24: Negative euro area **bank capital shock** - Symmetric calibration



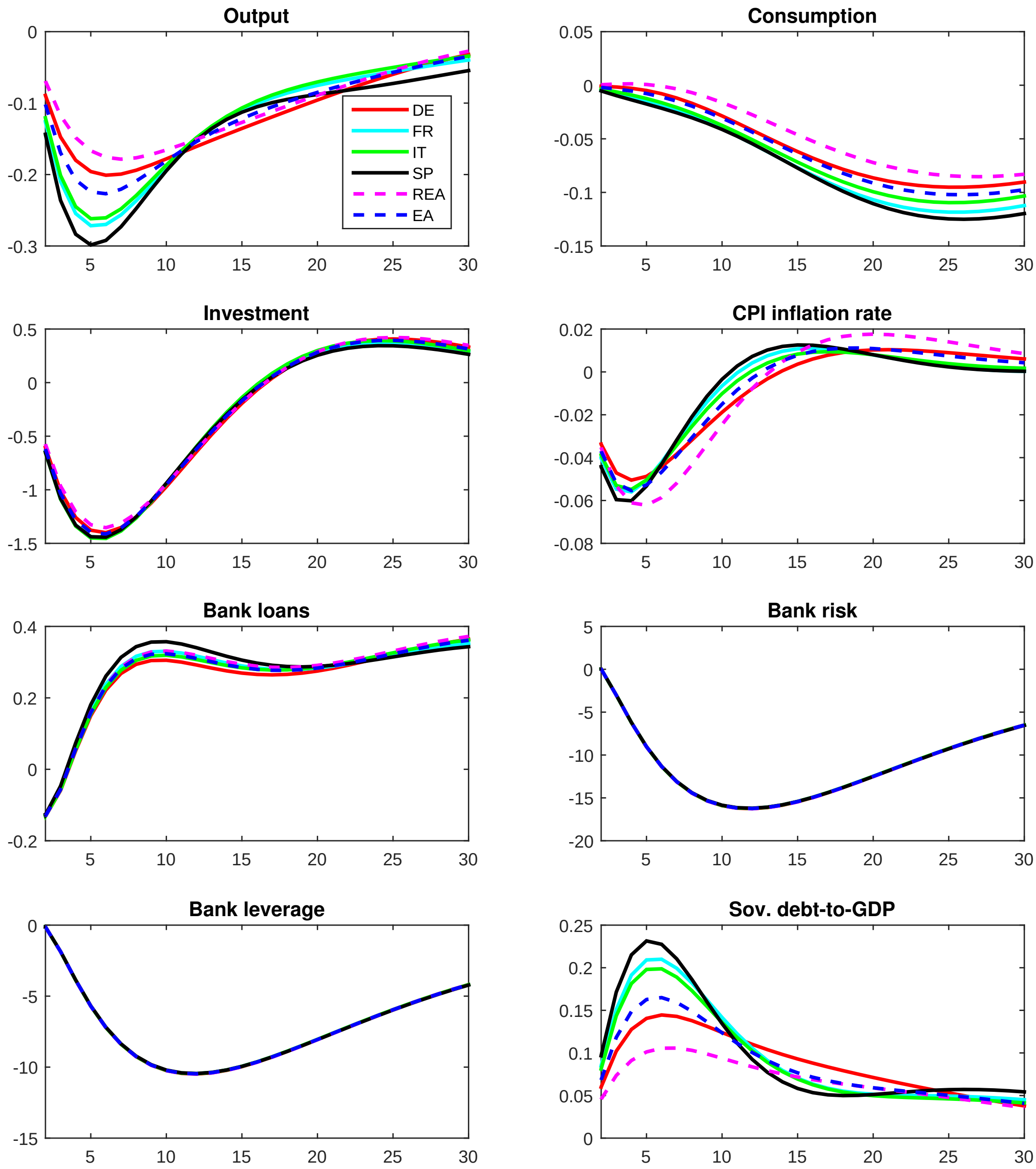
Notes: decrease of the euro area bank capital so that bankers financing rate increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed as a quarterly percentage-point deviation and except for inflation and debt-to-GDP which are expressed as annual percentage-point deviations. GDP, its components, bank loans and bank leverage are reported in real terms.

Figure 25: Negative euro area **bank capital shock** - Symmetric calibration



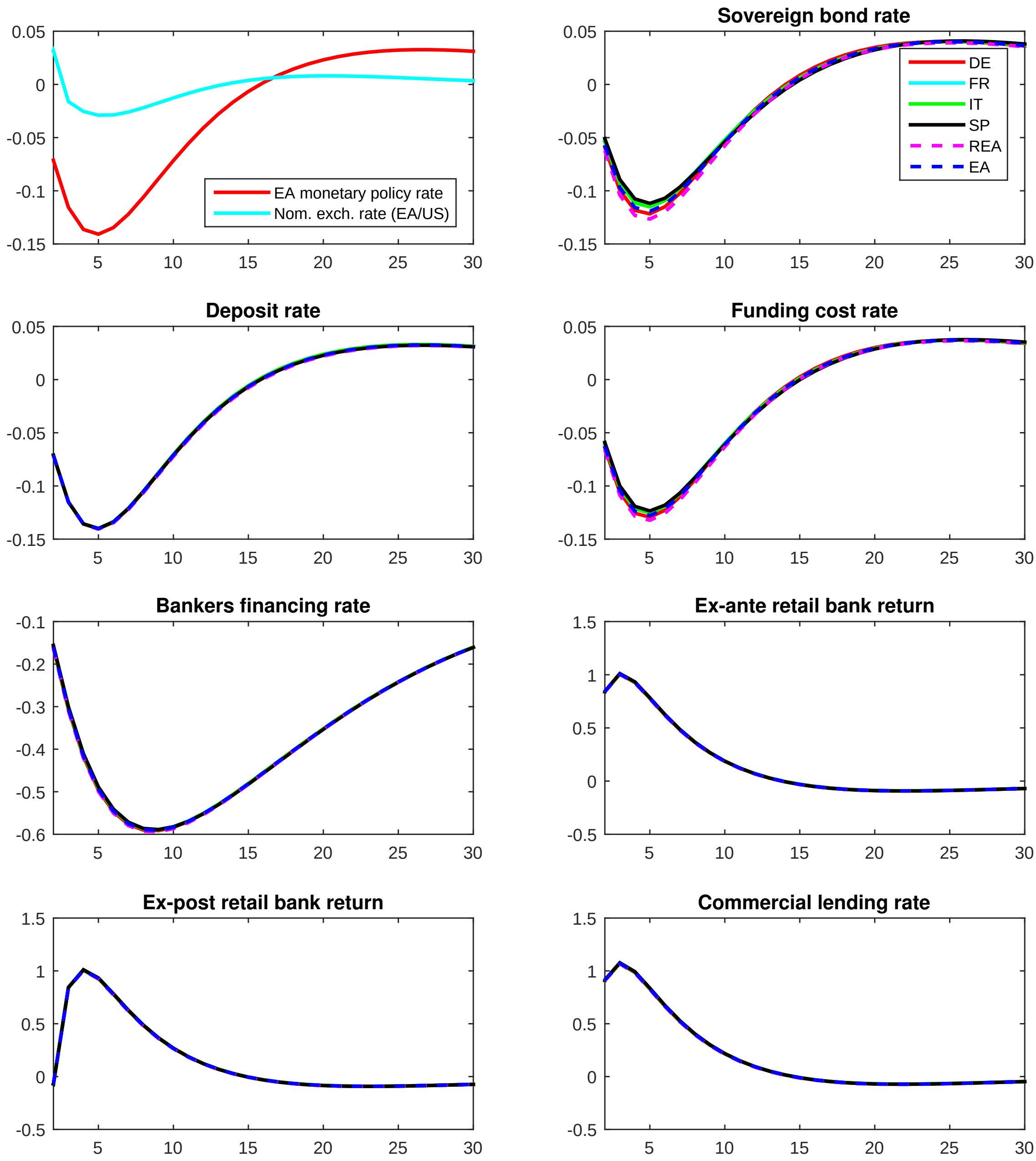
Notes: decrease of the euro area bank capital so that bankers financing rate increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 26: Positive temporary euro area **competitive mark-up shock** - Symmetric calibration



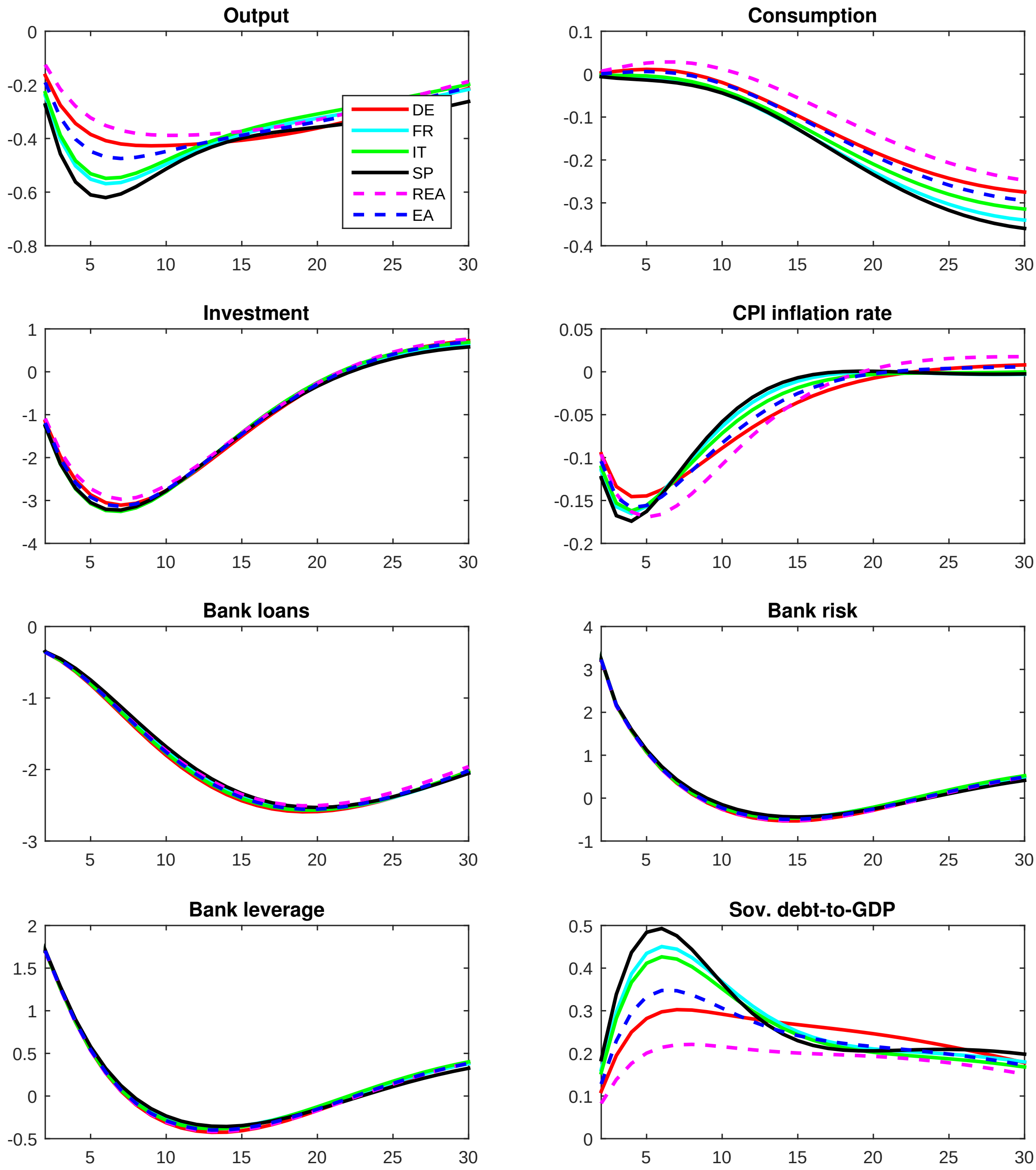
Notes: increase of the euro area bank mark-up μ_E^R so that the ex-ante retail bank return increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed as a quarterly percentage-point deviation and except for inflation and debt-to-GDP which are expressed as annual percentage-point deviations. GDP, its components, bank loans and bank leverage are reported in real terms.

Figure 27: Positive temporary euro area **competitive mark-up shock** - Symmetric calibration



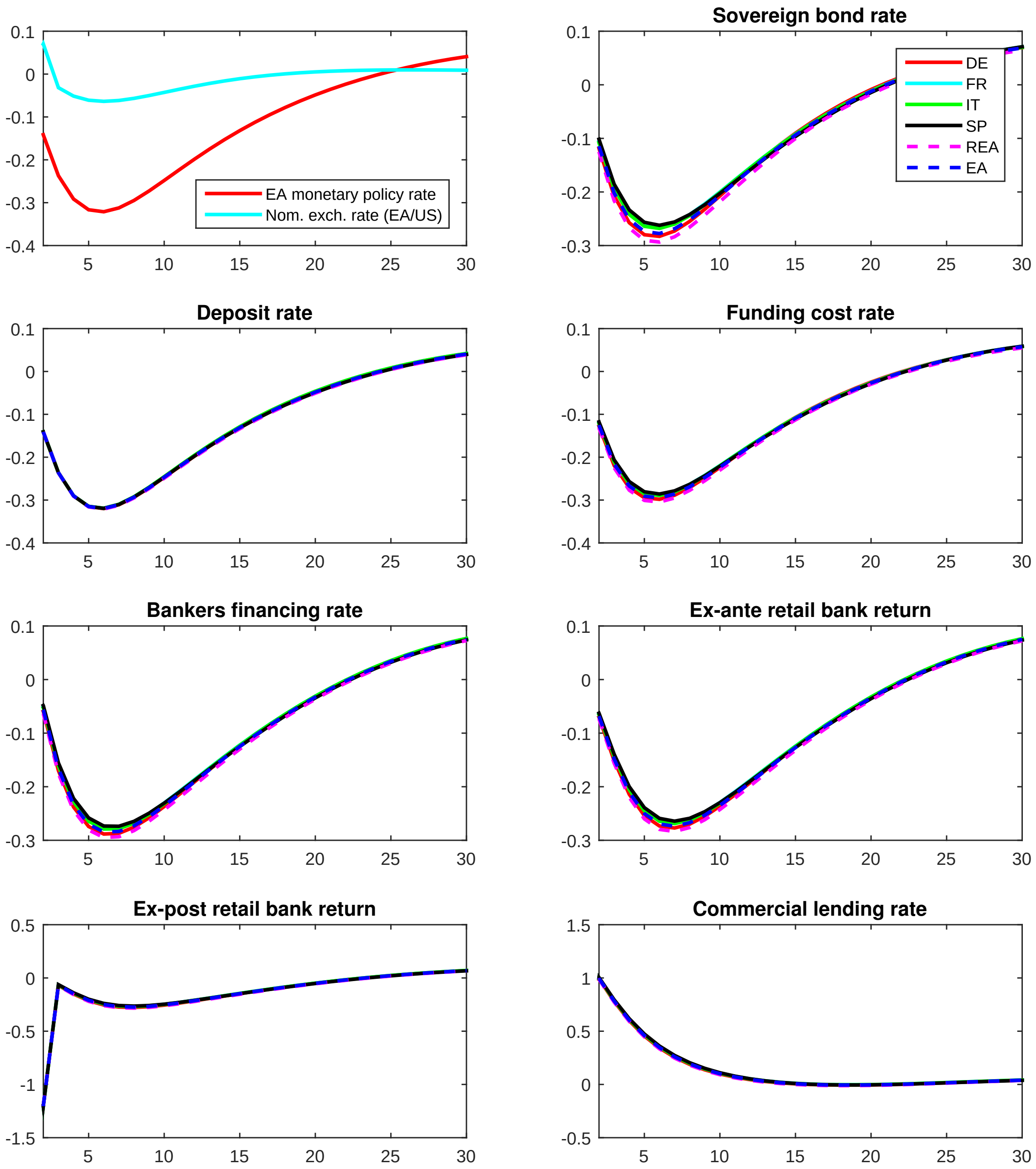
Notes: increase of the euro area bank mark-up μ_E^R so that the ex-ante retail bank return increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 28: Positive temporary euro area **entrepreneurs riskiness shock** - Symmetric calibration



Notes: increase of the euro area standard deviation of the multiplicative idiosyncratic shock of entrepreneurs $\sigma_{e,t}$ so that commercial lending rates increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed as a quarterly percentage-point deviation and except for inflation and debt-to-GDP which are expressed as annual percentage-point deviations. GDP, its components, bank loans and bank leverage are reported in real terms.

Figure 29: Positive temporary euro area **entrepreneurs riskiness shock** - Symmetric calibration



Notes: increase of the euro area standard deviation of the multiplicative idiosyncratic shock of entrepreneurs $\sigma_{e,t}$ so that commercial lending rates increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

E Sensitivity to cross-country heterogeneity in financial frictions

E.1 Sovereign risk

Figure 30: Positive **debt valuation shock** - Asymmetric sovereign risk calibration

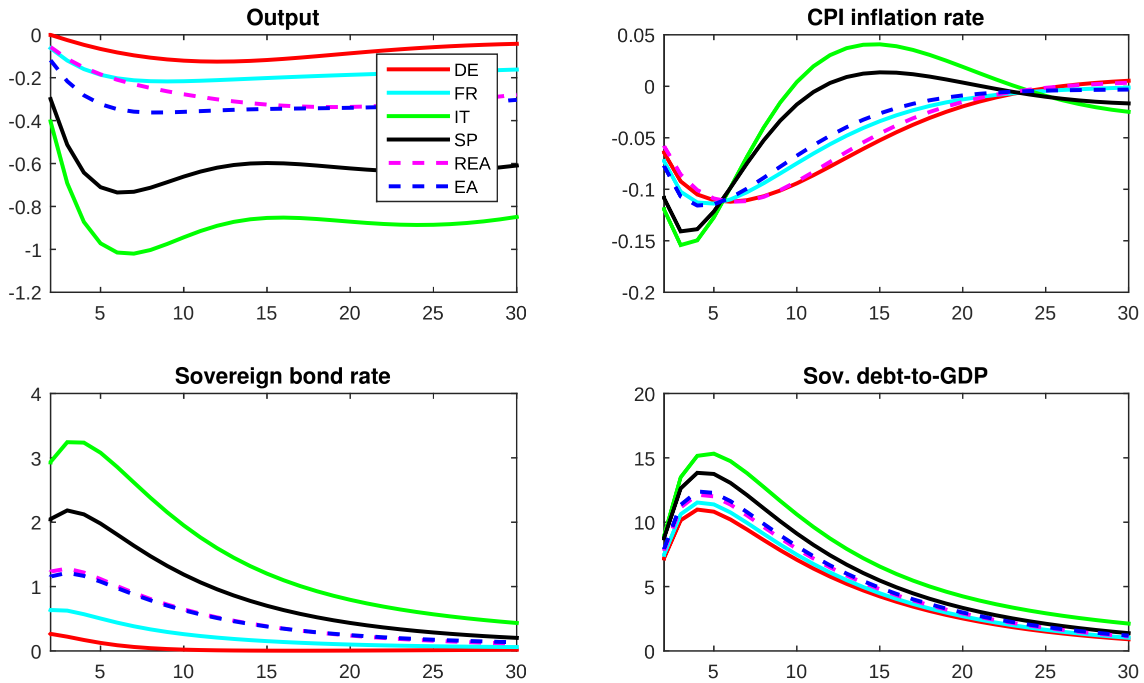
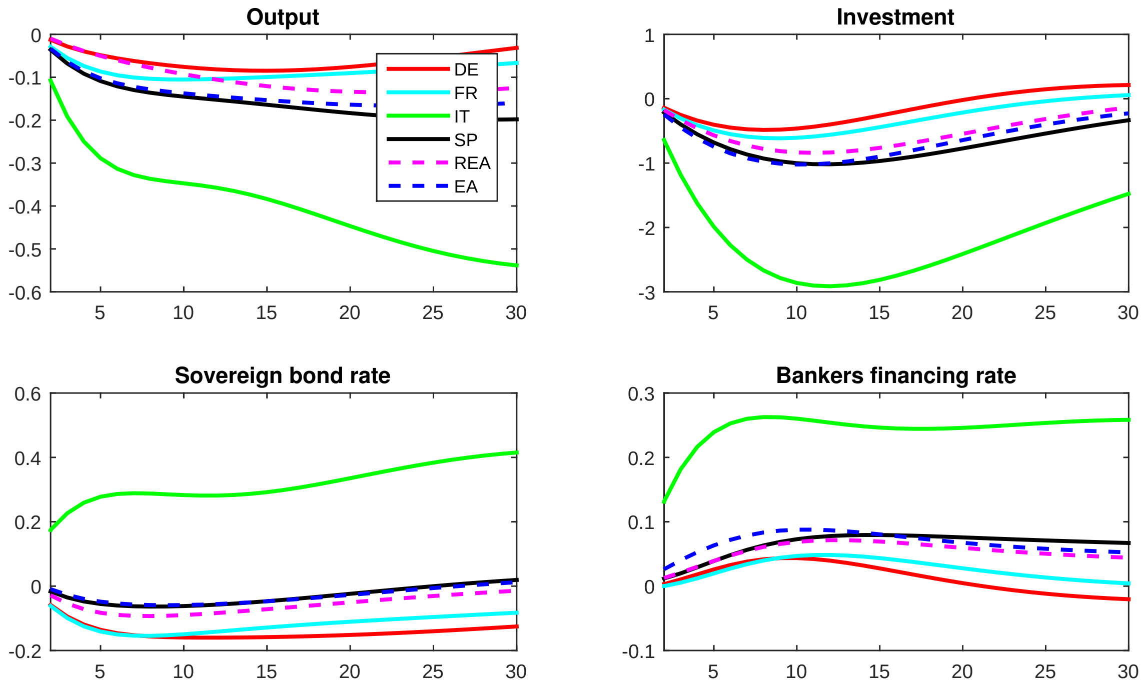


Figure 31: Negative euro area **bank capital shock** - Asymmetric sovereign risk calibration (difference from symmetric case)



E.2 Bank risk

Figure 32: Reduction in the euro area **monetary policy rate** - Asymmetric bank risk calibration (difference from symmetric case)

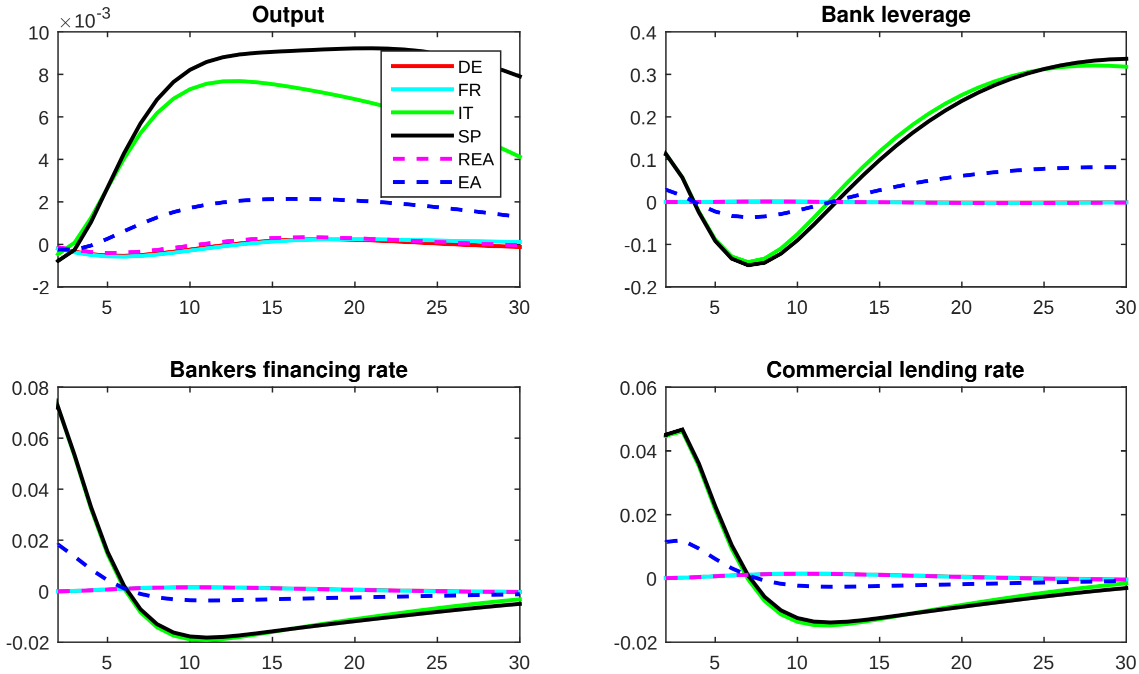


Figure 33: Negative euro area **bank capital shock** - Asymmetric bank risk calibration (difference from symmetric case)

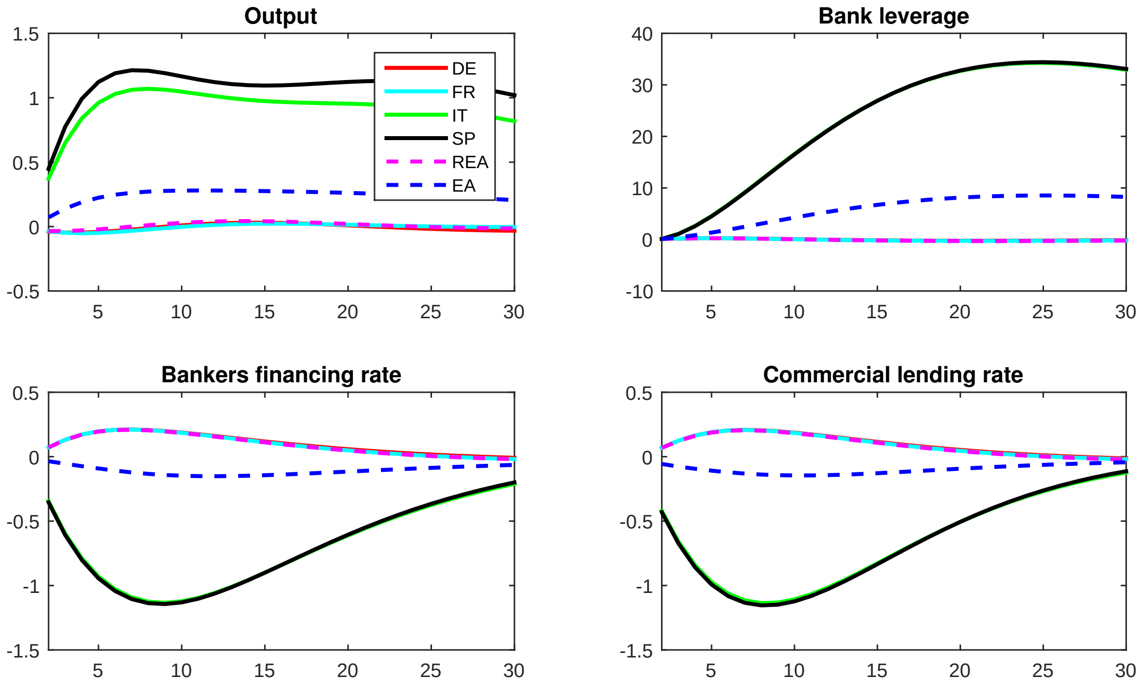


Figure 34: Negative euro area **bank capital shock without limited liability** - Asymmetric bank risk calibration (difference from symmetric case)

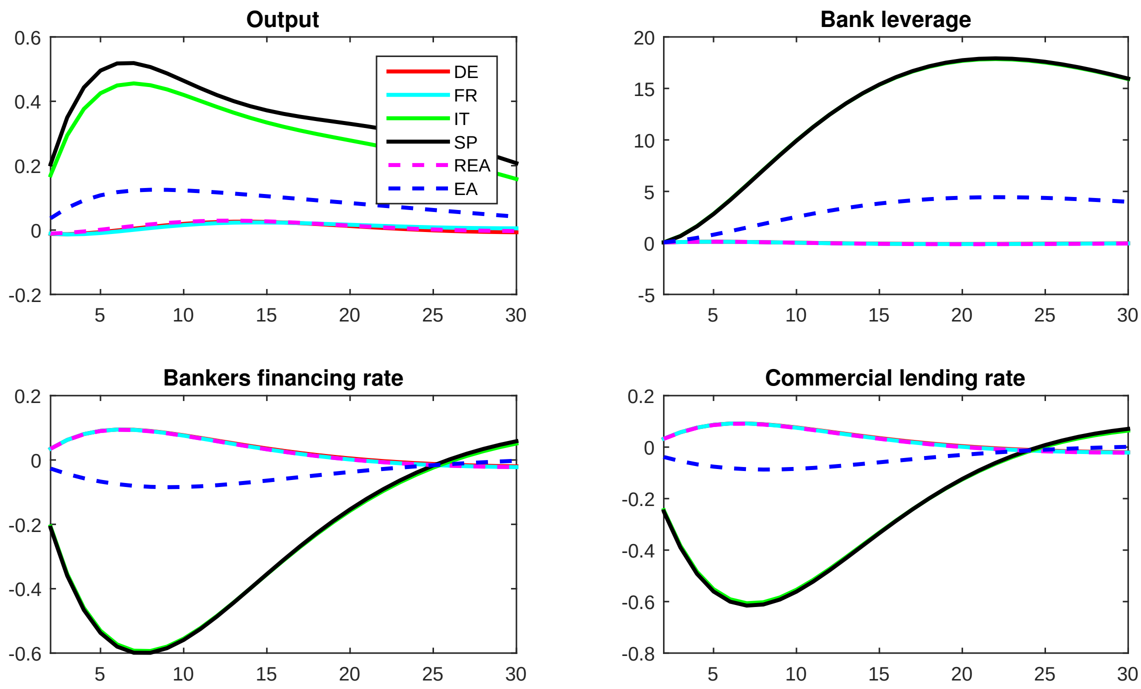
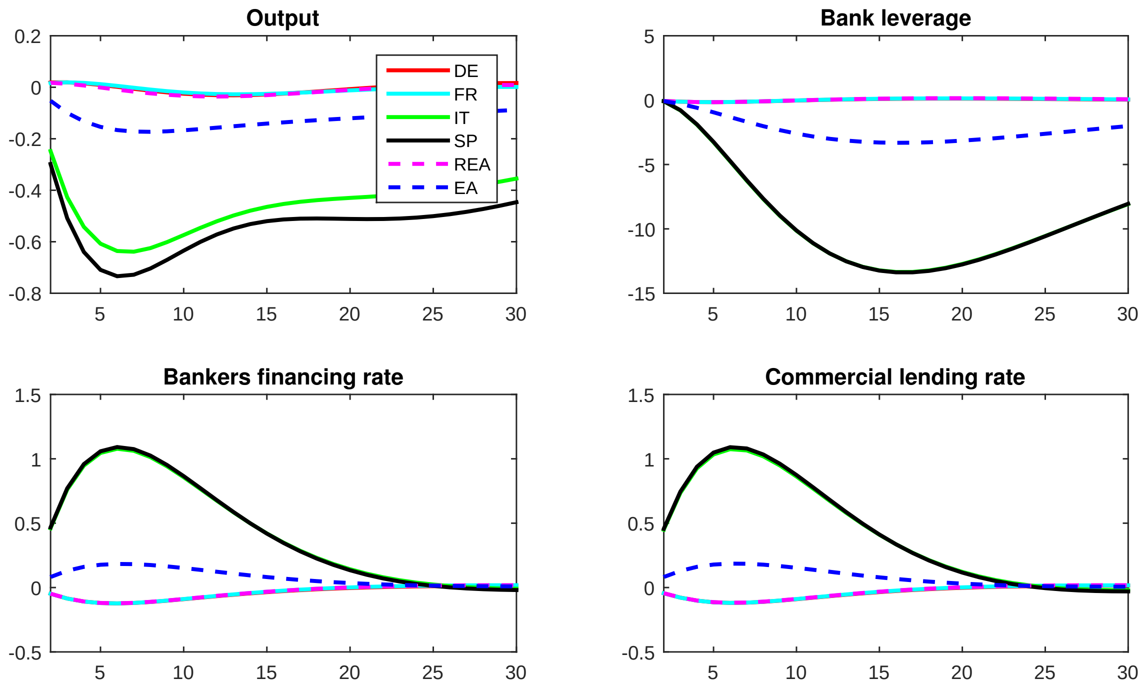


Figure 35: Negative euro area **bank capital shock** - Asymmetric bank risk calibration (difference from symmetric case)



E.3 Staggered lending rate setting

Figure 36: Reduction in the euro area **monetary policy rate** - Asymmetric staggered lending rate setting calibration (difference from symmetric case)

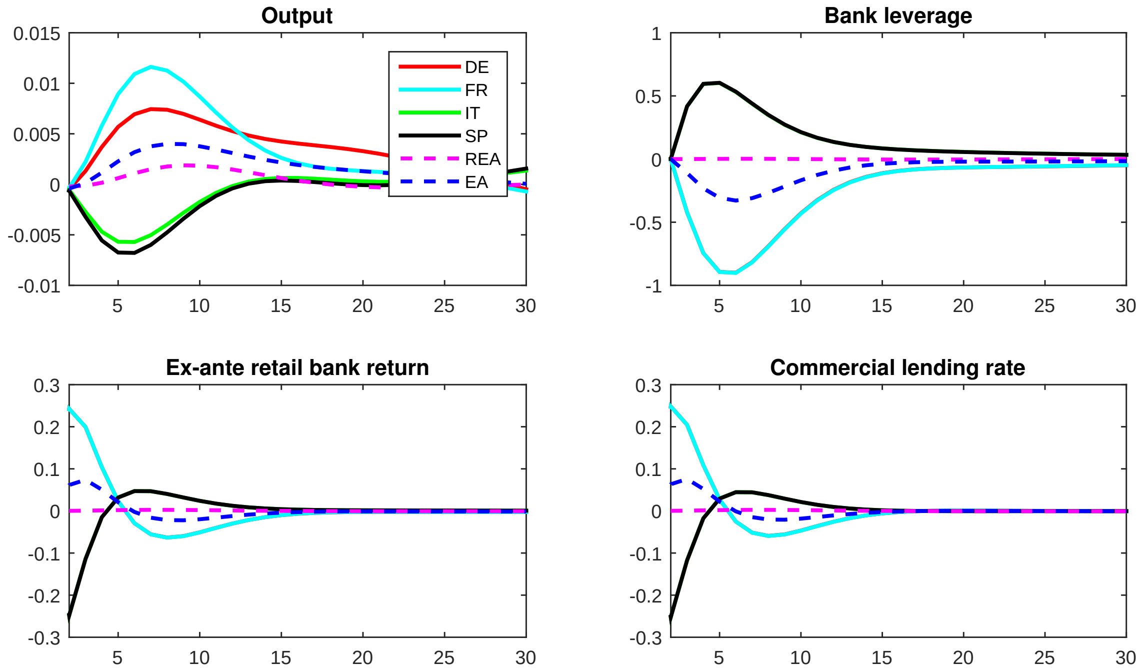
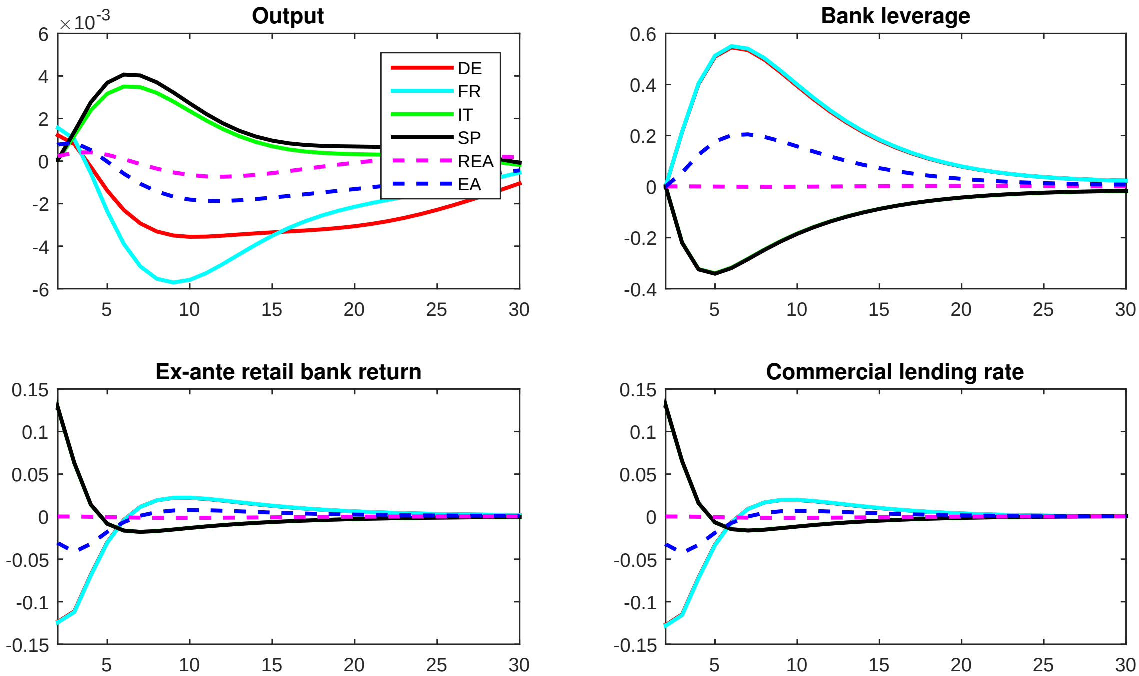


Figure 37: Increase euro area **sovereign risk premium** - Asymmetric staggered lending rate setting calibration (difference from symmetric case)



E.4 Corporate risk

Figure 38: Reduction in the euro area **monetary policy rate** - Asymmetric corporate risk calibration (difference from symmetric case)

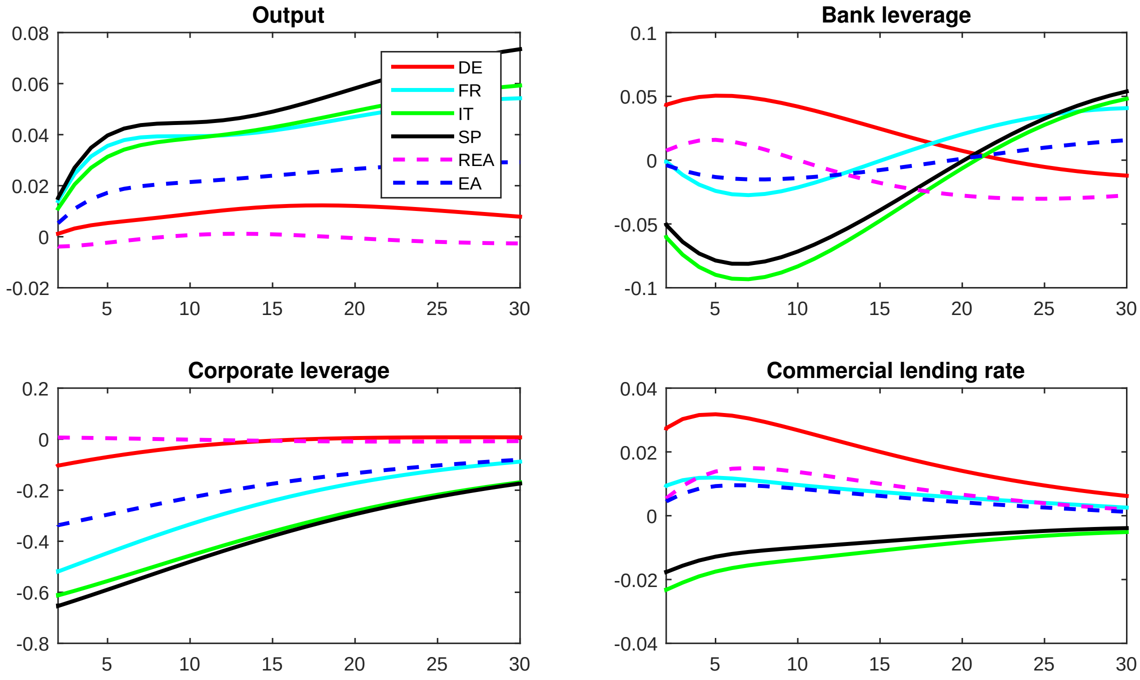
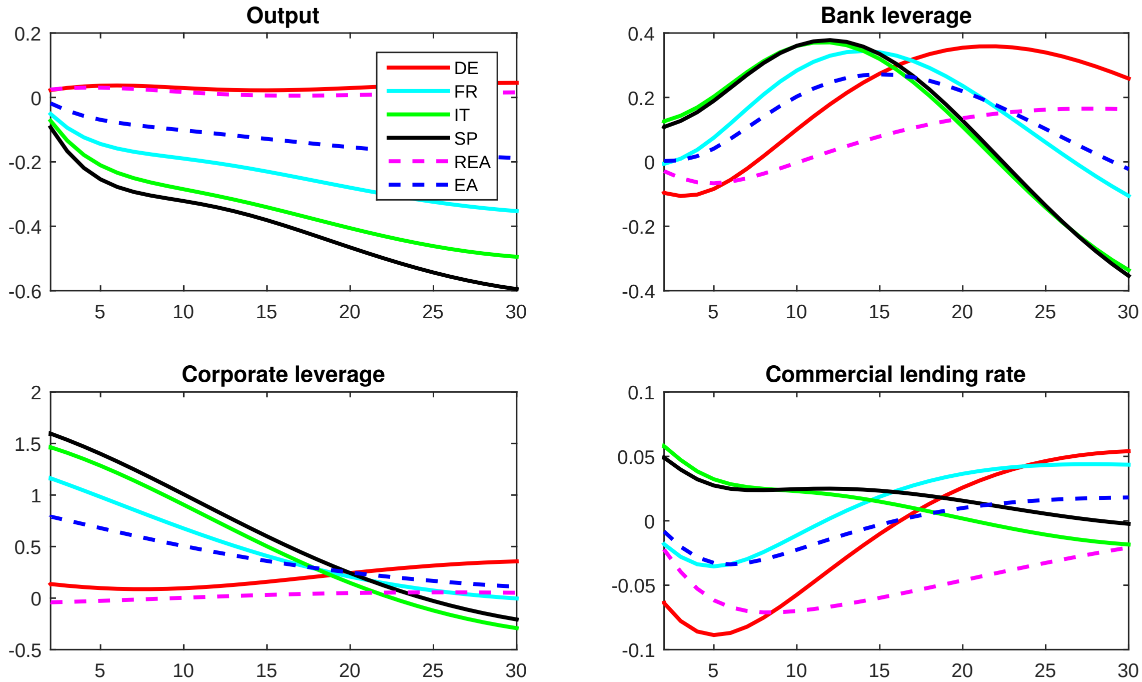
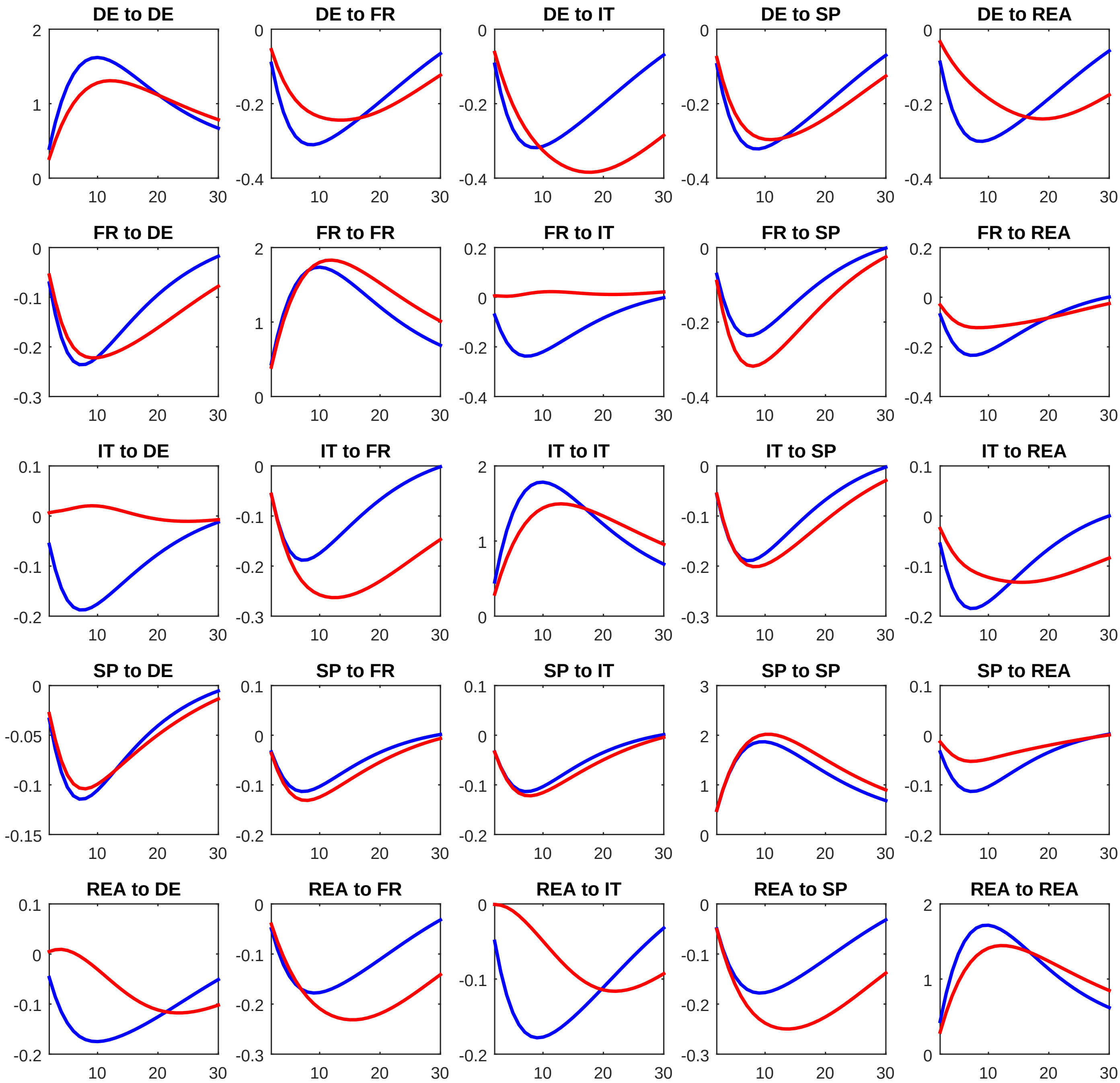


Figure 39: Negative euro area **bank capital shock** - Asymmetric corporate risk calibration (difference from symmetric case)



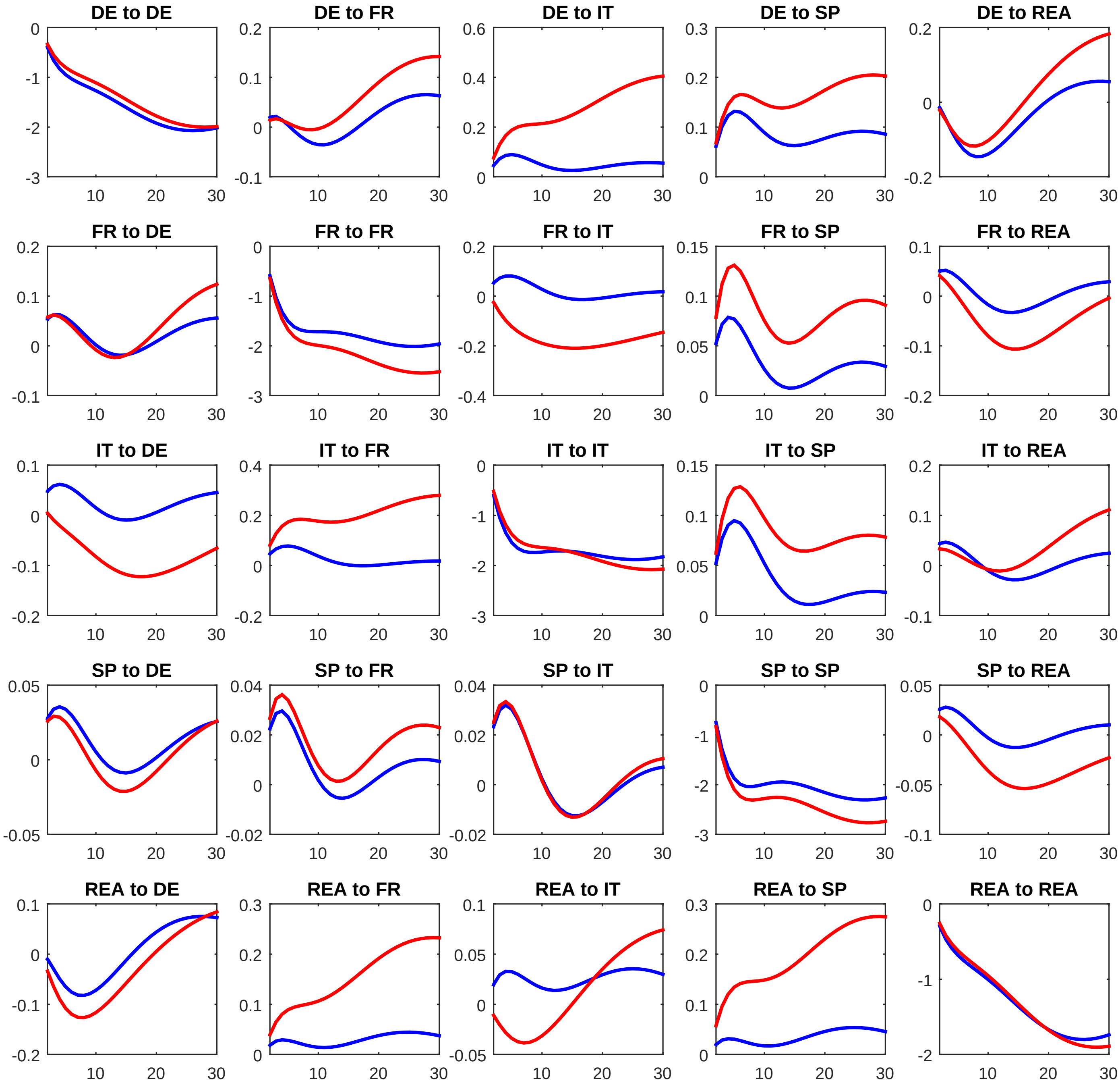
F Cross border financial linkages

Figure 40: Negative country specific **bank capital shock** - Effect on ***ex ante* retail bank return** - Comparison between with and without cross border financial linkages



Notes: decrease of bank capital; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline. Blue line: No cross border lending. Red line: With cross border lending.

Figure 41: Negative country specific **bank capital shock** - Effect on **real GDP** - Comparison between with and without cross border financial linkages



Notes: decrease of bank capital; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline. Blue line: No cross border lending. Red line: With cross border lending.

Acknowledgements

We thank seminar participants and discussants at the Working Group on Econometric Modelling (WGEM) meeting, 11th Dynare conference, UECE Conference on Economic and Financial Adjustments, EAGLE Network meeting of theWGEM, ECB/TT6 mini workshop and ECB Directorate Monetary Policy seminar series for their useful comments and suggestions. Assistance by Anca-Mihaela Paraschiv and Federica Brenna is gratefully acknowledged.

Matthieu Darracq Pariès

European Central Bank, Directorate Monetary Policy; email: matthieu.darracq_paries@ecb.europa.eu

Pascal Jacquinot

European Central Bank, Directorate General Research; email: pascal.jacquinot@ecb.europa.eu

Niki Papadopoulou

European Central Bank, Directorate Monetary Policy; email: niki.papadopoulou@ecb.europa.eu

Postal address	60640 Frankfurt am Main, Germany
Telephone	+49 69 1344 0
Website	www.ecb.europa.eu

ISSN	1725-2806 (online)
ISBN	978-92-899-2019-3
DOI	10.2866/069356
EU catalogue No	QB-AR-16-008-EN-N