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Mario Bellia, Ludovic Calès, Lorenzo Frattarolo, Andreea Maerean, Daniel P. Monteiro, Marco Petracco Guidici and Lukas Vogel

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The Sovereign-Bank Nexus in the Euro Area: Financial and Real Channels

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Abstract

The sovereign-bank nexus played a key role in the 2009-12 European debt crisis by enabling pernicious dynamics whereby governments and domestic banking sectors mutually enfeebled each other. This paper reviews the direct (financial) channels and the indirect (real) channels through which banks and sovereigns interact, and that can give rise to feedback loops between the two sectors. While significant progress has been achieved in mitigating the direct channel of the loop in recent years, the indirect mechanisms of the loop stayed largely intact. Policy options for improving the financial stability of both banks and sovereigns across the euro area have been discussed, including measures to increase the diversification of banks' sovereign debt holdings. Focusing on diversification as a standalone measure, a review of the literature and model-based simulations suggest an ambiguous impact on systemic risk. However, in those cases where diversification can either reduce total risks or keep them unchanged, it can also deliver an important shock-absorption effect in crisis periods. In such cases, simulations show that higher cross-border integration of banking sectors would dilute the impact of asymmetric shocks across the regions of a monetary union, thus increasing the overall welfare of risk averse households.

JEL Classification: G01, G21, G28.

Keywords: sovereign-bank loop, bank regulation, bailout, bail-in, SYMBOL, QUEST.

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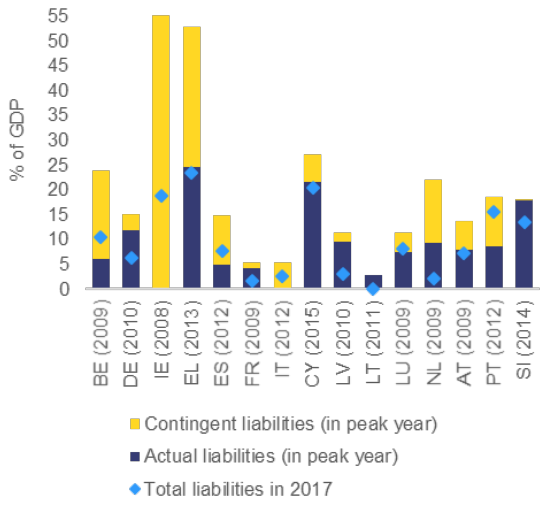
1. INTRODUCTION

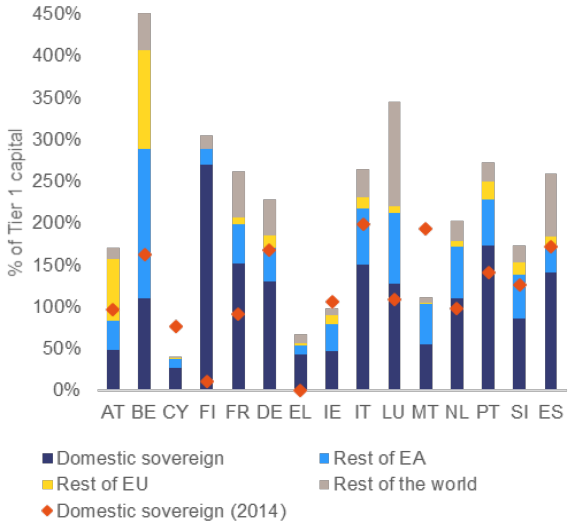
The 2008 financial crisis and the ensuing sovereign debt crisis revealed a progressive intertwining of risks between euro area sovereigns and their domestic banking sectors. While the theoretical mechanisms behind this phenomenon may be varied and are the subject of discussion of this paper, a number of empirical facts that characterised the euro area crisis can be ascertained upfront.

The first of these empirical facts relates to how bank failures led to government interventions in the financial sectors of several euro area countries, which put significant pressure on public finances (Graph 1.1). The second fact notes that banks' sovereign credit risk exposures have remained biased towards their domestic sovereign across the euro area (Graph 1.2). Thirdly, euro area sovereigns saw hikes in their default risk (Graph 1.3), which correlated with hikes in the default risk of domestic banks (Graph 2.2).

Graph 1.1 **General government liabilities due to interventions to support financial institutions**



Graph 1.2 **Geographical breakdown of sovereign exposures of euro area banking sectors (June 2018)**



Notes:
Graph 1.1: total liabilities equals the sum of actual and contingent liabilities; contingent liabilities relate mainly to the provision of government guarantees on assets and liabilities of financial institutions and special purpose vehicles; actual liabilities are those having an immediate impact on government debt; the peak year for total liabilities is written on the horizontal axis for each country; EE, MT, SK and FI are not plotted due to the absence of government liabilities linked to the support of financial institutions.

Source: own calculations based on Eurostat data (Graph 1.1); own calculations based on consolidated data for banking groups from the 2018 and 2015 transparency exercises of the EBA (Graph 1.2).

The fact that the troubles of banks and governments appear to have reinforced each other in the past decade has led academics, economists and policy makers to refer to "diabolic loops"[1] between weak bank balance sheets and sovereign fragility, and to consider this phenomenon a key feature of the euro area crisis.

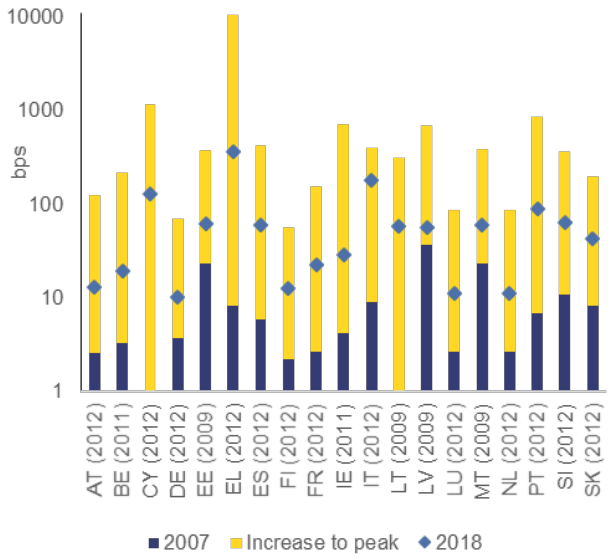
The situation in the euro area has improved significantly compared to the peak crisis period owing both to an improved institutional framework and to a more favourable economic environment. Sovereign risk has receded markedly – though it remains well above pre-crisis benchmarks in most countries –, while government liabilities linked to financial sector interventions are unwinding (Graphs 1.1 and 1.3).

[1] The term was coined in 2011 by the Euro-nomics group composed of academic economists from various euro area countries.

The degree of home bias in banks' sovereign debt holdings remains high, but appears to have decreased in recent years in a number of countries, although there are exceptions to this trend (Graph 1.2).[2] Still, many of the financial and real channels that drive the sovereign-bank nexus remain in place and could potentially re-ignite nocuous dynamics in some form or another.

The remainder of this article is structured as follows. Section 2 reviews the direct and indirect channels of the sovereign-bank loop, with references to the literature. Section 3 conducts assessments of the sovereign-bank loop using the Commission's SYMBOL and QUEST models. Besides baseline simulations, counterfactual scenarios are considered involving the diversification of banks' debt holdings and a higher degree of cross-border integration of banking sectors. Section 4 considers the progress achieved as regards the institutional setup of the euro area, discusses remaining challenges and explores possible policy responses. Finally, Section 5 concludes.

Graph 1.3 **5-year sovereign CDS spreads**



Note: non-linear scale; the year in the country legend refers to the peak year for CDS spreads; no data for 2007 for CY and LT.

Source: Bloomberg, own calculations.

2. THE SOVEREIGN-BANK LOOP

The interactions between the government and the banking sector occur through several channels, which can be split between direct and indirect. Graph 2.1 depicts both types of channels in a schematic manner and provides a visual reference for the next subsections that discuss, in turn, the direct channels (which operate via financial exposures between banks and sovereigns) and the indirect channels (which operate via real economy mechanisms).

2.1. THE DIRECT FINANCIAL CHANNELS

The direct channels are essentially born of banks' financial exposures to domestic sovereign debt and (of the possibility) of governments' financial interventions in the domestic banking system through nationalisations, bail-outs, capital injections,[3] provision of guarantees (including on deposits),[4]

[2] The notably large increase in the degree of home bias observed in Finland is driven both by a very large increase in the domestic sovereign exposures of one institution and by the inclusion of a new institution in the sample, itself highly exposed to the domestic sovereign. The choice of 2014 in Graph 1.3 as the initial data point is driven by comparability considerations regarding the EBA sample.

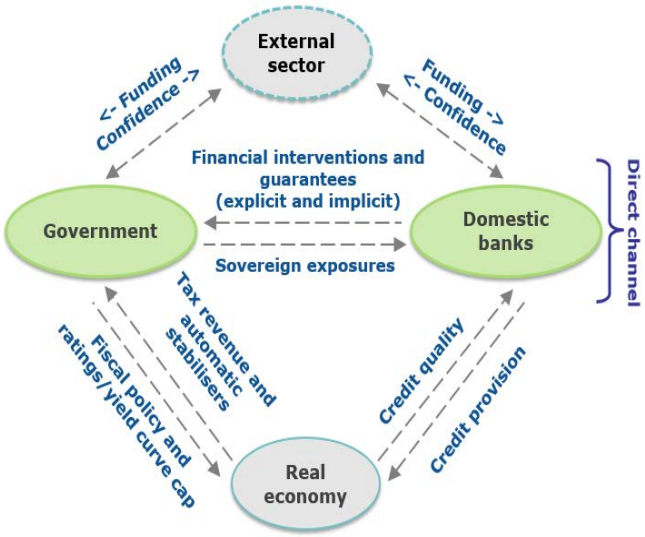
[3] A capital injection may not constitute a bail-out, strictly speaking, if it serves to reinforce the capital base of a bank that already meets the minimum capital requirements set out in the banking regulations.

[4] Given the seniority of deposits over other bank liabilities and the existence of deposit guarantee schemes that are funded ex ante to protect deposits up to € 100 000 in the event of a bank failure, any implicit governmental guarantee on deposits is only partial.

purchase of toxic assets and incurrence in other forms of contingent liabilities. Other measures by public authorities for dealing with banking crises include liquidity support from the central bank, deposit freezes and bank holidays.[5]

The sovereign-bank loop, whereby banks and their domestic sovereigns mutually enfeeble each other, can occur via the direct channel when bank losses lead to government-sponsored recapitalisations, the provision of guarantees, or other increases in the contingent liabilities of the government, either in actual or expected value terms. This leads to an increase in actual or expected government debt levels, thereby putting downward pressure on sovereign bond prices. Given banks' holdings of domestic sovereign debt, this contributes to further weaken their balance sheets (when measured in market value terms), which iterates the loop.[7] In addition, since sovereign bonds serve as collateral for financial transactions, a bank's ability to obtain funding can decline when the sovereign experiences financial difficulties.[8]

Graph 2.1 **Sovereign-bank loops**



Source: adapted from the sovereign-bank loop literature.[6]

It should be noted that the direct channel of the loop can also originate on the side of the sovereign, as when unsound fiscal policies lead to increases in government debt and sovereign risk, which transmits to domestic banks via valuation losses on sovereign debt.[9]

It is also worth noting that government guarantees and the possibility of government interventions can generate moral hazard in the banking sector, incentivising banks to take on more risk on their balance sheets and lowering their financing costs at the same time. Moral hazard can occur, for example, through rescue packages that transfer credit risk from the banking sector to the government. Evidence from credit default swap (CDS) spreads for the euro area countries and banks shows that the introduction of bank bailouts around October 2008 caused bank CDS premia to decrease while sovereign risk spreads surged.[10] Such risk shifting has led to policy action at EU level to break this direct channel by requiring the "bail-in" of bank creditors in the event of a bank failure as a pre-condition for a public intervention.[11]

[5] For details on different support measures employed by different countries in the 1970-2011 period see Laeven and Valencia (2012).

[6] See, e.g., Schnabel and Véron (2018) and Giudice (2019).

[7] See, e.g., Schnabel and Schüwer (2016). The authors confirm a positive correlation between the strength of the sovereign-bank nexus and factors such as a high degree of home bias, low bank capital ratios and high sovereign debt ratios.

[8] See Bank for International Settlements (2011).

[9] See, e.g., Stournaras (2016).

[10] See Ejsing and Lemke (2011).

[11] Bail-in is a resolution tool whereby bank creditor positions are converted into equity positions in the case of a failing bank. See also Section 4.1.

2.2. THE INDIRECT REAL CHANNELS

The indirect channel is in place via real economy linkages and operates even in the absence of government interventions or direct financial exposures from banks to sovereigns. A loop via the indirect channel can occur when a shock leads to constraints in banks' supply of credit, which then negatively affect private investment, consumption and the broader economy. An economic slowdown acts, in turn, to increase the government deficit through lower tax revenues and the operation of automatic stabilisers. Historical evidence shows that government debt can increase dramatically following banking crises, and that these surges are not necessarily due to bailout costs, but can be driven by a combination of collapsing tax revenues in the wake of output contractions and countercyclical fiscal policies aimed at mitigating the downturn.[12]

In the presence of such a downturn, government may see its debt increase (which can ignite the direct channel) or embark on a fiscal consolidation course (e.g., to avoid losing market access), further slowing down the economy through the withdrawal of stimulus. As economic activity is further depressed, it negatively impacts the balance sheet of banks through valuation and loan losses. This further lowers banks' capital ratios and their lending ability,[13] iterating the loop. The loop can also start on the government side, or simultaneously in both sectors, as when an adverse macroeconomic shock affects both government revenues and banks' assets.

The indirect channel also includes other mechanisms. For example, empirical evidence indicates that increases in government risk premia spill over to risk premia in the domestic private sector,[14] while sovereign ratings act as a de facto cap on the ratings of domestic companies.[15] Graph 2.2 illustrates risk premia interlinkages across sectors. As can be observed, both the credit risk premia of banks and of non-financial corporations (as measured by CDS spreads) have correlated strongly with sovereign risk premia over the past decade, particularly in the most acute crisis periods. This is true of "periphery" countries but also, to a smaller extent, of "core" euro area countries.

Additionally, banking crises may lead to a disappearance of external financing due to a fall in confidence among foreign investors. As a result, governments will have reduced ability to roll over and service their external debt,[16] with sudden stops of capital flows often generating sovereign defaults.

Finally, the real economy also intermediates the sovereign-bank loop through its effect on the sustainability of public finances (e.g., weak or negative growth imply less favourable government debt-to-GDP ratios which, in turn, tend to depress sovereign bond valuations).

[12] See Reinhart and Rogoff (2009a) and Baldacci and Gupta (2009).

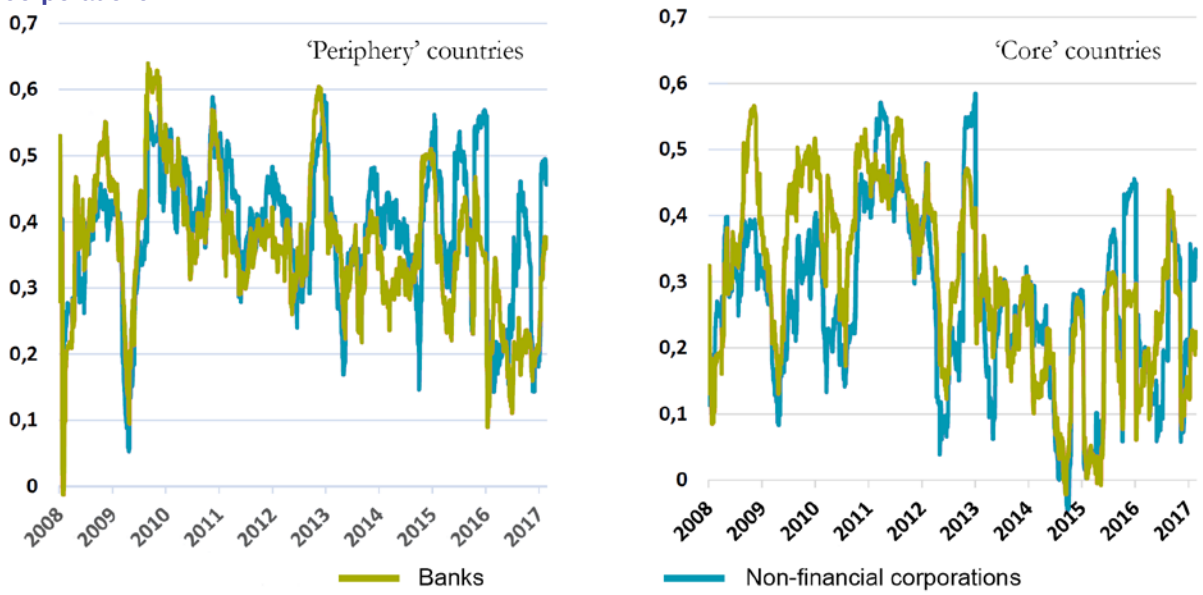
[13] For an analysis of how the need to improve capital ratios may constrain bank lending see, e.g., Monteiro and Priftis (2017).

[14] See, e.g., Theobald and Tober (2019) and Augustin et al (2016). For the role of country risk in driving the risk premia of NFCs, see also Horny et al (2016).

[15] Bank for International Settlements (2011) shows that sovereign downgrades often translate into lower ratings for domestic banks, which in turn can worsen their access to foreign financing and affect their borrowing conditions.

[16] See Reinhart and Rogoff (2009b).

Graph 2.2 **Average 60-day rolling correlations between sovereign CDS spreads and those of domestic corporations**



Notes: "periphery" countries correspond to IT, ES, IE, PT and EL, while "core" countries correspond to DE, FR, NL, AT and BE.

Source: presentation by V. Constâncio at the NBB/ECB/Solvay/TSE conference on "Managing financial crises: where do we stand?' (2018); based on Datastream data for 5-year senior CDS spreads running from June 2008 to October 2017.

2.3. MODELLING THE FEEDBACK LOOP

The previous subsections explored how direct and indirect channels may be at play in the sovereign-bank loop. The present subsection looks deeper into instances of how the loop itself has been modelled in the literature.

Most empirical papers explore the relationship between sovereigns and banks by measuring their credit risk through CDS spreads. Acharya et al (2014) introduce a theoretical model where bailouts and sovereign bond holdings interlink financial sector and sovereign default risk. Using CDS data in an empirical application, they not only show that bailouts lowered banks' default risk while sovereigns' risk increased, but also that changes in sovereign CDS spreads drove changes in banks' CDS spreads in the post-bailout period (i.e., that sovereign stress is transmitted to the financial sector, post bail-out). Alter and Schüler (2012) also rely on CDS data to show how bank default risk affected their host sovereign's at the beginning of the crisis, and confirm that bailouts strengthen the reverse causal relationship. Mody and Sandri (2012) proxy sovereign default risk through bond spreads and banks' fragility through the relative equity index of the financial sector. Their modelling of sovereign risk can be combined with the Commission's SYMBOL model to obtain another empirical tool to assess the sovereign-bank loop, as discussed in detail in Section 3.1.

As regards the theoretical literature, Brunnermeier et al (2016) provide a model of the sovereign-bank loop than is employed to show how such loops can be avoided by restricting banks' domestic sovereign exposures, in particular by shifting them to the senior tranche of a diversified sovereign bond portfolio (i.e., "ESBies"). Their theoretical model is extended in Brunnermeier et al (2017) to study the equilibrium effects of different ESBie portfolios. Farhi and Tirole (2018) contribute to the theoretical literature with a comprehensive model of the feedback loop that covers the supervisory function and inspects the mechanisms behind domestic bailouts of the banking system and sovereign debt forgiveness by international creditors, or solidarity by other countries. Cooper and Nikolov (2018) highlight the role of banks' decisions on equity issuance in preventing or enabling the feedback

loop. Finally, dynamic stochastic general equilibrium (DSGE) models with a banking sector can generally capture at least some of the elements of the sovereign-bank nexus. For instance, Gourinchas et al (2016) examine the Greek crisis of 2010 through the lens of such a model to examine the role of different drivers, including sovereign risk, credit costs and non-performing loans. A model from the same DSGE class – the Commission's QUEST model – is employed in Section 3.2.

3. FINANCIAL AND REAL CHANNELS: A MODEL-BASED ASSESSMENT

This section presents stylised simulations that illustrate the workings of the direct and indirect channels of the sovereign-bank loop using the European Commission's SYMBOL and QUEST models. The benefits that can be reaped by weakening the embrace between domestic banks and sovereigns are illustrated in counterfactual scenarios that show the effects of i) stronger diversification of banks' sovereign debt holdings and ii) cross-border diversification of bank ownership (in the case of QUEST). These counterfactuals quantify the potential for risk reduction and risk sharing from reducing banks' home biases and increasing cross-border integration of banking sectors.

3.1. DIRECT CHANNEL LOOPS: A SYMBOL MODEL ASSESSMENT

SYMBOL is micro-simulation credit portfolio model designed to, inter alia, assess the risks to public finances emanating from the banking sector. The model is particularly well suited for the assessment of loops via the direct "financial" channel, providing a high level of banking sector and geographical disaggregation. The model inputs include variables capturing the (initial) riskiness of banks and sovereigns, as well as the exposures of the former to the latter. By considering shocks to banks' assets and to sovereign bond prices, the model estimates "excess losses" corresponding to the possible impact on public finances via recapitalisation needs. The details of the model are provided in Annex I.

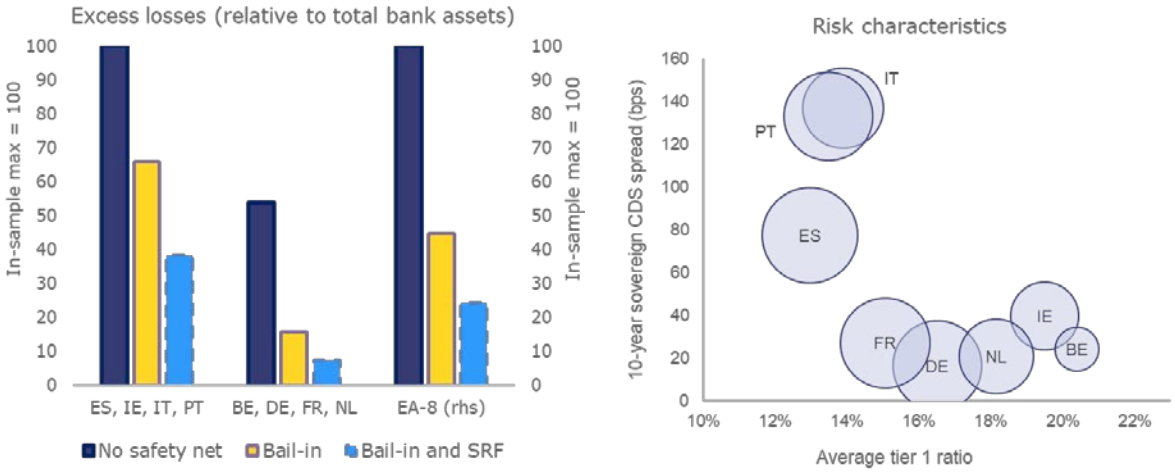
In the present exercise, the model covers a sample of euro area banks from eight Member States participating in the 2018 transparency exercise of the European Banking Authority (EBA). Together, sovereign exposures from these banks represent roughly 70% of the exposures included in the transparency exercise. For presentational purposes, the simulation results in this section are i) scaled up to reflect the size of the domestic banking sector of each Member State and ii) aggregated from bank level results into three blocs: a group of countries that were more severely affected by the crisis (i.e., Ireland, Spain, Italy and Portugal), a group of countries less severely affected (Belgium, Germany, France and the Netherlands) and a EU-8 bloc representing the sum of the previous two. The bank-level data refers to year-end 2017, unless otherwise noted.

Graph 3.1 compares "excess losses" (divided by total bank assets) arising from a severe systemic shock to the banking sectors of EA-8 countries. Here and elsewhere, excess losses are defined as the losses incurred by banks bringing the tier 1 capital ratio below a threshold of 10.5%. These are, therefore, the losses that need to be covered through government-sponsored recapitalisation if a bank is to continue to operate under a minimum required capital ratio of 10.5%. It should be noted that excess losses include both losses from an initial shock to banks' assets as well as additional losses born out of the sovereign-bank loop. Here and elsewhere, a severe shock is based on a loss percentile reflecting the order of magnitude of the 2008 financial crisis. That is, the shock is set to a very high magnitude, corresponding to losses falling beyond the 99.95th percentile of the loss probability distribution function under the Basel credit risk model.[17] For presentational purposes, and taking account of the

[17] It should be noted that the 99.95th loss percentile is a theoretical one, chosen to make model results agree with observed losses during the crisis. It should not therefore be taken as an actual event probability. In particular,

stylised and illustrative nature of the simulations, excess losses are presented in relative terms, with the maximum in-sample losses set equal to 100 in the following graphs. Thus, the region and scenario with the highest loss was normalised to 100, with the results for the other region and scenarios being expressed in relation to that maximum.[18]

Graph 3.1 **Excess losses from a severe systemic shock (relative to total bank assets) vs. risk characteristics**



Notes: excess losses relative to total bank assets correspond to the amount of losses incurred by banks bringing the tier 1 capital ratio below a threshold of 10.5% divided by that bank's total assets. The maximum figure was normalised to 100. The severe systemic shock reflects a loss falling beyond the 99.95th percentile under the Basel credit risk framework. In the right-hand side chart, the bubble width represents the degree of home bias.

Source: EBA, Bloomberg, SYMBOL simulations and own calculations.

As can be observed, excess losses (and related governmental capital injections) can be strongly reduced through the bail-in of bank creditors and the use of a euro area-wide single resolution fund (SRF). [19] Both measures are denoted hereafter as the "safety net". In fact, while all three scenarios depicted in Graph 3.1 are merely illustrative and should not be taken as precise estimates, the no-safety-net scenario is entirely theoretical given the new resolution framework discussed in Section 4. As regards the drivers of excess losses, these correlate with the initial levels of bank capitalisation and sovereign risk (e.g, it can be observed in Graph 3.1 that three of the countries of the group with the largest relative losses are also the ones with the highest sovereign CDS spreads and lowest tier 1 ratios).

Graph 3.2 highlights the amount of progress achieved over the past years in reducing risk levels in sovereign and banking sectors, and in mitigating the feedback loop between them. In particular, the

SYMBOL is consistent with probabilities of default under the Basel credit risk model, which is understood to underestimate actual bank default probabilities. It should be recalled that, under the Basel model (and therefore under SYMBOL), a bank holding its minimum capital requirement is expected to fail with a probability of 0.1% in a given year.

[18] Due to differences in scale, the EA-8 aggregate is represented on the secondary axis independently of the constituent regions, with its maximum across scenarios also set to 100.

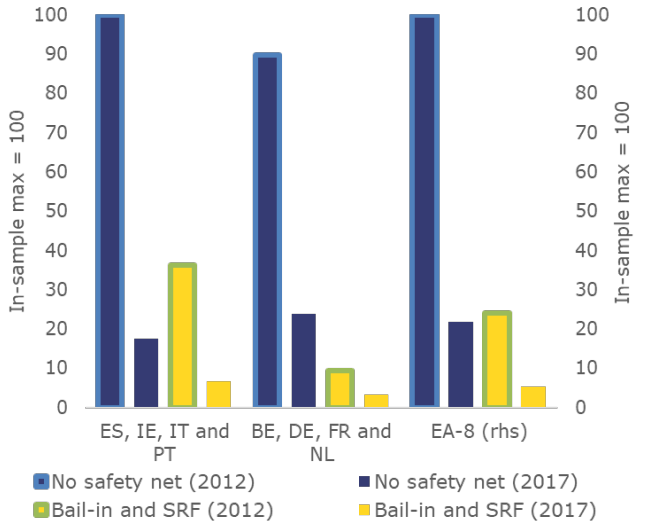
[19] Bail-in is a resolution tool whereby bank creditor positions are converted into equity positions in the case of a failing bank. Resolution funds are capitalised by the banking sector and can be tapped into to finance the restructuring of failing systemic banks. See also Section 4.1.

In the present simulations, bail-in was modelled as a "worst-case scenario", where total loss absorbing capacity, constituted of bail-in capacity and regulatory capital, is set at 8% of total assets. The SRF is here assumed to have been phased in to 40% of its target level. The SRF is also assumed to contribute to resolution by absorbing losses up to 5% of total assets of the insolvent bank provided that bail-in has already occurred.

graph compares excess losses of banks based on 2017 and 2012 data for the same systemic shock seen earlier.[20]

Overall, the results suggest that the new regulatory framework, other policy action and changes in the economic environment have worked to reduced potential losses to a very small fraction of those possible in 2012. This is patent when comparing the results for 2017 under bail-in and a SRF to the no-safety net scenario in 2012. Large reductions are also observed when removing the effects of the bail-in tool and the SRF, which were not available in 2012 (see blue bars in Graph 3.2). The same holds true when assuming bail-in and a SRF in both points in time (see yellow bars in Graph 3.2). Overall, the remarkable improvement owes much both to the new "safety net" as well as to the higher capitalisation levels of euro area banks, to the lower perceived sovereign credit risk, to a lower degree of home bias and, in some cases, to the lower implied risk in banks' portfolios.

Graph 3.2 **Total excess losses from a severe systemic shock: 2017 vs 2012**



Note: excess losses correspond to the amount of losses incurred by banks bringing the tier 1 capital ratio below a threshold of 10.5% (2017) or 8% (2012). The severe systemic shock reflects a loss falling beyond the 99.95th percentile under the Basel credit risk framework.

Source: SYMBOL simulations.

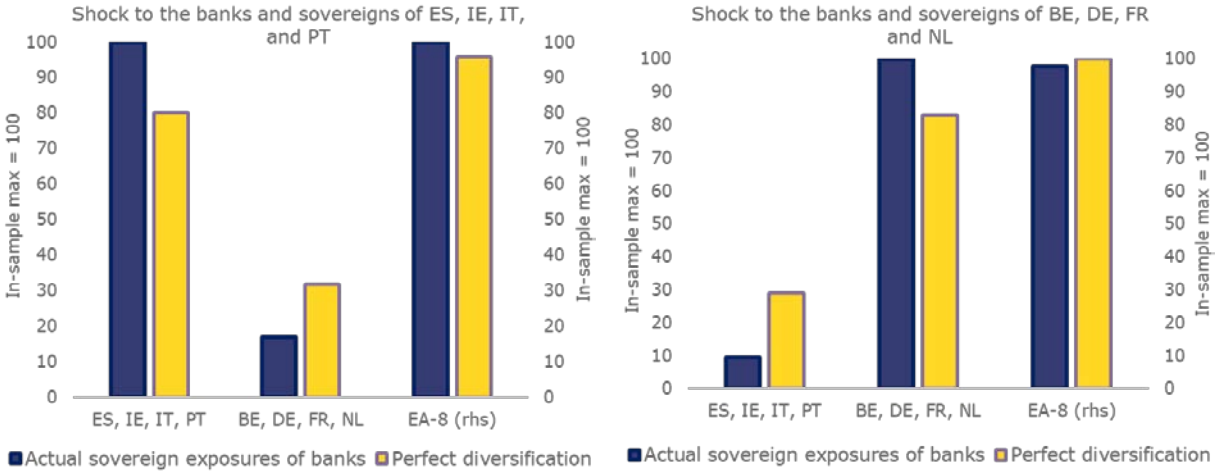
Graph 3.3 shows total excess losses caused by shocks to banks and sovereigns in different regional blocs. It presents results based on actual sovereign exposures as well as counterfactual scenarios where these exposures have been perfectly diversified (i.e., a situation where sovereign portfolio shares are the same for all banks, and equal to that sovereign's share in total sovereign exposures). This can be understood as a limit case where home bias has been fully eliminated across the euro area.

As can be observed, perfect diversification can have an important risk sharing effect as well as different risk reduction implications depending on the regional bloc affected by the asymmetric shock. The results suggest that in the case of a severe shock to the banks and sovereigns of the countries that were more affected by the crisis, diversification allows to mitigate losses in the affected region, and to distribute part of those losses with the unaffected region, while reducing total losses for the euro area aggregate (see left hand-side panel of Graph 3.3). A similar distribution of the impact is also in evidence in the case of an asymmetric shock to the countries that were less affected by the crisis (see right hand-side panel of Graph 3.3). However, in that case the total losses of the euro area aggregate increase marginally. This is due to the fact that stronger diversification and risk distribution can potentiate sovereign-bank loops and debt valuation losses in the more vulnerable region generated by losses in less vulnerable countries, so that total losses are increased.[21]

[20] Data for year-end 2012 are based on the results from the 2013 transparency exercise run by the EBA. Given the fact that the sample of bank included in the 2017 and 2012 vintages do not fully overlap, comparisons should be made with caution. Also, given the lower capital requirements in 2012, the minimum tier 1 capital ratio is set at 8% for that year.

[21] This qualitative result persists when sovereign shocks are excluded from the simulations and only bank-level shocks are retained.

Graph 3.3 **Total excess losses from severe asymmetric shocks to both banks and sovereigns**

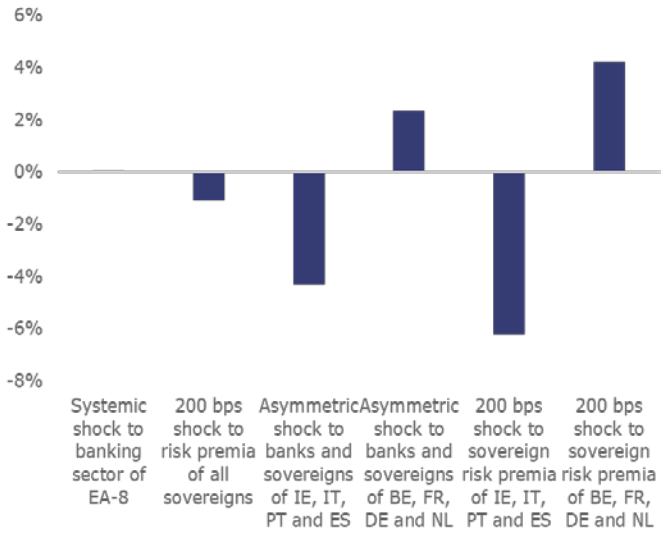


Notes: excess losses correspond to the amount of losses incurred by banks bringing the tier 1 capital ratio below a threshold of 10.5%. The bank-level shock reflects a loss falling beyond the 99.95th percentile under the Basel credit risk framework. The sovereign shock reflects an initial increase of 200 bps in risk premia. In each graph, the initial shocks are imposed in one of the regions only. Assuming a safety net (bail-in and SRF).

Source: SYMBOL simulations.

In some cases, the risk-reduction potential of diversification appears uncertain. While perfect diversification of banks' sovereign debt holdings should frequently lead to a reduction in total losses, it can also increase them in certain cases. Graph 3.4 depicts the simulated risk-reduction potential of perfect diversification under different types of shocks. As can be observed, the impact of diversification on total losses appears largely neutral in the case of a systemic, symmetric shock to all euro area banks or to all euro area sovereigns. Diversification is seen to allow for risk reduction in the case of an asymmetric shock to the banks and sovereigns of the most vulnerable bloc. To the extent that idiosyncratic shocks are more likely to affect the more vulnerable regions, diversification should often lead to overall risk reduction. However, diversification can also increase total losses somewhat in the arguably less likely case of a severe asymmetric shock to the banks and sovereigns of the "core" economies by igniting sovereign-bank loops in the more vulnerable Member States. This result is in line with other findings in the literature, according to which diversification of debt holdings has an ambiguous effect on systemic and bank-level risk (see Section 4). Such a result also highlights the possible limitations of diversification as a policy measure carried out in isolation.

Graph 3.4 **Change in total excess losses due to perfect diversification**



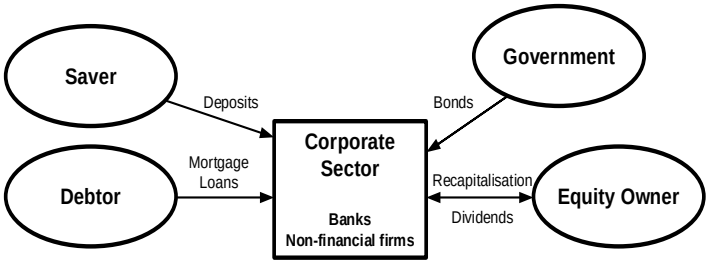
Note: shocks to banks reflect a loss falling beyond the 99.95th percentile under the Basel credit risk framework; total excess losses are summed across all banks in the sample; assuming a safety net (bail-in and SRF) for bank-originated losses.
Source: SYMBOL simulations.

3.2. GENERAL EQUILIBRIUM DYNAMICS: A QUEST MODEL ASSESSMENT

The QUEST model with a banking sector extension has been used as a complementary tool to analyse the bank-sovereign feedback loop and the effects on the macroeconomy of bond valuation and loan losses. Starting from a baseline in which euro area banks retain a largely domestic footprint, implying powerful indirect linkages via the domestic economy, this section discusses the effects of stronger geographical integration of banking sectors. The latter can occur mainly through three forms: (i) cross-border lending and other banking activities; (ii) cross-border funding, including cross-border deposit taking; and (iii) cross-border ownership of bank equity. This subsection considers versions of (i) and (iii), namely stronger diversification of banks' sovereign bond portfolios and stronger diversification of bank ownership across countries or regions.[22]

The model uses a higher level of institutional and geographical aggregation than SYMBOL. Notably, the set-up for this subsection uses a two-region version of the monetary union, with one representative (or, aggregate) bank and one fiscal authority in each region. The model details are described in Annex II while Graph 3.5 provides a visual overview.

Graph 3.5 **Overview of the QUEST model with a banking sector**



The general equilibrium approach of the model can capture in principle both the direct and indirect channels as described in Section 2, i.e. those involving recapitalisation by the government and a deterioration of the economic situation, leading to lower tax revenue and higher government spending.

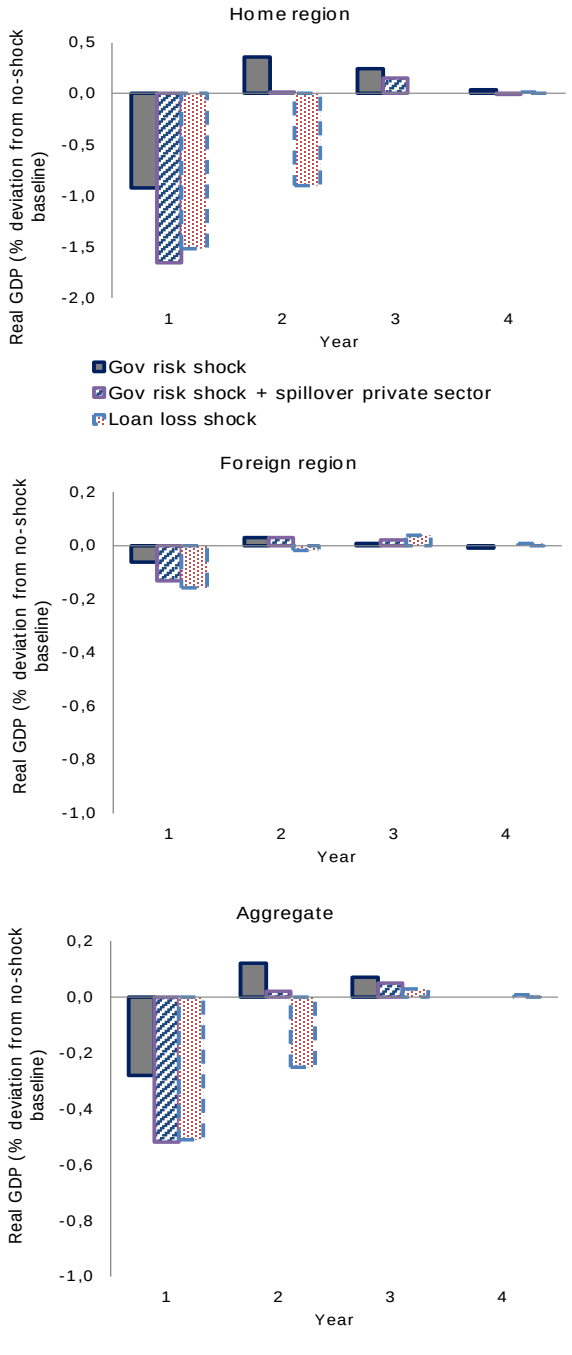
The simulations presented below do not consider, however, the possibility of bank recapitalisation by the national government. This assumption is line with the objectives of the Bank Recovery and Resolution Directive,[23] which seeks to avoid the use of public money when managing bank failures. Recapitalisation comes from equity owners instead, taking the form of lower dividend payments (or capital injections, in more extreme cases). The recapitalisation of banks by their shareholders can be also interpreted as reflecting the existence of a SRF that can ensure banks' continued activity by immediately recapitalising them to the minimum required capital ratio, at a cost of lower dividends and higher bank contributions over time to the SRF.

Excluding the possibility of government bail-outs excludes the possibility of loops starting via the direct channel. Therefore, diversification measures tend to act as mechanisms that distribute the impact of shokcs without affecting aggregate losses. To the extent that balance sheet diversification acts as an insurance mechanism for risk-averse households in both regions, it is in itself welfare increasing.

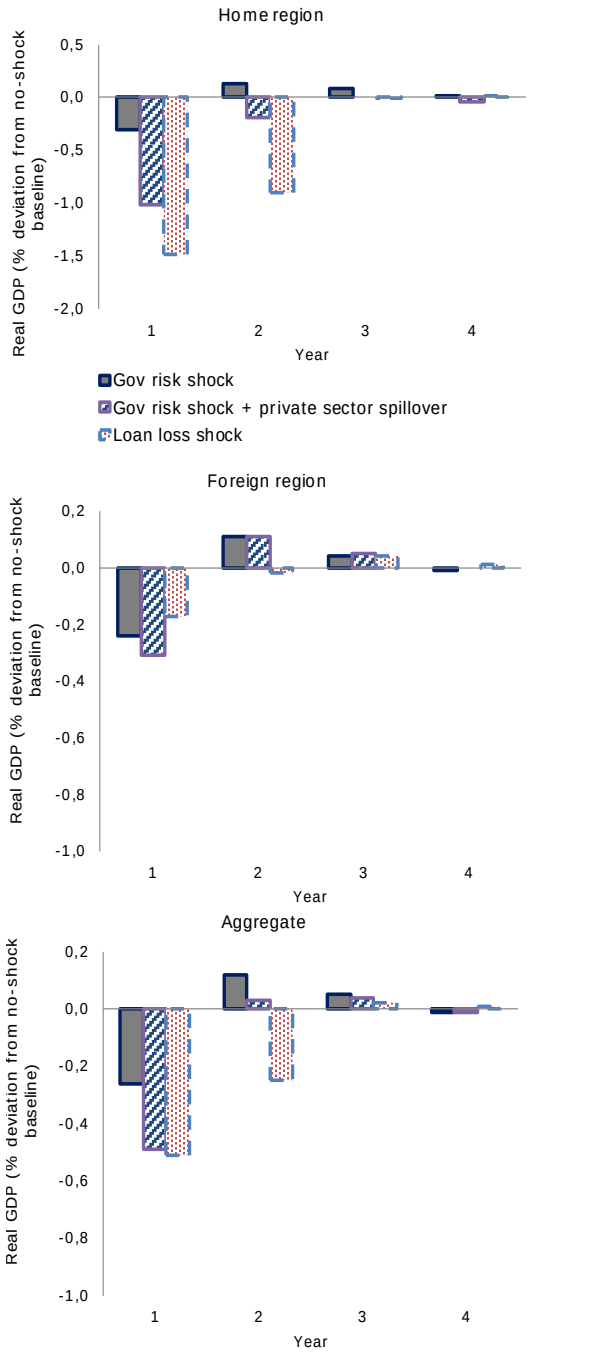
[22] While cross-border private sector lending constitutes an important element of cross-border risk sharing (see Nikolov, 2016), simulating this aspect of integration requires further assumptions on banks' investment decisions, which we leave for future research. In addition, cross-border ownership of bank equity, as discussed in this section, is expected to mimic to some extent the effects from cross-border bank lending.

[23] Directive 2014/59/EU of the European Parliament and of the Council of 15 May 2014 establishing a framework for the recovery and resolution of credit institutions and investment firms.

Graph 3.6 **Real GDP under full home bias in the banking sector**



Graph 3.7 **Real GDP under no home bias in bank holdings of sovereign debt**



Note: 'gov risk shock' corresponds to an increase in the sovereign risk premium of 10 pp; the spill-over to the private sector corresponds to an increase of 2 pp in its financing costs; the loan loss shock corresponds to losses of 10% on loans, cumulated over 3 years.

Source: QUEST simulations.

Graph 3.6 presents simulation results for the level of real GDP for shocks that start on either the government or the bank side. The trigger of the sovereign-induced loop ("gov risk shock") is a temporary rise in the sovereign credit risk premium by 10 pp (annualised) – a shock size in the order of magnitude of the risk premia in the euro area "periphery" at the height of the euro area crisis – with a half-life of one year. The trigger of the bank-induced loop ("loan loss shock") are frontloaded loan defaults that cumulate to 10% of outstanding mortgage debt over 3 years. This is broadly consistent with peak ratios for non-performing loans observed in "periphery" countries during the euro area

crisis.[24] The shock occurs in the "home" region, which is calibrated to account for ca. one quarter of euro area GDP. Underlying the scenarios in Graph 3.6 is the assumption of full home bias in banking, i.e. banks hold only domestic sovereign debt, receive deposits from and lend to domestic households only, and are exclusively owned by domestic equity investors. We add a second variant of the sovereign risk scenario, in which 20% of the government risk premium shock spills over to private sector financing costs, in line with the discussion in Section 2.[25]

Sovereign-induced and loan-induced bank losses require recapitalisation by domestic equity owners, which reduces private sector consumption and investment demand. As the sovereign risk shock is large but relatively short-lived, negative demand and GDP effects are stronger on impact, but less persistent than in the loan-loss scenario. In fact, GDP is seen to bounce back in the second and third years in the sovereign shock scenario. This is mainly due to the fact that the fading away of the shock produces valuation gains on banks' balance sheets. Given the recapitalisation efforts undertaken in the first year, subsequent valuation gains allow for additional dividend pay-outs, which temporarily boost the consumption and investment levels of equity owners. The spillover of sovereign risk to private-sector financing costs in the domestic economy amplifies the contraction of domestic demand and activity.

Spillovers to the foreign region (i.e., to the rest of the euro area) in response to financial-sector shocks in the domestic region are small in the case of (full) home bias in banking, and limited to spillovers via the trade channel (i.e., lower import demand and real effective exchange rate depreciation in the domestic region).

Graphs 3.7 and 3.8 illustrate to which extent cross-border diversification in banking mitigates the sovereign-bank loop and its macroeconomic implications. Graph 3.7 depicts a scenario in which the same shocks underlying Graph 3.6 hit banks with geographically diversified sovereign exposures. More specifically, the scenario assumes perfect diversification of government bond holdings, i.e. the domestic banking sector holds domestic and foreign government bonds according to their respective share in aggregate euro area government debt. Given the smaller calibrated size of the home economy, home banks hold predominantly foreign sovereign bonds in this scenario.

The GDP effects depicted in Graph 3.7 show that balance sheet diversification can be a powerful mechanism to mitigate the impact of higher government risk premia on the domestic economy. In particular, valuation losses have less of an impact on the balance sheet of domestic banks and hence their recapitalisation needs are lower. The initial real GDP contraction is reduced by around two thirds, from 0.9% to 0.3%. The contraction in activity is larger when higher sovereign risk spills over to private sector financing costs. Diversification of bond holdings allows for reducing the impact by approximately one third in this case, from -1.7% to -1.0% on impact. As expected, diversification strengthens international risk sharing mechanisms through stronger spillovers to foreign banks, which now hold the majority of risky "home region" sovereign bonds and are thus subject to capital losses via this channel.

[24] The stock of non-performing loans reached some 15% of total loans in Portugal and Italy, close to 10% in Spain, and some 40% in Cyprus and Greece. Taking into account that part of non-performing loans is recoverable, they suggest an upper bound for the magnitude of the loan loss shock.

[25] The strength of assumed spillover from domestic sovereign to domestic private-sector financing costs is in line with the evidence presented in Augustin et al (2016).

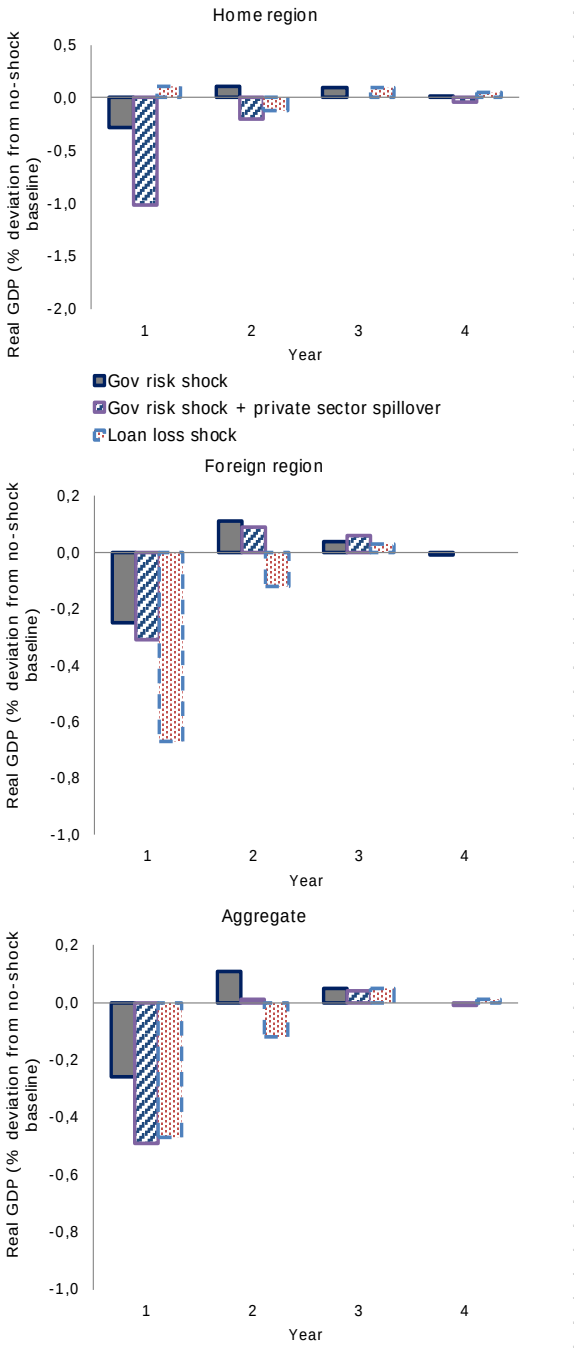
The fact that diversification does not materially change results in the loan loss scenario is a consequence of the inexistence of government bail outs in this particular model implementation, and of the fact that banks can continue to operate (well) below target capital ratios. This differs from the assumptions underlying the SYMBOL model, where diversification can change overall losses. As mentioned, the model setup in this subsection is akin to the existence of a large SRF that can immediately recapitalise banks at a cost of higher bank contributions to the SRF. It is also worth noting that a sizable reduction of the GDP loss in the home region in a loan-loss scenario would likely be achieved by cross-border lending, in analogy to the diversification of bank holdings of sovereign debt.

The diversification of bank equity is an alternative mechanism for diversification. Even with full home bias in bank portfolios, a distribution of bank losses between equity owners across the monetary union can damp the contractionary impact on economic activity in the home region in which the shocks occur.

The private recapitalisation of the domestic banking sector in this case implies lower dividend payments to home and foreign equity owners alike, whereas equity owners in the home economy still receive dividends from the ownership of a part of the foreign banking sector that is not hit by shocks. An alternative institutional interpretation relates cross-border bank ownership to the existence of a monetary union-wide SRF that immediately recapitalises the ailing bank, and is itself recapitalised by both regional banking sectors over time.

Graph 3.8 depicts a scenario with the same shocks underlying Graph 3.7, but where bank equity is fully diversified across the two regions. This means that domestic equity owners hold domestic and foreign bank equity according to the share of home and foreign banks in aggregate euro area bank equity. Given the limited size of the home economy's banking sector, domestic equity owners hold, by implication, predominantly foreign bank equity.

Graph 3.8 **Real GDP under no home bias in bank equity ownership**



Note: 'gov risk shock' corresponds to an increase in the sovereign risk premium of 10 pp; the spill-over to the private sector corresponds to an increase of 2 pp in its financing costs; the loan loss shock corresponds to losses of 10% on loans, cumulated over 3 years.

Source: QUEST simulations.

Graph 3.8 shows diversification of bank equity and bank losses to be an effective shock absorption tool both when the bank-sovereign loop is triggered by the sovereign (sovereign debt valuation loss) or the private sector (loan losses). Stabilisation gains for the sovereign risk shock scenario (without or

with contagion to private financing costs) in Graph 3.8 are practically identical to the ones with bank portfolio diversification in Graph 3.7.

In addition, bank equity diversification also distributes more evenly the losses from loan default. The initial decline of real GDP in the home region by 1.5% in Graphs 3.6 and 3.7 is fully offset in Graph 3.8. Instead, we observe a small positive home GDP effect in the first year, as default means that domestic households benefit from a lower debt burden. At the same time, the costs of default fall mainly on foreign bank shareholders, given the larger size of the foreign region. Expansionary monetary policy, i.e. a reduction of policy (risk-free) rates by the common central bank, stimulates interest sensitive demand in both regions. To the extent that diversification helps to improve synchronicity in business cycles across regions, it should also allow for a more effective monetary policy, with a more symmetric impact.

Bank equity diversification, where a part of the bank losses is borne by foreign households, amplifies spillovers to the foreign region. Real GDP in the foreign region falls by 0.7% in Graph 3.8 on impact compared to a 0.2% in Graphs 3.6 and 3.7. Stronger regional spillovers derive from a contraction in domestic demand in the foreign economy in addition to (the now reduced) spillovers from lower import demand in the home region.

The bank portfolio or bank loss diversification in Graphs 3.7 and 3.8 leaves GDP effects in the monetary union aggregate of the model practically unchanged. As mentioned, this is due to the assumption of no government bail-outs, which breaks the direct channel of the loop. It is also a consequence of the assumed linear response of government risk premia to the government debt ratio. In the presence of increasing sensitivity of interest rates to debt levels, broader distribution of losses would also imply loss reduction. Finally, the mechanism achieves a distribution of losses and associated negative demand effects across the two regions that would occur also if the initial shocks were applied to the foreign region.

Given the model's two-region monetary-union setup, there is no possibility of diversification with respect to the rest of the world that could otherwise entail stabilisation gains for the monetary union aggregate. Given standard risk aversion assumptions embedded in households' utility functions, a sequence of smaller losses is preferred to fewer large losses of the same aggregate size, so that sharing broader distribution of losses through diversification increases welfare even in the absence of aggregate risk reduction.[26]

4. ACHIEVEMENTS AND POLICY CHALLENGES

The next subsection offers a brief summary of the institutional progress achieved in the euro area on weakening the sovereign-bank loop while the following subsection discusses remaining challenges.

4.1. THE NEW INSTITUTIONAL SETUP OF THE EURO AREA

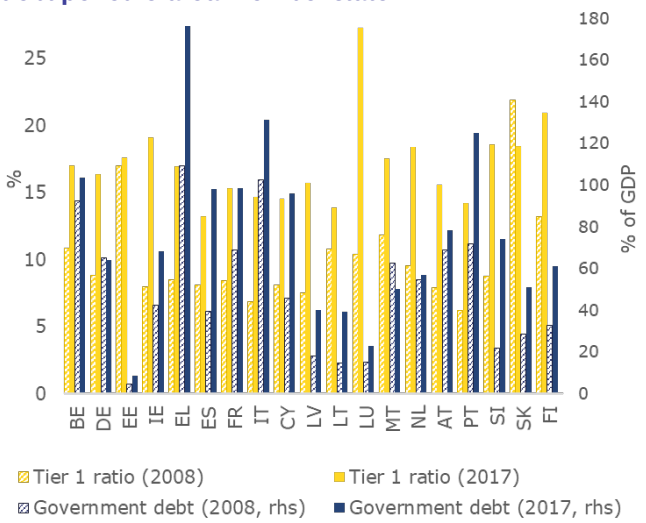
Generally speaking, safety buffers have increased in the euro area banking system, thus reducing the need for public interventions which contributed to increase debt levels in a several Member States over the past decade (Graph 4.1). Notwithstanding profitability challenges and the still elevated levels of non-performing loans in some jurisdictions, banks are now much more capitalised across the euro area owing to the introduction of more stringent capital requirements. At the same time, the crisis

[26] Other non-linearities, not considered in the simulated model, could also mean that losses that are more frequent, but smaller, are preferable from a welfare viewpoint.

period took a toll on public finances, and government debt ratios remain at high levels in some Member States.

A decisive improvement compared with the pre-crisis period was the introduction of single bank supervisory and resolution mechanisms at EU level. The Single Supervisory Mechanism has helped to increase convergence and effectiveness of supervisory practices across the EU, thereby helping to reduce insolvency risks ex ante. The new bank resolution framework aims to provide public authorities with the tools to restructure a failing bank while avoiding, or limiting, the use of public money and negative implications for the broader financial system.[27] The main operational aspects of the Single Resolution Mechanism entered into force in January 2016, placing at the disposal of the authorities a set of bank resolution tools: bail-in, asset separation, sale of business and bridge institution. The bail-in tool, in particular, allows for a clear shift of risks from governments to bank creditors by permitting the conversion of certain creditor positions into equity positions if the need arises to recapitalise a failing bank. Linked to the entry into force of the bail-in tool, banks now need to comply with minimum requirements for own funds and eligible liabilities (MREL) to ensure a sufficient issuance of bail-in-able instruments. In addition, a Single Resolution Fund (SRF) is in the process of being capitalised by the banking industry and can be tapped into to finance the restructuring of failing systemic banks when other options (such as the bail-in tool) have been exhausted.

Graph 4.1 **Banks' tier 1 capital ratio and government debt per euro area Member State**



Note: the definition of tier 1 capital is subject to a statistical break, with the 2017 figure being based on the Basel III concept.

Source: ECB, Eurostat, own calculations.

Together with improved supervisory practices, the new resolution tools carry the potential to break the direct channel of the loop running from distressed banks to the domestic sovereign. The European Commission's 2018 Fiscal Sustainability Report relies on an implementation of the SYMBOL model[28] to assess the bank-originated risks to public finances of a systemic event of a magnitude comparable to the 2008-12 crisis. Results reported therein indicate that, given banks' improved capitalisation levels, the possibility of bail-in and the presence of a SRF, such risks are minor for most Member States, and exist essentially over the short term.

Other improvements to the institutional framework of the euro area include i) the establishment of a European Stability Mechanism, which can grant loans to euro area governments in need of financial assistance, ii) the deployment of new monetary policy tools able to provide ample liquidity to the market, such as asset purchase programmes, targeted long-term refinancing operations and outright monetary transactions and iii) the enhancement of macroeconomic surveillance mechanisms through the introduction of a Macroeconomic Imbalance Procedure, the reform of fiscal rules and the institutionalisation of the "European Semester", an annual economic policy coordination exercise. These improvements should also help to mitigate the operation of the indirect channels of the sovereign-bank loop.

[27] For the strategic importance of having available a good resolution "technology" see DeYoung et al (2013).
[28] This implementation is based on a different sample and assumptions from those underpinning the stylised simulations in Subsection 3.1.

4.2. REMAINING CHALLENGES AND POSSIBLE POLICY RESPONSES

Notwithstanding the progress achieved in severing the sovereign-bank loop, a number of challenges remain. Deposit insurance is still compartmentalised along national lines, banks are still in the process of building up their MREL capacity, supervisory practices and rules are not yet fully aligned (particularly as regards less significant institutions), and the SRF is still being capitalised with the goal of reaching a size equivalent to at least 1% of euro area deposits by year-end 2023. A common backstop doubling the firepower of the SRF, to be provided by the European Stability Mechanism, has been agreed in principle but is not yet operational.

Also, even though the new resolution framework carries evident potential, not all available resolution tools have been tested in actual bank failure cases so far. For instance, the failure of Spain's Banco Popular in 2017 was dealt with by selling the bank at no cost to Santander, another Spanish bank. It was a resolution with write-down of own funds but without a proper bail-in, and which relied on the liquidity and solvency of the acquiring bank. Also in 2017, the failures of Italy's Banca Popolare di Vicenza and Veneto Banca were managed under normal insolvency proceedings,[29] while Monte dei Paschi di Siena underwent a precautionary recapitalisation. In the last three cases, the use of state aid was involved.

The European Commission proposed in 2015 a European deposit insurance scheme (EDIS) to constitute the third pillar of the Banking Union. EDIS would ultimately ensure that guarantees on deposits of up to € 100 000 are provided by a common scheme funded by the banking system of the euro area, thus severing the link between national deposit guarantees and the domestic banking system. Negotiations among Member States on the adoption of EDIS have not started yet.

Beyond the direct channels, which have been the focus of policy measures and discussion so far, the indirect channels of the sovereign-bank loop remain essentially intact. Mitigating them would require stronger cross-border integration of banking and financial markets, so as to make domestic economies less dependent on the health of the domestic banking sector, and vice-versa. In particular, the home biases of banks as regards private sector lending appear to be a key obstacle to improving private-sector risk sharing in the euro area, which is seen to lag behind that in the US.[30] The fracturing of sovereign debt markets along national lines, which appears to have been driven at times by divergent market sensitivities or other factors unrelated to economic fundamentals,[31] is also likely to be detrimental given their pivotal role in the sovereign-bank nexus, and for the functioning of the European economy at large.

Another question relates to banks' home biases in their holdings of sovereign debt, a phenomenon that is understood to have delayed progress in the implementation of the EDIS proposal[32]. The observed high degree of home bias has also been considered to be facilitated by the current regulatory framework, which exempts banks' exposures to the sovereign debt of euro area Member States from capital charges or quantitative limits.[33] This regulatory treatment together with liquidity requirements and the collateral policy of the Eurosystem provide for a specific regulatory environment as regards bank holdings of sovereign debt. At the same time, since the reversal in the integration of sovereign bond markets experienced during the financial crisis, these holdings have become more strongly

[29] Normal insolvency proceedings also applied to ABLV, a small bank under the remit of the Single Resolution Mechanism that failed in 2018.

[30] For a comparison of risk-sharing mechanisms in the euro area and in the US, see Nikolov (2016).

[31] See Monteiro and Vašíček (2019).

[32] See Véron (2017a).

[33] This contrasts with the capital requirements for credit risk and to the large exposures limit that generally apply to other forms of bank lending. In particular, according to the large exposures limit, banks may not hold claims worth more than 25% of their tier 1 capital with respect to a single counterparty.

skewed towards the domestic sovereign in some countries. The latter phenomenon has been explained both as a kind of "carry trade", whereby banks resort to easily available funding to load up on high yielding bonds, and as the result of moral suasion, whereby governments pressure banks to absorb their debt issuance in periods of distress.[34] It has also been claimed that increases in the degree of sovereign home bias during the crisis period reallocated credit from the private to the public sector, displacing productive investment.[35] On a more positive note, the absorption by domestic banks of sovereign debt in times of distress can have a stabilising effect by containing interest rate volatility and by facilitating the smooth conduction of fiscal policy.[36] It could also act as a commitment device for governments.[37] The latter effect is related to the fact that a sovereign default in the presence of strong home bias is particularly damaging for the domestic banking sector and, by extension, for the domestic economy. As such, while potentially acting as a commitment device, increases in the degree of home bias in times of stress also tend to increase the tail risks confronting the economy.

In recent years, several options have been discussed to incentivise banks to reduce their degree of home bias. Some options focus on adapting bank regulations, for instance by applying capital charges to sovereign exposures based either on their assessed risk or degree of concentration, or by imposing quantity-based limits.[38] However, regulatory incentives to promote diversification need to contend with at least four challenges. First, they may result in pro-cyclical effects, in the sense of imposing harsher conditions on banks and issuing sovereigns in crisis periods. The second challenge relates to difficulties in assessing the likely impact of such reforms due to uncertainty regarding banks' behaviour under a different regulatory regime. Third, diversification may in some circumstances increase the riskiness of banks' sovereign bond portfolios and make them more vulnerable to cross-border spill-overs.[39] Finally, decreasing concentration in banks' exposures should not lead to the build-up of excessive concentration in other financial institutions, as the latter may also be subject to their sovereign risk nexus.

Besides other possible benefits, the introduction of a common European safe asset could also help to weaken sovereign-bank loops by reducing the amount and riskiness of (domestic) national exposures in banks' balance sheets. In particular, a common safe asset is understood to potentially resolve the fundamental tension in reducing, at the same time, concentration and sovereign risk in banks' portfolios.[40] Different options for such an instrument have been discussed, including sovereign bond-backed securities[41] and senior sovereign debt issuance by a common European institution.[42] In both

[34] See, e.g., Altavilla et al (2016) and Acharya and Steffen (2013). Also, for how the ownership structure of euro area banks may render them prone to political interference, see Véron (2017b).

[35] See, e.g., Broner et al (2014) and Altavilla et al (2012).

[36] Tabellini (2018) argues why domestic banks may have an incentive to perform this stabilisation function, as their own survival may be at risk in the event of a sovereign default.

[37] See, e.g., Asonuma et al (2015). For a rationalisation of home biases in capital markets, see also Coeurdacier and Rey (2013).

[38] See European Systemic Risk Board (2015), Basel Committee on Banking Supervision (2017) and Véron (2017a).

[39] Research suggests that, depending on the combination of specific factors (such as banks' diversification patterns, their capitalisation levels and the severity of shocks), diversification can increase systemic risk and render financial institutions more vulnerable by exposing them to foreign shocks in addition to domestic ones. See, e.g., Bolton and Jeanne (2011), Wagner (2010) and Acemoglu el al (2015). In addition, if low-risk sovereign bonds are scarcely available, the sovereign debt portfolio of some banks can see an increase in their credit risk as a result of diversification, as banks with initially low-risk exposures may have little option but to diversify into higher-risk assets. See Alogoskoufis and Langfield (2018) and Craig et al (2019).

[40] See Alogoskoufis and Langfield (2018).

[41] See, e.g., ESRB High-Level Task Force on Safe Assets (2018).

[42] See , e.g., Monti (2010), Leandro and Zettelmeyer (2018) and Giudice et al (2019).

cases, one important aim is the increase in the supply of safe assets, which would then partially substitute national sovereign bonds in banks' balance sheets. Given their intrinsic diversification and low sovereign risk, research suggests that banks' portfolio reallocation towards safe assets can break the direct channel of the loop.[43]

5. CONCLUSION

This paper reviewed the sovereign-bank nexus in the euro area, also in light of its past crisis experience. Some salient empirical observations from this period include i) the fact that past government-sponsored financial sector interventions put strong pressure on the public finances of several euro area Member States in the form of actual and contingent liabilities; ii) evidence of a clear home bias in banks' sovereign debt holdings, which furthermore tended to increase during the crisis; and iii) the fact that the euro area crisis saw hikes in government risk premia correlate with similar hikes in the domestic corporate sector, both financial and non-financial.

From a theoretical viewpoint, the interactions between banks and sovereigns can be understood as taking place via direct and indirect channels. The former relates to banks' holdings of domestic sovereign debt and to the possibility of public interventions to bail out, or otherwise safeguard, the financial sector, carrying fiscal implications for the sovereign. The indirect channel captures real economy dynamics, including the fact that i) credit constraints and restrictive fiscal policies can mutually reinforce each other and ii) private sector funding costs can experience contagion from rises in sovereign funding costs. A review of the literature and analysis using the Commission's SYMBOL and QUEST models shows how adverse loops may emerge along either dimension.

Taking stock of the advances in mitigating the sovereign-bank loop, it can be concluded that significant progress has been achieved as regards the direct channel. While government debt levels have increased compared with the pre-crisis period, the banking sector is more strongly capitalised and the institutional framework of the euro area underwent important improvements. Chief among these are a single supervisory mechanism and a new resolution framework, including the creditor bail-in tool and a fledging single resolution fund. Simulations using the SYMBOL model show a marked reduction in risks to the government sector originating from a banking crisis when comparing the current situation with the crisis year of 2012. An impressive reduction is observed, in particular, when one considers the use of the bail-in tool and of a single resolution fund, which suggests that policy action taken since the crisis has helped to reduce potential losses to a small fraction of those previously possible.

While the new institutional framework carries much actual and potential benefits, it is still missing a European deposit insurance scheme that could further weaken the direct channel between banks and sovereigns. Other policy options include regulatory action to decrease concentration and other risks in banks' sovereign debt portfolios. Promoting pure diversification through regulatory policies should, however, be approached with caution as a review of the literature and SYMBOL simulations suggest that they can have an ambiguous effect on systemic- and bank-level risk insome cases. However, diversification of banks' sovereign debt holdings can operate as an important mechanism for distributing the impact of shocks, a fact also confirmed in simulations using the QUEST model. Another form of achieving these positive results is through further cross-border integration of banking sectors. QUEST simulations assuming a particular form of integration (i.e., cross-border bank equity ownership) show how asymmetric shocks may be diluted across regional blocs, increasing the overall welfare of risk-averse households.

[43] See Brunnermeier et al (2016).

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ANNEX I

The SYMBOL model

SYMBOL (Systemic Model of Banking Originated Losses) is a tool developed by the European Commission's Joint Research Centre in collaboration with academics and other experts to simulate banking crises. The model is flexible and allows for the inclusion of modules to incorporate the effects of interbank contagion and the direct channel of the sovereign-bank loop.[44] The model takes as input a rich dataset covering actual balance sheet data of banks in multiple euro area countries. Coupled with data on sovereign exposures and a sovereign risk module, it can be used to explore how losses originating on banks' balance sheets or hikes in sovereign risk premia can mutually reinforce each other, potentially driving increases in government debt due to interventions to recapitalise banks.[45]

The sovereign risk module of SYMBOL is based on the model presented in Mody and Sandri (2012), which calculates a non-arbitrage sovereign credit risk spread based on a country's debt level *D*, the GDP level *G*, the risk-free rate r^f, a long-term average GDP growth rate *g* and standard deviation σ, a recovery rate in the event of sovereign default *R*, the debt-to-GDP ratio at which the country is inferred to default $\overline{DY}$ and the current CDS spread *C*. Given that *G*, r^f, *g*, σ, *R* and $\overline{DY}$ are assumed to remain constant in the simulations, the Mody-Sandri function, *MS*, returns a new credit risk spread *C'* as a function of the initial spread and the new debt level *D'*:

$$C' = MS(D', C|G, r^f, g, \sigma, R, \overline{DY}).$$

The haircut H_i is the percentage loss on bank *i*'s holdings of sovereign debt induced by changes its market value.[46] It is a function of the risk-free rate r^f, the CDS spread *C* and the change in the spread ΔC:

$$H_i = Haircut(r^f, C, \Delta C).$$

Bank-level losses on sovereign debt holdings are obtained based on the set of all bank-level haircuts, *H*, and the matrix of banks' exposures to different sovereigns, *E*. Together with banks' actual and minimum required capital ratios, *CR* and CR^{min} respectively,[47] one can determine the amount of losses *L* incurred by the domestic sovereign through recapitalisations aimed at raising the capital ratio of domestic banks to their regulatory minimum following a change in the valuation of existing sovereign exposures:[48]

$$L = Loss(H, E, CR, CR^{min}).$$

The simulation procedure starts with the calibration of *G*, r^f, *g*, σ, *R* and initial *D*. Subsequently, $\overline{DY}$ is calibrated as the only remaining unknown in the *MS* function given the current sovereign CDS spreads *C*.

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[44] For the full model details see De Lisa el al (2008) and Fontana and Langedijk (2019). The interbank contagion channel is not considered in the present implementation of the model.

[45] Sovereign interventions are regulated at EU level. In the present exercise, we avoid a discussion of the conditions and limits imposed on such interventions, and focus on abstract "worst case" scenarios.

[46] The SYMBOL model assumes that losses on assets that are not marked-to-market impact investors' perceptions of banks' capitalisation levels and may lead to de facto recapitalisation needs through market discipline mechanisms.

[47] In the present exercise, the minimum required tier 1 capital ratio is set at 10.5%, which includes requirements linked to the capital conservation buffer.

[48] The model assumes that investors consider banks' balance sheets in market value terms in their risk assessments, meaning that market pressure renders all sovereign exposures *de facto* mark-to-market for recapitalisation purposes.

An initial shock may either occur on the side of the sovereign via an increase in the sovereign risk spread, ΔC, or on banks' side, via losses on their assets, as will be explained below. Such losses may then translate into a sovereign loss L through recapitalisation needs. This increases government debt, so that the $D' = D + L$, which in turn increases the sovereign risk spread, ΔC, via the *MS* equation. From this point onward, the iterations are the same whether the initial shock was on the side of the sovereign or of the bank. In particular, ΔC implies a haircut H, which increases L, which increases D, which further increases C. This loop is iterated until convergence to final levels of government debt, spreads and bank losses is achieved.

It remains to explain how initial bank losses are simulated in SYMBOL. The average implied probability of default on a bank's asset portfolio is first derived based on Basel's asymptotic single risk factor (ASRF) model using bank balance sheet data.[49] Starting from this probability of default, SYMBOL relies on Monte Carlo simulations, the ASRF loss distribution and assumptions for cross-bank asset correlation to produce loss realisations at bank and national level. After taking into account actual capitalisation levels in excess of minimum requirements and the presence of safety nets (e.g., bail-in and resolution funds), part of these losses may then be passed on to the government sector.

For the purposes of the present exercise, the main model input data were taken from the EBA (risk-weighted assets, total capital and sovereign exposures), Bloomberg (10-year sovereign CDS spreads), AMECO (GDP and government debt levels), Orbis BankFocus and SNL (total bank assets) and the ECB data warehouse (total assets of national banking sectors, used to scale up losses derived from the available subsamples).

[49] In particular, data on 'fully loaded' effective capital and risk-weighted assets, taking into account the full application of Basel III/CRD IV rules.

ANNEX II

The QUEST model with a banking sector

QUEST is a neoclassical–Keynesian synthesis ("New Keynesian") dynamic general-equilibrium macroeconomic model, combining a neoclassical growth model with nominal (price and wage stickiness) and real (including capital and employment adjustment frictions) rigidities. The model equations that characterise the aggregate dynamics of the economy are derived from microeconomic theory of household and firm behaviour. Similar to other macroeconomic models, QUEST offers a stylised and simplified representation of economic agents (households, firms and government) and their interactions in goods and factor markets.[50]

The QUEST version used in this paper comprises two regions that form a monetary union. The parameters that determine the speed of price, wage, employment and investment adjustment are set the same across the two regions. Baseline (steady-state) values of the model variables are calibrated to available data, which implies that the two regions differ with respect to (bilateral) trade openness, fiscal policy variables, employment rates and bank assets and liabilities in the steady state. Each region is home to a representative (or, consolidated) bank. The banks collect deposits from risk-averse saver households, invest in government and foreign bonds, and provide loans to the private sector. Banks maximise their profits, which are the difference between the return on the banks' asset portfolio (loan rates and return on government bonds) and the interest paid on deposits (plus some operating costs). Bank profits are paid to equity-owner households. The equity owners use the profit income for consumption and investment in productive corporate capital.[51]

Bank assets are risky. In particular, the government bonds are subject to valuation and (partial) default risk, and loans to the private sector face the risk of loan losses (i.e. defaults by debtors). In case of valuation or loan losses, banks need recapitalisation in order to re-converge to a target capital ratio, which can take the following forms: (i) recapitalisation by the government, or (ii) recapitalisation via retained earnings, where banks increase their capital base at the cost of lower dividend payments to bank equity owners.

Recapitalisation by the government sets in motion the direct channel of the feedback loop described in Section 2, because the value of government bonds depends (also) on the level of public debt, so that rising government debt in response to bank rescues increases government financing costs and depreciates the value of government bonds held by banks, which then require further recapitalisation.

Recapitalisation by bank equity holders sets in motion the indirect feedback loop described in Section 2 by lowering consumption and productive investment in the economy, which in turn reduces aggregate demand, activity and the economy's productive potential. Contracting economic activity deteriorates the government's fiscal position (through lower tax revenues, increased spending on automatic stabilisers and adverse denominator effects), which lowers the value of government debt and feeds back adversely to the asset side of the bank balance sheet.

In the baseline version of the model we assume (full) home bias in the banking sector, which means that domestic banks (i) hold only domestic government bonds, (ii) are owned exclusively by domestic households, and (iii) provide loans only to the domestic private sector. The assumption will be relaxed in the counterfactual scenarios in the directions of introducing (i) a geographical diversification of banks' government bond portfolios, i.e. domestic banks will hold bonds of domestic and foreign government, implying a diversification of bond valuation losses across domestic and foreign banks, and (ii) a geographical diversification of bank ownership, where equity of domestic banks is held by domestic and foreign households alike, implying a diversification of bank losses across domestic and foreign owners of bank equity.

[50] See Ratto et al (2009) for a presentation of the basic QUEST model. The model extension with tradable goods, non-tradable goods and a housing sector is described in Roeger and In't Veld (2009).

[51] Breuss et al (2015) provides a detailed presentation of the QUEST version with a banking sector.

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