Modelling the Loop between Bank and Sovereign Credit Risk

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Abstract

We propose a model that captures the link between bank and sovereign credit risk and is a flexible tool for evaluating policy options. In severe stress situations, in which banks realize large and unexpected losses, the government issues new debt to recapitalise banks to their minimum regulatory levels. The resulting increase in gross government debt raises sovereign risk and in turn generates further bank losses via their sovereign bond holdings (i.e. haircuts). Hence, an initial shock originating either in the banking or sovereign sector is amplified by the feed-back relation. We set up a framework based on actual bank balance sheets and test the model on 64 large EU banking groups, across 21 European countries, for which the EBA provides banks' exposure amounts to sovereign debt. The results of the analysis for some selected countries (DE, FR, NL, IE, IT, PT and SP) are the followings:

a) The model generates sizeable effects from the feedback loops, exacerbating the initial effects of the banking sector shock on the banking sector losses, sovereign debt risk premia and bond haircuts. The effects of the feedback loops in most cases more than doubles the effect of the initial shock. However, the effect of the loop is not explosive as gross debt stabilises in all countries below the default tresholds that are calibrated on end-2012 CDS premia.

b) The importance of the feedback loops 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. The feedback loops are relatively benign in France and Germany, and very important in Spain, Portugal and Ireland.

c) The model allows the assessment of a potential ESM intervention as an effective tool that dampens the effect of the bank-sovereign loop.

d) The model is easily extendable to include further feedback loops in particular through GDP growth.

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

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1. Introduction

The recent 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 (see Panetta, 2012). On the other, sovereign creditworthiness is crucially affected by the health of the banking sector. 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, such as bail-ins or safety nets (resolution fund, deposit guarantee scheme), to break this so called "vicious cycle" have been proposed in the financial supervision and macro-prudential regulation debate.

In this preliminary work we propose a basic stylised model that captures the link between bank and sovereign credit risk and is aimed at evaluating alternative policy options. In our setup, in severe stress situations, in which banks realise large and unexpected losses, the government issues new debt to recapitalise banks to their minimum regulatory levels. The increase in gross government debt raises sovereign risk and in turn generates further bank losses via government bond holdings (i.e. haircuts). Hence, an initial shock originated either in the banking or government sector is amplified by the feed-back relation. The model can easily be extended to include further feedback loops, in particular by adding effects of risk premia and reduced bank capital on investment and output.

The 2011 Mody-Sandri model is a main building block for our model. In the Mody-Sandri model, the government is assumed to default when the *debt-to-GDP ratio* approaches a certain threshold level. Sovereign credit risk is thus directly determined by the dynamics of both GDP and government debt. GDP in their model is determined, among other factors, by the amount of bank capital allowing provision of credit for investment in the economy. This model considers exclusively one direction of the risk transmission, namely the one from the banking sector to the government sector and is, therefore, useful to analyse situations in which banking crisis might cause sovereign debt crisis. In case of a banking crisis, the

government faces a tradeoff between increases in gross debt (due to bank recapitalisation) and a fall in GDP due to a reduction of banks capital, and hence investment.

In our characterization of the model the *debt-to-GDP ratio* is driven by the dynamics of *government debt outstanding*. This is endogenously determined in the sense that when banks face stress conditions and large unexpected losses the government issues new debt to inject capital to maintain banks to their minimum regulatory levels. Our main modelling contribution is to extend the Mody-Sandri 2011 framework so that sovereign risk shocks affect the health of banks through the channel of government bond holdings, i.e. the application haircuts. In this way we capture the circular nature of banking and sovereign sector credit risk. In the stylised model presented in this paper, we focus on the direct feedback loops through gross government debt, haircuts, bank capital and recapitalisations, disregarding the GDP growth channel.

In order to investigate some of the critical issues highlighted by the recent euro-area sovereign debt crisis we test our model using data for 64 large EU banking groups, across 21 European countries, for which the EBA provides sovereign debt holdings at the bank level. In our analysis, we focus on banks' balance sheet data and investigate the domestic link between bank and sovereign risk, but also cross-border spillover effects as banks are internationally exposed to sovereign debt. The analysis is based on data as of December 2012.

In a first exercise, we analyse the impact of a severe banking sector crisis on banking and sovereign sector credit risk. The focus is on feedback loop effects triggered by this initial shock. Bank unexpected losses in stress situations are generated by means of the *Systemic Model of Banking Originated Losses* model (SYMBOL) (see De Lisa et al. (2011)). SYMBOL generates the losses deriving from bank defaults on the basis of the Basel II FIRB (Foundation Internal Ratings Based) formula, which is commonly used to analyses banks' riskiness by regulators. The model simulates distribution probabilities of individual bank credit losses for each bank in a system. The loss distribution of each bank is calibrated to the credit risk implied by its regulatory capital requirement. In our exercise, we focus on bank losses

affecting public finances. We do not consider scenarios in which bond holders are bailed-in, or safety-nets (resolution fund, deposit guarantee scheme) cover part of the losess. Losses in excess of capital are financed by public finances. Public finances also provide for the recapitalization up to 4.5% RWA or 8% of RWA. 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 bank recapitalisations, such that any recapitalization leads to an increase in government debt. New government debt issuance, needed to recapitalize banks, to their minimum regulatory levels, increases sovereign risk and in turn generates further banks losses via government bond holdings (i.e. haircuts applied on government debt holding).

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.

Finally, we briefly discuss and analyse the role of potential ESM interventions in stabilizing the system.

2. The Model

2.1 Sovereign Credit Risk and the Banking Sector

Our starting point is the following stylized two-period model proposed in Mody-Sandri 2011. The government issues, in period 1, an amount of bonds *B1*, offering an expected rate of return *r*. Its ability to repay this debt, in period 2, depends on the *debt-to-GDP* ratio as given by $B_2 = \frac{B_1(1+r)}{Y_2}$. The government is assumed to default whenever B2 exceeds an exogenously predetermined threshold level $\bar{b}$. 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. The GDP is determined by: $Y_2 = A_1(1+g)K_1\varepsilon_2$ where *K1* is capital invested in the economy by the banking sector at time 1, *A1* 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 government (risk-neutral) probability of default is:

$$RNDef\ \Pr = \Pr ob\left[\frac{B_1(1+r)}{A_1(1+g)k_1\varepsilon_2}\right] \geq \bar{b} = \Pr ob\left[\frac{B_1(1+r)}{\bar{b}A_1(1+g)K_1} \geq \varepsilon_2\right]$$

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 $(1-RNDef\ \Pr ob)(1+r) + RNDefprob \bullet (1-LGD)(1+r) = (1+R_f)$ where LGD is loss in case of default (1-recovery rate). The banking sector determines the capital investment *K1*. Banks leverage their equity *E1* 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 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 tresholds can be affected by changes in global liquidity, risk aversion or country-specific risk shocks (e.g. political risks).

In the described Mody-Sandri 2011 model the dynamics of sovereign credit risk (i.e. the debt-to-GDP ratio) depends on both the level of government debt and the health of the banking sector via *GDP ("real economy" channel)*. The level of GDP is determined by the amount of K1, i.e. the banking capital that determines investment in the economy. The focus of the model is on the causality going from banks to sovereign credit risk.

We extend the model by introducing two additional features. First, we introduce a spillover mechanism that transmits the risk from the sovereign to the banking sector. In fact, higher sovereign spreads weakened the banking sector quite substantially during the recent 2010-2012 euro-area sovereign debt crisis. Among other things this is due to the fact that banks hold government securities which were typically marked-down when sovereign credit spreads raised generating unexpected losses, i.e. a reduction of bank capital.

Secondly, we develop and focus on the dynamics of *government debt outstanding* as driver of the *debt-to-GDP ratio*. It is endogenously determined in the sense that when banks face stress conditions and large unexpected losses the government issues new debt to inject new capital to maintain banks to their minimum regulatory levels. Hence, sovereign credit risk depends on the health of the banking sector because of the potential increase of *debt outstanding ("weakening of public finances"* channel).

This is how the circularity between bank and sovereign credit risk plays out in our setup. In severe stress situations when banks face large unexpected losses the government issues new debt in order to keep bank capital to minimum regulatory standards. As the government debt level rises, the likelihood that the debt-to-GDP ratio ($B_2 = \frac{B_1(1+r)}{Y_2}$) reaches its threshold default level increases and so does the credit spread on government bonds, hence the haircuts applied. The shock in the government sector transmits to the banking sector because banks realise unexpected losses when haircuts are applied to their sovereign bond holdings. Notice that, independently on whether the shock generates in the banking or in the sovereign sector a feedback loop between bank and sovereign credit risk is triggered. As sovereign credit risk increases, banks assets values deteriorate and so does their financial health and this in turn increases sovereign credit risk which drives banks further into distress.

Note that Galliani and Zedda (2013) analyse the effects on sovereign risk premia on four small European countries (BE, DK, GR, NL). They consider an initial banking sector shock that feeds into a government deficit (i.e. governments 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 part of it is recorded a financial transaction.[1] 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. Our focus for modelling the spill-over channel from bank to sovereign risk is through government debt instead of deficit. This overcomes these issues.

2.2 Simulation of Banking Sector Distress

We model the banking sector distress as a tail realisation (corresponding 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).[2] [3]

SYMBOL simulates the distribution of losses in excess of banks' capital within a banking system (usually a country) by aggregating individual banks' losses. 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.[4] 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.[5] The loss distribution of each bank is calibrated on

[1] 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.

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

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

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

[5] 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

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 an 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 frourth step in obtaining the distribution of aggregate losses at the country level.[6]

Details of the four steps are as follows:

- **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[7] 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, SYMBOL assumes 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

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.

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

[7] 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 SYMBOL is that all risk can be approximated as credit risk.

particular common influence of the business cycle[8]. 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.

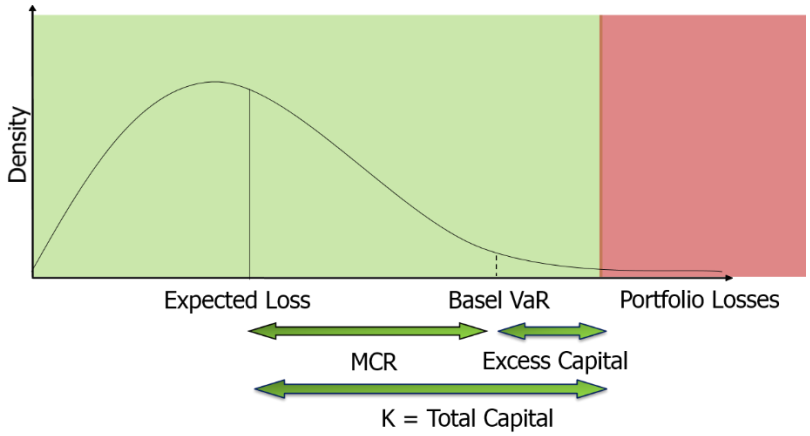
Given the matrix of correlated losses, SYMBOL determines which banks fail. As illustrated in Figure 1, a bank default happens when simulated obligor portfolio losses exceed the sum of the expected losses (EL) and the total actual capital (K) given by the sum of its MCR plus the bank's excess capital,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

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

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.

[8] 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.

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 oustanding debt, we consider the amount of funds necessary to recapitalize all banks to a 4.5% or an 8% level of RWA.

These two differente 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. [9]

2.3 Tests and other modelling issues

[9] 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

In the next section, as a first step, we conduct an exercise to 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. This effect is measured by evaluating the variation of the default probability, the increase in credit spread and haircut for some selected Euro area government and the banks losses on sovereign bond holding. The shock on the banking sector is at the European level (i.e. we run SYMBOL on the pool of 64 banking groups in the EBA sample). The capital injection to recapitalize banks is done by the domestic government. We analyses two cases, one in which the government has to recapitalize banks at the 8% regulatory capital level 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. Finally, losses on government holdings are attributed on the basis of the complete exposure matrix. Through this channel we account for international spillover effects.

As a second step we conduct an exercise in which the shock originates in the sovereign sector and we test how banks react when they are in stress conditions. 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. So, the capital to be considered in the SYMBOL model, for bank *i*, after the haircut is $CAP_i - HC_i$

The two analyses are based on banks information and on country specific macroeconomic variables as of December 2012.

The following points, of our exercise, should be considered when reading our results:

1. When we input losses on bond holdings (haircuts), the value of banks' government bond holdings are assumed to change on a mark-to-market basis. We base on the idea that the market evaluation of bank capital takes sovereign risk into account and we ignore that bonds might be held on the banking book;

2. We do not analyse recapitalisation needed after the complete feed-back loop has played out.

3. We ignore interest rate risk and we focus only on the credit risk component of government bond yields;

4. 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.

5. The SYMBOL model does not take into account the rating of the bank, eventual provisions or the possibility that banks can raise capital.

6. We take into account systemic effects as bank are exposed to different sovereigns, hence sovereign sector instability might spillover to cross-border banks. However, the exercise does not take into account possible systemic effects of contagion between banks via the interbank market or due to fire-sales and liquidity spirals;

7. Government bonds are all assumed to have a 10 year maturity.

Notice that, in our modelling setup sovereign credit risk affects banks only via the "asset value reduction" channel". We ignore that also bank funding conditions deteriorate if the value of bond holdings reduce ("collateral" channel) as a) funding by mean of collateral reduces, b) that guarantees provided by the government weaken ("government guarantees" channel) and that (c) the government rating act as ceiling for bank rating so that banks are downgraded too when the sovereign is. d) Higher sovereign credit spreads may, moreover, increase borrowing rates for banks and hence for corporations and households. 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.

3. The Data

The analysis is based on the following data:

- Sovereign debt exposures amounts of a sample of banks which participated in the 2012 European Banking Authority (EBA) capital exercise[10]. These data are taken from SNL Financial.

- Balance sheet data from Bankscope as of December 2012. In particular for the analysis of capital levels and for SYMBOL 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 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**. Data are as of December 2012. The table aggregates per country the data for the considered 64 EU 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					
Country	GDP	Government Debt Outstanding Amount	Debt to GDP Ratio	Sovereign CDS Level	Total Asset Banking Sector	Total as % GDP	Total as % of Total Assets	Domestic as % GDP	Domestic as % of Total Assets	Share of Domestic onTotal Holdings	Share of Exposure to the 7 Selected Countries
	Billions	Billions		Basis Points	Billions						
DE	€ 2.666	€ 2.161	81,0%	78	€ 8.435	26%	11,8%	14%	6,6%	55,95%	70,25%
FR	€ 2.032	€ 1.841	90,6%	139	€ 7.908	22%	6,5%	8%	2,2%	34,31%	58,88%
NL	€ 599	€ 427	71,3%	78	€ 2.528	38%	7,9%	15%	3,0%	38,06%	67,93%
IE	€ 164	€ 193	117,4%	250	€ 903	10%	6,3%	8%	5,2%	82,53%	92,72%
IT	€ 1.567	€ 1.990	127,0%	313	€ 4.247	14%	13,7%	10%	9,5%	69,09%	81,63%
PT	€ 165	€ 205	124,1%	471	€ 560	14%	11,3%	11%	8,7%	77,27%	84,45%
SP	€ 1.029	€ 885	86,0%	319	€ 3.587	31%	11,2%	18%	6,5%	58,34%	64,49%

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

[10] Greek banks were not included in the EBA exercise because already object of specific measures within the EU / IMF financial programme.

that banks' overall holdings of government debt in % on the GDP varies across countries, ranging from 10 to 38% (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, when we shock sovereign risk we do it at the world wide level, but when we study the banks sovereign feed-back we focus only on the seven selected countries (DE, FR, NL, IE, IT, PT and SP), as if banks were exposed only to these countries. The exposure of the banks located in the these selected countries with respect to the same countries ranges between 58 and 92 (column 12) %.

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

Table 2*:* **Banks' Sovereign Bond Holdings.** Data as of December 2012 and expressed in Euro. The table aggregates per country the data for the considered 64 EU banks consolidated in the country of the parent. The selected Euro area countries are Germany (DE), France (FR), Netherlands (NL), Ireland (IE), Italy (IT), Portugal (PT) and Spain (ES).

Country	FR	DE	IE	IT	NL	PT	SP
	Billions						
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

German banks have some exposure towards Italian and Spanish government debt (respectively 34 and 16 Billion Euro). French banks have some exposure towards German and Italian debt (respectively 42 and 38 Billion Euro). In any case, these are negligible with respect to the total amount of bond holdings. Dutch banks are largely exposed to German government bonds. Irish, Portuguese and Spanish banks are characterized only minor non-domestic exposures. This also holds for Italian banks with the exception of a 30 Billion exposure towards 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 by the domestic sovereign debt exposures.

4. Results of the Analysis

Our model allows a simulation of the allocation of bank losses across different stakeholders (equity-holders, bond-holders, public finances and safety nets) depending on the chosen regulatory context and scenarios for bank capitalization. In this exercise, we focus on bank losses affecting public finances. We do not consider scenarios in which bond holders 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. Public finances also provide for the recapitalization up to 4.5% RWA or 8% of RWA. 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.

The banking crisis 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. 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 3A and 3B show 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 extended version of the Mody-Sandri 2011 model. The reduced market valuation of banks sovereign bond holdings (both domestic and foreign)

results in further capital shortfalls[11] 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.

Table 3: 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 feed-back loop, of a shock originating in the banking sector on both banks and sovereign credit risk. The following information is reported: SYMBOL excess losses and the corresponding debt to GDP increments (relative to the its initial value), sovereign risk premium shifts, haircuts and losses on sovereign holdings. The table aggregates per country the data for the considered 64 EU banks consolidated in the country of the parent. In table A Public finances (i.e. 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

		Bank vs. Sovereign Feedback - First Order Effect				Bank vs. Sovereign Feedback - Total Effect			
Country	**Symbol - Excess Losses**	**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**
	Billions		Bps		Billions		Bps		Billions
DE	€ 44,803	1,7%	20	1,7%	€ 22,581	4,2%	55	6,6%	€ 68,168
FR	€ 78,921	3,9%	64	5,2%	€ 18,435	6,0%	105	10,5%	€ 43,100
NL	€ 22,661	3,8%	55	4,6%	€ 7,128	6,9%	119	11,5%	€ 18,492
IE	€ 12,929	7,9%	171	12,5%	€ 6,179	16,2%	391	27,7%	€ 13,667
IT	€ 70,271	4,5%	91	6,7%	€ 29,466	9,2%	206	16,9%	€ 73,907
PT	€ 13,085	7,9%	242	15,8%	€ 8,109	18,6%	556	33,6%	€ 17,556
SP	€ 70,400	6,8%	235	16,3%	€ 39,953	15,8%	605	37,4%	€ 92,413

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

		Bank vs. Sovereign Feedback - First Order Effect				Bank vs. Sovereign Feedback - Total Effect			
Country	**Symbol - Excess Losses**	**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**
	Billions		Bps		Billions		Bps		Billions
DE	€ 76,948	2,9%	35	3,0%	€ 38,996	6,7%	102	10,2%	€ 101,299
FR	€ 129,962	6,4%	115	9,1%	€ 32,897	9,8%	196	16,9%	€ 69,076
NL	€ 38,052	6,3%	110	9,0%	€ 13,571	11,6%	247	20,5%	€ 31,755
IE	€ 21,843	13,3%	313	21,3%	€ 10,578	26,1%	704	42,0%	€ 20,984
IT	€ 119,247	7,6%	164	11,6%	€ 50,974	14,6%	344	24,7%	€ 109,616
PT	€ 22,366	13,5%	395	24,0%	€ 12,453	27,8%	864	45,0%	€ 23,535
SP	€ 119,873	11,6%	434	27,6%	€ 67,404	24,0%	991	51,3%	€ 126,632

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 3A show that the model generates sizeable effects from the feedback

[11] 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 cathegories holdings have to be reported at the marked-to-market value. We belive market valuations of sovereign bonds reflect expectations about risks of sovereign default, about bank recap needs, including the sovereign feedback loops. Soveriegn and bank capital and bank funding conditions will reflect these market expectations about default risks and expected losses.

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 Euro. The effect of the loop is not explosive. Basically haircuts, CDS levels and debt to GDP ratios stabilise around some equilibrium value. 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 loops differ across countries. The main factors driving the dynamics are: the characteristics of the domestic banking sector[12], the initial debt to GDP ratio, the initial sovereign risk premium, and the banks holdings of domestic sovereign bonds. The feedback loops are relatively benign in France and Germany, and very important in Spain, Portugal and Ireland.

The effect of direct recap by the ESM can be gauged by looking at the differences between Tables 3A and B. ESM can directly recapitalize the banks if the bank has been recapitalized by the national authorities to at least 4.5% of RWA. If all capital in excess of 4.5% RWA is provided for by ESM direct recap, the sovereign feedback loop is significantly weakened. Take the case of the Netherlands: Taking the difference between the 4.5% RWA recap and the 8% RWA recap, 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

[12] In particular, the size of the banking sector to GDP, the riskiness of the assets (RWA to TA), and the capitalisation of the banks. These determine the size of the initial banking sector shock.

recap (in exchange for shares in the banks). As a result, the sovereign CDS is estimated to increase by 119 bps rather than 247 bps, lowering losses on sovereign holdings due to feedback loops by EUR 13.3 billion (from EUR 31.8 billion to EUR 18.5 billion). 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.

Table 4 shows the dynamics of the key variables over a number of loops. It shows that the effects level of significantly after the second loop. 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 relatively high risk premium on Spain compared to the initial debt level by end 2012.

Table 4: Banking Sector Shock and the Feed-back Loop. This table shows the feed-back 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

Table 1.2 and 1.3 in Annex 1 provide the results as in Table 3 and 4, but for a scenario in which the initial shock originates in the sovereign sector.

6. Final Remarks and Further Investigations

Next we plan to complete this preliminary work by: (a) analyzing the effect of various policy measures applied to weaken the bank vs. sovereign link: (bail-in, resolution fund and ESM), (b) modeling the banking sector risk spillover to the sovereign via the GDP ("real economy"); (c) implementing asymmetric sovereign risk shocks across countries to stress haircuts, (d) calibrating, estimating and running sensitivity test on the country parameters we use in our extended version of the Mody-Sandri 2011 model, (e) investigating whether the initial size of the shock, or the introduction of other feed-backs channels in the model make the dynamics explosive.

Other broader issues we plan to investigate are: (f) The effect of the banking sector deleveraging on capital provision to the real economy and (g) Whether the bank vs. sovereign CDS correlation is "in line" with banks' exposure to sovereign bonds.

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Annex 1: Further tables.

Table 1.1: List 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 feed-back 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

Table 1.2: 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 the 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 ricapitalisation up to 8% of RWA.

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

		Bank vs. Sovereign Feedback - First Order Effect				Bank vs. Sovereign Feedback - Total Effect			
Country	**Symbol - Excess Losses**	**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**
	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

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

Table 1.3: 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 world wide governments. In table A Public finances (domestic government) provide for the recapitalisation up to 4.5% RWA while in Table B for the ricapitalisation 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 2: 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[13] 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 PD_l is the default probability of exposure *l*, ϱ is the correlation among the exposures in the portfolio, *LGD* is the Loss Given Default[14] and M(PDi) a maturity adjustment

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

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

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

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

[13] 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.

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