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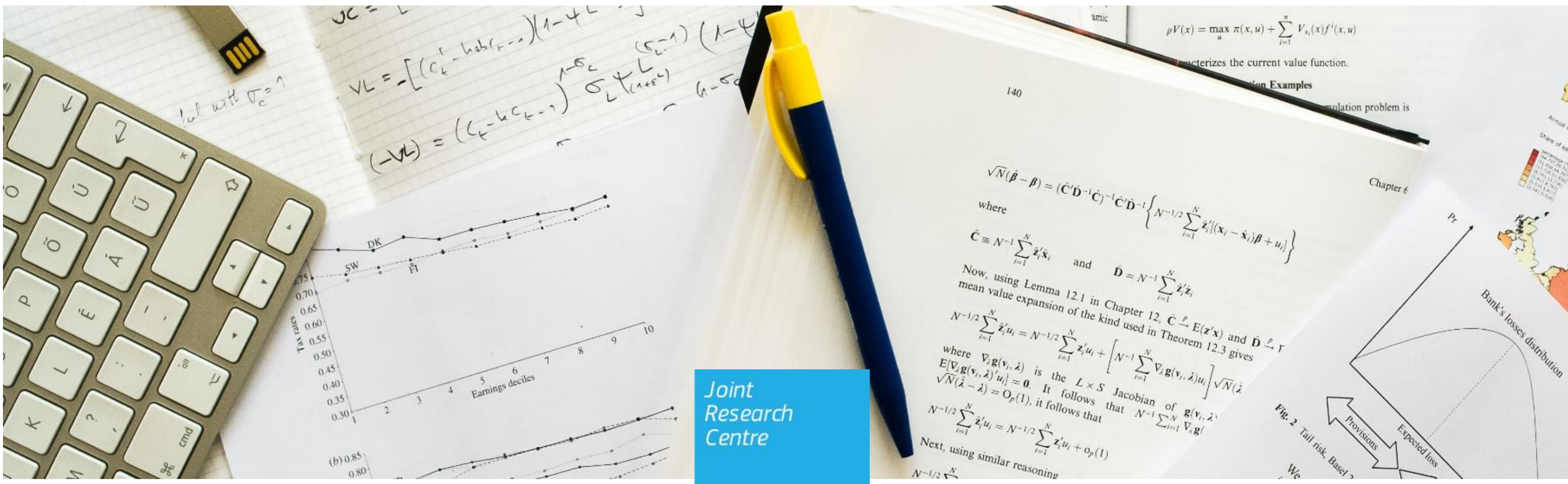

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The Bank-Sovereign Loop and Financial Stability in the Euro Area

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Abstract

We propose a simple model that captures the link between bank and sovereign credit risk. It allows evaluating policy options to address this 'doom loop' in which the government may need to raise debt to recapitalise banks, and an increase in government debt raises sovereign risk and in turn generates potential bank losses via their (sovereign) bond holdings. Hence, an initial shock originating either in the banking or sovereign sector is amplified by the feedback relation. We set up a framework based on detailed actual bank balance sheets and test the model on 35 large EU banking groups, across 7 European countries. The effects of the feedback loops in most cases more than double the effect of the initial shock on bank losses and the sovereign risk premium. We show that a single EU bank resolution mechanism, European Stability Mechanism (ESM) direct bank recapitalisations, and bondholder "bail-in" can be effective to dampen the bank-sovereign loop. Addressing the home bias in banks sovereign bond holdings by reducing excessive exposure to domestic sovereigns has only limited benefit in terms of lower crisis doom loop effects as contagion effects increase.

Keywords: Credit Risk, Banks, Sovereign, Financial Stability, ESM, Direct Recapitalisation

JEL codes: E44, G01, G21, H63, H81

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Table of Contents

1. **Introduction**
2. **Related Literature**
3. **Modelling the Bank-Sovereign Loop**

   3.1 The Model

   3.2 Calibration

   3.3 Banking Sector Distress

   3.4 Modelling Issues
4. **Data**
5. **Results of the Analysis**

   5.1 The Feed-Back Loop

   5.2 The ESM Direct Bank Recapitalisation

   5.3 Cross-country Spillovers

   5.4 Banks Exposures: the Full Integration Case

   5.5. Bank Bondholders Bail-in

   5.6 Takeaways from the Model and the Analysis

6. Final Remarks

References

Annex 1

Annex 2

1. Introduction

The euro-area sovereign debt crisis has highlighted the strong link between banks and sovereign credit risk, its circular nature and the fact that interconnections are multiple and complex.

On one side, banks are adversely affected by sovereign credit risk deterioration via multiple channels, including directly through their exposure to sovereign bonds (see Panetta (2012), Merler and Pisany-Ferry (2012)). Banks in the euro area are particularly exposed to sovereign bonds. Total exposure of the EBA-covered large banking groups in the euro area to sovereign debt amounts to 25-40% of home country GDP in most countries. Moreover, a surprisingly strong home bias to sovereign debt of their home country leads to a strong link from sovereign risk to banking risk within countries.

On the other side, sovereign creditworthiness is crucially affected by the health of the banking sector. The most obvious way banking system stress spills over to sovereigns is through the perceived cost of bank rescues raising government debt. This became obvious during the Irish and Spanish crises when despite relatively low starting levels of government debt, the sovereign risk premia rose dramatically as the banking sector came under stress. Further channels include the potential impact of a weak banking sector on credit availability, private sector interest rates and thus GDP growth.

These multiple feedback loops may lead to an unstable system in which an initial shock, originating either in the banking or sovereign sector, is amplified with dramatic effects on the real economy. For this reason various policy tools, to break this so-called "vicious cycle" have been proposed in the financial supervision and macro-prudential regulation debate, such as ESM direct recapitalization[1], bondholder bail-in, a single bank resolution fund, deposit guarantee schemes.[2]

We propose a basic stylised model that captures the link between bank and sovereign credit risk and allows evaluating alternative policy options. Our main modelling contribution is to extend a basic version of the Mody-Sandri (2012) framework so that sovereign risk affects the health of banks through their sovereign bond holdings. A calibrated debt-default threshold allows endogenously

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[1] The ESM direct recapitalisation instrument (DRI) was introduced in December 2014. It will in future be replaced by the ESM backstopping the Single Resolution Fund (SRF), as decided at the 14 December 2018 Euro Summit. The European Council explicitly states that the objective of the DRI is help break the banking-sovereign loop: "*The objective of an ESM direct recapitalisation shall be to preserve the financial stability of the euro area as a whole and of its Member States in line with Article 3 of the ESM Treaty, and to help remove the risk of contagion from the financial sector to the sovereign by allowing the recapitalisation of institutions directly*." DRI may be used in very specific circumstances to directly recapitalise financial institutions, as a last resort instrument when all other instruments, including bail-in as mandated by the Bank Recovery and Resolution Directive (BRRD), have been applied and after the Single Resolution Fund (SRF) has been used.
See http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ecofin/137569.pdf.

[2] The EU single resolution mechanism's (SRM) objective is to allow resolving banks with minimal costs to public finances and the real economy by requiring bondholder bail-in and establishing a single resolution fund. It will apply to all banks in the euro area and other Member States that decide to participate. See http://europa.eu/rapid/press-release_IP-12-570_en.htm?locale=en.

determining sovereign credit risk as the government issues new debt to recapitalise banks to their minimum regulatory levels when banks face stress conditions and large unexpected losses. The sovereign feedback loop raises bank losses further, triggering further recapitalisations.[3] Thus, we capture the circular nature of banking and sovereign sector credit risk.

Our aim is to analyse the feedback loop effects triggered by a banking sector shock as in the euro-area sovereign debt crisis and to evaluate alternative policy options to break the loop. We simulate banking sector losses with a micro-simulation model of systemic banking stress based on actual bank balance sheets as in De Lisa et al. (2011). The loss distribution of each bank reflects the credit risk implied by its regulatory capital requirement on the basis of the Basel II FIRB (Foundation Internal Ratings Based) formula, which is commonly used to analyses banks' riskiness by regulators.

We investigate the link between bank and sovereign risk within countries, and cross-border spillover effects as banks are internationally exposed to sovereign debt. We then apply the model in some scenario analyses illustrating how different policy measures contribute to reducing the adverse feedback loop. These measures include ESM direct recapitalization, a single resolution fund, bondholder bail-in and limiting home bias of sovereign exposures.

In the remainder of the paper, we consecutively discuss related literature, present the model, the data, and the results of our analysis, before we conclude.

2. Related Literature

Following the euro area debt sovereign crisis there is a growing literature on the relation between banks and sovereign credit risk. *Panetta et al (2011)* discuss anecdotally the main transmission channels through which sovereign risk affects banks funding. They suggest that banks are negatively affected by sovereign credit risk as (a) the value of their assets reduces (government bonds); (b) they face liquidity issues as the value of collateral used to get funding from the central bank reduces; (c) the country's banks rating tends to be downgraded together with the sovereign (sovereign debt ceiling); (d) government guarantees are perceived to weaken, reducing any rating uplift; (e) banks tend to be exposed to banks and firms in other countries which in turn are exposed to sovereign debt (international spillovers); (f) an increase in sovereign credit risk might trigger a generalized decline in asset prices in a country affecting both bank and non-financial firms (risk aversion channel); (g) banks

[3] Formally, the impact of the deterioration in the sovereign creditworthiness on bank capital depends on how banks account for government bonds in their balance sheet. In our modeling exercise we consider that market evaluation of bank capital takes sovereign risk fully into account even if regulatory capital does not.

tend to have lower (non-interest) income in recessions; and finally (h) banks suffer from crowding-out effects due to sovereign debt issuance.

Dieckmann and Plank (2011) study the default risk of advanced economies. Their results show that higher pre-crisis exposure of a country to its financial sector is associated with a higher sovereign CDS spread, moreover they show that a deteriorating state of the financial sector is associated with a larger sovereign CDS spread, that the association between the financial sector and the sovereign CDS spread is magnified in the post-crisis and, moreover, that EMU countries exhibit stronger sensitivity to the financial sector.

Acharya, Drechsler and Schnabl (2013) model the loop between bank and sovereign risk. They propose a model in which the government can finance a bailout through increased taxation, at the cost of reducing the incentives of the non-financial sector to invest and via dilution of existing government debt holders, leading to a deterioration of sovereign creditworthiness. Also, sovereign credit risk feeds back into the financial sector. In the empirical analysis they document that post-bailout changes in sovereign CDS explain bank CDS even after controlling for aggregate and bank level determinants of credit spreads, providing evidence of the sovereign bank loop.

Mody-Sandri (2012) present a model which illustrates the impact of financial shocks on sovereign credit spreads. In the Mody-Sandri model, the government is assumed to default when the *debt-to-GDP ratio* approaches a threshold level. Sovereign credit risk is thus directly determined by the dynamics of both GDP and government debt. GDP is affected, among other factors, by the amount of bank capital determining provision of credit for investment in the economy. This model considers exclusively one direction of the risk transmission, namely the one from the banking to the government sector and is, therefore, useful to analyse situations in which a banking crisis might cause sovereign debt crisis. In case of a banking crisis, the government faces a tradeoff between increases in gross debt (to recapitalize banks) and a fall in GDP due to a reduction of banks capital and hence investment[4].

Galliani and Zedda (2013) discuss the role of the bail-in in breaking the vicious cycle of banks and public finance distress. In their analysis they focus on four small European countries (BE, DK, GR, NL) and they assume[5] that the banking sector shock feeds into the government deficit (i.e. governments

[4] When banks are in trouble the government has to inject new funds otherwise these reduce lending to the real economy. If the GDP declines the debt-to-GDP ratio increases and this generates an increase of sovereign credit risk. Sovereign credit risk may increase also when the government issues new debt to recapitalize banks. Hence, there is a trade-off when doing the bail-out.

[5] They also assume a reaction coefficient for the sovereign risk premium for every percent increase in the deficit that leads to haircuts on banks' sovereign debt holdings. This coefficient may significantly overestimate the effects, as one-off increases in the deficit due to bank recapitalization are assumed to generate a similar impact on the risk premium as a structural increase in the deficit.

are subject only to a one-off shock in case of bank recapitalization). However, not all recapitalisation can be assumed to feed into the deficit, as most of it often is a financial transaction.[6] To overcome these issues we model the spill-over from bank to sovereign risk through the government debt channel instead of the deficit.

3. Modelling the Bank-Sovereign Loop

Section 3.1. discusses an extension to the Mody-Sandri (2012) framework. We add the government debt increase due to bank recapitalisation to the model to get an impact on the sovereign credit risk premium. Bank recapitalization takes places whenever banks face severe distress and fail to meet regulatory requirements. We apply a 'Haircut' to government bond holdings by banks according to the sovereign credit risk premium effect and EBA information on actual banks' exposure to sovereign debt. Section 3.2 discusses the micro-simulation model of systemic banking sector losses that we use to generate banking losses using actual bank balance sheets. We build a multi-country framework which allows analysing how the amplification mechanisms plays out and evaluating several policy options to break the loop between bank and sovereign credit risk in the euro area.

3.1. The Model

In our stylized two-period model, the government issues, in period 1, an amount of bonds B_0, offering an expected rate of return r. The government also issues new debt to recapitalize banks in distress, i.e. when banks fall short of capital below the required regulatory level, so that the total outstanding government debt is

$$B_1 = B_0 + \text{Bank Recap} \qquad (1)$$

Banks distress is in a first stage due to the losses faced on lending activity to the real economy. Subsequently, as in our model government debt depreciation is related to recapitalization needs as result of the initial banking sector losses, bank distress can be due to losses faced on government bonds holdings. The ability of the government to repay this debt, in period 2, depends on the *debt-to-GDP* ratio as given by

$$b_2 = \frac{B2}{Y_2} \qquad (2)$$

[6] For example, if banks initial capital is EUR 2 billion and the bank suffers losses amounting to EUR 3 billion, the government needs to cover EUR 1 billion of losses in excess of capital. This translates into a one-off deficit increase. The remaining EUR 2 billion recapitalisation to the regulatory minimum is recorded as financial transaction and only increases the government gross debt and not the deficit.

where $B_2 = B_1(1+r)$ (3)

The government is assumed to default whenever b_2 exceeds a threshold level[7] $\bar{b}$ =$debt_{max}$.

GDP (Y) is determined by:

$$Y_2 = A_1(1+g)K_1\varepsilon_2 \qquad (3)$$

where K_1 is capital invested in the economy by the banking sector at time 1, A_1 is the level of productivity of the economy, g is the growth rate and ε_2 is a mean-one log-normally distributed shock with standard deviation σ. The banking sector determines the capital investment K_1. Banks leverage their equity E_1 so that $K_1 = \lambda E_1$ where lambda is the leverage factor. Hence, a reduction of banks capitalization reduces investments in the real economy having an adverse effect on GDP.

The government (risk-neutral) probability of default is:

$$RNDef\ \Pr = \Pr ob\left[\frac{B_2(r, recap)}{Y(\varepsilon)}\right] \geq debt_{\max} = \Pr ob\left[\frac{B_2(r, recap)}{debt_{\max}Y(\varepsilon)} \geq \varepsilon_2\right] \qquad (4)$$

To compensate for the government's risk of default, risk neutral investors require a premium over the risk-free interest rate *Rf*. Hence, for no-arbitrage reasons the expected return (r) on government bonds has to satisfy the following relation

$$(1 - RNDef\ \Pr ob)(1+r) + RNDefprob \bullet (1 - LGD)(1+r) = (1 + R_f) \qquad (5)$$

where LGD is loss given default (1-recovery rate). The realization of a sufficiently large negative GDP shock, ε_2, drives the debt-to-GDP ratio above the threshold, hence to default. Features of the economy such as lower capital productivity, lower total factor productivity growth, higher GDP volatility (ε_2) would increase default risk. Also, default thresholds can be affected by changes in global liquidity,

[7] This captures the idea from models à la Eaton and Gersovitz (1981) where a risk-averse sovereign endogenously decides to default in order to smooth consumption. The sovereign incentive to default is higher during recessions and when facing a large debt burden, i.e. when the debt-to-GDP ratio is high, as in these circumstances, avoiding debt repayments is an expedient to sustain consumption despite falling GDP.

risk aversion or country-specific risk shocks (e.g. political risks). All this parameters are kept fixed in our model so that $Y_2(\varepsilon_2)$.

3.2 Calibration

The benchmark calibration is summarized as follows and is based on values in Mody-Sandri (2012). Parameters are on an annualized basis, but note that as we focus on 10-year benchmark bonds these values are consistent with a 10 horizon. The *standard deviation of the GDP* shock is set to 20%[8], the *default recovery rate* to 80%, the *risk-free rate* to 2%, *capital productivity* to 10%, *productivity growth* to 0, banking sector leverage to 10 and equity to 100; this is set to 100 so that k_1 is 1000[9] and that the expected GDP is equal to 100.

Parameter	Description	Value
σ	STD of GDP shock	20%
μ	Bond recovery rate	80%
i	Risk-free rate	2%
A	Capital Productivity	10%
g	Productivity Growth	0%
K1	Bank capital	100
$debt_{max}$	Default threshold	Calibrated

$Debt_{max}$ is calibrated on a country basis so as to match the actual credit spread (CDS premium) observed for each government by end 2012. We perform sensitivity analysis by calculating $debt_{max}$ for each country in different years with different observed debt-to-GDP ratio and CDS premia. We find that even if $debt_{max}$ tends to differ across countries (IT, IE, PT approx. 160%, DE, FR, NL, SP approx. 110-120%) it is relatively stable over time.

8 This number might seem quite large, but note that the price of a 10 year bond incorporates instantaneously the changes in expectations of the debt sustainability and thus GDP dynamics in the long run. Growth paths change dramatically in a financial crisis. Laeven and Valencia (2012) report that for example for Italy the output loss from in the period 2008-2012 has been approximately of 32% and for some other euro area countries much more.

9 As bank capital is set to be 100 and the leverage 10 the total capital provision to the real economy by banks is 1000.

3.3. Banking Sector Distress

We model banking sector distress as a tail realisation (corresponding approximately to the amount of losses and recapitalization needs observed in the 2008 crisis) of a simulated distribution of bank's excess losses, which we obtain by mean of the so called *Systemic Model of Banking Originated Losses* (SYMBOL).[10] [11]

SYMBOL simulates the distribution of losses in excess of banks' capital within a banking system by aggregating individual banks' losses by country. Individual banks' losses are generated via Monte Carlo simulation using the Basel FIRB loss distribution function, which is commonly used to analyse banks' riskiness by regulators.[12] This function is in turn based on the Vasicek model (see Vasicek, 2002), which in broad terms extends the Merton model (see Merton, 1974) to a portfolio of borrowers.[13] The loss distribution of each bank is calibrated on an estimate of the average default probability of its portfolio of assets, which is derived from the ratio of the banks' Minimum Capital Requirements and its Total Assets (TA).

The model operates in four steps: the first step consist is estimating the average default probability for the loans of any individual bank, by means of the features of the Basel FIRB function; the second in numerically generating the bank's excess losses and capital reduction. The third step consists in checking which banks are in default. Finally, the fourth step in obtaining the distribution of aggregate losses at the country level.[14]

Details of the four steps are as follows:

[10] The model is introduced in De Lisa et al. (2011) without the SYMBOL acronym, which was adopted at a later stage.

[11] Note that Galliani and Zedda (2013) also start from a SYMBOL generated banking sector shock to analyse the effects on sovereign risk premia.

[12] Basel Committee on Banking Supervision, 2005, 2006 and 2011.

[13] The Basel Committee permits banks a choice between two broad methodologies for calculating their capital requirements for credit risk. One alternative, the Standardised Approach, measures credit risk in a standardised manner, supported by external credit assessments. The alternative is the Internal Rating-Based (IRB) approach which allows institutions to use their own internal rating-based measures for key drivers of credit risk as primary inputs to the capital calculation. Institutions using the Foundation IRB (FIRB) approach are allowed to determine the borrowers' probabilities of default while those using the Advanced IRB (AIRB) approach are permitted to rely on own estimates of all risk components related to their borrowers (e.g. loss given default and exposure at default). The Basel FIRB capital requirement formula specified by the Basel Committee for credit risk is the Vasicek model for credit portfolio losses, default values for all parameters except obligors' probabilities of default are provided in the regulatory framework. On the Basel FIRB approach, see Basel Committee on Banking Supervision, 2005, 2006 and 2010 rev. 2011.

[14] It should be noted that in other applications, an additional optional step simulating direct bank-to-bank contagion is introduced between steps 3 and 4 described here.

- **STEP 1**: Estimation of the Implied Obligors' Probability of Default (IOPD) of the portfolio of each individual bank.

The model estimates the average IOPD of the portfolio of each individual bank using its total MCR[15] declared in the balance sheet by numerical inversion of the Basel FIRB formula for credit risk. Individual bank data needed to estimate the IOPD are banks' RWA and TA, which can be derived from the balance sheet data. All other parameters are set to their regulatory default values. Annex 2 gives additional technical details on the FIRB formula for the interested reader.

- **STEP 2**: Simulation of correlated losses for the banks in the system.

Given the estimated average IOPD, it is assumed that correlated losses hitting banks can be simulated via Monte Carlo using the same FIRB formula and imposing a correlation structure among banks (with a correlation set to *R*=50%). This correlation exists either as a consequence of the banks' common exposure to the same borrower or, more generally, to a particular common influence of the business cycle[16]. In each simulation run *j*, losses for bank *i* are simulated as:

$$L_{i,j} = LGD \cdot N\left[\sqrt{\frac{1}{1-R}}N^{-1}(IOPD_i) + \sqrt{\frac{R}{1-R}}N^{-1}(\alpha_{i,j})\right]$$

where *N* is the normal distribution function, $N^{-1}(\alpha_{i,j})$ are correlated normal random shocks, and $IOPD_i$ is the average implied obligors' probability of default estimated for each bank in Step 1. *LGD* is the Loss Given Default, set as in Basel regulation to 45%.

- **STEP 3**: Determination of the default event.

Given the matrix of correlated losses, it is determined which banks fail. As illustrated in Figure 1, a bank default happens when simulated obligor portfolio losses exceed the sum of the expected losses (EL) and the total actual capital (K) given by the sum of its MCR plus the bank's excess capital, if any:

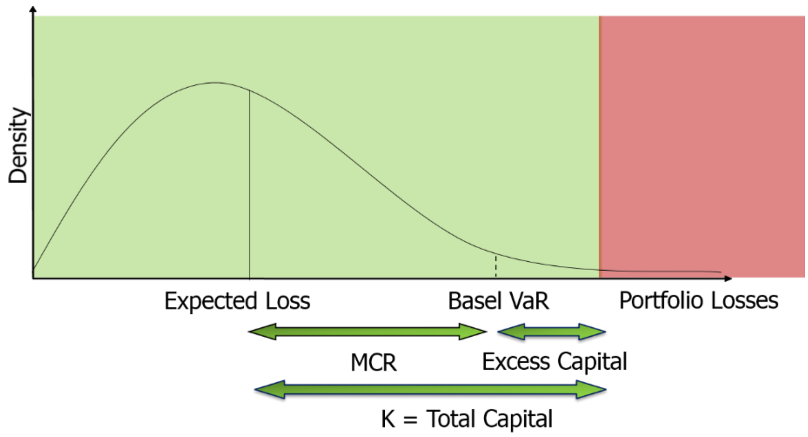
$$L_{n,i} \geq EL_i + K_i$$

[15] Banks must comply with capital requirements not only for their lending activity and credit risk component. Banks assets are in fact not only made up of loans, and there are capital requirements that derive from market risk, counterparty risk, and operational risk, etc. The main assumption currently behind this methodology is that all risk can be approximated as credit risk.

[16] The choice of the 50% correlation is based on Sironi and Zazzara, 2004. A discussion and a sensitivity check on this assumption can be found in De Lisa et al., 2011.

The green-shaded area in Figure 1 represents the region where losses are covered by provisions and total capital, while the red-shaded one shows when banks default under the above definition. It should be noted that the probability density function of losses for an individual bank is skewed to the right, i.e. there is a very small probability of extremely large losses and a high probability of losses that are closer to the average/expected loss. The Basel Value at Risk (VaR) corresponds to a confidence level of 0.1%, i.e. the MCR covers losses from the obligors' portfolio with probability 99.9%. This percentile falls in the green-shaded area as banks generally hold an excess capital buffer on top of the MCR.

Figure 1: Individual bank loss probability density function



- **STEP 4**: Aggregated distribution of losses for the whole system.

Aggregate losses are obtained by summing losses in excess of capital plus potential recapitalisation needs of all distressed banks in the system (i.e. both failed and undercapitalised banks) in each simulation run.

In order to compute losses increasing outstanding debt, we consider the amount of funds necessary to recapitalize all banks to a 4.5% or an 8% level of RWA.

These two different levels are chosen as follows: 8% is the level of minimum capitalization under which a bank is considered viable under Basel rules and the minimum level to which banks were recapitalized by public interventions in the past crisis; on the other hand it could be considered that banks do not need to be fully recapitalized by public finances money if they still hold a certain amount of capital which could allow them to access the markets or other sources of financing. We therefore consider a recapitalisation to 4.5% of the RWA of each bank, a level which coincides with the minimum amount of Core Tier 1 capital and with the minimum capitalization level required to access direct recapitalization by ESM. [17]

3.4. Modelling issues

The following points should be considered when reading the results. First, in our modelling exercise we consider that the market evaluation of bank capital takes sovereign risk fully into account even if regulatory capital does not. Formally, the impact of the deterioration in the sovereign creditworthiness on bank capital depends on how banks account for government bonds in their balance sheet. A reduction in the market value of sovereign bond holdings that are held in the banking book at amortised costs are not marked-to-market and do not formally affect banks' regulatory capital until realisation of losses. When held in the trading book, available-for-sale and in the fair value option book, sovereign holdings directly impact the capital of banks.[18] Second, we ignore interest rate risk and we focus only on the credit risk component of government bond yields. Government bonds are all assumed to have a 10-year maturity. Third, we ignore other financial intermediaries than banks, as no information is so far available on the exposures of other (non-banks) investors to the considered government bonds. These investors are most likely investment and pension funds and insurance companies. Fourth, our bank distress micro-simulation model does not take into account the rating of the bank, eventual provisions or the possibility that banks can raise capital. Fifth, we take into account that sovereign risk might spillover cross-border. However, we do not take into account possible systemic effects of contagion between banks via the interbank market or due to fire sales and liquidity spirals;

Finally, in our framework, investment is not related to the rate paid on borrowed funds, but this realistically will be the case. Therefore, investment and growth would decline.

4. Data

Data are taken from several sources. *Sovereign debt exposures amounts* of a sample of banks which participated in the 2012 European Banking Authority (EBA) capital exercise[19] are taken from SNL

[17] According to the agreement reached in June 2013, banks with a capital below 4.5% of RWA would have to receive help from their own government before the ESM can step in via direct recapitalisation. ESM direct bank recapitalisation instrument http://www.eurozone.europa.eu/media/436873/20130621-ESM-direct-recaps-main-features.pdf

[18] As of June 2013 this is the average distribution (across the EBA sample) of sovereign exposures: 48% is held in the "available for sale portfolio", 30% in the "hold to maturity", 18% in the "held for trading" and 4% is marked under the "fair value option". Only for the last two categories holdings have to be reported at the marked-to-market value. We believe market valuations of sovereign bonds reflect expectations about risks of sovereign default, about bank recap needs, including the sovereign feedback loops. Sovereign and bank capital and bank funding conditions will reflect these market expectations about default risks and expected losses.

[19] Greek banks were not included in the EBA exercise because already subject of specific measures within the EU/IMF financial

Financial. *Banks Balance sheet data* from Bankscope as of December 2012. In particular, for the analysis of capital levels and for bank losses estimations we use the variables: capital requirements, total capital and total assets. *Country level macroeconomic variables* such as amount of government debt outstanding and GDP are taken from Datastream. *Sovereign CDS Premia* have 10 years maturity and are taken from Markit. These data are summarized at the country level in Table 1.

Table 1*:* **Macro Variables, Banks' Total Assets and Sovereign Debt Exposures**. Observations are as of December 2012. The table aggregates per country the data for the considered 35 banks consolidated in the country of the parent. The selected Euro area countries, in the analysis, are: Germany (DE), France (FR), Netherlands (NL), Ireland (IE), Italy (IT), Portugal (PT) and Spain (ES). Total government bond holdings includes bonds issued by all worldwide governments.

						Government Bond Holdings			
	GDP	Government Debt Outstanding Amount	Debt to GDP Ratio	Sovereign CDS Level	Total Asset Banking Sector	Total as % GDP	Total as % of Total Assets	Share of Domestic on Total Holdings	Share of Exposure to the 7 Selected Countries
	Billion €	Billion €		Bps	Billion €				
DE	2.666	2.161	81,0%	78	8.435	37%	11,8%	55,9%	70,2%
FR	2.032	1.841	90,6%	139	7.908	25%	6,5%	34,3%	58,8%
NL	599	427	71,3%	78	2.528	33%	7,9%	38,0%	67,9%
IE	164	193	117,4%	250	903	35%	6,3%	82,5%	92,7%
IT	1.567	1.990	127,0%	313	4.247	37%	13,7%	69,0%	81,6%
PT	165	205	124,1%	471	560	38%	11,3%	77,2%	84,4%
SP	1.029	885	86,0%	319	3.587	39%	11,2%	58,3%	64,4%

Debt to GDP ratios diverge substantially across "core" (DE 81%, FR 90% and NL 71%) and "peripheral" countries (IE 117%, IT 127 90%, PT 124% and SP 86%), meaning that for the latter group public finances are substantially weaker. This aspect is also captured by higher sovereign credit spreads of the "peripheral" countries as measured by the 10-year maturity Credit Default Swap (CDS) Premium, which are all above 250 Bps. Data on exposures show that banks' overall holdings of government debt in percentage of GDP is relatively constant across countries, ranging from 25 to 39% (column 7). Sovereign exposure constitutes a substantial fraction of banks total assets, ranging from the 6.3% of Irish banks to the 13.7% of Italian banks. There is a strong domestic bias in sovereign debt holdings as the share of holdings of own sovereign bonds ranges between 34% for French banks to 82% for Irish banks (column 11). In the analysis, we study the banks sovereign feedback focusing only on the seven selected countries (DE, FR, NL, IE, IT, PT and SP). The exposure of the banks located in these selected countries with respect to the same countries ranges between 58 and 92 %. Summary figures

programme.

on holdings of government bonds of the countries considered in our analysis are presented in Table 2.

German banks are exposed to Italian and Spanish government debt (for an amount of respectively 34 and 16 Billion Euro). French banks are exposed towards German and Italian debt (respectively 42 and 38 Billion Euro). In any case, these exposures are negligible with respect to the total amount of bond holdings by German and French banks. Dutch banks are largely exposed to German government bonds. Irish, Portuguese and Spanish banks are characterized by only minor non-domestic exposures. This also holds for Italian banks with the exception of a 30 Billion exposure to German government debt. As banks with substantial cross-border sovereign exposure are either those located in countries with strong public finances (DE, FR and NL) or those exposed to safe/low-risk government debt (as for the case of IT), we expect the results in our analysis to be driven mainly by the domestic sovereign debt exposures.

Table 2: **Banks' Sovereign Bond Holdings.** Observations are as of December 2012. In the table, rows show per each country Sovereign bond holdings of the considered 35 banks of bonds issued by government-countries in the sample.

Country	FR	DE	IE	IT	NL	PT	SP
	Billion €						
DE	12,954	312,367	1,411	34,882	10,700	3,477	16,375
FR	141,068	42,480	0,931	38,618	10,223	1,241	7,507
NL	14,426	29,398	0,175	3,430	62,215	0,620	0,775
IE	1,018	0,306	16,283	0,283	0,379	0,025	0,000
IT	1,786	30,341	0,053	197,716	0,432	0,203	3,090
PT	0,215	0,022	0,581	1,070	0,012	21,938	0,140
SP	3,270	4,356	0,000	4,803	0,905	3,324	157,934

To motivate the importance of focusing on the government bond holdings "channel" we calculate aggregate figures by country of the "maximum mark-to-market losses" faced by banks due to the fact that they were holding government bonds in the 2010-2012 period. These losses are obtained based on the banks' actual government debt holdings in December 2012[20]. The haircut applied is based on a credit risk premium increase approximated by the difference between the minimum and maximum credit spread observed throughout the considered period[21]. As shown in Table 3, in the considered two-year period, Italian banks where holding 286 Billion euro in government bonds and

[20] These are time varying, but tend to be relatively stable in time.

[21] Notice these are not actual realized losses, but can be seen as a sort of upper bound.

faced losses for approximately 64 Billion (haircut applied is 24,8 %) corresponding to 3,1% of their total assets and to approximately 8,4 % of the Italian GDP.

Banks in core countries lost on their government bond holdings an amount which corresponds approximately to a percentage of their total assets in the order of 1,1 to 1,6%[22]. Banks in peripheral countries realized larger losses, i.e. going from 2,8 to 5,2% of their total assets.

Table 3: Banks maximum mark-to-market losses on government debt. Data on banks government debt exposure are as of December 2012. The table aggregates per country the data for the considered 35 banks consolidated in the country of the parent.

	CDS Min	CDS Max	Bond Haircut	Banks Government Bond Holdings	Total Losses	Total Losses/GDP	Total Losses/Total Assets
	Bps			Billion €			
DE	29,3	95,25	5,6%	558,280	75,569	5,0%	1,6%
FR	37,7	184,23	12,0%	411,110	74,121	4,6%	1,2%
NL	29,2	138,5	9,1%	163,449	23,408	4,8%	1,1%
IE	118,5	980,6	49,1%	19,730	8,606	15,2%	2,8%
IT	89,9	432,6	24,8%	286,187	64,783	8,4%	3,1%
PT	98,6	1027	51,9%	28,393	13,112	17,7%	5,2%
SP	99,29	366,3	20,0%	270,736	58,876	8,5%	2,4%

5. Results of the Analysis

5.1 The Feed-back Loop

Our model allows a simulation of the allocation of bank losses across different stakeholders (equity-holders, bondholders, public finances and safety nets) depending on the chosen regulatory context and scenarios for bank capitalization. At this stage, we focus on bank losses affecting public finances, we do not consider scenarios in which bondholders are bailed-in, or safety-nets (resolution fund, deposit guarantee scheme) cover part of the losses. Losses in excess of capital are financed by public finances.

The shock to which the banking sector is exposed[23] is at the euro area level (i.e. we run SYMBOL on the pool of 35 banking groups in the EBA sample). The capital injection to recapitalize banks is done

[22] This is the maximum mark-to-market loss that have occurred throughout the considered two-year period. This exercise does not consider that losses might have been hidden in bank balance sheet or that banks might have been helped in indirect ways by the government.

[23] We also conduct a parallel exercise in which there is a shock originating in the sovereign sector and we test how banks react when they are in stress conditions (joint banking and sovereign shock). We take as an adverse scenario one in which the term structure of credit spreads of all Euro area government shifts unexpectedly by 40% (compared to the baseline where the term structure stays constant) and we work out the corresponding sovereign bonds' haircuts. The actual available capital in case of a haircut on sovereign bonds is considered to be proxied as the actual capital of the bank minus the reduction in value of the bonds held on the balance sheet.

by the domestic government. The effect of the shock is measured by evaluating the increase in credit spread and haircut for the selected Euro area governments and the banks losses on sovereign bond holdings. Banks' losses on government holdings are attributed on the basis of the complete exposure matrix. Through this channel we account for international spillover effects. We analyse two cases, one in which the government has to recapitalize banks at the 8% regulatory capital level[24] and one in which it only has to recapitalize banks to the 4.5% level because the European Stability Mechanism (ESM) would step funding the remaining part.

The shock to which the banking sector is exposed that is considered in this exercise reflects a percentile of the loss distribution from SYMBOL for which bank losses for the EU as a whole are of the same order of magnitude as the 2008-2010 financial crisis. This is the 99.95th percentile of the loss distribution.[25] The initial sovereign risk premium (CDS) is the one prevailing in December 2012. This can be considered a period of risk aversion that already reflects high risk of a systemic crisis and some risk of a euro area break-up. The *debt-to-GDP* thresholds calibrated to fit this risk premium may thus be rather low historically. Table 4 shows for each country: first SYMBOL generated bank excess losses that are to be covered by public finances and the resulting debt increase due to the recapitalizations of the banks. Then its shows the CDS increase and haircut on sovereign bonds due to higher debt (and default risk) from our model. The reduced market valuation of banks sovereign bond holdings (both domestic and foreign) results in further capital shortfalls and increases in countries' debt. The columns 7-10 report the final results after 5 iterations from bank losses to sovereign debt and risk premium increase.

Let us first consider the most realistic scenario in which the domestic government recapitalizes bank to 4.5% as the ESM does provide direct recapitalizations for the remaining part. Results in Table 4 show that the model generates sizeable effects from the feedback loops, exacerbating the initial direct effects of the banking sector shock on the banking sector losses, sovereign debt, risk premia and bond haircuts. In the case of Italy for example, the CDS shift is 206 bps, i.e. 115 bps larger than the initial shift of 91 bps, the haircut rises from 6.7% to 16.9% and banks losses from 29 to 73 Billion

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So, the capital to be considered in the SYMBOL model, for bank i, after the haircut is . The two analyses are based on banks information and on country specific macroeconomic variables as of December 2012.

24 Recap to 8% reflects a scenario in which no private sector capital can be generated (through equity issuance, or mergers) and the ESM does not provide direct recapitalizations.

25 When considering the relevant loss distributions for individual banks at the 99.95th percentile, after the loss matrix has been generated, we first group the banks in the SYMBOL-generated loss matrix per country and then take the loss distribution at the runs of the 99.95th percentile for an individual country as we are primarily interested in the sovereign banking doom loop within a single country. This contrasts with an approach in which the runs of the 99.95th percentile are taken when all EU banks are taken together. Note that in our approach where individual country losses are taken at the 99.95th percentile, the aggregate losses at EU level will be higher than those of the 99.95th percentile when taking all EU banks together. Later versions of SYMBOL simulations moreover applied a HP filter to smoothen the individual run's loss distributions for single country losses.

Euro. The effect of the loop is not explosive meaning that haircuts, CDS levels and debt to GDP ratios tend to stabilise around some equilibrium value.

Table 4: Banking Sector Shock and the Total Effect on Banks Losses and Sovereign Risk. This table shows results of the analysis in which we estimate the total effect, accounting for the complete feedback loop, of a shock originating in the banking sector on both banks and sovereign credit risk. The following information is reported: SYMBOL excess losses (99.95 percentile of the distribution) and the corresponding debt-to-GDP increments (relative to its initial value), sovereign risk premium shifts, haircuts and losses on sovereign holdings. The table aggregates per country the data for the considered 35 banks consolidated in the country of the parent. Public finances (i.e. domestic government) provide for the recapitalization up to 4.5% RWA.

		First order effect				Total Effect			
	Banks Excess Losses + gov. recap	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings
	Billion €		Bps		Billion €		Bps		Billion €
DE	44,803	1,70%	20	1,70%	22,581	4,20%	55	6,60%	68,168
FR	78,921	3,90%	64	5,20%	18,435	6,00%	105	10,50%	43,100
NL	22,661	3,80%	55	4,60%	7,128	6,90%	119	11,50%	18,492
IE	12,929	7,90%	171	12,50%	6,179	16,20%	391	27,70%	13,667
IT	70,271	4,50%	91	6,70%	29,466	9,20%	206	16,90%	73,907
PT	13,085	7,90%	242	15,80%	8,109	18,60%	556	33,60%	17,556
SP	70,401	6,80%	235	16,30%	39,953	15,80%	605	37,40%	92,413

As the debt to GDP ratio increases one could ex-ante have expected sovereign risk to explode, but as haircuts increase, the value at risk reduces sharply. The potential increase in the sovereign debt as result of bank losses on sovereign debt holdings is effectively capped by the total amount of sovereign debt holdings. As long as the sum of the countries' initial debt, the banking sector losses generated by SYMBOL and the countries' banks' sovereign debt holdings are lower than the debt threshold, the premium and the haircut will stabilize at a level that does not reflect a certain default. If in a later stage additional feedback loops will be added to the model dynamics, instability and explosive patterns may arise more easily, in particular through the growth channel. The importance of the feedback loop differs across countries. The main factors driving the dynamics are: the characteristics of the domestic banking sector, the initial debt to GDP ratio, the initial sovereign risk premium, and the banks holdings of domestic sovereign bonds. In particular, the size of the banking sector to GDP, the riskiness of the assets (RWA to TA), and the capitalisation of the banks. All these ingredients determine the size of the initial banking sector losses. Notice that the feedback loops are relatively benign in France and Germany, and very important in Spain, Portugal and Ireland. Table 5 shows the dynamics of the key variables over a number of loops[26]. The effects level off significantly after the second loop and stabilizes after 4 loops.

Table 5: Banking Sector Shock and the Feedback Loop. This table shows the feedback loop dynamics for the first 5 iterations, of a shock originating in the banking sector on: haircuts, debt-to-GDP ratios and shift in the sovereign CDS level. In table A Public finances (domestic government) provide for the recapitalization up to 4.5% RWA while in Table B for the recapitalization up to 8% of RWA.

A SYMBOL output (64 EBA Banks) Excess losses + recap (4.5%) 99.95

	HAIRCUT					DEBT-TO-GDP						CDS Shift (from T0)					
	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4
BE	7,0%	10,7%	14,7%	17,0%	18,3%	101,1%	106,9%	109,5%	110,8%	112,3%	113,1%	124	87	136	164	198	217
DE	1,7%	2,7%	5,4%	6,1%	6,8%	81,0%	82,7%	83,6%	84,0%	84,8%	85,1%	78	20	32	40	49	57
FR	5,2%	6,7%	9,3%	10,2%	10,6%	90,6%	94,5%	95,4%	95,8%	96,3%	96,5%	139	64	84	89	101	107
NL	4,6%	6,9%	9,6%	11,0%	11,6%	71,3%	75,0%	76,2%	76,8%	77,6%	77,9%	78	55	83	94	112	120
IE	12,5%	18,8%	23,9%	26,4%	27,6%	117,4%	125,3%	129,1%	130,9%	132,5%	133,3%	250	171	270	320	367	388
IT	6,7%	10,1%	13,6%	15,7%	16,5%	127,0%	131,5%	133,3%	134,3%	135,3%	135,9%	313	91	141	153	187	200
PT	15,8%	24,1%	30,4%	33,5%	34,0%	124,1%	132,0%	136,9%	139,5%	141,5%	141,5%	471	242	396	482	553	565
SP	16,3%	25,6%	32,3%	35,7%	37,7%	86,0%	92,8%	96,7%	98,9%	100,5%	101,3%	319	235	396	490	565	613

B SYMBOL output (64 EBA Banks) Excess losses + recap (8%) 99.95

	HAIRCUT					DEBT-TO-GDP						CDS Shift (from T0)					
	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4
BE	14,4%	22,6%	29,2%	32,8%	34,7%	101,1%	111,6%	116,8%	119,8%	122,1%	123,3%	124	187	313	398	463	502
DE	3,0%	5,0%	8,1%	9,5%	10,0%	81,0%	83,9%	85,4%	86,2%	87,1%	87,6%	78	35	60	74	93	99
FR	9,1%	12,2%	15,4%	16,7%	17,1%	90,6%	97,0%	98,6%	99,3%	100,0%	100,3%	139	115	158	174	193	200
NL	9,0%	13,0%	17,4%	19,4%	20,6%	71,3%	77,6%	79,9%	81,0%	82,1%	82,6%	78	110	164	201	231	248
IE	21,3%	31,8%	38,1%	40,9%	42,2%	117,4%	130,7%	137,2%	140,3%	142,3%	143,1%	250	313	509	610	675	710
IT	11,6%	16,8%	21,6%	23,5%	24,5%	127,0%	134,6%	137,8%	139,3%	140,7%	141,3%	313	164	245	287	321	341
PT	24,0%	36,4%	43,0%	44,9%	45,2%	124,1%	137,6%	145,2%	149,0%	151,1%	151,2%	471	395	672	803	861	872
SP	27,6%	41,0%	47,9%	50,6%	51,5%	86,0%	97,6%	104,2%	107,3%	109,0%	109,7%	319	434	733	885	969	999

The system stabilizes earlier with larger initial shocks. This is the result of two countervailing forces. On the one hand the risk premium increase accelerates as debt gets closer to the default threshold. On the other had the scope for further losses is reduced as the market value of sovereign debt holdings is reduced due to losses in earlier loops. The relatively strong dynamics of Spain when compared to Portugal are surprising considering the lower debt-to-GDP ratio. This may be due to the high risk premium on Spain compared to the initial debt level by end 2012.

5.2 The ESM Direct Bank Recapitalisation

If all capital in excess of 4.5% RWA is provided for by ESM direct recap, the sovereign feedback loop is significantly weakened.

[26] Table 11 and 12 in Annex 1 provide the results as in Table 3 and 5, but for a scenario in which the initial shock originates both in the banking and in the sovereign sector.

Table 6: The Effect of the ESM intervention on the Feed-Back Loop. This table reports recapitalization effort done by the government due to the SYMBOL excess losses (99.95 percentile of the distribution). In the first case public finances (i.e. domestic government) provide for the recapitalization up to 8 RWA, while in the second case public finances (i.e. domestic government) provide for the recapitalization up to 4.5% RWA as the remaining part to reach the 8% required regulatory level is integrated by the ESM.

	Banks excess losses + gov. recap to 8%	Banks excess losses + gov. recap to 4.5%	ESM Funds Injection	Reduction of losses on Government Bond Holdings (in case ESM intervenes)
	Billion €	Billions €	Billion €	Billion €
DE	76,948	44,803	32,145	33,131
FR	129,962	78,921	51,041	25,976
NL	(38,052 -	22,661)	= 15,391	13,263
IE	21,843	12,929	8,914	7,318
IT	119,247	70,271	48,977	35,709
PT	22,366	13,085	9,281	5,980
SP	119,873	70,400	49,473	34,219

As an example, in the case of the Netherlands the amount of recapitalization to be covered by the Dutch government could be reduced from EUR 38.1 billion to EUR 22.7 billion, as the ESM could cover EUR 15.4 billion recap. As a result, the sovereign CDS is estimated to increase by 119 bps rather than 247 bps (as reported in Table 4), lowering losses on sovereign holdings due to feedback loops by EUR 13.3 billion (from EUR 31.8 billion to EUR 18.5 billion). For other countries the loss reduction, due to ESM fund injection, is substantial as well. Notice that while part of government injections constitutes a loss, the ESM injection is an equity investment. An additional benefit, not considered in our model, consists in the lower interest rate that the government will have to pay on the outstanding debt.

5.3. Banks Losses due to International Exposures

In the model, government debt depreciation affects banks cross-border. For example, as German banks are exposed for approximately 34 Billion to the Italian government debt these will face losses whenever Italian Government debt depreciates. In order to quantify banks losses due to international spillovers we proceed as follows. We assume in one case (1) that banks are exposed only to national government bonds, i.e. we run the model "blocking" the "cross-border transmission channel and we compare the results with the baseline case (i.e. the case developed in Chart B in Table 5 where recapitalisation by the national government is at 8%).

Table 7: Banking Sector Shock and the Total Effect on Banks Losses and Sovereign Risk. This table shows results of the analysis in which we estimate the total effect, accounting for the complete feedback loop, of a shock originating in the banking sector on both banks and sovereign credit risk. The following information is reported: debt-to-GDP increments (relative to its initial value), sovereign risk premium shifts, haircuts and losses on sovereign holdings. The table aggregates per country the data for the considered

35 banks consolidated in the country of the parent. Public finances (i.e. domestic government) provide for the recapitalization up to 8% of RWA. In Case 1 banks are exposed only to their home government bonds.

SYMBOL output: Banks excess losses + gov. recap to 8% (99.95 percentile of the distribution)

	Baseline Case -Total Effect				Case 1 -Total Effect			
	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings
		Bps		Billion €				Billion €
DE	6,7%	102	10,2%	101,299	4,3%	59	6,9%	38,797
FR	9,8%	196	16,9%	69,076	7,5%	139	12,9%	23,259
NL	11,6%	247	20,5%	31,755	8,1%	151	13,9%	10,614
IE	26,1%	704	42,0%	20,984	25,1%	677	40,9%	19,380
IT	14,6%	344	24,7%	109,616	13,7%	330	24,0%	95,801
PT	27,8%	864	45,0%	23,535	26,6%	838	44,1%	21,602
SP	24,0%	991	51,3%	126,632	23,2%	959	50,3%	118,516

For peripheral countries the increment of banks losses due to international sovereign exposure is negligible. As an example for Italy the difference across the two scenarios is of about 14 billion Euro. As a result of this, the debt-to-GDP ratio increment is only of 0,9% (from 13,7 to 14,6%), while the CDS premium increment is of 14 bps (from 330 to 344 bps). Differently, for Germany, France and the Netherlands initial banks' losses are substantial. In the case of Germany banks losses increase from 38 to 101 Billion Euro and the sovereign CDS spread shift (102 bps) is double, but notice that the debt-to-gdp ratio remains negligible, i.e. it goes only from 4,3 to 6,7%. Overall, international spillover effects have a negligible impact. This was expected given that banks are mainly exposed to national government bonds. And that core countries' banks which are the most exposed to peripheral countries benefit from the solid public finances.

5.4. Bank Exposure: The Full Integration Case

In this section we perform an exercise where banks are assumed to hold an amount of government bonds issued by a country proportional to the share of the debt of the selected country on the total bonds hold by all banks. The idea is to challenge the "home bias". The total amount invested in government bonds issued by each country, by any given bank, corresponds to the sum of the actual holdings found in the EBA matrix. Results are compared against the benchmark case developed in Chart A in table 5 where recapitalisation by the national government is at 4.5%).

Table 8: Banking Sector Shock and the Total Effect on Banks Losses and Sovereign Risk. This table shows results of the analysis in which we estimate the total effect, accounting for the complete feedback loop, of a shock originating in the banking sector on both banks and sovereign credit risk. The following information is reported: debt-to-GDP increments (relative to its initial value), sovereign risk premium shifts, haircuts and losses on sovereign holdings. The table aggregates per country the data for the considered 35 EU banks consolidated in the country of the parent. Public finances (i.e. domestic government) provide for the recapitalization up to 4.5% of RWA.

SYMBOL output: Banks excess losses + gov. recap to 4.5% (99.95 percentile of the distribution)										Baseline
		First Order Effect				Total Effect				Actual Exposures
	Bank excess losses + gov. recap	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Losses on Sovereign Holdings
	Billion €		Bps		Billion €		Bps		Billion €	Billion €
DE	76,948	2,9%	35	3,0%	77,358	8,6%	138	12,9%	152,034	101,299
FR	129,962	6,4%	115	9,1%	33,659	9,7%	196	16,9%	66,152	69,076
NL	38,052	6,3%	110	9,0%	15,097	11,3%	245	20,3%	29,670	31,755
IE	21,843	13,3%	313	21,3%	5,886	20,4%	530	34,6%	11,568	20,984
IT	119,247	7,6%	164	11,6%	52,866	14,2%	340	24,5%	103,899	109,616
PT	22,366	13,5%	395	24,0%	5,935	20,6%	647	37,3%	11,664	23,535
SP	119,873	11,6%	434	27,6%	28,680	17,1%	671	40,1%	56,366	126,632
				Sum	219,481			Sum	431,353	482,897

Compared to the baseline case German bank have larger losses on sovereign holdings (152 vs. 101 Billions), but other countries have either comparable losses (France, Netherlands and Italy) or substantially lower losses as in the case of Ireland, Portugal and Spain. In the full integration case, total losses amount to around 430 Billion, i.e. approximately 50 Billion less than in the baseline case (483 Billions). Notice that losses on sovereign holdings in the first round (219 Billions) are equal across the baseline exercise and this application meaning that the 50 Billion reduction in losses is due to lower feed-back loop effects. The benefits come from the fact that losses are reallocated to banks in Germany that benefit from stronger public finances. The non-linear relation between debt-to-GDP ratio and the default risk is flatter for countries where distance to default is higher. This exercises shows that there are limited benefit of having a "full integration".

5.5. Bank Bond Holder Bail-in

The model also allows assessment of other instruments and tools that dampen the effect of the bank-sovereign loop, such as the required bail-in under the BRRD and the establishment of a resolution fund. According to the burden sharing cascade of the BRRD and SRM regulations, banking resolution needs to comply with the "burden sharing cascade".

In case of a severe distress, bondholders are supposed to bail-in the bank up to 8% of a bank's Total Assets. Here, we consider the situation in which the domestic government recapitalizes bank to 8% of the RWA after banks bondholders provide direct recapitalizations. The first column shows that even if bondholders participate to the recapitalization of the banks the contribution of the local government remains sizable[27], i.e. from 12 up to 39 Billion Euro, for peripheral countries (IE, IT, PT and SP). The 8% bail-in of total banks' balance sheets is effective in breaking the cycle only in the case of France and the Netherlands.

Table 9: Banking Sector Shock and the Total Effect on Banks Losses and Sovereign Risk with the "Bail-In". This table shows results of the analysis in which we estimate the total effect, accounting for the complete feedback loop, of a shock originating in the banking sector on both banks and sovereign credit risk. The following information is reported: SYMBOL excess losses (99.95 percentile of the distribution) and the corresponding debt to GDP increments (relative to its initial value), sovereign risk premium shifts, haircuts and losses on sovereign holdings. The table aggregates per country the data for the considered 35 banks consolidated in the country of the parent. Public finances (i.e. domestic government) provide for the recapitalization up to 8% RWA after bondholders have provided direct recapitalization up to 8% of Total Assets.

Banks excess losses + gov. recap to 8% (99.95 percentile of the distribution)

		First Order Effect				Total Effect			
	Bank Excess Losses + Gov. Recap	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings
	Billion €		Bps		Billion €		Bps		Billion €
DE	8,092	0,3%	0	0,0%	6,579	1,9%	32	4,7%	42,351
FR	1,252	0,1%	3	0,2%	4,032	1,0%	21	4,1%	19,965
NL	1,224	0,2%	3	0,3%	0,954	1,4%	19	3,7%	7,313
IE	13,047	8,0%	174	12,7%	6,026	16,1%	380	27,1%	13,405
IT	39,748	2,5%	52	3,9%	16,302	5,6%	114	11,0%	48,768
PT	12,7183	7,7%	219	14,4%	7,322	17,5%	500	31,2%	16,160
SP	37,958	3,7%	120	8,8%	21,497	9,3%	320	23,6%	58,044

[27] Zedda and Galliani (2014) propose a computational approach to study the effects of the circular relation between bank and sovereign risk. Their analysis shows that the 8% bail-in of total bank balance sheets is effective in breaking the cycle, hence preventing contagion between banks. They focus their analysis on Belgium, Denmark, Greece, and the Netherlands.

Let us now compare the government and the bondholder recapitalization effort in the case of bail-in vs. no bail. Moreover, the first round and total effect on sovereign holding losses.

Table 9: Government and bondholders recap effort and the first round and total effect on banks losses on Sovereign bond holdings.

Banks excess losses + gov. recap to 8% (99.95 percentile of the distribution)

	No Bail-In	Bail-in		No Bail-In	Bail-In		No Bail-In	Bail-In	
	Symbol Excess Losses+gov. recap		Diff. (Bond holders)	Losses on Sov. Holdings (First round)		Diff.	Losses on Sov. Holdings (Total Effect)		Diff.
	Billion €						Billion €		
DE	76,948	8,092	-68,855	38,996	6,579	-32,417	101,299	42,352	-58,947
FR	129,962	1,253	-128,710	32,897	4,032	-28,865	69,076	19,966	-49,110
NL	38,052	1,225	-36,827	13,571	0,954	-12,616	31,755	7,314	-24,441
IE	21,843	13,047	-8,796	10,578	6,026	-4,552	20,984	13,406	-7,578
IT	119,247	39,748	-79,499	50,974	16,302	-34,671	109,616	48,769	-60,847
PT	22,366	12,718	-9,648	12,453	7,323	-5,130	23,535	16,160	-7,375
SP	119,873	37,958	-81,915	67,404	21,498	-45,906	126,632	58,045	-68,587
Tot.	528,292	114,041	-414,250	226,874	62,715	-164,159	482,897	206,011	-276,886

In the case of Italy for example the government effort would be of 119 Billion with no bail-in while only 29 Billion in the case of a bail-in. This means that bondholders contribute to the recap of the bank with 79 Billion. After the bail-in still something remains to be injected by the government. In the case of PT and IE these amounts are relatively low, i.e. 8,6 and 8,7 Billion, as in these countries banks are well capitalized with equity. For Italy and Spain the need for government intervention remains high, most likely because banks hold assets with high risk weight. Banks with the most risk assets are, by definition, the ones with the least bail in capacity.

Due to the bail-in aggregate losses on sovereign bonds by banks reduce in the first round by 164 while second round by 276 Billion. Hence, the bail-in has the effect of reducing both bank losses and the sovereign credit risk. Two points are noteworthy here. First, with the bail-in final losses on sovereign bond holdings are larger than initial bank losses 206 vs. 114, while with no bail-in losses on sovereign holdings are smaller 528 vs 482. This means that the bail-in is effective in reducing the initial government contribution, but notice that the loop remains active. Second, in the case of the bail-in, the total contribution of bondholders in the case of a systemic crisis in Europe is of around 414 Billion. Part of these has to be considered as equity investment while a large part constitutes losses. These losses enter in the system again as bonds are held by banks, insurance companies, pension funds, other financial institutions and is some cases by households.

5.6. Takeaways from the model and the analysis

Our model allows disentangling two different issues. First, the determinants of the initial “recapitalization need” (i.e. the trigger of the feedback loop). These are: (a) the “scale” of the aggregate shock to which the banking sector is exposed. (b) The “health” of the domestic banking sector (capital ratios, risk weighted assets, etc.) and the (c) size of the banking sector. The government fund injection depends on country-level banks’ Total Asset of which the losses are a proportion (i.e. TA to GDP). Second, the determinants of the feed-back loop, which are: the (d) strength of the public finances, i.e. debt-to-GDP (or Sovereign CDS), the (e) growth prospects of the economy (GDP growth rate and volatility) and (f) banks’ exposure to domestic sovereign credit risk (e.g. bond holdings), but also (g) the policy setting (ESM, SRM and Bail-in in place or not).

Notice also that the shocks, the transmission (propagation) mechanism and the feedback loops (amplification) are three distinctive issues. We propose the following clarifying example. If a shock originates in the banking sector the government might potentially have to, or actually needs to do inject new funds to rescue them. Hence, when banks face large unexpected losses sovereign credit risk increases as well. This is the transmission mechanism. Given that the government in trouble now, banks will face new unexpected losses on their bond holdings. Then the government will have to recap again and so on and so forth. As a final result due to the described feed-back loop banks risk will increase by a larger amount with respect to the initial increase (original shock), and sovereign credit risk will increase by a larger amount with respect to what caused in the first round. If the model would include also a third sector, i.e. the real economy the transmission mechanisms could be both direct and/or indirect. In fact, when sovereign risk increases there is a direct effect on bank risk as already described above. Then there is also a direct effect on the real economy as the government might increase taxes to face debt repayment. But there is also an indirect effect to the real economy via banking sector, as when banks are in trouble they tend to reduce lending to the real economy. And there is also an indirect effect to banks as these suffer from a weaker economy. Feedbacks are now multiple as also troubles in the real economy, not only in the banking sector might feed back to the sovereign.

6. Final Remarks and Further Investigations

The model provides a simple but powerful tool to analyse the bank-sovereign feedback loop and evaluate the effectiveness of policy options. Even though considering only the basic and most direct channels, the effects are sizeable. The Mody-Sandri framework that we start from is well suited to extend the analysis and include other feedback channels. Future work could focus in particular on feedback channels through the real economy. Also model parameters could be estimated, and the conditions under which an initial shock would generate explosive dynamics could be investigated.

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Annex 1: Further tables.

Table 1.1: List of 64 large EU banking groups, across 21 European countries, for which the EBA provides banks' exposure amounts to sovereign debt. The focus of the bank vs. sovereign risk feedback loop analysis is on the following seven selected countries: DE, FR, NL, IE, IT, PT and SP.

EBA Company Name	Country Name
Erste Group Bank (EGB)	Austria
Raiffeisen Zentralbank Österreich (RZB)	Austria
KBC BANK	**Belgium**
BANK OF CYPRUS PUBLIC CO LTD	Cyprus
DANSKE BANK	Denmark
Jyske Bank	Denmark
Nykredit	Denmark
Sydbank	Denmark
OP-Pohjola Group	Finland
BNP PARIBAS	**France**
CREDIT AGRICOLE	**France**
BPCE	**France**
SOCIETE GENERALE	**France**
Bayerische Landesbank	**Germany**
COMMERZBANK AG	**Germany**
DekaBank Deutsche Girozentrale, Frankfurt	**Germany**
DEUTSCHE BANK AG	**Germany**
DZ BANK AG Dt. Zentral-Genossenschaftsbank	**Germany**
HSH Nordbank AG, Hamburg	**Germany**
Hypo Real Estate Holding AG, München	**Germany**
Landesbank Baden-Württemberg	**Germany**
Landesbank Berlin AG	**Germany**
Landesbank Hessen-Thüringen GZ, Frankfurt	**Germany**
Norddeutsche Landesbank -GZ	**Germany**
WGZ BANK AG Westdt. Geno. Zentralbk, Ddf	**Germany**
EFG EUROBANK ERGASIAS S.A.	Greece
NATIONAL BANK OF GREECE	Greece
PIRAEUS BANK GROUP	Greece
OTP BANK NYRT.	Hungary
ALLIED IRISH BANKS PLC	**Ireland**
BANK OF IRELAND	**Ireland**
Permanent TSB	Ireland
BANCA MONTE DEI PASCHI DI SIENA S.p.A	**Italy**
BANCO POPOLARE - S.C.	**Italy**
INTESA SANPAOLO S.p.A	**Italy**
UNICREDIT S.p.A	**Italy**
UNIONE DI BANCHE ITALIANE SCPA (UBI BANCA)	**Italy**
BANQUE ET CAISSE D'EPARGNE DE L'ETAT	Luxembourg
ESPÍRITO SANTO FINANCIAL GROUP, SA (ESFG)	Luxembourg
BANK OF VALLETTA (BOV)	Malta
ING BANK NV	**Netherlands**
ABN AMRO BANK NV	**Netherlands**
RABOBANK NEDERLAND	**Netherlands**
SNS BANK NV	**Netherlands**
DnB NOR Bank ASA	Norway
POWSZECHNA KASA OSZCZ?DNO?CI BANK POLSKI S.A. (PKO BANK POLSKI)	Poland
Banco BPI, SA	**Portugal**
BANCO COMERCIAL PORTUGUÊS, SA (BCP OR MILLENNIUM BCP)	**Portugal**
CAIXA GERAL DE DEPÓSITOS, SA	**Portugal**
NOVA KREDITNA BANKA MARIBOR D.D. (NKBM d.d.)	Slovenia
NOVA LJUBLJANSKA BANKA D.D. (NLB d.d.)	Slovenia
BANCO BILBAO VIZCAYA ARGENTARIA S.A. (BBVA)	**Spain**
BANCO POPULAR ESPAÑOL, S.A.	**Spain**
BANCO SANTANDER S.A.	**Spain**
CAJA DE AHORROS Y PENSIONES DE BARCELONA	**Spain**
Nordea Bank AB (publ)	Sweden
Skandinaviska Enskilda Banken AB (publ) (SEB)	Sweden
Svenska Handelsbanken AB (publ)	Sweden
Swedbank AB (publ)	Sweden
BARCLAYS plc	United Kingdom
HSBC HOLDINGS plc	United Kingdom
LLOYDS BANKING GROUP plc	United Kingdom
ROYAL BANK OF SCOTLAND GROUP plc	United Kingdom

Annex 2: Shock originating in the Sovereign sector

In a second exercise, we analyses the impact of an adverse shock originating in the sovereign sector. We aim at quantifying the impact of haircuts applied on sovereign debt on banking losses and sovereign sector credit risk via the feed-back loop. We model the initial shock as an exogenous and unexpected shift of the level of the government credit spread term structure by 40%, for all euro-area countries. As in the first step, bank unexpected losses in stress situations are generated by means of the SYMBOL model and are augmented with the losses realised on bond holdings due to the haircuts applied.

Table 11: Joint Sovereign and Banking Sector Shock and the Feed-back Effect on Banks Losses and Sovereign risk. This table shows results of the analysis in which we estimate the total effect, accounting for the complete feed-back loop, of a shock originating both in the sovereign and in the banking sector on both banks and sovereign credit risk. We take as an adverse scenario one in which the term structure of credit spreads of all Euro area government shifts unexpectedly by 40% (compared to the baseline where the term structure stays constant) and we work out the corresponding sovereign bonds' haircuts. The following information is reported: SYMBOL excess losses and the corresponding debt to GDP increments (relative to its initial value), sovereign risk premium, haircuts and losses on sovereign holdings. In table A Public finances (domestic government) provide for the recapitalisation up to 4.5% RWA while in Table B for the recapitalisation up to 8% of RWA.

A Sovereign Shock & SYMBOL output (64 EBA Banks) Excess losses + recap (4.5%) 99.95

Country	Symbol - Excess Losses	Bank vs. Sovereign Feedback - First Order Effect: Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Bank vs. Sovereign Feedback - Total Effect: Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings
	Billions		Bps		Billions		Bps		Billions
DE	€ 56,470	2,1%	24	2,0%	€ 28,533	5,2%	70	7,8%	€ 80,865
FR	€ 88,714	4,4%	76	6,1%	€ 23,845	7,0%	124	11,9%	€ 52,746
NL	€ 25,998	4,3%	71	5,9%	€ 9,565	8,2%	152	14,0%	€ 23,378
IE	€ 14,593	8,9%	193	13,9%	€ 6,920	18,1%	440	30,2%	€ 15,042
IT	€ 94,566	6,0%	127	9,1%	€ 39,898	11,9%	276	21,0%	€ 91,967
PT	€ 17,187	10,4%	310	19,5%	€ 10,063	22,7%	697	39,2%	€ 20,275
SP	€ 92,630	9,0%	317	21,2%	€ 51,864	19,6%	780	44,3%	€ 108,817

B Sovereign Shock & SYMBOL output (64 EBA Banks) Excess losses + recap (8%) 99.95

Country	Symbol - Excess Losses	Bank vs. Sovereign Feedback - First Order Effect: Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings	Bank vs. Sovereign Feedback - Total Effect: Debt-to-GDP Increment	Shift Sovereign CDS Level	Haircut	Losses on Sovereign Holdings
	Billions		Bps		Billions		Bps		Billions
DE	€ 99,797	3,7%	49	4,1%	€ 52,227	8,4%	131	12,4%	€ 124,185
FR	€ 151,195	7,4%	146	11,4%	€ 42,558	11,6%	250	20,4%	€ 84,019
NL	€ 42,988	7,2%	132	10,7%	€ 17,067	13,7%	315	24,8%	€ 38,897
IE	€ 24,349	14,9%	356	23,8%	€ 11,895	28,8%	797	45,5%	€ 22,847
IT	€ 161,319	10,3%	232	16,0%	€ 69,839	19,1%	478	31,4%	€ 138,636
PT	€ 28,996	17,6%	552	31,4%	€ 16,229	33,8%	1075	51,3%	€ 26,833
SP	€ 154,218	15,0%	581	34,6%	€ 84,895	28,7%	1208	57,3%	€ 141,656

Table 12: Joint Sovereign and Banking Sector Shock. This table shows the feed-back loop dynamics for the first 5 iterations, of a shock originating both in the sovereign and in the banking sector on: haircuts, debt to GDP ratios and shift in the sovereign CDS level. We take as an adverse scenario one in which the term structure of credit spreads of all Euro area government shifts unexpectedly by 40% (compared to the baseline where the term structure stays constant) and we work out the corresponding sovereign bonds' haircuts. Total exposure includes bond holdings of all worldwide governments. In table A Public finances (domestic government) provide for the recapitalisation up to 4.5% RWA while in Table B for the recapitalisation up to 8% of RWA.

A Sovereign Shock & SYMBOL output (64 EBA Banks) Excess losses + recap (8%) 99.95

	HAIRCUT					DEBT-TO-GDP						CDS Shift (from T0)					
	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4
BE	19,1%	30,7%	38,8%	42,7%	44,9%	101,1%	114,7%	121,6%	125,6%	128,5%	129,8%	124	258	453	587	675	728
DE	4,1%	7,0%	10,4%	11,8%	12,5%	81,0%	84,8%	86,7%	87,8%	88,8%	89,2%	78	49	84	104	122	133
FR	11,4%	14,8%	18,6%	20,0%	20,2%	90,6%	98,0%	100,1%	101,0%	101,8%	102,1%	139	146	195	222	245	247
NL	10,7%	16,0%	20,7%	23,6%	24,6%	71,3%	78,4%	81,3%	82,7%	84,0%	84,7%	78	132	206	250	296	312
IE	23,8%	35,3%	42,0%	44,6%	45,7%	117,4%	132,3%	139,5%	143,0%	145,0%	145,8%	250	356	583	703	771	802
IT	16,0%	23,2%	28,5%	30,7%	31,2%	127,0%	137,3%	141,7%	143,8%	145,3%	145,9%	313	232	357	417	462	473
PT	31,4%	44,3%	49,7%	51,5%	51,5%	124,1%	141,6%	151,5%	155,5%	157,3%	157,3%	471	552	889	1018	1083	1083
SP	34,6%	49,2%	55,1%	56,8%	57,4%	86,0%	100,9%	109,2%	112,7%	114,1%	114,5%	319	581	964	1125	1188	1212

B Sovereign Shock & SYMBOL output (64 EBA Banks) Excess losses + recap (4.5%) 99.95

	HAIRCUT					DEBT-TO-GDP						CDS Shift (from T0)					
	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4	Initial Level	Shock Banking Sector	Loop 1	Loop 2	Loop 3	Loop 4
BE	11,5%	18,5%	23,8%	27,1%	28,4%	101,1%	109,9%	114,1%	116,5%	118,4%	119,5%	124	147	247	304	360	382
DE	2,0%	3,5%	6,2%	7,3%	7,8%	81,0%	83,2%	84,2%	84,8%	85,7%	86,0%	78	24	41	50	64	71
FR	6,1%	7,5%	10,5%	11,6%	11,9%	90,6%	95,0%	96,1%	96,6%	97,2%	97,5%	139	76	94	105	121	125
NL	5,9%	8,3%	11,6%	13,0%	14,0%	71,3%	75,6%	77,2%	77,9%	78,9%	79,3%	78	71	101	120	139	153
IE	13,9%	21,0%	26,2%	28,8%	30,2%	117,4%	126,3%	130,5%	132,6%	134,2%	135,0%	250	193	306	361	411	440
IT	9,1%	13,4%	17,6%	19,9%	20,7%	127,0%	133,0%	135,5%	136,7%	138,0%	138,6%	313	127	191	219	257	271
PT	19,5%	29,8%	36,3%	39,3%	39,2%	124,1%	134,5%	140,6%	143,7%	145,8%	145,9%	471	310	515	622	700	697
SP	21,2%	32,7%	40,0%	43,0%	44,4%	86,0%	95,0%	100,0%	102,7%	104,5%	105,2%	319	317	538	668	744	783

Annex 3: Estimation of the IOPD, further details.

For each exposure *l* in the portfolio of bank *i*, the FIRB formula derives the corresponding capital requirement needed to cover unexpected losses[28] over a time horizon of one year, with a specific confidence level equal to 99.9% (see Figure 1):

$$CR_{i,l} = \left[LGD \cdot N\left(\sqrt{\frac{1}{1-\rho}} N^{-1}(PD_l) + \sqrt{\frac{\rho}{1-\rho}} N^{-1}(0.999) \right) - PD_l \cdot LGD \right] \cdot M(PD_l)$$

where is the default probability of exposure *l*, ϱ is the correlation among the exposures in the portfolio, *LGD* is the Loss Given Default[29] and M(PD_l) a maturity adjustment

$$\rho = 0.12 \frac{1-e^{-50PD}}{1-e^{-50}} + 0.24\left(1 - \frac{1-e^{-50PD}}{1-e^{-50}}\right)\rho = 0.12 \frac{1-e^{-50PD}}{1-e^{-50}} + 0.24\left(1 - \frac{1-e^{-50PD}}{1-e^{-50}}\right)$$

and

$$M = \frac{1.06}{1 - 1.5\left(0.11856 - 0.05478 \cdot ln(PD)\right)^2}$$

MCR of each bank is obtained summing up the capital requirements for all exposures:

$$MCR_i = \sum_l CR_{i,l} \cdot A_{i,l}$$

where $A_{i,l}$ is the amount of the exposure *l*.

The average IOPD of a bank's asset portfolio can be derived as

$$IOPD_i\colon CR(IOPD_i) \cdot \sum_l A_{i,l} = MCR_i$$

where and A $_{j,l}$ are the minimum capital requirement and the total assets of the banks, publicly available in the balance sheet.

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[28] Banks are expected to cover their Expected Losses on an ongoing basis, e.g. by provisions and write-offs. The Unexpected Loss, on the contrary, relates to potentially large losses that occur rather seldom. According to this concept, capital would only be needed for absorbing Unexpected Losses.

[29] Set in Basel regulation equal to 45%.

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