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Parsing Financial Frictions Underlying Bank Lending Fragmentation during the Euro Area Crisis *

Matthieu Darracq Pariès[†] Pascal Jacquinot[‡] Niki Papadopoulou[§]

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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. Focusing specifically on the credit intermediation process, we claim that sources of impairments in the monetary policy transmission mechanism can arise from five distinct segments, related both to the demand and the supply of credit, namely: *(i)* deposit spread, *(ii)* market-funding cost spread, *(iii)* bank capital charges, *(iv)* compensation for expected losses and *(v)* competitive wedge. These intermediation wedges constitute specific types of financial frictions which may independently be the epicenter of financial disturbances. Against this background we design a DSGE model spanning 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. Our main results are the following. First, we show that the cross-country heterogeneity of micro-structure of financial frictions are relevant to explain the divergence in lending rates. Second, sovereign risk, bank risk and corporate risk have been the most relevant channels to explain the financial heterogeneity observed during the banking crisis (bank capital shock). Third, the corporate risk channel has been the main source of impairment of the monetary policy transmission across euro area countries. Fourth, a 10 pp increase in the annual debt-to-GDP ratio triggers a surge in sovereign yields by than 300 bps and 200 bps for Italy and Spain respectively. Fifth, cross-border financial linkages are more important for Italy and Germany and affect for both countries the transmission of bank capital shocks.

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

JEL classification: E4, E5, F4.

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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.

In this respect, 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.

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. 3 shows that the sovereign bond spread channel is the source of heterogeneity while deposit spreads and bank capital charges are contributing less.

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.

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 will cover 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...). Moreover, the euro area crisis manifested itself through very asymmetric financial shocks among these countries.

Against this background, the main 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. The set of 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. Our specification choices also benefitted from 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. 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. Compared to the existing literature (Gerali et al. (2010), Darracq Pariès et al. (2011), Kollmann et al. (2011), Benes and Kumhof (2011); Benes et al. (2014b,a)), 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.

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 main results are the following. First, we show that the cross-country heterogeneity in financial frictions does matter to explain the divergence in lending rates. Second, the bank capital shock suggests that sovereign risk, bank risk and corporate risk are the most relevant channels to explain the financial heterogeneity observed during the banking crisis. Third, the corporate risk channel has been the main source of impairment of the monetary policy transmission across euro area countries. Fourth, the surge in sovereign yields observed in Italy and Spain is mainly explained by the increase in debt-to-GDP ratio. Fifth, cross-border financial linkages are more important for Italy and Germany and affect for both countries the transmission of bank capital shocks.

The remainder of this paper is organized as follows. Section 2 describes the model. Section 3 discusses the calibration strategy and the parameterizing of the model. Section 4 shows the main financial wedges in the model. Section 5 focuses on the importance of financial frictions on the transmission of monetary policy shock. Section 6 deals with sensitivity analysis to cross-country heterogeneity in financial frictions while Section 7 is devoted to financial spillovers and cross-border linkages. Finally, section 8 summarizes and concludes.

2 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)). 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. 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 4 in a simplified schematic representation (leaving the more detailed description in Darracq Pariès et al. (2016)). 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.

2.1 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.

2.1.1 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.

2.1.2 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.[1] 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

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

[1] 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).

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.

2.1.3 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 cumulative distribution function (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

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

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 CDF $F_g(B_{Y,t+1})$, 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.[2] Except if stated otherwise, we assume that the risk weight is constant and equal to 1. This assumption will

[2]For corporate exposures, the risk weights are given by

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

where PD_t^E and LGD_t^E 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_t^E denotes the asset-value correlation which parameterizes cross-borrower dependencies and being a decreasing function be relaxed in the final sections of the paper. It is also worth noticing 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*, the 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.[3]

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

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

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

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of PD^E_t is equal to

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

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

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

The formula, derived from an extension of Gordy (2003) portfolio model, is detailed in BIS (2004) and BIS (2005).

[3] 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.

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.

2.1.4 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

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

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.

2.1.5 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 $t+1$.

2.1.6 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

$$R_{KK,t+1} \equiv \frac{((1-\tau^K_{t+1})(r_{K,t+1}u_{t+1} - \Gamma_u(u_{t+1}))P_{I,t+1} + \tau^K_t \delta P_{I,t+1} + (1-\delta)Q_{t+1})}{Q_t \Pi_{C,t+1}} \tag{33}$$

where τ^K_t 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

$$\widetilde{E}\left[\mathbb{E}_t\left(\omega_{e,t+1}R_{KK,t+1}\right)\right] = \mathbb{E}_t\left(\int_0^\infty \omega_{e,t+1}\mathrm{d}F_{e,t}(\omega)\, R_{KK,t+1}\right) = \mathbb{E}_t\left(R_{KK,t+1}\right) \tag{34}$$

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

$$Q_t K_t = NW_{E,t} + L_{E,t} \tag{35}$$

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

$$\overline{\omega}_{e,t+1}\chi_e R_{KK,t+1}\kappa_{e,t} = (R_{LLE,t}+1)(\kappa_{e,t}-1) \tag{36}$$

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

$$\kappa_{e,t} = \frac{Q_t K_t}{NW_{E,t}}. \tag{37}$$

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

$$\widetilde{R}_{LE,t} = G(\overline{\omega}_{e,t})\chi_e R_{KK,t}\frac{\kappa_{e,t-1}}{\kappa_{e,t-1}-1} \tag{38}$$

where

$$G_e(\overline{\omega}) = (1-F_e(\overline{\omega}))\overline{\omega} + (1-\mu_e)\int_0^{\overline{\omega}} \omega \mathrm{d}F_e(\omega). \tag{39}$$

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

$$\max_{\{R_{LLE,t},\kappa_{e,t}\}} \mathbb{E}_t\left[(1-\chi_e\Gamma_e(\overline{\omega}_{e,t+1}))R_{KK,t+1}\kappa_{e,t}\right] \tag{40}$$

subject to the participation of constraint of the lender (32), the equation (36) for the default threshold $\overline{\omega}_{e,t+1}$, and where

$$\Gamma_e(\overline{\omega}) = (1-F_e(\overline{\omega}))\overline{\omega} + \int_0^{\overline{\omega}} \omega \mathrm{d}F_e(\omega). \tag{41}$$

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

$$\mathbb{E}_t\left[(1-\chi_e\Gamma_e(\overline{\omega}_{e,t+1}))R_{KK,t+1}\kappa_{e,t}\right] = \frac{\mathbb{E}_t\left[\chi_e\Gamma'_e(\overline{\omega}_{e,t+1})\right]}{\mathbb{E}_t\left[\Xi^I_{t,t+1}G'_e(\overline{\omega}_{e,t+1})\right]}\mathbb{E}_t\left[\Xi^I_{t,t+1}\right]R_{LE,t} \tag{42}$$

where

$$\Gamma'_e(\overline{\omega}) = (1-F_e(\overline{\omega})) \tag{43}$$

$$G'_e(\overline{\omega}) = (1-F_e(\overline{\omega})) - \mu_e\overline{\omega}\mathrm{d}F_e(\overline{\omega}). \tag{44}$$

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 $R_{LE,t-1}$.[4]

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[5] while the contractual lending rate is state contingent. This implies

[4] Log-linearising equation (42) and the participation constraint (32), one can show that innovations in the *ex post* return are notably driven by innovations in $R_{KK,t}$.

[5] 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.

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

$$NW_{E,t} = \zeta_e \left(1 - \chi_e \Gamma_e(\overline{\omega}_{e,t})\right) R_{KK,t} \kappa_{e,t-1} \frac{NW_{E,t-1}}{\Pi_{C,t}} + \Psi_{E,t}. \tag{45}$$

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.

2.1.7 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 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

$$L_{E,t} = \left[v_{LE}^{\frac{1}{\xi_{LE}}} \left(L_{E,t}^{H}\right)^{\frac{\xi_{LE}-1}{\xi_{LE}}} + (1 - v_{LE})^{\frac{1}{\xi_{LE}}} \left(RER_t L_{E,t}^{H \leftarrow F}\right)^{\frac{\xi_{LE}-1}{\xi_{LE}}} \right]^{\frac{\xi_{LE}}{\xi_{LE}-1}} \tag{46}$$

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

$$\left(\widehat{R}_{BLE,t}\right)^{1-\xi_{LE}} = v_{LE} \left(R_{BLE,t}^{H}\right)^{1-\xi_{LE}} + (1 - v_{LE}) \left(R_{BLE,t}^{F}\right)^{1-\xi_{LE}}. \tag{47}$$

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

$$L_{E,t}^{H} = v_{LE} \left(\frac{R_{BLE,t}^{H}}{\widehat{R}_{BLE,t}} \right)^{-\xi_{LE}} L_{E,t} \tag{48}$$

$$RER_t L_{E,t}^{H \leftarrow F} = (1 - v_{LE}) \left(\frac{R_{BLE,t}^{F}}{\widehat{R}_{BLE,t}} \right)^{-\xi_{LE}} L_{E,t}. \tag{49}$$

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.

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

$$L_{BE,t} = \Delta^{R}_{E,t} L^{H}_{E,t} + \Delta^{R*}_{E,t} L^{F \leftarrow H}_{E,t} \tag{50}$$

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

2.2 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

$$R_{BD,t} = \phi_R \left(R_{BD,t-1}\right) + \left(1 - \phi_R\right) \left[\left(\overline{R}\right) + \phi_\Pi \left(\Pi_{C,t} - \overline{\Pi}\right)\right] + \phi_Y \left(\Delta Y_t - 1\right) \tag{51}$$

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 $\overline{R}$.

3 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. 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. To evaluate their impacts on the transmission of shocks we have considered two sets of calibrations for the financial bloc: before the crisis when countries are relatively homogeneous and after. We also allow for international financial and trade linkages via detailed calibration of cross-border lending and trade of consumption and investment goods. 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).

3.1 Non-financial block

The discount factor, β, is set symmetrically across countries to 0.995. This implies that the equilibrium gross annual real interest rate is approximately equal to 1.02. The parameters for the inter-temporal elasticity of substitution and the inverse of the Frisch elasticity of labour are equal to 1 and 2 respectively. Wage markups in the euro area are around 30% compared to the rest of the world which is around 16%. Calvo wage parameters are equal to 0.75. The indexation parameters are equal to 0.65. As concerns only the Ricardian whose share is set to 0.75 in all region, their deposit preferences 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 is calibrated symmetrically and equal to 1.25.

In the intermediate goods sector, the bias towards capital is higher for tradable goods than for nontradable goods. As for the final goods baskets, the degree of substitutability between domestic and imported tradables is higher than that between tradables and nontradables consistent with existing literature (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.[6] In most countries, the bias towards the tradable bundle is higher in the investment basket than in the consumption baskets.

Price markups in the two sectors are higher in the EA than in ROW. Specifically, the net price markup in the tradables sector is around 20% in the euro area and around 15% in the rest of the world. The markup in the nontradable good's sector is equal to 40% in the euro area and below 30% in ROW. Calvo price parameters in the domestic tradables and non-tradables sectors are set to 0.90 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 are equal to 0.75 in all the regions. The indexation parameters on prices are equal to 0.40.

3.2 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. Lastly, when dealing with the dynamic model, we try to specify sensitivities and degrees of adjustments through the usage of information on elasticies 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

[6] These numbers are broadly in line with related literature, see Imbs and Méjean (2009), Imbs and Méjean (2010) and Corbo and Osbat (2013) for details.

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. We will start the presentation by the symmetric case.

3.2.1 Symmetric Calibration

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,[7] 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 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).

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.

Regarding the calibration of the **bankers** 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.

As concerns the calibration of the **retail banking branches**, the elasticity of substitution μ_D^R of

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

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)).

Concerning entrepreneurs, 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 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.

3.2.2 Asymmetric Calibration

Table 1 shows the calibration of the sovereign risk in the non-symmetric case where 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.

Concerning bankers, as shown in Table 2, 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 6 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 3 presents retail banking branches. 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 concerns entrepreneurs, as indicated in Table 4, 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.[8] 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 5 shows the calibration of the **cross-border lending** matrix which allows for 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 granted 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 granted 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 5 and 6 attempt to show an accounting decomposition of lending rates in order to identify the major source of risks in the determination of lending rates. As shown in Table 5, 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.

[8]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.

4 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.

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.

5 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.

5.1 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 5 and 6.

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.

5.2 Sovereign risk premium shock

Figures 7 and 8 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.

5.3 Bank capital shock

Figures 9 and 10 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.

5.4 Lending rate markup shock

Figures 11 and 12 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.

5.5 Corporate risk shock

Figures 13 and 14 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 14. 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.

6 Cross-country heterogeneity in financial frictions

This section is devoted to implications of cross-country asymmetries in sovereign for the transmission of shocks with a special interest in the sovereign-banking nexus, bank capital frictions, monopolistic competition in the banking sector and corporate balance sheet frictions.

6.1 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 15 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 16 report the corresponding IRFs, in deviation from the symmetric case of section 5.3.[9] 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.

6.2 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 5. 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

[9] The transmission of monetary policy is not affected significantly by asymmetries in sovereign risk, therefore due to space limitations it is not reported.

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 2.1.1 of the model description).

Looking first at the monetary policy shock in Figure 17, 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 18, 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 19, 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 20 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.

6.3 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 3.2 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 21 and 22, respectively. The IRFs are presented in deviation form the symmetric cases of section 5.

After a monetary policy shock (Figure 21), 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 (Figure 22), 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.

6.4 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 5. Figure 23 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 24 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.

7 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 3.2 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 25 and 26 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 3.2, 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.

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. The fifth channel on deposit spread appears to be a minor source of heterogeneity. 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.

Our main results are the following. First, we show that the cross-country heterogeneity of micro-structure of financial frictions has meaningful implications both for the steady-state features and the dynamic properties of the model. Second, sovereign risk, bank risk and corporate risk have been the most relevant channels to explain the financial heterogeneity observed during the banking crisis (bank capital shock). Third, the corporate risk channel has been the main source of impairment of the monetary policy transmission across euro area countries. Fourth, a 10 pp increase in the annual debt-to-GDP ratio triggers a surge in sovereign yields by than 300 bps and 200 bps for Italy and Spain respectively. Fifth, cross-border financial linkages are more important for Italy and Germany and affect for both countries the transmission of bank capital shocks.

From a policy perspective, the 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. 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 under-capitalized banks tighten credit conditions and put at the risk the ability of the corporate sector to cope with persistent fall in demand. Nevertheless, 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.

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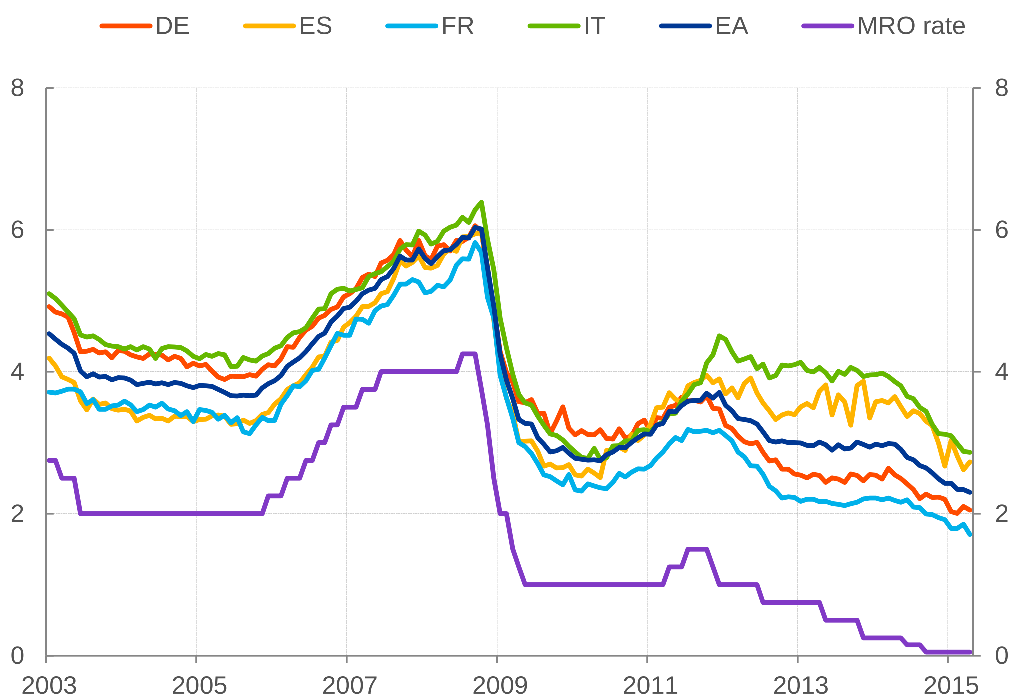
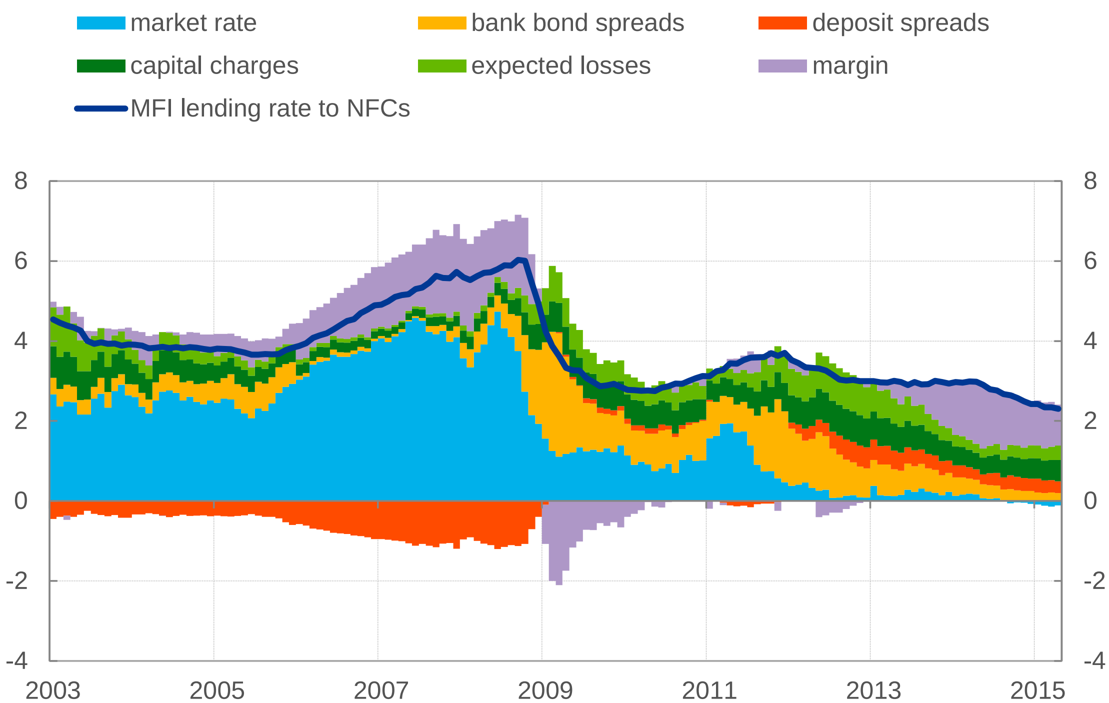
Figure 1: Cost of borrowing indicators for non-financial corporations (percentages per annum)



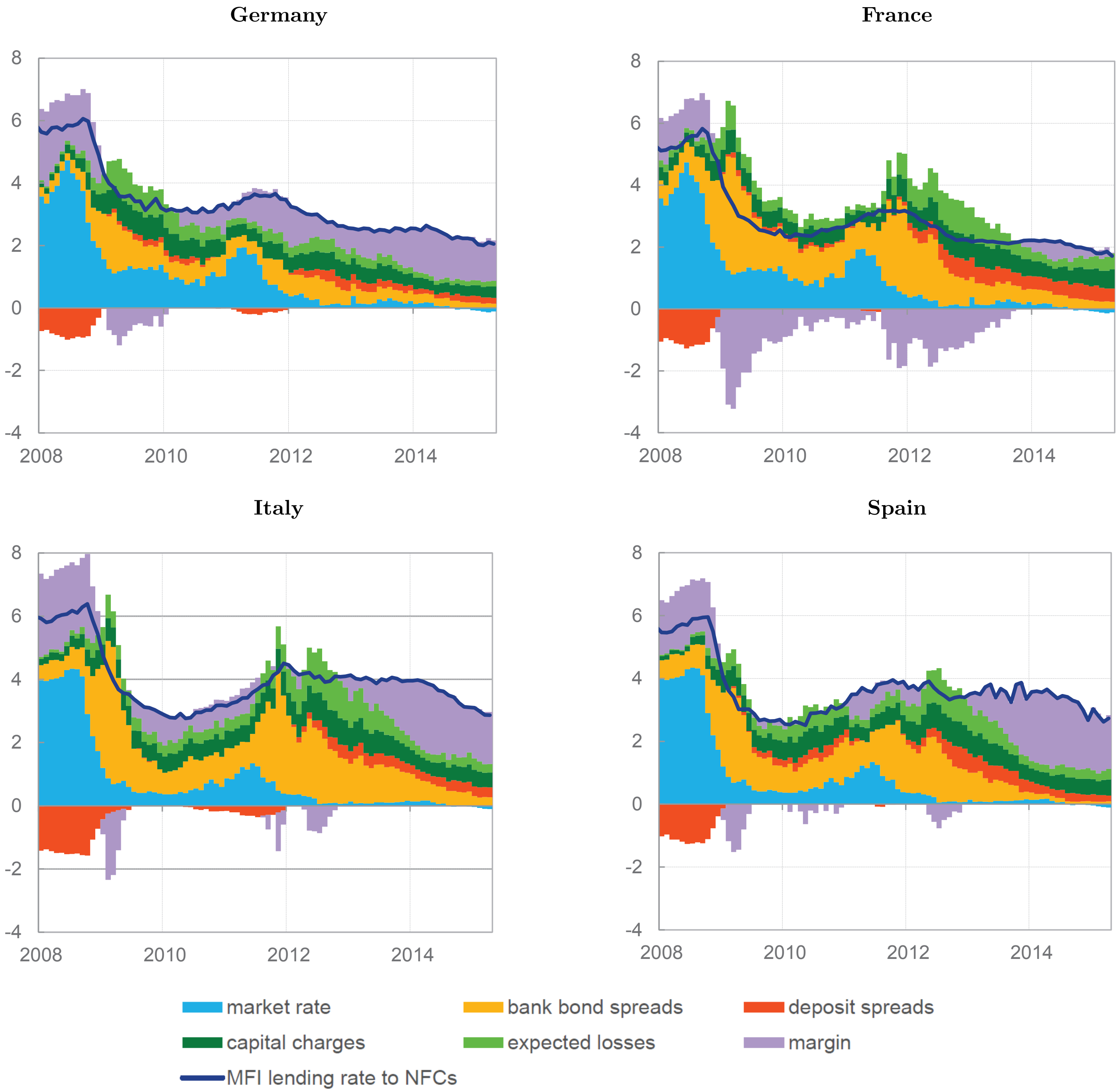
Source: ECB and ECB calculations.
Notes: The indicator for the cost of borrowing is calculated by aggregating short and long-term rates using a 24-month moving average of new business volumes.

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: Schematic representation of the model with cross border lending

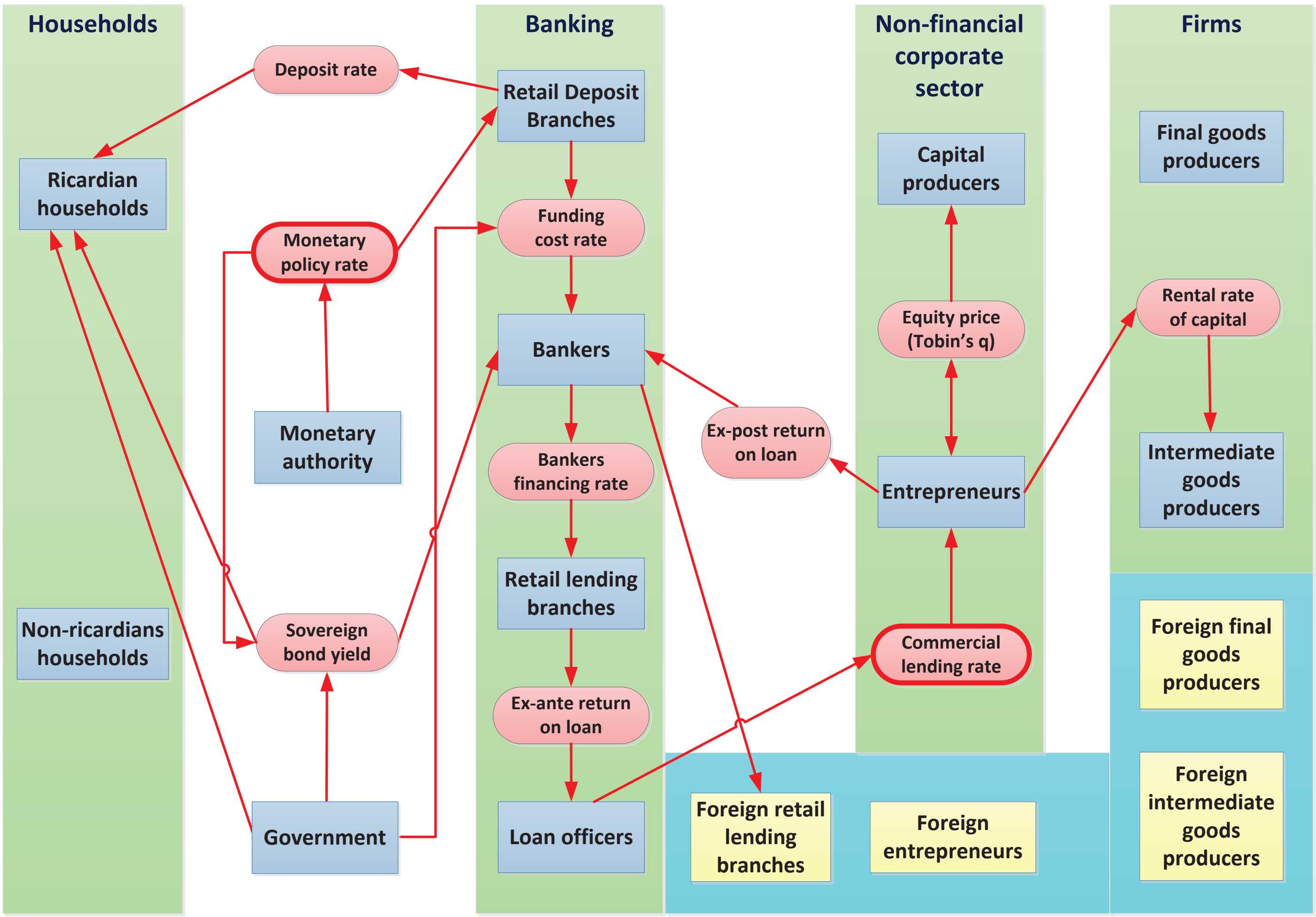


Table 1: Sovereign risk (cross-country heterogeneity)

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 2: 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)	$1-(1-F(\overline{\omega}_b^{\nu}))^4$	15.07	15.07	15.07	15.07	15.07	15.07
Prob. of default (percent)	$1-(1-F(\overline{\omega}_b))^4$	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 3: 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 4: 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 5: 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

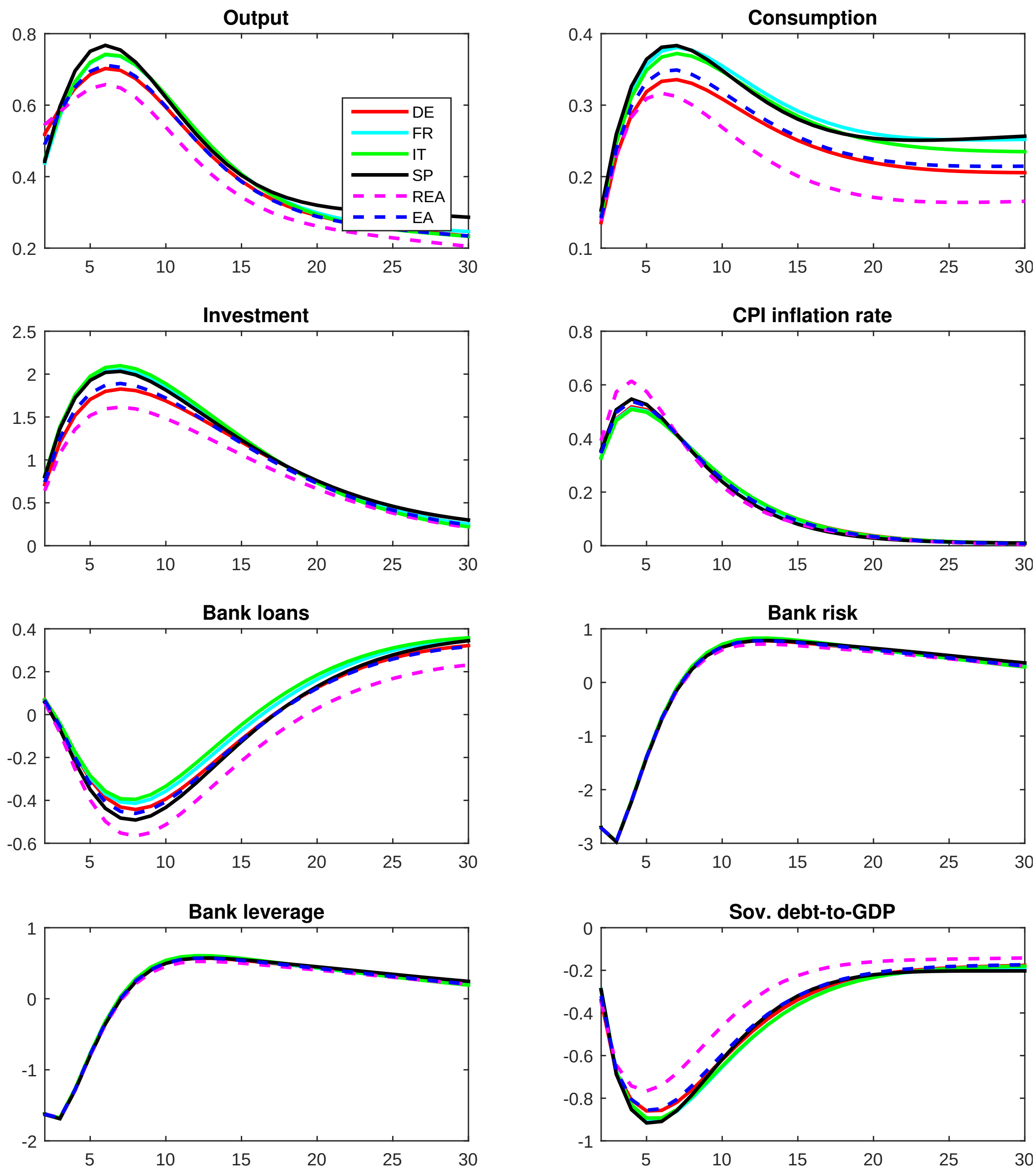
Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world.

Table 6: 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

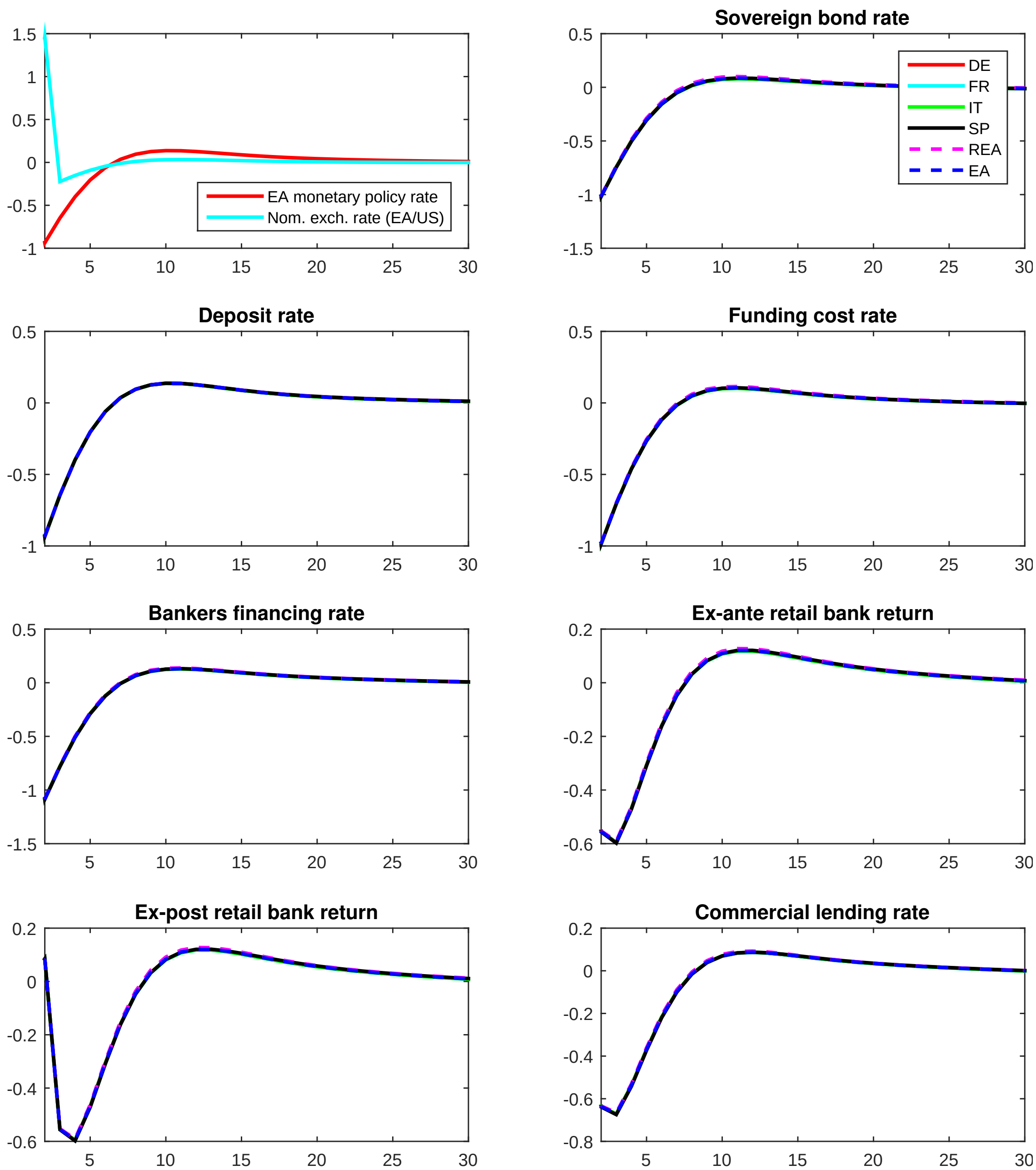
Notes: DE = Germany; FR = France; SP = Spain; IT = Italy; REA = Rest of euro area; ROW = Rest of the world. In annualised terms.

Figure 5: Reduction in the euro area **monetary policy rate** - Symmetric calibration



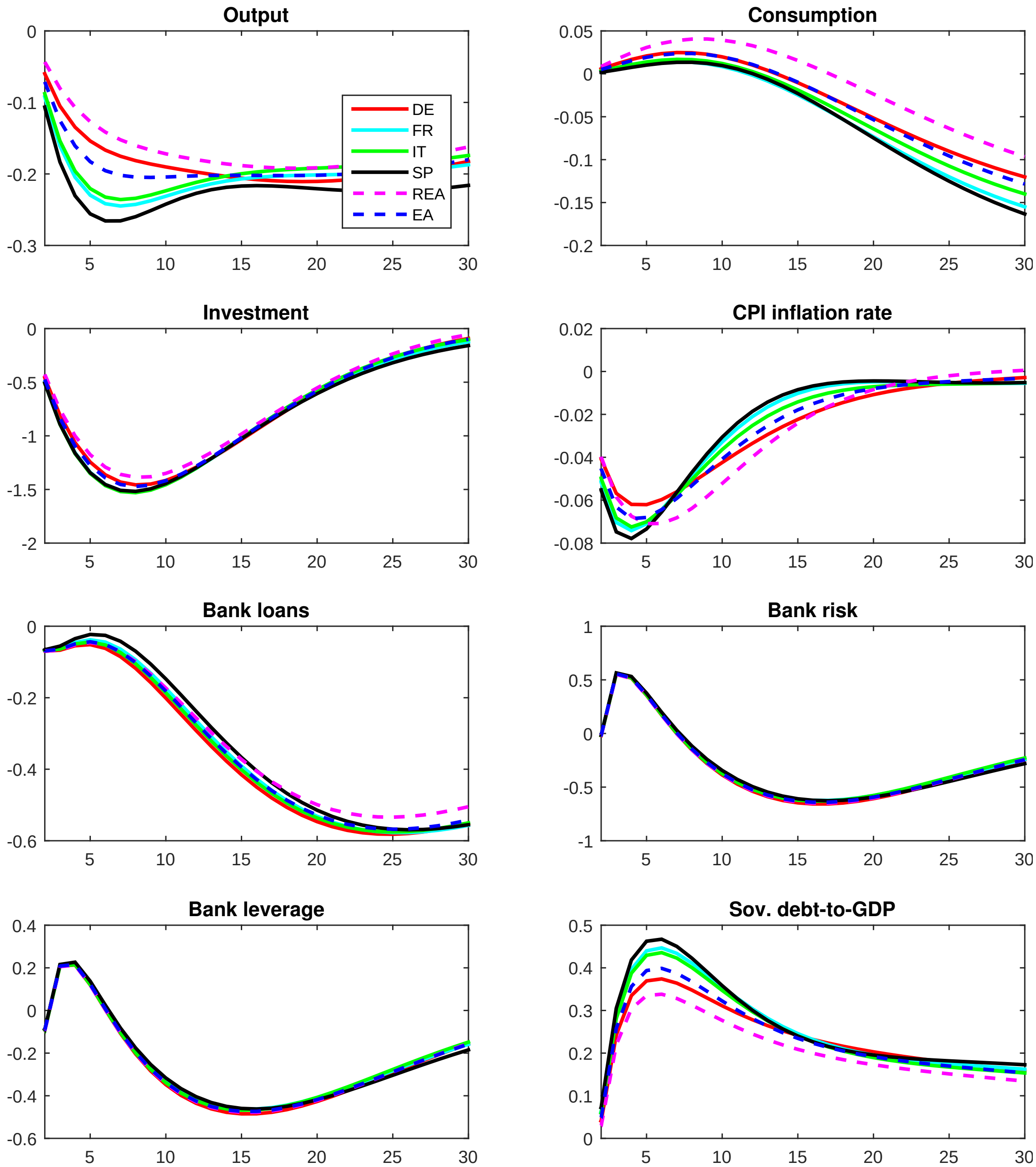
Notes: decrease of euro area monetary policy rate $\varepsilon_{R,t}$ by 1 percent in annual terms in the first period. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed as a quarterly percentage-point deviation and except for inflation and 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 6: Reduction in the euro area **monetary policy rate** - Symmetric calibration



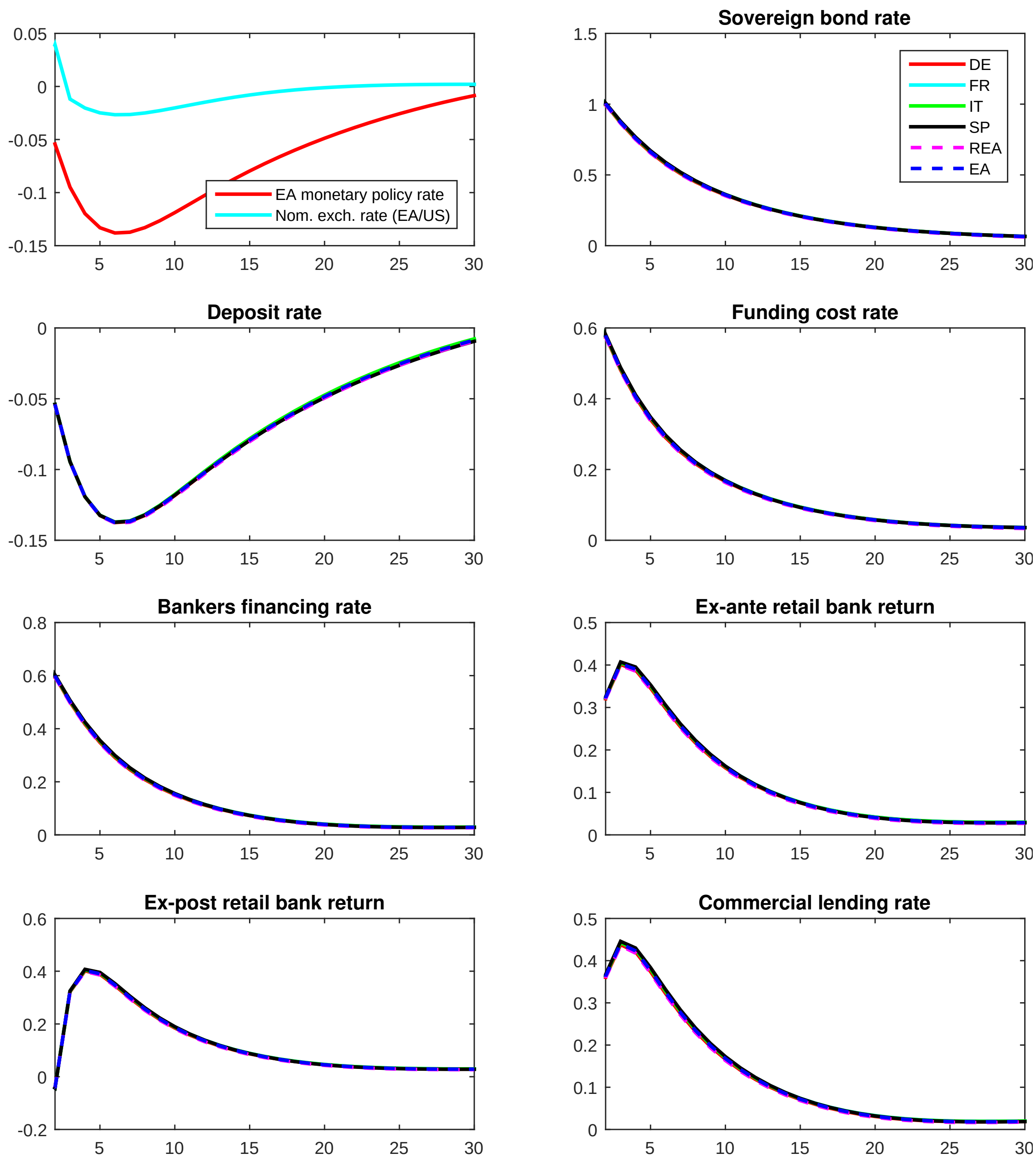
Notes: decrease of euro area monetary policy rate $\varepsilon_{R,t}$ by 1 percent in annual terms in the first period. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 7: Increase euro area **sovereign risk premium** - Symmetric calibration



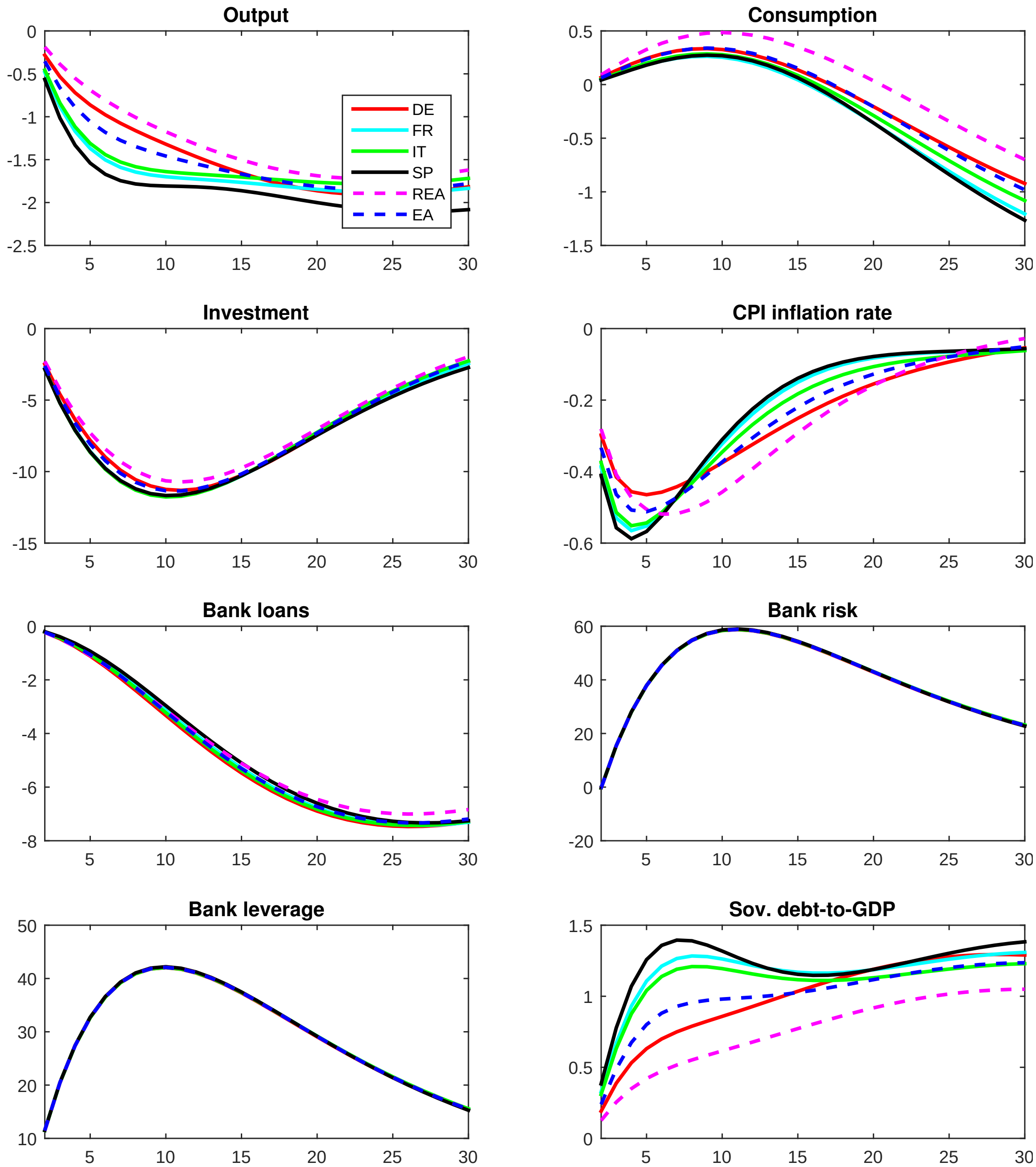
Notes: increase of the euro area loss given default so that sovereign bond yields increase approximately by 1 percent in the first period; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, 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 8: Increase euro area **sovereign risk premium** - Symmetric calibration



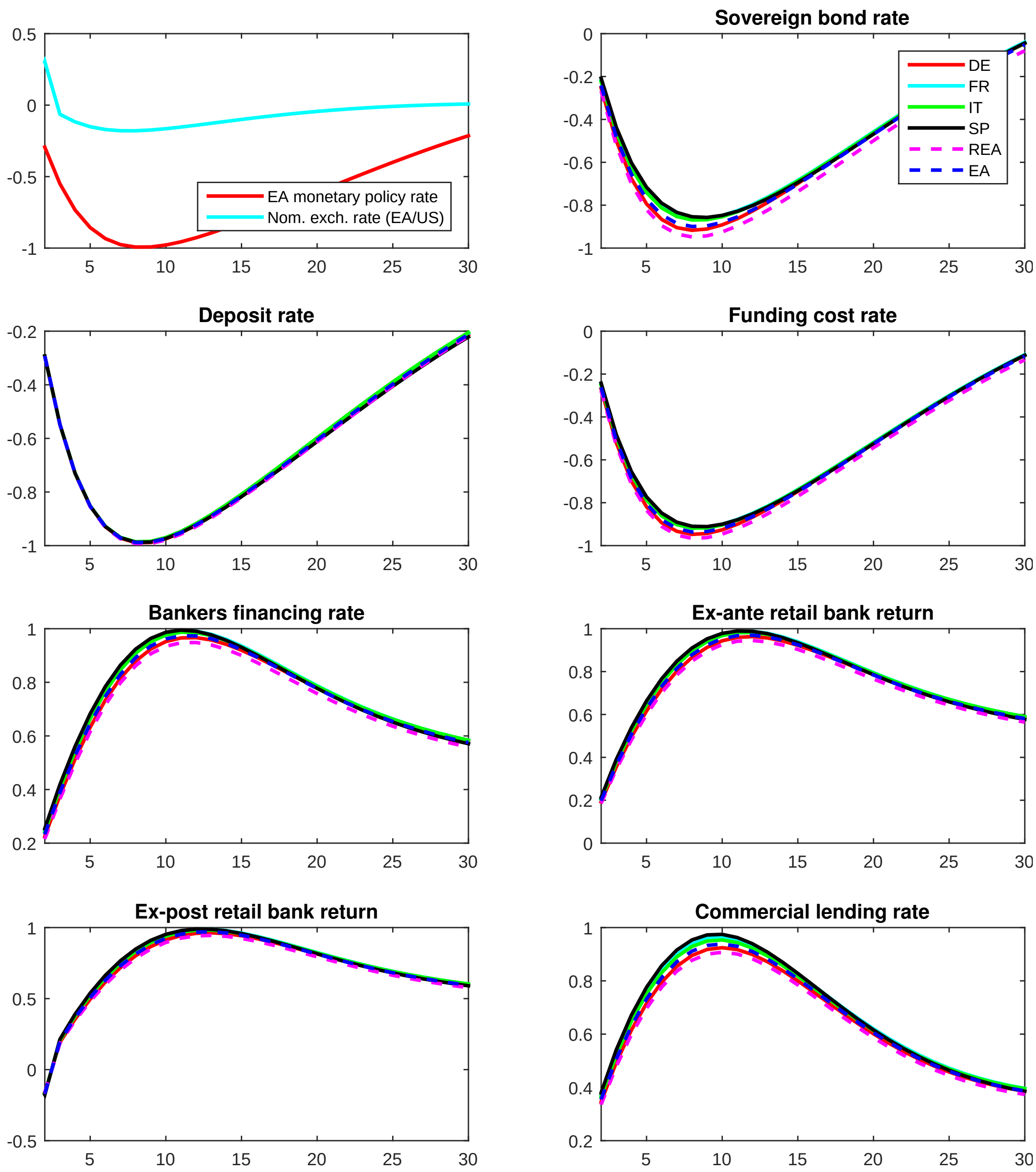
Notes: increase of the euro area loss given default so that sovereign bond yields increase approximately by 1 percent in the first period; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from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

Figure 9: Negative euro area **bank capital shock** - Symmetric calibration



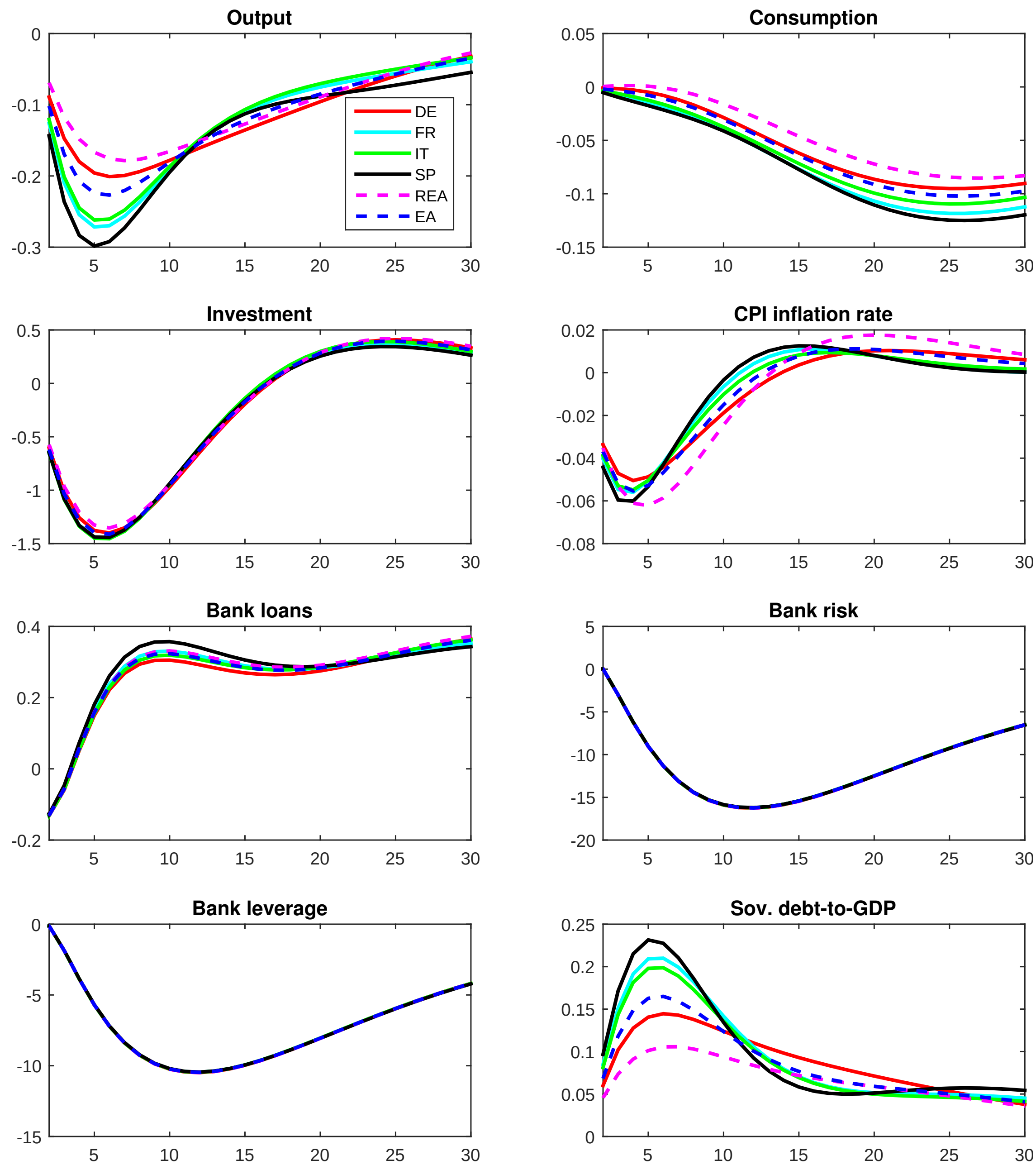
Notes: decrease of the euro area bank capital so that bankers financing rate increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for bank risk expressed 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 10: Negative euro area **bank capital shock** - Symmetric calibration



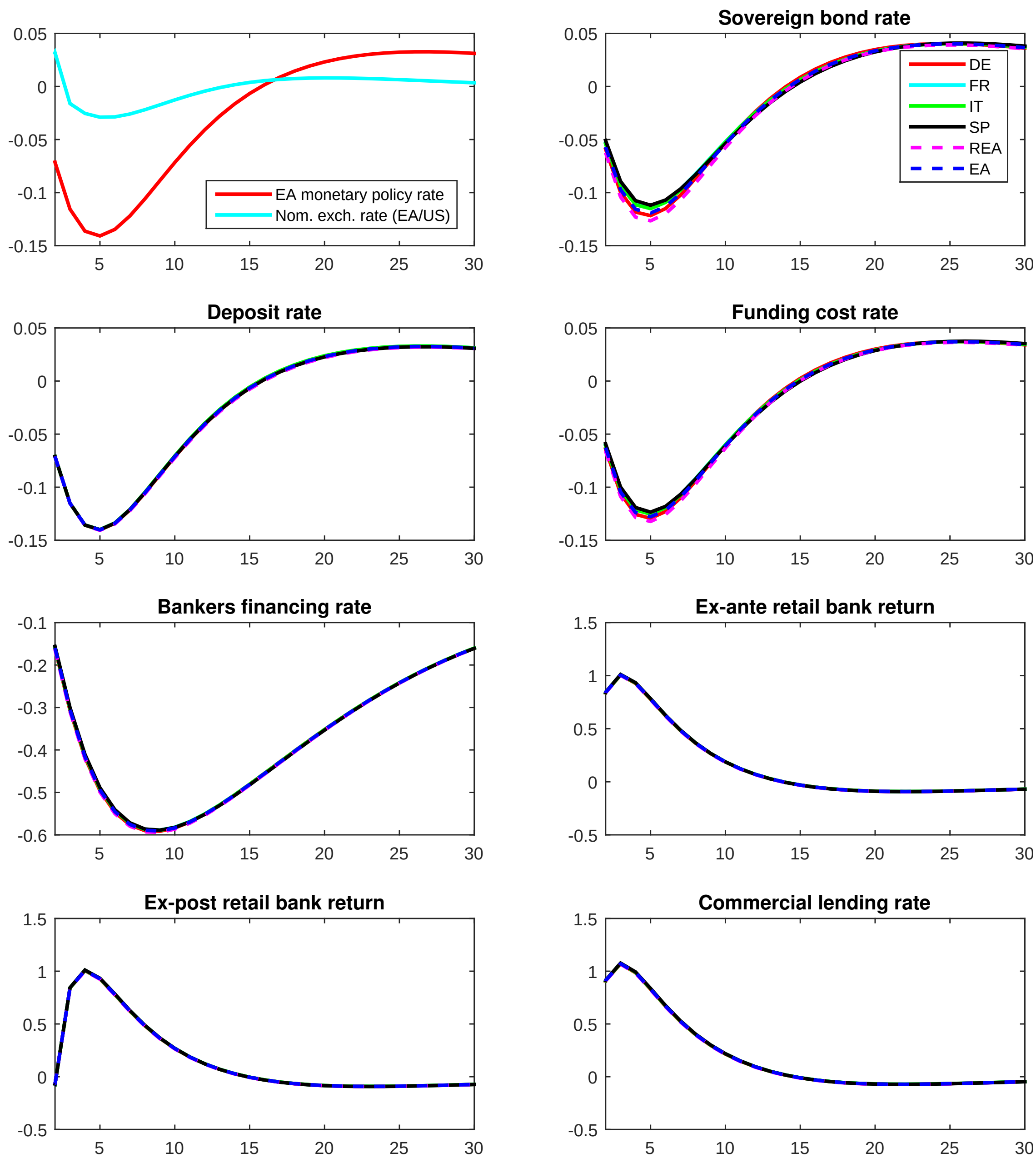
Notes: decrease of the euro area bank capital so that bankers financing rate increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 11: Positive temporary euro area **competitive mark-up shock** - Symmetric calibration



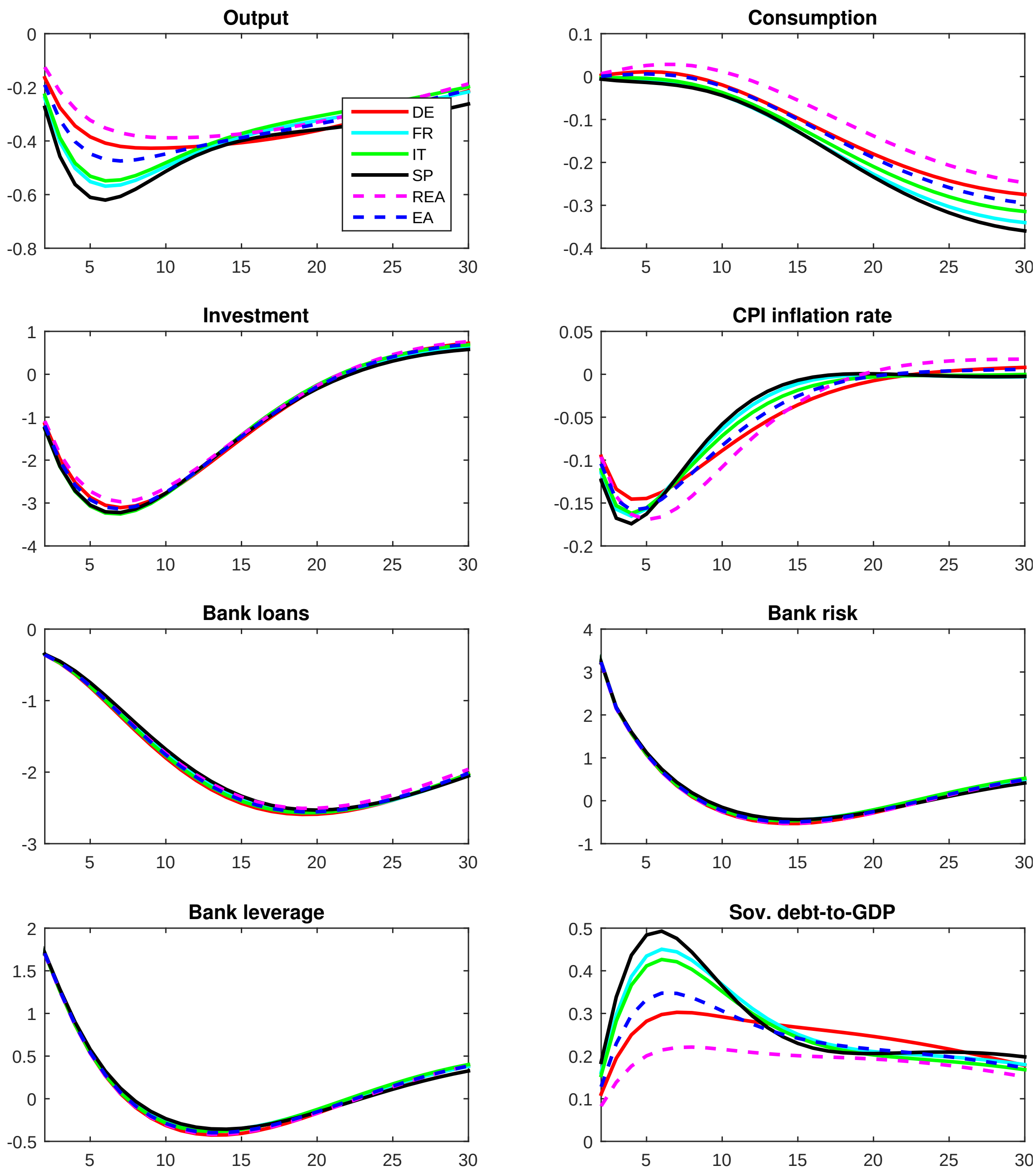
Notes: increase of the euro area bank mark-up μ_E^R so that the ex-ante retail bank return increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: percentage deviations from baseline, except for 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 12: Positive temporary euro area **competitive mark-up shock** - Symmetric calibration



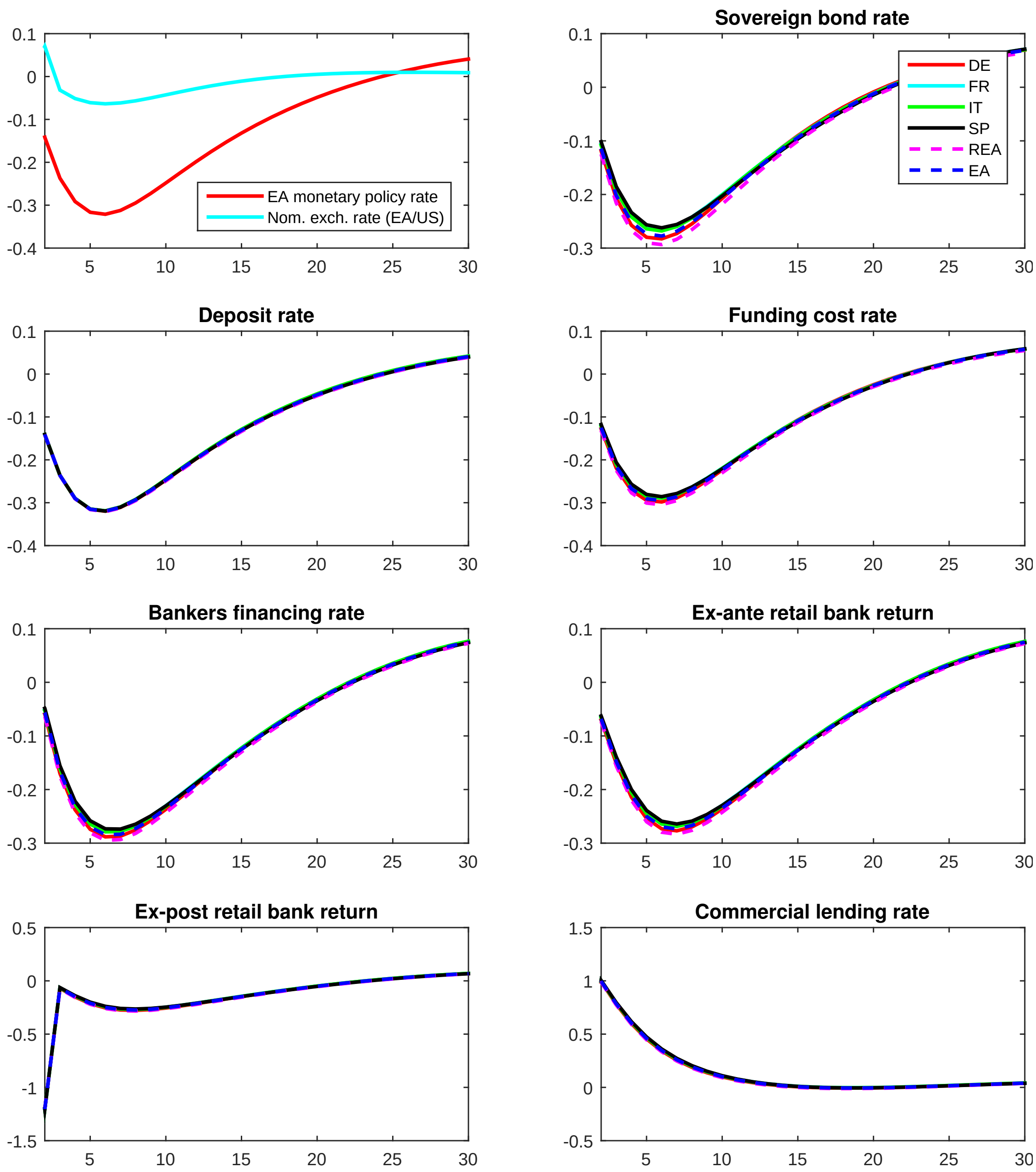
Notes: increase of the euro area bank mark-up μ_E^R so that the ex-ante retail bank return increase by 1 percent approximately; shock is persistent, i.e. follows an AR(1) process with autocorrelation being 0.9. Horizontal axis: quarters. Vertical axis: annual percentage-point deviations from baseline.

Figure 13: 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 14: 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.

Figure 15: Positive **debt valuation shock** - Asymmetric sovereign risk calibration

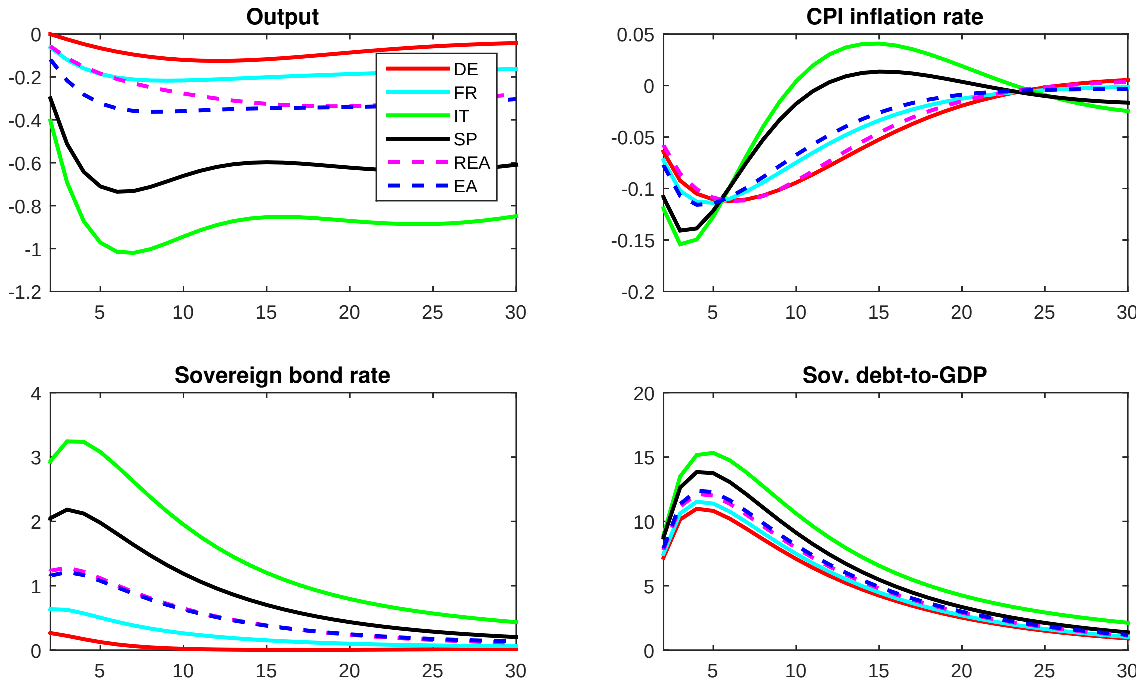


Figure 16: Negative euro area **bank capital shock** - Asymmetric sovereign risk calibration (difference from symmetric case)

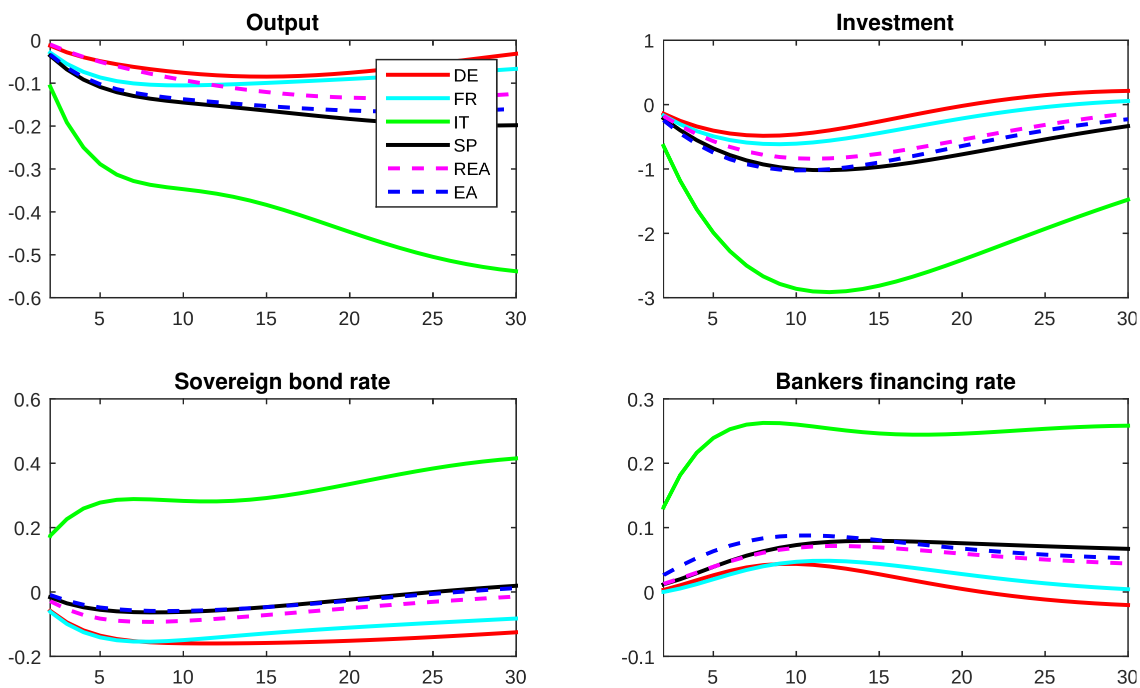


Figure 17: Reduction in the euro area **monetary policy rate** - Asymmetric bank risk calibration (difference from symmetric case)

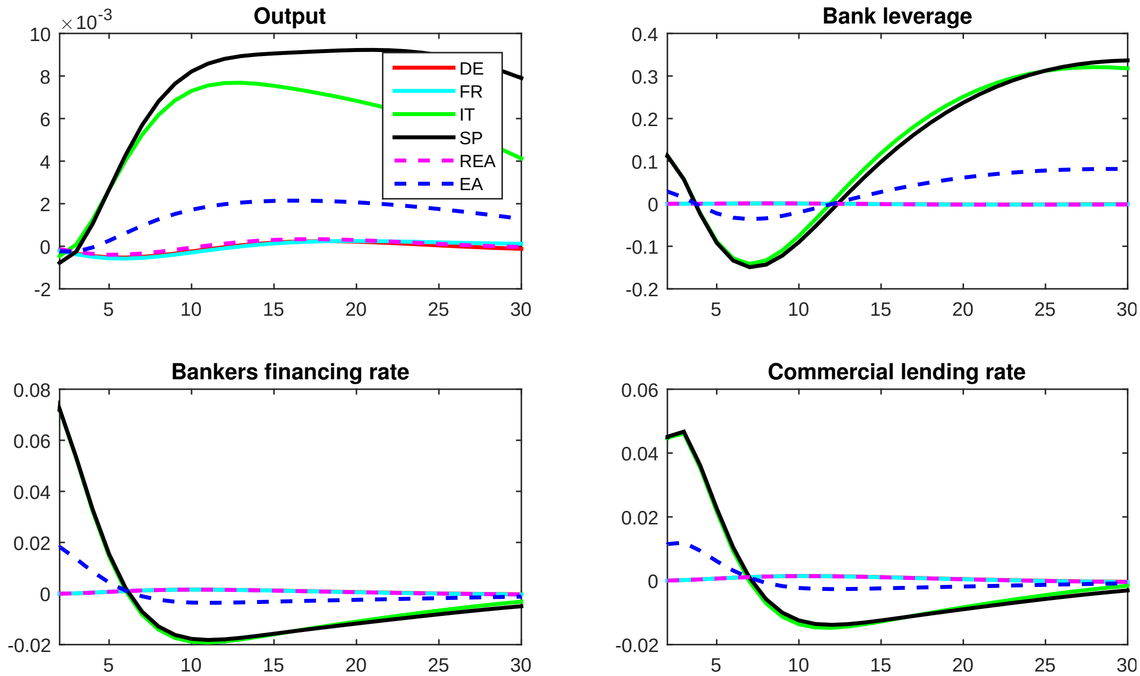


Figure 18: Negative euro area **bank capital shock** - Asymmetric bank risk calibration (difference from symmetric case)

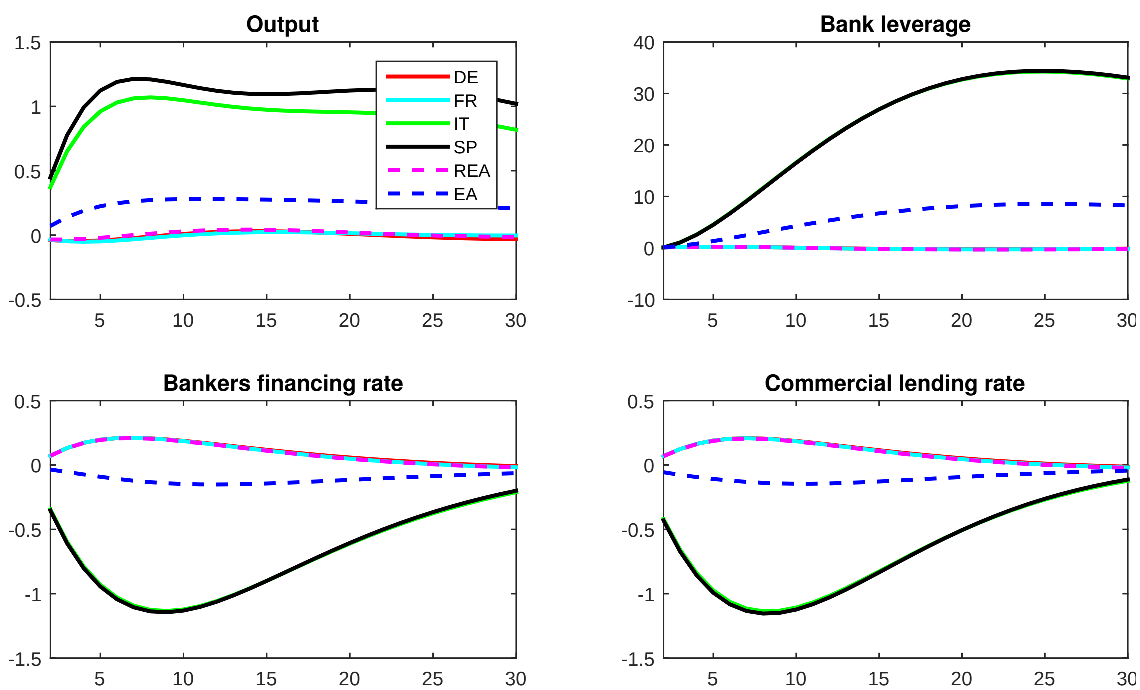


Figure 19: Negative euro area **bank capital shock without limited liability** - Asymmetric bank risk calibration (difference from symmetric case)

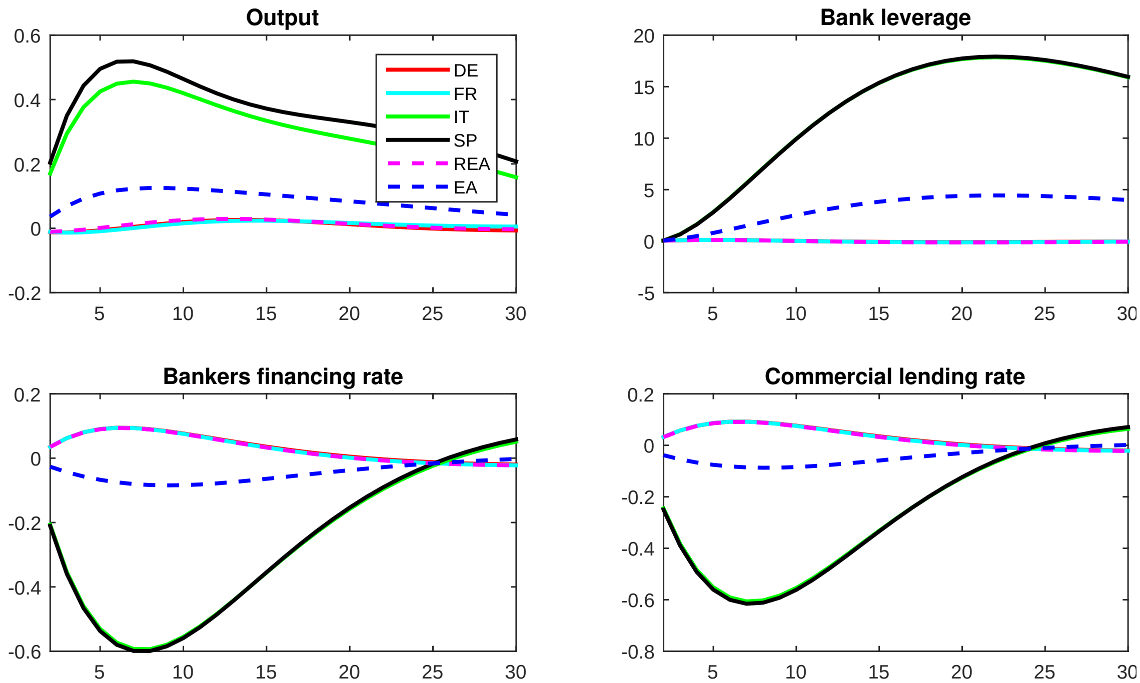


Figure 20: Negative euro area **bank capital shock** - Asymmetric bank risk calibration (difference from symmetric case)

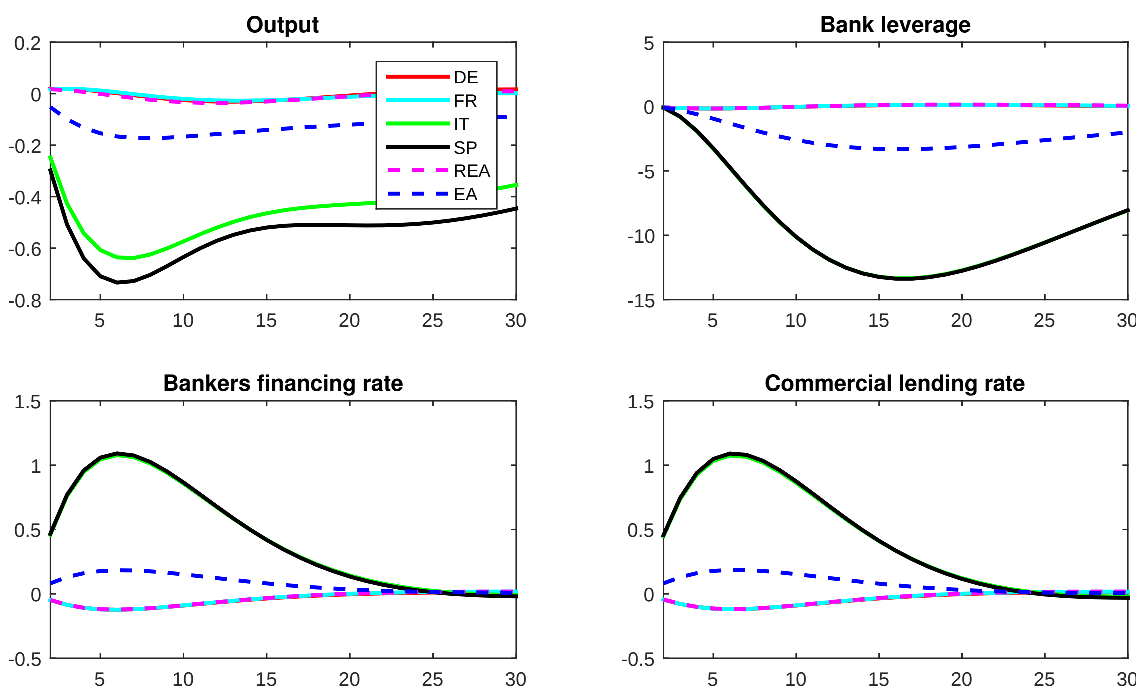


Figure 21: Reduction in the euro area **monetary policy rate** - Asymmetric staggered lending rate setting calibration (difference from symmetric case)

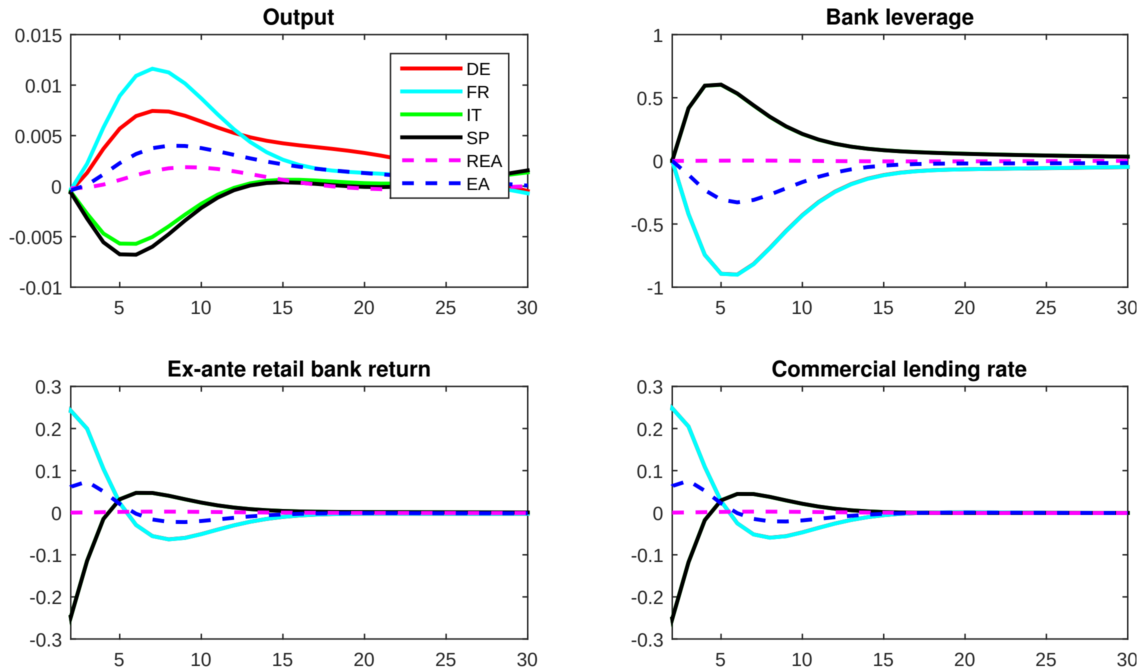


Figure 22: Increase euro area **sovereign risk premium** - Asymmetric staggered lending rate setting calibration (difference from symmetric case)

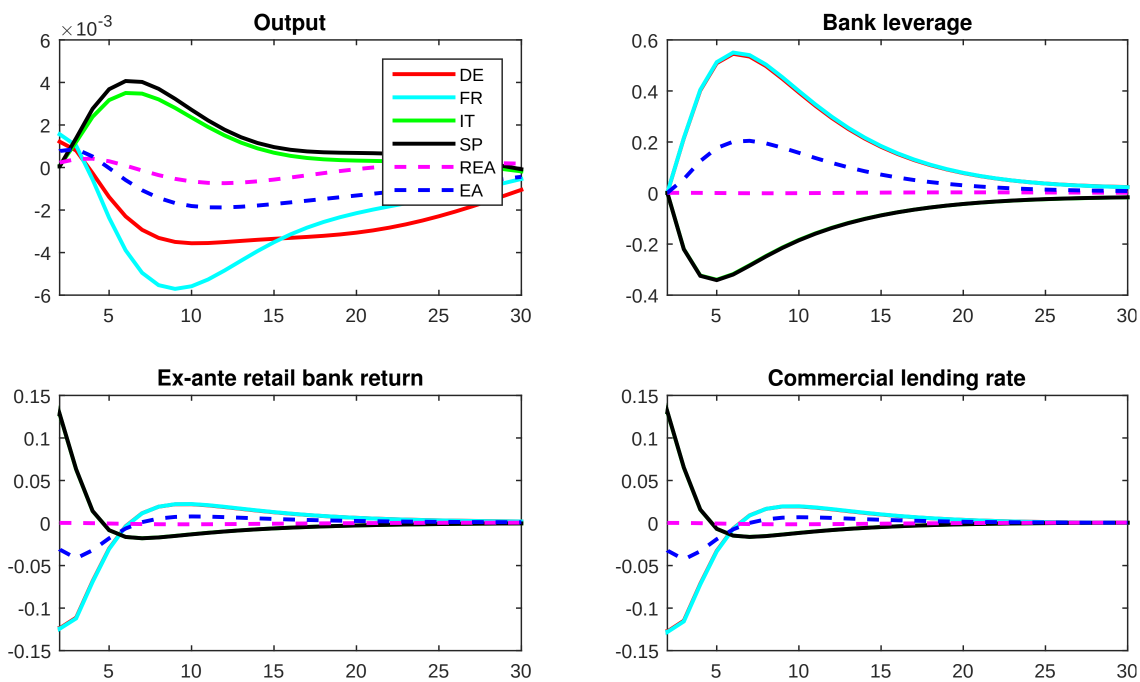


Figure 23: Reduction in the euro area **monetary policy rate** - Asymmetric corporate risk calibration (difference from symmetric case)

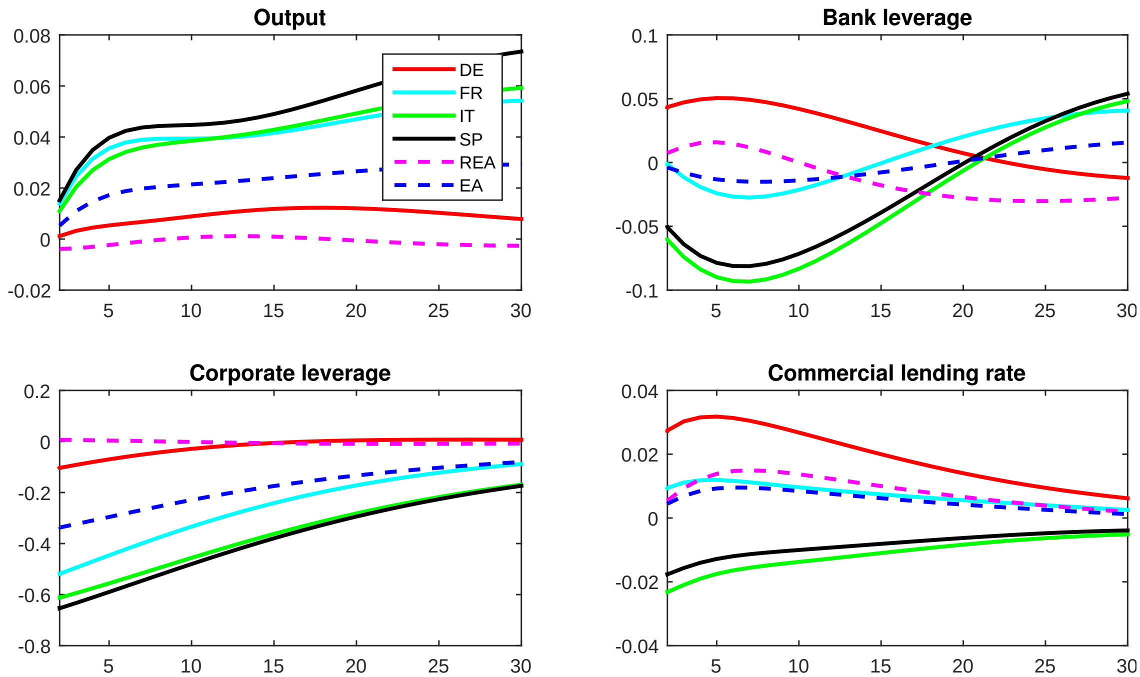


Figure 24: Negative euro area **bank capital shock** - Asymmetric corporate risk calibration (difference from symmetric case)

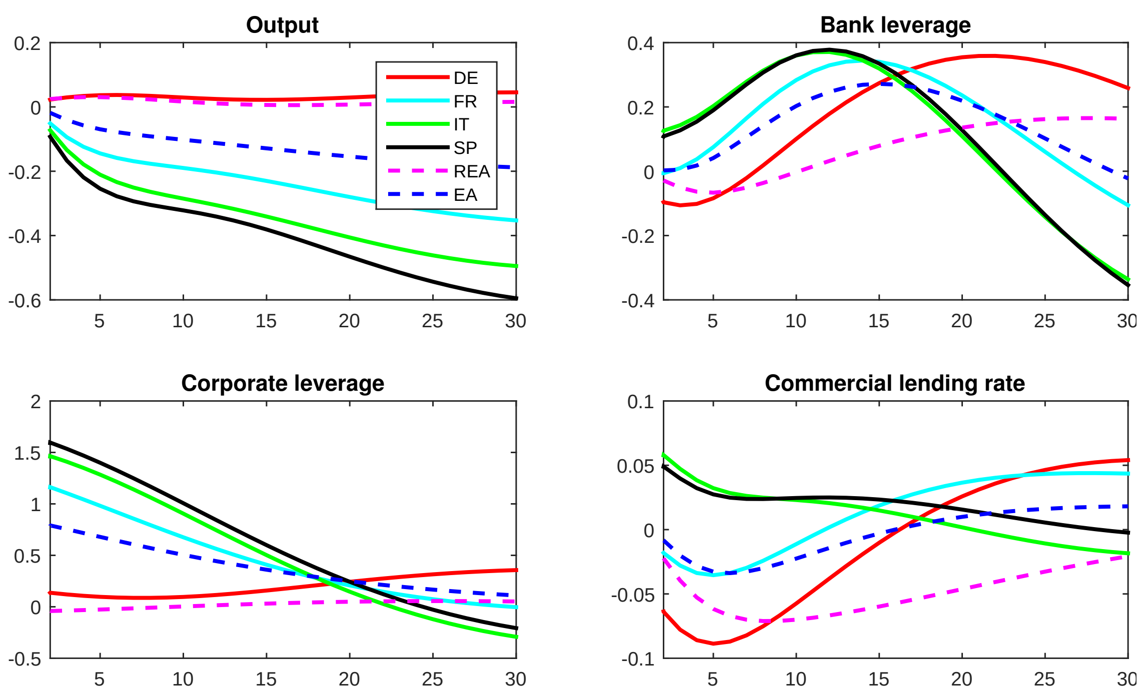
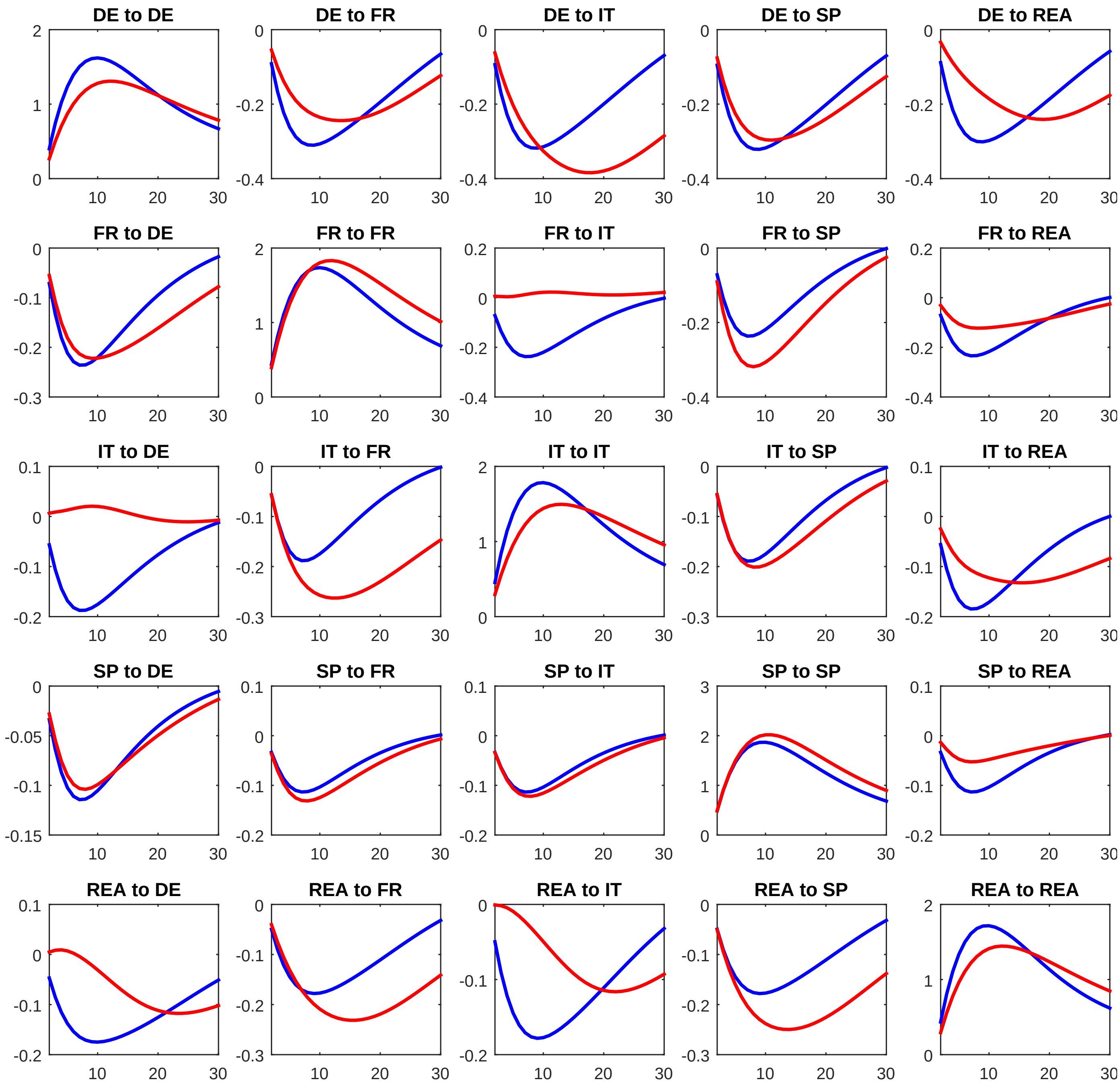
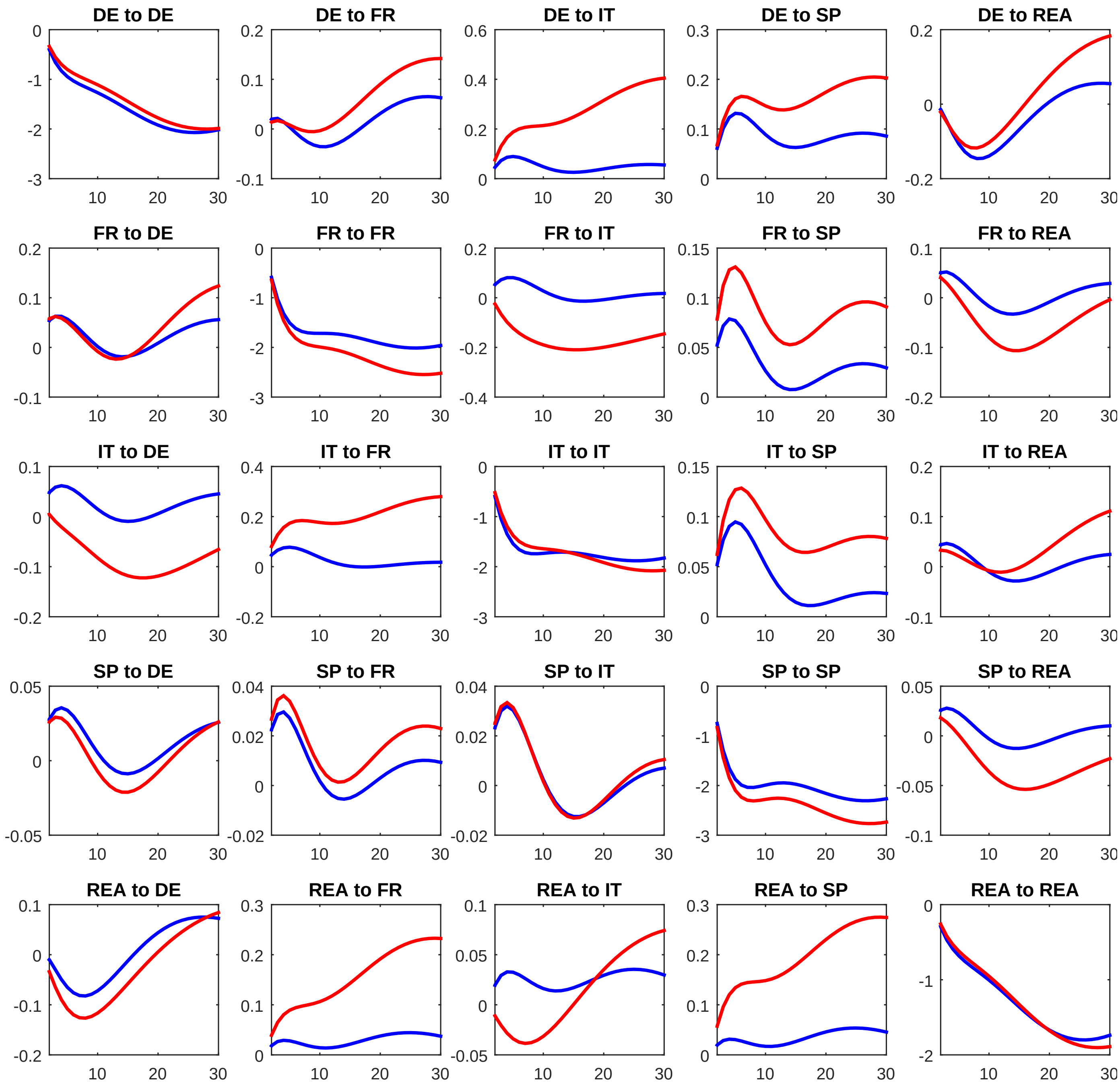


Figure 25: Negative country specific **bank capital shock** - Effect on ***ex ante* retail bank return** - Comparison between with and without cross border financial linkages



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 26: 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.