European Commission

JRC SCIENCE FOR POLICY REPORT

Estimation of potential benefits of the implementation of the fundamental review of the trading book and leverage ratio

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2016

EUR 28269 EN

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JRC Science Hub
https://ec.europa.eu/jrc

JRC103768

EUR 28269 EN

PDF ISBN 978-92-79-64119-0 ISSN 1831-9424 doi:10.2791/988150

Luxembourg: Publications Office of the European Union, 2016

How to cite: Author(s); Title; EUR; doi

Title Estimation of potential benefits of the implementation of the fundamental review of the trading book and of Leverage Ratio

Abstract
This report assesses the potential benefit for public finances of the fundamental review of the trading book, as agreed in the Basel Committee on Banking Supervision. The new legislation proposal may be able to reduce the amount of potential public financial support for the banking system from 11% up to 48%.

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Executive summary

The Fundamental Review of the Trading Book (FRTB) introduces changes in capital requirements as a consequence of changes in the calculation of risk weighted assets (RWAs), as agreed in the Basel Committee on Banking Supervision. This report performs an ex-ante assessment of the potential benefits of this new legislative proposal and is included as an annex to the Impact Assessment of the Capital Requirement Regulation II (CRR II) which was published on 23 November 2016.

The analysis is conducted by estimating the required variation in banks' capital following the implementation of the legislative changes by using econometric and statistical techniques. The estimated capital requirements are then used to feed a simulation model of losses originating from the banking sector in the event of a banking crisis.

Results of the crisis simulation before and after the introduction of the legislative changes are compared to arrive at an estimation of the impacts. Benefits are measured as reduction in banks' losses that need to be absorbed by different stakeholders, starting from shareholders and including the whole loss absorption cascade and financial safety net (i.e. bail-in and resolution funds).

The main conclusions are:

1. If one ignores the leverage ratio (LR) requirement and only focusses on the impact of the FRTB, results are the following:

    a. When assuming banks' capital equal to the minimum capital requirement (MCR), the implementation of the FRTB implies higher capitalization levels/needs due to higher RWAs. The estimated reduction in potential public finance contingent liabilities from the banking sector in case of a crisis similar to the last one is of 15%.

    b. However, when considering the excess capital buffers which the vast majority of banks have set aside over the last few years, the implementation of the FRTB does not imply additional capital needs to meet the increased requirements and does not reduce potential contingent liabilities from the banking sector compared to the status quo. In fact, if buffers are not increased, contingent financial liabilities would increase, owing to increased recapitalization needs following the increase in RWAs.

2. Irrespective of whether RWAs are computed following the current regulation or under the FRTB, capitalization levels/needs tend to be higher under an LR requirement. Moreover, for all banks for which the LR requirement would be binding, recapitalization needs would increase in case of crisis in case no additional buffers on top of the minimum LR requirement would be held. However, if we assume that banks will hold additional "conservation" buffer on top of the LR, the amount of potential contingent liabilities can be reduced up 48% with the implementation of the FRTB.

1 Introduction

This report is an ex-ante assessment of the potential effects of the implementation of the Fundamental Review of the Trading Book (FRTB, henceforth), which is intended to strengthen capital requirements for market risks, and the introduction of a binding leverage ratio, as envisaged by the Capital Requirement Regulation II (CRR II) proposal adopted by the Commission on 23 November 2016. The content of this report has been included as an annex to the Impact Assessment of the CRR II proposal.

The analysis is conducted in two main steps: i) first, we estimate the variation in banks' capital requirements following the implementation of the legislative changes; ii) in a second step, we use the estimated capital requirements to feed a simulation model of losses originating from the banking sector in the event of a banking crisis.

In particular, the estimated capital requirements under the FRTB are derived as follows:

(1) The average risk-weights for trading activities and non-trading activities are estimated via a panel regression methodology, which has been already used for the Impact Assessment of bank structural separation.
(2) The impact of the FRTB on risk-weighted assets (RWAs) is estimated based on expected changes to risk-weights. In this respect, the median impact estimated by the European Banking Authority (EBA) is used as a reference.

RWAs estimated as per points 1 and 2, and hence the new capital levels implied by the 8% of RWAs requirement, are then used as inputs to run simulations. In this step of the analysis, we simulate crisis scenarios via the Systemic Model of Banking Originated Losses (SYMBOL).[1] This model is based on bank level data and able to simulate crisis scenarios where banks fail, depending on their level of capital and risk weighted assets, as well as on the severity of the negative shock.

The impact of the FRTB is measured in relation to the aggregate banks' losses (including recapitalization needs) resulting from the various SYMBOL simulations, compared to the losses that would be resulting under the status quo. In particular, we assess the impact of the FRTB by following two approaches, i.e.: i) ignoring the concurrent leverage ratio (LR) requirement and, ii) considering it as potentially binding.

The resulting losses and recapitalization needs are covered by different stakeholders, starting from shareholders and including the whole loss absorption cascade and financial safety net (i.e. bail-in and resolution fund). It is assumed that what is not covered by regulatory capital, bail-inable liabilities and the resolution fund intervention would ultimately remain as a potential contingent liability for public finances.

[1] See R. De Lisa, S. Zedda, F. Vallascas, F. Campolongo, M. Marchesi; "Modelling Deposit Insurance Scheme Losses in a Basel 2 Framework"; Journal of Financial Services Research; December 2011, Volume 40, Issue 3, pp 123-141. First Online November 2010. Please note that at the time of submission the acronym SYMBOL was not yet employed.

2 Dataset

This section describes the dataset and the methodology we apply in order to estimate RWAs at the individual bank level. Data on banks' balance sheets are collected from the SNL database. The dataset contains yearly data on a consolidated basis from 2006 to 2014, hence covering the global financial crisis from 2008 and the European sovereign debt crisis in 2010. The original dataset is unbalanced, i.e. there are some missing observations for some banks/years. The final dataset, which we use to estimate the model in the following section and for the simulations in Section **Error! Reference source not found.**, comprises 186 institutions located in the EU28 and covers 83% of EU banks' total assets (TAs). The figures used for the simulations are as of 2014.

Market RWAs, affected by the FRTB, are not available as hard data. Hence, they need to be estimated. In order to do so, we focus on 9 categories of assets and liabilities, reported in Table 1. The procedure followed for the estimation is illustrated in the next section.

TABLE 1: : List of assets and liabilities used to estimate RWAs

Short name	Description
LB	Net loans to banks
NCL	Net loans to customers
AMZ	Total assets held at amortized cost excluding loans to banks and customers held at amortized cost
HTM	Securities held to maturity
AFS	Available for sale assets excluding loans
FVFV	Assets held at fair value excluding loans
TSA + TSL	Securities held for trading excl. derivatives (volume in assets and liabilities side)
DA+DL	Derivatives held for trading (volume in assets and liabilities side)
DHV	Derivatives held for hedging purposes (volume in assets and liabilities side)

3 Panel analysis to estimate risk weighted assets for trading activities and non-trading activities

This section describes the methodology we apply in order to estimate RWAs for trading activites.

3.1 Estimation procedure

In order to estimate how individual banks' RWAs would change with the introduction of the FRTB, we need first to estimate the current level of trading assets RWAs.

In order to do so, we run a regression analysis based on the balance sheet categories listed in Table 1 to obtain an average risk weights for all the major assets categories held by a bank. Once an average risk weight has been obtained for each category, we use the average risk weights for the activities that would be affected by the review (i.e. trading activities) to estimate RWAs for them before the reform. These pre-reform estimated RWAs are then modified and the pre-reform and post-reform balance sheets are used to run simulations of losses in the banking sector under different scenarios.

In particular, we implement the following panel fixed-effect model for overall RWAs:

$$\begin{aligned} RWA_{i,t} = \alpha_i + \beta_1 LB_{i,t} + \beta_2 NCL_{i,t} + \beta_3 AMZ_{i,t} + \beta_4 HTM_{i,t} + \beta_5 AFS_{i,t} + \beta_6\, FV_{i,t} \\ + \beta_7\, 0.5\left(TSA_{i,t} + TSL_{i,t}\right) + \beta_8\, 0.5\left(TSA_{i,t} + TSL_{i,t}\right) d_t^{B3} + \beta_9\, 0.5\left(DA_{i,t} + DL_{i,t}\right) \\ + \beta_{10}\, 0.5\left(DA_{i,t} + DL_{i,t}\right) d_t^{B3} + \beta_{11} DHV_{i,t} + \sum_{j=1}^{8} \gamma_j d_{t,j}^{year} + u_{i,t}, \end{aligned} \tag{1}$$

where $\mathrm{d}_\mathrm{t}^{\mathrm{B3}}$ is the dummy variable that represents the entry into force of Basel 3, i.e. admits value 1 in 2014, and $d_{t,j}^{year}$ are dummy variables for time-fixed effects. Standard errors are built through a robust clustered variance estimator.

3.2 Empirical results

Table 2 reports the estimated coefficients of Equation (1) from the panel regression. The coefficients for net loans to banks and customers, and the TAs held at amortized cost are positive and statistically significant (i.e., p-values, in brackets, are smaller than 1%). The estimated coefficients $\hat{\beta}_4$ and $\hat{\beta}_6$ for securities held to maturity and for assets held at a fair value are positive but not significantly different from zero at the 10% level. The same is true for the coefficient for the volume of trading assets. As expected, the coefficient on available for sale assets is positive. The coefficient attached to the volume of derivatives for trading is always positive and significant. Finally, the coefficient for derivatives held for hedging indicates a negative relation of this category w.r.t. the RWAs. As for the dummies $d_{t,j}^{year}$, with $j = 1, \dots, 8$, the estimated coefficients $\hat{\gamma}_j$ (not shown) are all statistically significant at the 10% level.

Table 2 also reports a very high R-squared. This extremely good regression fit is explained by the fact that the dependent variable, RWAs, is itself derived from balance sheet posts, including the ones on the right-hand-side of the regression.

Table 2: Coefficients from the panel regression, p-values are reported in parentheses and *, **, *** denote significance at 10, 5 and 1 percent level, respectively. Moreover, + denote significance at 20 percent.

	Eq. (1)
LB	0.3372*** (0.001)
NCL	0.4410*** (0.000)
AMZ	0.5023*** (0.000)
HTM	0.4656 (0.355)
AFS	0.1650* (0.084)
FV	0.1422^{+} (0.113)
0.5 * (TSA + TSL)	0.1365^{+} (0.161)
0.5 * (TSA + TSL) * d^{B3}	0.0350 (0.684)
0.5 * (DA + DL)	0.0669*** (0.001)
0.5 * (DA + DL) * d^{B3}	0.1184*** (0.005)
DHV	-1.291*** (0.000)
Number of observations	1.466
R-squared:	
within	0.6762
between	0.9590
overall	0.9490

In fact, based on the estimation results described above, in what follows we consider the following more parsimonious model:

$$RWA_{i,t} = \alpha_i + \beta_1 LB_{i,t} + \beta_2 NCL_{i,t} + \beta_3 AMZ_{i,t} + \beta_5 AFS_{i,t} + \beta_6\, FV_{i,t} + \beta_7\, 0.5\left(TSA_{i,t} + TSL_{i,t}\right) + \beta_9\, 0.5\left(DA_{i,t} + DL_{i,t}\right) + \beta_{10}\, 0.5\left(DA_{i,t} + DL_{i,t}\right) d_t^{B3} + \beta_{11} DHV_{i,t} + \sum_{j=1}^{8} \gamma_j d_{t,j}^{year} + u_{i,t}. \quad (2)$$

where variables in Model (1) whose coefficients are not significantly different from zero (at the 20% level) are dropped. The estimation results from regressions (2) and (1) are very similar.

Finally, we separately estimate trading activities RWAs and non-trading activities RWAs (see Table 3). RWAs for each type of activity are predicted according to the relevant coefficients estimated in the econometric model. Predicted trading and non-trading RWAs are calculated for each bank and are then re-normalised to sum up to the total RWAs as reported in the balance sheet.

TABLE 3: Allocation of assets and liabilities categories to trading and non-trading activities

Short name	Category	Approach for RWA allocation
LB	Net loans to banks	non-trading
NCL	Net loans to customers	non-trading
AMZ	Total assets held at amortized cost excl. loans to banks and customers held at amortized cost	non-trading
HTM	Securities held to maturity	non-trading
AFS	Available for sale assets excluding loans	non-trading
FV	Assets held at fair value excl. loans	non-trading
TSA + TSL	Securities held for trading excl. derivatives (assets & liabilities)	**trading**
DA+DL	Derivatives held for trading (assets & liabilities)	**trading**
DHV	Derivatives held for hedging purposes (assets & liabilities)	*Proportional allocation*

3.3 Estimated RWAs

Fig 1 - Fig 3 describe the characteristics of the distribution of trading RWAs estimated in the previous step. The scatterplot in Fig 1 shows a positive relationship between the size of trading assets and trading RWAs, as expected. The share of trading RWAs ranges from 0 to 15% of total RWAs for most of the banks in the sample over the 2006-2014 time span, while it is above 20% only in a few cases.

Fig 2 shows the distribution of the share of trading RWAs focussing on 2014. This distribution is very skewed: most of the banks in the sample have a share of trading RWAs below 5%, while only few outliers present a share of trading RWAs that spans from 10% to 35%.

Fig 3 investigates the share of RWAs over total RWAs by institution size. Banks are grouped by the size of their TAs into small (92 banks, with TAs below €30 bn), medium (76 banks, with TAs between €30 and €500 bn) and large banks (18 banks, with TAs above €500 bn). The share of trading RWAs is below 5% for the vast majority of small and medium size banks, while large banks are the most involved in trading activities. The share of trading RWAs is in general quite steady over time, with the exception of 2014 when it substantially increases, especially for the larger banks in the sample. This is due to the larger coefficient for some trading activites estimated for 2014 compared to the previous years. It should be noted that this result is robust to alternative model specifications.

These results are in line with the composition of RWAs reported by the EBA in the "CRD IV–CRR/Basel III monitoring exercise report" (see European Banking Authority (2015)). In the EBA approach, total RWAs are split into 5 components: credit risk (attributable to non-trading activities), credit value adjustment (for trading activities), market risk (for trading activities), operational risk (that can be proportionally attributed to trading and non-trading activities) and other RWAs. In 2014 the sum of market risk, credit value adjustment and the share of operational risk is around 10% for the largest, internationally active banks and roughly 4% for smaller banks. These figures, which represent averages for the sample considered by EBA, are consistent with the average share of trading RWAs as estimated by our model for the large banks (13%) and for medium/small banks (around 3%).

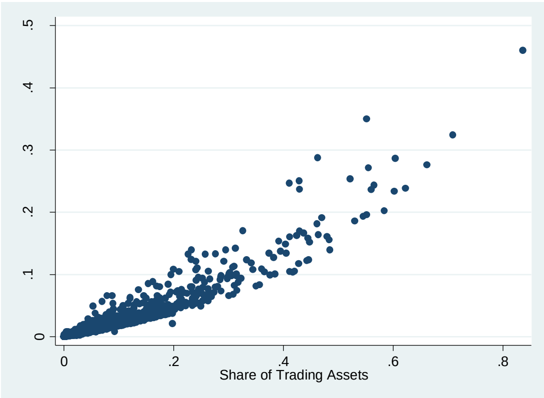

Fig 1: Scatter plot of estimated share of trading assets and estimated share of trading risk weights (2006-2014).

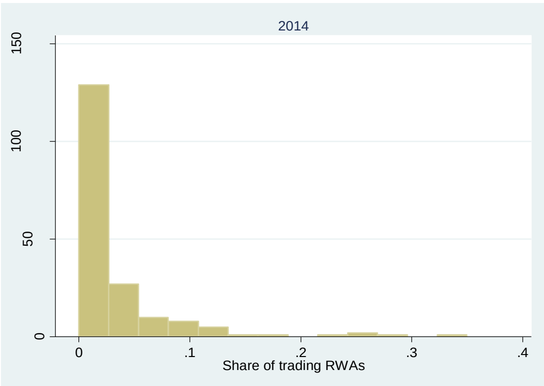

Fig 2: Histogram of the share of trading RWAs in 2014.

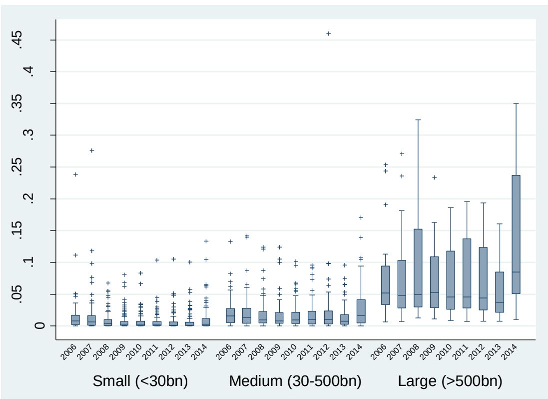

Fig 3: Box plots of share of trading RWAs, with institutions grouped by size. One box-plot for each year from 2006 to 2014.

4 Pre and post FRTB RWAs

In this section, we illustrate how we adjust the estimated RWAs in order to obtain a projection of how figures would look like under the full implementation of Capital Requirement Directive IV (CRDIV) – CRR requirements. We apply correction factors to RWAs and Total capital, which are sourced from the EBA's "CRD IV–CRR/Basel III monitoring exercise report" (see European Banking Authority (2015)). The application of correction factors results in an overall reduction in the level of effective capital and a slight increase in RWAs under full implementation of CRDIV in its current form, as shown in Table 4. These figures are used in the simulation analysis in the baseline scenario, representing the 'status quo' before introduction of the FRTB.

Table 4: Changes in total capital and RWA relative to the current amounts under full CRDIV-CRR implementation.

		Total Capital	**RWA**
Group 1 banks		-12.8%	0.1%
	G-SIBs	-13.3%	0.0%
Group 2 banks		-7.0%	0.9%
	Large banks	-7.1%	1.3%
	Medium banks	-7.2%	0.6%
	Small bank	-6.1%	0.0%

Source: EBA.

Finally, we derive RWAs under FRTB based on the BCBS estimation of the FRTB impact. In particular, we refer to the median impact estimated by the BCBS, which corresponds to a 27% increase of market risk RWAs (see BCBS, 2016).

5 Financing needs and potential contingent liabilities for public finances

The analysis presented in this section estimates the potential benefits for public finances of implementing the new rules established by the FRTB. Benefits for public finances are measured as a decrease in the potential contingent liabilities due to bank defaults and recapitalization needs that would remain uncovered by the available tools, i.e. the safety-net setup in the EU legislation, thus potentially hitting public finances.

Banking losses are simulated using the SYMBOL model (Systemic Model of Banking Originated Losses, see Annex 2). SYMBOL simulates losses for individual banks using information from their balance sheets. We assume that a bank goes into insolvency when simulated losses are larger than the available level of capital. Recapitalization needs are defined as the amount necessary to allow under-capitalized banks to continue operating, i.e. the gap with respect to the minimum capitalization under which a bank can be considered viable. We refer to losses in excess of capital plus recapitalization needs as *financing needs* hereafter.

Before contingent liabilities from the banking sector could be passed on to public finances, the financial safety-net is first called upon covering banks excess losses and recapitalization needs. In particular, we assume that this safety-net includes the bail-in tool and the Resolution Fund (RF). The improved standards on minimum capital requirements and capital conservation buffer set up in the CRR/CRD IV package are also taken into account in the simulation exercise. First, undercapitalized banks make use of their bail-in-able liabilities. Since data on the actual amount of bail-in-able liabilities held by banks are not available, we assume that each bank has a total loss absorbing capacity equal to twice the minimum capital requirement. Should bail-in not be enough to cover recapitalization needs, the RF intervenes. We assume that the RF has at its disposal a target fund equal to 1% of the amount of covered deposits of banks in the sample. Moreover, the RF can cover financing needs up to a ceiling equal to 5% of each bank's TAs. The remaining financing needs are finally remaining as potential contingent liabilities for public finances. It should be noted that this does not imply any form of obligation on behalf of public finances, but is simply an assessment of the potential risk due to the presence of financing needs that cannot be covered by capital and the existing safety net.[2]

5.1 Scenarios

The analysis is structured around four scenarios, which differ with respect to the level of capital that is assumed to be held by banks before the crisis, and the level of capital at which a bank undergoing recovery or resolution is assumed to be left as a viable institution. The scenarios are as follows: a case where the FRTB and LR requirement are not in place (baseline), the implementation of the FRTB (scenario A), and a final situation where both FRTB and LR requirements are in force (scenarios B and C) (see also Table 5).

1. **Baseline**: the FRTB is not implemented and the LR requirement is ignored

This scenario represents the 'status quo'. The LR requirement is ignored at this stage in order to focus on the effects of the implementation of the FRTB only, which correspond to Scenario A, and avoid the distortions that might be due to the concurrent LR requirement.

As for the initial capital, we consider the following two options:

[2] The same approach has been used in other publications (see e.g. European Commission, 2012 and 2014a or Benczur at al., 2015).

a) All banks hold no more than the minimum capital requirement (MCR) plus the capital conservation buffer (CCB), as per CRR/CRD IV (i.e. 10.5% of RWAs under a fully implemented Basel 3 environment).

b) Each bank holds capital as per 2014 figures.[3]

As for the recapitalisation needs, the viability requirement is set at 8% of RWAs.

2. Scenario A: The FRTB is in place and the LR requirement is ignored.

This scenario is developed to identify the effects of the implementation of the FRTB only, compared to the status quo, hence the LR is not considered. The two sub-scenarios are analogous to those in the baseline. The only difference between the baseline scenario and Scenario A stands in the level of RWAs used to estimate the MCR and the recapitalisations needs, which is larger in Scenario A owing to the FRTB.

3. Scenario B: The FRTB is in force and the LR requirement is considered

In this scenario, RWAs are computed as per FRTB, and the LR requirement is also taken into account. The LR requirement implies that the amount of capital held by a bank needs to be at least equal to 3% of TAs.[4] Hence, with respect to the initial capital amount we have the following two options:

a) All banks hold no more than the required amount of capital. This is given by the larger between: i) the minimum capital requirement (MCR) plus the capital conservation buffer (CCB), as per CRR/CRD IV (i.e. 10.5% of RWAs under a fully implemented Basel 3 environment), and ii) the LR requirement (i.e. 3% of TAs).

b) Each bank holds capital as per 2014 figures.

At the same time, the LR plays a role in defining recapitalization needs. Indeed, once the LR is considered, recapitalization needs are defined as the largest amount between 8% of RWAs and 3% of TAs. It should be noticed that, while the recapitalization requirement based on RWAs allows banks to recapitalize to a level which is below the pre-crisis capitalization, the recapitalization requirement based on the LR forces banks to fully replenish the capitalization gap.

4. Scenario C: This scenario is analogous to Scenario B, with the following difference. In Scenario C, banks are assumed to hold more capital before the crisis compared to Scenario B, in those cases where the LR is binding. In particular, we assume that banks hold an extra capital buffer on top of 3% TAs, which brings the total regulatory capital equal to at least 4% of TAs. By doing so, we create a scenario where banks can more easily meet the recapitalization requirement based on the LR. Thus, this scenario is comparable to Scenario A, where banks are requested to meet a lower recapitalization level compared to the pre-crisis situation. The size of the capital buffer is set equal to 1% of TAs, which is proportional to the 2.5% CCB in Scenario A.

TABLE 5: Scenarios.

Scenario		**Total regulatory capital**		**Recapitalization levels**
Baseline	**a**	No buffers	10.5% $RWA^{no\ FRTB}$	8% $RWA^{no\ FRTB}$
	b	Top up	Max{K, 10.5% $RWA^{no\ FRTB}$ }	

[3] For 15 banks, after taking account the remaining corrections to effective capital and RWA due to the full implementation of CRDIV, the amount of capital in 2014 is below 10.5% of RWAs. In these cases, it is assumed that these banks hold regulatory capital equal to 10.5% of RWAs.

[4] The policy refers to Tier 1 capital. However, the current version of the SYMBOL model is not able to keep track separately of T1 and T2 capital. The requirement is thus considered with respect to Total Regulatory Capital, leading to a slight under-estimation of the increase in capital needs.

Scenario		Total regulatory capital		Recapitalization levels
Scenario A	**a**	No buffers	10.5%·RWA^{FRTB}	8% RWA^{FRTB}
	b	Top up	Max{K, 10.5% RWA^{FRTB} }	
Scenario B	**a**	No buffers	Max{10.5%·RWA^{FRTB}, 3%TA}	Max(8% RWA^{FRTB}, 3%TA)
	b	Top up	Max{K, 10.5%·RWA^{FRTB}, 3%TA}	
Scenario C	**a**	No buffers	Max{10.5%·RWA^{FRTB}, 4%TA}	Max(8% RWA^{FRTB}, 3%TA)
	b	Top up	Max{K, 10.5%·RWA^{FRTB}, 4%TA}	

5.2 Results

For each of the four scenarios described above, we simulate 100000 banking crisis situations. A banking crisis is defined as a simulation where at least one bank fails.

Table 6 summarizes the potential public contingent liabilities under each of the scenarios described above, across simulations spanning from the less severe to the most severe crisis, while Tables 7 and 8 focus on a crisis of a magnitude similar to the one occurred in 2008.[5] The tables also offer a breakdown of financial needs coverage for different parts of the financial safety net, starting from excess losses (i.e. what is left over after capital is depleted), then indicating what still needs to be covered after bail-in, and finally what remains as potential contingent liabilities for public finances after intervention of the RF.

Across all crisis situtations, under the choice of not including any extra-capital buffer (Option a), Scenarios A and C outperform the Baseline, implying that the FRTB has a positive impact in reducing the amount of public support to the banking system in a situation where no voluntary additional capital buffers are being held on top of the minimum required CCB. Between the two scenarios A and C, scenario C is possibly more realistic, as it takes into account the LR on top of the FRTB, and the fact that an additional buffer on top of the binding LR requirement could be held to avoid that minimal losses push the banks into an infraction situation. It is precisely in this scenario that the benefits of the FRTB are the largest in terms of public financies, with a reduction of potential public contingent liabilities between roughyl 30% and 50% compared to the baseline scenario, corresponding to a reduction of up to 22bn in the most severe crisis scenario.

Scenario B points to a different direction. The reason for this stands in the fact that under this scenario, recapitalization requirements are far more demanding than in the baseline, owing to the LR recapitalization requirement set at 3% of TAs, which is exactly the same level at which capital is set for all banks which have a binding LR. Indeed, while the recapitalisation level is in fact set below the initial MCR in terms of RWAs (i.e. banks enter into the crisis with a capital buffer, the CCB, above the minimum viability threshold), the recapitalization level in terms of LR is set at the same level as the pre-crisis required capital for all banks for which the LR is binding. As a consequence, any bank for which the 3% LR is a binding capital requirement (i.e. 3% of TAs is larger than

[5] The distribution of financing needs is flat up to percentile 98. Percentiles beyond 99.99 are not reported due to small sample sizes in the extreme tail. In order to provide a term of comparison we also identify a percentile where total financing needs are comparable to those of the last financial crisis of 2008. To this end we use data on state aid to the financial sector during the crisis: the total amount of recapitalization measures in the period 2008–2012 was 428 bn (European Commission, 2014b). A total of roughly 180 bn was also provided to the financial sector via asset relief. These figures lead to an estimate of total financing needs of up to 600 billion. A simulated figure compatible with the above is observed around the 99.95th percentile of the distribution of financing needs. Detailed results, for crises of different degrees of severity, are available in Annex 3.

10.5% of RWAs) will need to be recapitalized up to the full pre-crisis capital level. This calls for more resources with respect to the situation where the capital requirement is based on RWAs, as the CCB can be used to absorb losses but is not assumed to need to be reconstituted.

When banks are assumed to start from a capitalization level in excess of the required minimum (Option b), the benefits of the FRTB in terms of potential public support are comparatively marginal. Indeed, when we assume that banks start from capitalization levels above the required minimum, the introduction of the FRTB increases recapitalization needs (by increasing RWAs, which determine the MCR), while for most banks it does not increase starting capitalization levels due to the presence of the voluntary buffers. This, in turn, increases the amount of resources needed to bring back troubled banks to a viability status. At the same time, our results indicate that in general, banks have already set aside enough capital to face the increases in capital requirements, including recapitalization needs, implied by the FRTB. Hence, the introduction of the FRTB, while not dramatically decreasing potential public finance support in case of a banking crisis, would also place no additional burden on banks.

TABLE 6: Range of the distribution of financing needs FN (i.e. resources needed due to bank defaults and recapitalization needs) for different parts of the financial safety net, from a less severe crisis to a most severe crisis (corresponding to percentiles of the distribution of aggregate bank losses from 99 to 99.99[6]), for all scenarios.

		Option a)		Option b)	
		Share of GDP	**Billion €**	**Share of GDP**	**Billion €**
Baseline	**FN net of capital**	0.34% - 4.27%	46.65 – 586.12	0.10% - 2.64%	13.51 – 362.40
	FN after bail-in	0.01% - 0.88%	1.52 – 120.76	0.00% - 0.39%	0.31 – 53.30
	Contingent liabilities after RF	0.00% - 0.34%	0.03 – 46.29	0.00% - 0.09%	0.01 – 12.12
Scenario A	**FN net of capital**	0.33% - 4.23%	45.21 – 579.72	0.11% - 2.74%	14.69 – 375.58
	FN after bail-in	0.01% - 0.82%	1.47 – 113.13	0.00% - 0.40%	0.31 – 55.52
	Contingent liabilities after RF	0.00% - 0.29%	0.03- 40.38	0.00% - 0.09%	0.01 – 12.89
Scenario B	**FN net of capital**	0.60% - 4.93%	82.76 – 676.47	0.18% - 3.19%	24.41 – 437.64
	FN after bail-in	0.01% - 0.92%	1.62 – 126.66	0.00% - 0.47%	0.39 – 64.34
	Contingent liabilities after RF	0.00% - 0.37%	0.03 – 51.10	0.08% - 0.12%	0.01 – 15.87
Scenario C	**FN net of capital**	0.28% - .3.95%	38.32 – 541.81	0.13% - 2.97%	17.36 – 407.93
	FN after bail-in	0.01% - 0.64%	0.90 – 87.14	0.00% - 0.39%	0.34 -54.10
	Contingent liabilities after RF	0.00% - 0.18%	0.02 – 24.66	0.00% - 0.09%	0.01 - 11.75

Table 7 and Table 8 summarize the contribution of the various safety net tools in reducing the impact for public finances, across the various scenarios and in comparison to the baseline. These results are based on a representative crisis simulation of a comparable severity to the global financial crisis started in 2008, in terms of banking sector losses and recapitalization needs.[7]

The first row corresponds to a situation where only capital absorbs losses. Under option a) (Table 7) capital is equal to the MCR. Scenario C yields the highest reduction in financial needs (9%) under option a). When including 'top up capital' (option b), Table 8), the starting level of capital includes excess capital held on top of minimum requirements. In this case in each regulatory scenario implementing the FRTB, the

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[6] the part of the distribution beyond the 99.99th percentile is not reported due to insufficient sample size in the extreme tail.

[7] Such a crisis is located approximately at the 99.95th percentile of the aggregate loss distribution yield by all SYMBOL simulations.

amount of excess losses plus recapitalization needs increase with respect to the Baseline. The increase is equal to 4%, 25%, and 14% under Scenario A, Scenario B, and Scenario C, respectively.

The second row in the tables reports results after bail-in. Scenario C provides the highest financial needs reduction compared to the baseline. The variation is equal to –32% and 0% under options a) and b), respectively.

Also after the intervention of the RF (third row in the tables), Scenario C yields the largest reduction in financial needs. The reduction is equal to 48% and 11% under options a) and b), respectively. Therefore the implementation of the FRTB reduces potential public finance contingent liabilities towards the banking sector up to 48% under this scenario, for a crisis of a comparable magnitude to the global financial crisis.

Table 7: Variation in financial needs for a crisis similar to the 2008 one (percentile 99.95) when moving between scenarios, option a.

	Baseline to Scenario A	**Baseline to Scenario B**	**Baseline to Scenario C**	**Scenario A to Scenario B**	**Scenario A to Scenario C**	**Scenario B to Scenario C**
Financial needs after capital	-1%	+22%	-9%	+24%	-8%	-25%
Financial needs after bail-in	-8%	+6%	-32%	+15%	-26%	-36%
Public support after RF	-15%	+13%	-48%	+33%	-39%	-54%

Table 8: Variation in financial needs for a crisis similar to the 2008 one (percentile 99.95) when moving between scenarios, option b.

	Baseline to Scenario A	**Baseline to Scenario B**	**Baseline to Scenario C**	**Scenario A to Scenario B**	**Scenario A to Scenario C**	**Scenario B to Scenario C**
Financial needs after capital	+4%	+25%	+14%	+20%	+9%	-9%
Financial needs after bail-in	+6%	+30%	-0%	+23%	-6%	-23%
Public support after RF	+10%	+56%	-11%	+42%	-19%	-43%

Finally, Table 9 focuses on option a) and reports the amount of financing needs split into losses and recapitalisation needs, as well as the amount absorbed by capital, bail-in-able liabilities, and the RF. From this table, it is possible to clearly see how recapitalization needs increase when the LR is introduced under the assumption that banks will not hold an additional buffer for leverage, while they decrease once potential buffers for leverage are considered. Moreover, it is possible to see how under scenarios A and C, the share of financial needs which needs to be absorbed by all tool will decrease.

Table 9: Initial financing needs and absorbed by the safety-net tools for a crisis similar to the 2008 one (percentile 99.95), option (a), billion Euro.

	Baseline	Scenario A	Scenario B	Scenario C
Financing needs = Losses + Recap needs (FN = L+R)	862	862	945	851
of which: Losses (L)	*595*	*595*	*595*	*595*
of which: Recap (R)	*267*	*267*	*350*	*255*
FN absorbed by Capital	516	521	523	536
FN absorbed by bail-in-able liabilities	296	295	368	280
FN absorbed by RF	45	42	47	31
Contingent liabilities after RF	5	5	6	3

6 Conclusion

The FRTB is aimed at introducing changes in capital and RWAs agreed in the Basel Committee on Banking Supervision. This report performs an ex-ante assessment of the potential benefits of this new legislative proposal and of the proposal for a binding requirement on the leverage ratio.

The analysis makes use of an econometric model to estimate the share of trading activities held by each bank. Based on this estimate, we compute the projected increase in the amount of RWAs implied by the FRTB and hence, and the new minimum capital requirement.

These estimated amounts are used to feed a simulation model of losses originating from the banking sector, i.e. SYMBOL. SYMBOL produces banking crisis simulations based on which we compute the amount of aggregate banks' losses. After taking into account bail-in and the intervention of the RF, we compute the amount of residual financing needs for the banking sector that may remain as a contingent liability potentially hitting public finances. Such calculations are implemented under various pre- and post-FRTB scenarios.

Based on the results, and considering a crisis of a comparable magnitude to the last global financial crisis, the main conclusions are the following:

(1) When assuming that banks hold no capital in excess of their MCR, the implementation of the FRTB alone reduces contingent liabilities from the banking sector by 15% (Scenario A, option a)

(2) When considering the excess capital that banks have set aside in their balance sheet, the implementation of the FRTB does not ultimately lead to a significant reduction in potential public financial support. Indeed, banks are already relatively well capitalised, hence the effect of the new legislative proposal would be to impose a higher recapitalisation requirement, while potentially not inducing further increases in the starting capitalization level. This, in turn, implies an increase of 10% in the estimated contingent liabilities (Scenario A, option b).

(3) When considering the interplay between the LR requirement and the FRTB (Scenario B), the impact on potential public support in case of a crisis is negative compared to the baseline scenario where the LR is ignored. This is due to the fact that the LR imposes higher recapitalization needs compared to the capital requirement based on RWAs if no buffers held in case the LR requirement is binding.

(4) When considering the role of the LR, a more realistic scenario assumes that banks hold more capital than 3% of TAs. In this case, they can count on a capital buffer which

helps meeting recapitalization requirements. In this case, potential public support is reduced from 11% up to 48% (Scenario C) compared to the baseline scenario.

Annex 1: Literature review on the impact of EU bank capital and liquidity regulation

This complementary literature review on the cumulative impact of capital and liquidity regulation focuses on recent works, mostly released in the 2014-2016 period. It preferably covers studies published in peer-reviewed journals. However, the document still refers to several working papers, mostly by central banks and international institutions. The reason for the relative scarcity of (published) studies on the impact of the regulation lies in the short time period passed from its introduction. This makes the available sample too short for most pre/post regulation comparisons. Moreover, reasonably researchers would use micro-data to study how banks may respond to the Basel III requirements. However, relevant data, in particular liquidity ratios, are generally not published or at best not freely available.

In this section, we provide the description of the dataset and the empirical application in order to estimate risk weighted assets.

This panel regression analysis builds on a work developed for the Impact Assessment of bank structural separation.

Papers on both capital and liquidity requirements

Gambacorta (2011) investigates the impact of the Basel III capital and liquidity regulation on the long-term economic performance of the US by using a Vector Error Correction Model (VECM) over the period 1994–2008. As for liquidity requirements, the focus is on the NSFR. As for capital requirements, the focus is on the Tangible Common Equity/RWA ratio. For liquidity, the scenarios considered are a 25% and a 50% increase in the ratio between banks' liquid and total assets. The tightening in capital requirements is proxied by a 2, 4 or 6 percentage points increase in the TCE/RWA ratio. Overall, results indicate that tighter capital and liquidity requirements have negative (but rather limited) effects on the level of long-run steady-state output and more sizeable effects on banks' return on equity. The economic costs are considerably below the estimated positive benefit of the reform, as the probability of banking crises and the associated banking losses are reduced.

The study by Nicoló et al. (2014) offers a joint assessment of capital regulation, liquidity requirements, and prompt corrective action (PCA) policies. The authors assess the impact of microprudential regulatory restrictions in a dynamic model where banks: (i) enjoy deposit insurance, (ii) are exposed to credit and liquidity risks arising from systematic and idiosyncratic shocks, (iii) undertake maturity transformation, (iv) invest in risky loans, (v) issue secured debt and costly equity, and (vi) may face financial distress. Their main findings are the following: (a) there exists an inverted U-shaped relationship between bank lending, welfare, and capital requirements, (b) liquidity requirements reduce lending, efficiency, and welfare, and (c) resolution policies contingent on observed capital, such as prompt corrective action, dominate in efficiency and welfare terms (noncontingent) capital and liquidity requirements.

Schmaltz et al. (2014) argue that the introduction of LR, LCR and NSFR constrains increases banks' management complexity, also because there are interactions among them. The authors provide a framework, through the use of linear programming, for an optimal transition from Basel II to Basel III. The model is applied to a typical German bank that complies with Basel II, but not with Basel III. The authors find that this bank would achieve compliance restructuring its funding side by replacing interbank funding by capital and retail deposits.

Angelini et al. (2015), using the models that are selected for the Long-term Economic Impact study by the BCBS, assess the long-term economic costs of capital and liquidity requirements of the Basel III reform, in terms of long-term economic performance and output fluctuations. Some of the selected models feature bank capital, others bank liquidity, while, a few feature both bank capital and bank liquidity. The policy scenarios considered are the same as in Gambacorta (2011). Results indicate that the economic costs of the new capital and liquidity requirements are considerably below existing estimates of the benefits that the reform should have by reducing the probability of banking crises. In particular, the reform dampens output volatility modestly, although there is some heterogeneity across models and the adoption of countercyclical capital buffers can substantially amplify the dampening effect on output volatility.

Figuet et al. (2015) use a push and pull framework for mapping the effects of Basel III reforms on cross-border banking claims held by internationally active banks located in advanced economies on emerging countries. The authors, in addition to the classical push and pull factors, include global factors that proxy for the costs associated with the new regulation. The authors use statistics on cross-border banking claims provided by the Bank for International Settlements (BIS) covering the period from 1999 to 2010. The sample comprises 30 emerging market economies while claims are held by internationally active banks located in 16 advanced economies. Results indicate that the new regulation could result in an overall decrease of 20% in cross-border claim inflows.

Bandt and Chahad (2015) assess the impact of the regulations via a large scale Dynamic Stochastic General Equilibrium (DSGE) model with a real and a financial sector, as well as a distinction between retail and wholesale banking. A key feature of their model is that most of the assets have more than a one period maturity. Moreover, households hold deposits and sovereign bonds, SMEs can only borrow from the banking sector, while large corporates could issue bonds. The authors find that both capital and liquidity requirements widen the discrepancy in terms of availability of credit between small and large companies in favor of the latter.

Finally, using a large bank-level dataset, Chiaramonte and Casu (2016) test the relevance of both structural liquidity and capital ratios, as defined in Basel III, on banks' probability of failure. To include all relevant episodes of bank failure and distress occurring in the EU-28 member states over the past decade, they develop a broad indicator that includes information not only on bankruptcies, liquidations, under receivership and dissolved banks, but also accounts for state interventions, mergers in distress and EBA stress test results. Estimates from several versions of the logistic probability model indicate that the likelihood of failure and distress decreases with increased liquidity holdings, while capital ratios are significant only for large banks. Their results provide support for Basel III's initiatives on structural liquidity and for the increased regulatory focus on large and systemically important banks.

Papers with a focus on liquidity requirements

The empirical literature on liquidity requirements is not extensive. In the paper by Dietrich et al. (2014) the characteristics and drivers of NSFR for a sample of 921 Western European banks between 1996 and 2010 are analyzed. The authors find that a majority of banks have historically not fulfilled NSFR minimum requirements, in particular larger and faster growing institutions as well as banks also active in asset management and investment banking. Many of them have started increasing NSFR with the onset of financial crisis 2008, while this ratio had been sliding in earlier years. Interestingly, the authors find that potential advantages in funding costs for low NSFR banks do not seem to translate into higher profitability, and results of these banks are more volatile.

King (2013) estimates the NSFR for banks in 15 countriesand argues that the most cost-effective strategies to meet the NSFR are to increase holdings of higher-rated securities and to extend the maturity of wholesale funding. These changes reduce net interest margins by 70–88 basis points on average, or around 40% of their year-end 2009 values. The author also finds that universal banks with diversified funding sources and high trading assets are penalized most by the NSFR.

Hong et al. (2014) present a comprehensive analysis to calculate the Basel III LCR and NSFR of U.S. commercial banks using Call Report data over the period 2001–2011, and provide indirect empirical evidence on net cash outflow rates of certain liability categories. In addition, they examine potential links between Basel III liquidity risk measures and bank failures using a model that differentiates between idiosyncratic and systemic liquidity risks. They find that while both the NSFR and the LCR have limited effects on bank failures, the systemic liquidity risk is a major contributor to bank failures in 2009 and 2010. This finding suggests that an effective framework of liquidity risk management needs to target liquidity risk at both the individual level and the system level.

Turning to theoretical papers on liquidity requirements, Van den End and Kruidhof (2013) investigate the role of the LCR as a macroprudential instrument in extreme stress scenarios. The liquidity stress-testing model is operationalized by switching rules, introduced by the authors, that the macroprudential authority can apply in stress times. The three switching rules used in order to make the LCR more flexible are: (i) reducing the minimum LCR requirement (ii) widening the buffer definition (iii) acknowledging central bank funding. The model simulates banks' liquidity profiles: (i) after the first round effects of a stress scenario (i.e. when the LCR is based on available balance sheet and cash flow information of a bank) (ii) after the mitigating measures introduced by the banks and, (iii) after the central bank reaction. The authors show that recognizing less liquid assets in the buffer is a useful macroprudential instrument to mitigate its adverse side-effects during times of stress. However, at extreme stress levels the instrument becomes ineffective and the lender of last resort has to underpin the stability of the system.

One of the side effects of liquidity regulation is that encouraging banks to hold less risky liquid assets with a lower interest income may lead to a reduced supply of loans. Covas and Driscoll (2014), using a nonlinear dynamic general equilibrium model, find that liquidity regulations on top of a capital requirement, in the long run, reduce loans outstanding on banks' books by nearly 3%, and aggregate output and consumption by about 0.3% and 0.1%, respectively. On the other hand, the authors find that relaxing liquidity requirements during a crisis period could reduce the effect of wealth shocks on aggregate output.

König (2015) investigates under which conditions short-term liquidity ratios improve bank's resilience in times of stress. As the author argues, under certain conditions liquidity ratios may cause the opposite outcome (i.e. obstruct bank's resilience). This is due to the so-called liquidity and solvency contradicting effects. The liquidity effect arises because a bank mitigates its risk of illiquidity when it increases its liquidity buffer. On the other hand, a larger liquidity buffer reduces bank's returns and insolvency risk increases (solvency effect). The analysis shows that liquidity requirements are only effective in strengthening the resilience of a bank once the liquidity effect dominates the solvency effect.

Another perspective regarding the consequences of the NSFR regulation is given in Kauko (2016). The author presents a model with money supply being endogenous and determined by lending. In order not to violate the NSFR requirement, under the case of insufficient deposit supply, banks may need to restrict lending. However, in the current monetary system deposit money is created by lending. Hence, a conflict arises, as it becomes difficult for any particular bank to acquire stable funding for satisfying the NSFR requirement if the NSFR itself restricts lending by other banks. Although this is not a problem in a closed economy, in an indebted open economy it could be a concern. Indeed, as the author argues, if there is a substantial amount of foreign debt financed via the international interbank market, a minor shock can have a drastic impact on loan and deposit stocks.

Papers with a focus on capital requirements

An overview of the empirical literature pointing out the different effects of capital regulation on economic growth is provided by Martynova (2015). This literature is not vast and takes into account three main indirect effects: (i) higher bank capital requirements may reduce bank lending, especially to the most bank-dependent borrowers, decreasing output; (ii) higher capital requirements lead to higher cost of equity, which is passed on to borrowers in the form of higher lending rates; and (iii) higher capital promotes financial stability, thereby smoothing credit supply. Overall, there is not much direct evidence on whether higher bank capital requirements ultimately increase or decrease economic growth. However, there seems to be a consensus that that imposing capital requirements higher than the current level may result in higher economic growth.

Cohen and Scatigna (2014) examine the broad patterns in how banks have gone about achieving higher risk-weighted capital ratios since the crisis. They find that retained earnings account for the bulk of the higher risk-weighted capital ratios, while reductions in risk weights play a secondary role. The authors find that advanced-economy banks increased their assets by 8% from 2009 to 2012, and that European banks have increased their lending more slowly than banks based in other regions. They also show that more profitable banks have expanded assets and lending faster than others, and that banks that came out of the crisis with relatively lower levels of capital have been more likely to pursue adjustment strategies involving slow asset growth.

Dagher et al. (2016) analyze how capital increases banks' capacity to absorb losses and the associated benefits. They find that capital in the range of 15–23% of RWAs would have been sufficient to absorb losses in the majority of past banking crises (at least in advanced economies). Considering that other bail-in-able instruments can contribute to loss-absorption capacity, minimum capital requirements may still be appropriate below this range. The authors also show that the costs of transitioning to higher capital standards might be substantial, hence new regulatory minima should be imposed gradually and when conditions allow – though markets tend to anticipate full compliance.

Kisin and Manela (2016) estimate the shadow cost of capital requirements using data on a costly loophole, that allowed banks to relax these constraints. The authors find that the shadow costs of capital requirements during the pre-crisis period (when the loophole was available) were modest. In particular, the shadow cost of a one-percentage-point increase in required tier 1 capital ratios would on average correspond to 0.4% of the annual profits, with an upper bound of 2-3%. These estimates imply that the recent modest increase in capital requirements will have a negligible effect on bank profits as well as on banks' economic capital, as banks appear to neutralize the increase in regulatory requirements by exploiting weaknesses of risk-weighting rules, shifting activities into softer regulatory environments, and using other loopholes.

Basten and Koch (2015) focus on the effects of the introduction of the Countercyclical Capital Buffer on mortgage pricing, based on Swiss data. They find that following the activation of the buffer, relatively capital-constrained and mortgage-specialized banks raise prices more than their competitors do. The also find that risk-weighting schemes linked to borrower risk do not amplify the Countercyclical Capital Buffer's effect. Overall, the authors conclude that the introduction of the Countercyclical Capital Buffer has achieved its intended effect in shifting mortgages from less resilient to more resilient banks, but stricter capital requirements do not appear to have discouraged less resilient banks from risky mortgage lending.

Some recent theoretical papers analyze the role of capital requirements in a general equilibrium setting, where financial regulation both optimally responds to and influences business and financial cycles. For example, Clerc et al. (2016) develop a dynamic stochastic general equilibrium model with multiple financial frictions, with an emphasis on default risk. In this model, bank capital regulation tackles several distortions that may push credit provision away from the first-best solution. The authors find that a reasonable compromise between reducing these distortions and ending up constraining credit supply excessively can be found at levels of the capital ratio around 10.5%.

In the model by Malherbe (2015), the regulator sets capital requirements to trade off expected output against financial stability. The main result of the paper is that optimal capital requirements are tighter in good times than in bad times. In other words, assets, and loans in particular, should expand less than proportionally compared to equity. This is due to diminishing returns to capital on the real side of the economy, and to banks' incentives to take on too much risk. This result is in line with the notion of counter-cyclical capital buffers of Basel III.

Corbae and D'Erasmo (2014) study the interaction between the structure of the banking sector and policy. In particular, the model is characterized by the presence of big, dominant banks interacting with small, competitive fringe banks. The authors find that a rise in capital requirements by 50% (from 4% to 6%) leads to a 45% reduction in exit rates of small banks, as the reduction in loan supply by big banks induces entry by small banks. They also find that capital ratios are much larger in an economy with dominant banks than in one with only competitive banks, because in this latter case the loan interest rate is lower than in the benchmark, resulting in lower default frequencies and ultimately, in a less risky environment.

Finally, the macroeconomic model developed by Lambertini and Uysal (2014) predicts that the improvement in the capital ratio from Basel II to III stems mainly from a large reduction in bank assets, namely loans. As for output, the model predicts that a fall by 2.5-2.7 percentage points under Basel III owing to banks cutting lending. On the positive side, Basel III makes banks more resilient to shocks by reducing significantly the volatility of bank variables, hence smoothing the business cycle, owing to countercyclical capital requirements.

Annex 2: SYMBOL description

The Systemic Model of Banking Originated Losses (SYMBOL) model has been developed by JRC in cooperation with members of academia and representatives of DG FISMA. The original article describing the working of the model appeared in the peer-reviewed Journal of Financial Services Research (De Lisa 2011).

The core of the model is the Fundamental Internal Risk Based formula from the Basel III regulatory framework. The Basel III Fundamental Internal Risk Based formula works on the idea that credit assets outcomes fundamentally depend on a single factor.[8] This allows modelling and simulations to be carried out very easily. The formula has two additional useful characteristics in terms of modelling: (a) it uses a very limited number of parameters expressing the riskiness of credit assets and their correlation; (b) it gives comparable results when used on a set of sub-portfolios of assets, each with its own parameters, and then summing up results, or when directly considering the whole portfolio using average parameters values.

The model thus assumes that: (a) the Basel 3 regulatory model for credit risk is correct; (b) banks report risks accurately and in line with this model;[9] (c) all risks in the bank can be represented as a single portfolio of credit risks.[10] It is then possible to use publicly available data on total regulatory capital, RWAs and TAs to obtain parameters representing the average riskiness of each bank's portfolio of assets.[11]

Once parameters are obtained for all banks, a set of loss scenarios are simulated. In each scenario, a number representing a realization of the single risk factor is randomly generated for each bank. To represent the fact that banks all operate in the same economy, the risk factors are correlated between themselves.

Given the realisation of the risk factors and the parameters above, it is possible to obtain from the model a simulated loss for each bank in each loss scenario.[12] These losses can then be applied to bank capital to see which banks "default" (i.e. exhaust or severely deplete regulatory capital) in the simulated scenario. If the policy set-up allows for or any other loss-absorbing or re-capitalization tool (e.g. bail-in) these can also be applied at individual bank level. Losses, interventions of other tools and counts of defaults can then be aggregated across the whole banking sector. Moreover, given that the simulations work at individual bank level, other characteristics of banks subject to "default" can be tracked, such as covered deposits or TAs held.[13]

Given a sufficient number of loss scenario simulations (hundreds of thousands to millions), it is possible to obtain statistical distributions of outcomes for the banking sector as a whole.

It is finally possible to use such distribution to estimate the probability of events such as the probability that losses in excess of capital will be above a certain threshold (i.e. the

[8] In a very simplified way: given the general situation of the economy, each asset will have a certain probability of defaulting. By considering such probabilities of default as the expected loss conditional on the economic situation and summing across assets it is possible to obtain an expected loss of the portfolio conditional on any economic scenario. The capital requirement is then the loss on a particularly adverse scenario.

[9] When this is not the case, we need to rely on self-reported or supervisory assessments of the correction that would be needed when moving from the current system to a Basel III compatible system. It should be noted that the original framework of the model employed Basel II (and not III) compatible data, as this was the regulatory framework of reference at the time.

[10] This does not mean that other risks are not considered, simply that they can be "mapped" in credit risk terms and modelled using the same framework.

[11] Other parameters are fixed at the default levels set in the regulation.

[12] It should be noted that SYMBOL is a "purely static" model. Losses are all realized (or known) at the same point in time for all systems' participants and banks do not dynamically react to events.

[13] It is important to stress that, though the model simulates losses at individual bank level, individual bank results are not deemed to be usable per se.

statistical distribution of losses for resolution tools and/or public interventions), or the probability that banks holding more than a certain amount of covered deposits will be in default (i.e. the statistical distribution of intervention needs for the DGS).[14]

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. This function is based on the Vasicek model (see Vasicek, 2002), which in broad terms extends the Merton model (see Merton, 1974) to a portfolio of borrowers.[15] Simulated losses are based on an estimate of the average default probability of the portfolio of assets of any individual bank, which is derived from data on banks' Minimum Capital Requirements (MCR) and TAs.

The model includes also a module for simulating direct contagion between banks, via the interbank lending market. In this case, additional losses due to a contagion mechanism are added on top of the losses generated via Monte Carlo simulation, potentially leading to further bank defaults (see also Step 4 below). The contagion module can be turned off or on depending on the scope of the analysis and details of the simulated scenario.

In addition to bank capital, the model can take into account the existence of a safety net for bank recovery and resolution, where bail-in, DGS, and RF intervene to cover losses exceeding bank capital before they can hit Public Finances.

Estimations are based on the following assumptions:

- SYMBOL approximates all risks as if they were credit risk; no other risk categories (e.g. market, liquidity or counterparty risks) are explicitly considered;
- SYMBOL implicitly assumes that the FIRB formula adequately represents (credit) risks that banks are exposed to;
- Banks in the system are correlated with the same factor (see Step 2 below);

All events happen at the same time, i.e. there is no sequencing in the simulated events, except when contagion between banks is considered.

STEP 1: Estimation of the Implied Obligor Probability of Default of the portfolio of each individual bank.

The main ingredient of the model is the average implied obligor probability of default of a bank. It is a single parameter describing its entire loss distribution. It is obtained by numerical inversion of the Basel IRB formula for credit risk, based on total minimum capital requirements declared in the balance sheet. Individual bank data needed to estimate the implied obligor probability of default are banks' risk-weighted assets and TAs, which can be derived from the balance sheet data. We present a brief overview of

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14 Technically, what is obtained is the Value at Risk (VaR), or the loss which should not be exceeded under a certain confidence level. The confidence is given by the probability of observing a realization of the risk factor which is more extreme than the one corresponding to the reference scenario.

15 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, 2011.

the main ingredients below. Benczur et al (2015)[16] offers some additional details and discussion.

For each exposure *l* in the portfolio of bank *i*, the IRB formula derives the corresponding capital requirement $\mathrm{CR_{i,l}}$ needed to cover unexpected losses[17] over a time horizon of one year, with a specific confidence level equal to 99.9%:

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

where $\mathrm{PD_{i,l}}$ is the default probability of exposure *l*, *R* is the correlation among the exposures in the portfolio, defined as

$$\mathrm{R(PD)} = 0.12 \cdot \frac{1-\mathrm{e^{-50PD}}}{1-\mathrm{e^{-50}}} + 0.24 \cdot \left(1 - \frac{1-\mathrm{e^{-50PD}}}{1-\mathrm{e^{-50}}}\right) - 0.04 \cdot \left(1 - \frac{\mathrm{S}-5}{45}\right)$$

with obligor size *S* =50.

Here LGD is the loss given default[18] and $\mathrm{M}\left(\mathrm{PD_{i,l}}\right)$ is an adjustment term, defined as

$$\mathrm{M}\left(\mathrm{PD_{i,l}}\right) = \frac{(1 + (\mathrm{M} - 2.5) \cdot \mathrm{b_{i,l}}) \cdot 1.06}{1 - 1.5 \cdot \mathrm{b_{i.l}}}$$

with $\mathrm{b_{i,l}} = \left(0.11856 - 0.05478 \cdot \ln\left(\mathrm{PD_{i,l}}\right)\right)^2$ and maturity M=2.5. Note that here all parameters are set to their regulatory default values.

The minimum capital requirement of each bank *i* is obtained summing up the capital requirements for all exposures:

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

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

As there are no available data on banks' exposures towards each obligor, the model estimates the default probability of a single obligor (implied obligor probability of default, IOPD) equivalent to the portfolio of exposures held by each bank by inverting the above formulas. Mathematically speaking, the model computes the IOPD by numerically solving the following equation:

$\mathrm{CR(IOPD_i)} \cdot \sum_\mathrm{l} \mathrm{A_{i,l}} = \mathrm{MCR_i}$,

where $\mathrm{MCR_i}$ and $\sum_\mathrm{l} \mathrm{A_{i,l}}$ are respectively the minimum capital requirement, set equal to 8% of the RWAs, and the TAs of the bank.

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

Given the estimated IOPD, SYMBOL simulates correlated losses hitting banks via Monte Carlo, using the same IRB formula and imposing a correlation structure among banks.[19] The correlation exists either as a consequence of the banks' exposure to common borrowers or, more generally, to a particular common factor (for example, the business cycle). In each simulation run $n = 1, \ldots, N_0$, losses for bank *i* are simulated as:

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[16] http://ec.europa.eu/economy_finance/publications/economic_paper/2015/pdf/ecp548_en.pdf

[17] 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.

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

[19] The asset value of each bank's debtors evolves according to $X_{A,k} = \sqrt{R_A}\left(\sqrt{\rho}\beta + \sqrt{1-\rho}\beta_A\right) + \sqrt{1-R_A}Z_{A,k}$. Here $Z_{A,k}$ is the idiosyncratic shock to the debtor, β_A is the bank specific shock, while β is a common component. The parameter ρ controls the degree of commonality in the shocks of two different banks.

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

where N is the normal distribution function, and $N^{-1}(\alpha_{n,i})$are correlated normal random shocks with correlation matrix Σ.

STEP 3: Determination of bank failure.

Given the matrix of correlated losses, SYMBOL determines which banks fail. As illustrated in Fig 4 , a bank failure happens when simulated obligor portfolio losses (L) exceed the sum of the expected losses (EL) and the total actual capital (K) given by the sum of its minimum capital requirements plus the bank's excess capital, if any :

$$\text{Failure} \coloneqq L_{n,i} - EL_i - K_i > 0.$$

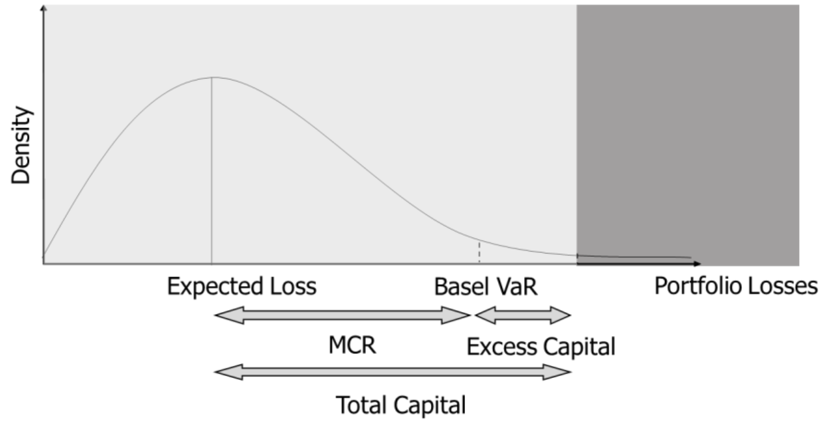

Fig 4: Individual bank loss probability density function

Notes. MCR: minimum capital requirements. VaR: value-at-risk.

The light grey area in Fig 4 represents the region where losses are covered by provisions and total capital, while the dark grey one shows when banks fail 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 minimum capital requirement covers losses from the obligors' portfolio with probability 99.9%. This percentile falls in the light grey area, as banks generally hold an excess capital buffer on top of the minimum capital requirements. The actual level of capital hold by each bank *i* determines the failure event.

STEP 4: Aggregate distribution of losses for the whole system.

Aggregate losses are obtained by summing losses in excess of capital of all distressed banks in the system in each simulation run.

Annex 3: Detailed SYMBOL simulation results

This Annex reports the distribution of financial needs after the use of each tool. Each percentile corresponds to a crisis with a specific magnitude: lower percentiles refer to a less severe crisis; higher percentiles refer to a much severe crisis with larger aggregated banking losses. The row in bold is the reference row for a crisis of a comparable size as of 2008.

The distributions are zero up to the 98^{th} percentile, after which there is a steep increase.

Total financing needs are comparable to those of the last financial crisis of 2008 around percentile 99.95. To find this percentile, we use data on state aid to the financial sector during the crisis. The total amount of recapitalization measures in the period 2008–2012 was 428 bn (European Commission, 2014b), a total of roughly 180 bn was also provided to the financial sector via asset relief. These figures lead to an estimate of total financing needs of up to 600 billion.

Table 10: Distributions of financing needs FN (i.e. potential costs for public finances due to bank defaults and recapitalization needs) for all scenarios, option a. FN are reported as a share of EU GDP

Percentiles	Baseline:			Scenario A1			Scenario 2			Scenario 3		
	FN after capital	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**
99	0.34%	0.01%	0.00%	0.33%	0.01%	0.00%	0.60%	0.01%	0.00%	0.28%	0.01%	0.00%
99.5	0.81%	0.04%	0.00%	0.79%	0.03%	0.00%	1.17%	0.04%	0.00%	0.70%	0.02%	0.00%
99.9	1.90%	0.23%	0.01%	1.87%	0.21%	0.01%	2.38%	0.25%	0.02%	1.72%	0.15%	0.01%
99.91	1.98%	0.24%	0.02%	1.95%	0.22%	0.01%	2.47%	0.26%	0.02%	1.79%	0.16%	0.01%
99.92	2.11%	0.26%	0.02%	2.08%	0.24%	0.02%	2.63%	0.28%	0.02%	1.91%	0.17%	0.01%
99.93	2.24%	0.30%	0.02%	2.21%	0.28%	0.02%	2.76%	0.32%	0.03%	2.02%	0.19%	0.01%
99.94	2.36%	0.32%	0.03%	2.32%	0.30%	0.03%	2.89%	0.34%	0.03%	2.14%	0.22%	0.02%
99.95	***2.52%***	***0.37%***	***0.04%***	***2.49%***	***0.34%***	***0.03%***	***3.08%***	***0.39%***	***0.05%***	***2.29%***	***0.25%***	***0.02%***
99.96	2.75%	0.41%	0.05%	2.71%	0.38%	0.05%	3.32%	0.44%	0.06%	2.50%	0.28%	0.03%
99.97	3.05%	0.50%	0.09%	3.01%	0.47%	0.08%	3.64%	0.53%	0.10%	2.78%	0.35%	0.05%
99.98	3.47%	0.62%	0.16%	3.43%	0.58%	0.13%	4.10%	0.65%	0.17%	3.19%	0.44%	0.08%
99.985	3.80%	0.74%	0.24%	3.75%	0.70%	0.21%	4.44%	0.78%	0.26%	3.50%	0.54%	0.13%
99.99	4.27%	0.88%	0.34%	4.23%	0.82%	0.29%	4.93%	0.92%	0.37%	3.95%	0.64%	0.18%
99.995	5.23%	1.20%	0.63%	5.18%	1.13%	0.57%	5.93%	1.25%	0.68%	4.87%	0.89%	0.35%
99.999	8.36%	2.74%	2.16%	8.31%	2.62%	2.05%	9.13%	2.85%	2.27%	7.92%	2.11%	1.53%
100	9.61%	3.38%	2.81%	9.55%	3.25%	2.67%	10.40%	3.52%	2.94%	9.14%	2.63%	2.05%

Table 11: Distributions of financing needs FN (i.e. potential costs for public finances due to bank defaults and recapitalization needs) for all scenarios, option a. FN are reported in billion €.

Percentiles	Baseline:			Scenario 1			Scenario 2			Scenario 3		
	FN after capital	FN after bail-in	Public support after RF	FN after capital	FN after bail-in	Public support after RF	FN after capital	FN after bail-in	Public support after RF	FN after capital	FN after bail-in	Public support after RF
99	46.65	1.52	0.03	45.21	1.47	0.03	82.76	1.62	0.03	38.32	0.90	0.02
99.5	111.40	5.15	0.11	108.87	4.57	0.11	159.86	5.98	0.12	95.76	2.82	0.09
99.9	260.61	31.63	1.98	256.61	28.91	1.73	326.45	34.12	2.35	235.49	20.02	1.04
99.91	271.66	33.60	2.16	267.53	30.72	1.94	338.64	35.84	2.56	245.45	21.73	1.15
99.92	289.83	35.27	2.42	285.43	32.31	2.18	360.13	37.90	2.97	261.40	23.04	1.36
99.93	307.21	41.27	3.15	302.70	37.83	2.66	379.24	43.83	3.78	277.54	26.41	1.55
99.94	323.14	44.12	4.23	318.45	40.48	3.66	396.48	46.63	4.55	293.00	29.65	2.47
99.95	***346.32***	***50.68***	***5.49***	***341.48***	***46.64***	***4.67***	***421.91***	***53.55***	***6.23***	***314.49***	***34.36***	***2.87***
99.96	377.11	56.21	7.47	371.99	51.96	6.48	455.75	59.82	8.46	343.47	37.92	4.06
99.97	418.29	68.89	12.85	412.92	64.19	11.24	499.87	72.79	14.31	381.74	47.93	7.24
99.98	476.28	85.19	21.27	470.45	79.36	18.39	562.68	89.61	23.67	437.26	60.37	11.24
99.985	520.92	102.11	32.52	514.93	95.53	28.65	608.49	106.66	35.86	479.85	74.08	18.05
99.99	586.12	120.76	46.29	579.72	113.13	40.38	676.47	126.66	51.10	541.81	87.14	24.66
99.995	717.66	164.13	86.31	710.64	155.14	77.69	814.00	171.12	93.20	667.65	121.67	48.43
99.999	1,147.55	375.45	296.93	1,139.57	359.28	280.68	1,253.08	390.35	311.87	1,087.12	289.24	210.51
100	1,317.90	464.18	385.60	1,309.61	445.21	366.51	1,426.18	482.26	403.72	1,254.06	360.59	280.94

TABLE 12: Distributions of financing needs FN (i.e. potential costs for public finances due to bank defaults and recapitalization needs) for all scenarios, option b. FN are reported as a share of EU GDP

Percentiles	Baseline:			Scenario 1			Scenario 2			Scenario 3		
	FN after capital	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**
99	0.10%	0.00%	0.00%	0.11%	0.00%	0.00%	0.18%	0.00%	0.00%	0.13%	0.00%	0.00%
99.5	0.35%	0.00%	0.00%	0.37%	0.00%	0.00%	0.51%	0.01%	0.00%	0.42%	0.01%	0.00%
99.9	1.04%	0.07%	0.00%	1.09%	0.08%	0.00%	1.33%	0.10%	0.00%	1.19%	0.08%	0.00%
99.91	1.10%	0.08%	0.00%	1.15%	0.09%	0.00%	1.40%	0.11%	0.00%	1.26%	0.08%	0.00%
99.92	1.17%	0.09%	0.00%	1.22%	0.09%	0.00%	1.49%	0.12%	0.01%	1.34%	0.09%	0.00%
99.93	1.24%	0.10%	0.00%	1.30%	0.11%	0.00%	1.58%	0.14%	0.01%	1.42%	0.10%	0.00%
99.94	1.34%	0.11%	0.01%	1.40%	0.12%	0.01%	1.68%	0.15%	0.01%	1.52%	0.11%	0.01%
99.95	***1.44%***	***0.13%***	***0.01%***	***1.51%***	***0.14%***	***0.01%***	***1.81%***	***0.18%***	***0.02%***	***1.64%***	***0.13%***	***0.01%***
99.96	1.59%	0.16%	0.01%	1.66%	0.17%	0.02%	1.99%	0.20%	0.02%	1.81%	0.16%	0.01%
99.97	1.79%	0.20%	0.03%	1.86%	0.21%	0.03%	2.22%	0.25%	0.04%	2.03%	0.20%	0.03%
99.98	2.08%	0.25%	0.04%	2.16%	0.27%	0.04%	2.55%	0.31%	0.06%	2.35%	0.26%	0.04%
99.985	2.31%	0.31%	0.06%	2.39%	0.32%	0.07%	2.80%	0.38%	0.09%	2.60%	0.32%	0.07%
99.99	2.64%	0.39%	0.09%	2.74%	0.40%	0.09%	3.19%	0.47%	0.12%	2.97%	0.39%	0.09%
99.995	3.35%	0.55%	0.15%	3.46%	0.58%	0.16%	3.99%	0.66%	0.21%	3.75%	0.56%	0.15%
99.999	5.92%	1.38%	0.84%	6.06%	1.42%	0.87%	6.77%	1.60%	1.04%	6.49%	1.43%	0.88%
100	6.96%	1.73%	1.15%	7.11%	1.78%	1.20%	7.88%	2.01%	1.42%	7.59%	1.80%	1.22%

TABLE 13: Distributions of financing needs FN (i.e. potential costs for public finances due to bank defaults and recapitalization needs) for all scenarios, option b. FN are reported in billion €.

Percentiles	Baseline:			Scenario 1			Scenario 2			Scenario 3		
	FN after capital	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**	**FN after capital**	**FN after bail-in**	**Public support after RF**
99	13.51	0.31	0.01	14.69	0.31	0.01	24.41	0.39	0.01	17.36	0.34	0.01
99.5	47.35	0.66	0.03	50.73	0.67	0.03	69.30	0.88	0.03	57.82	0.75	0.03
99.9	142.80	10.00	0.28	149.73	10.65	0.28	182.12	13.64	0.34	163.50	10.30	0.32
99.91	150.68	11.35	0.44	158.02	12.10	0.47	192.15	15.31	0.68	172.41	11.25	0.48
99.92	159.96	11.90	0.50	167.69	12.70	0.54	204.60	16.02	0.84	183.66	11.74	0.55
99.93	170.70	13.64	0.58	178.64	14.69	0.60	217.36	18.95	1.09	195.48	13.44	0.63
99.94	183.30	15.49	1.25	191.68	16.43	1.36	230.37	20.20	1.83	208.93	15.40	1.10
99.95	***198.22***	***18.46***	***1.50***	***207.04***	***19.58***	***1.65***	***248.15***	***24.03***	***2.35***	***225.60***	***18.43***	***1.33***
99.96	217.76	22.04	2.02	227.30	23.22	2.24	272.38	27.96	3.05	248.14	21.60	1.67
99.97	245.13	27.19	4.01	255.39	28.62	4.23	304.79	34.43	5.25	279.12	27.60	3.71
99.98	285.29	34.83	5.51	296.72	36.57	5.95	350.05	43.17	7.70	322.74	35.25	5.07
99.985	316.24	42.57	8.86	328.28	44.40	9.47	384.65	51.58	11.89	356.99	43.98	8.93
99.99	362.40	53.30	12.12	375.58	55.52	12.89	437.64	64.34	15.87	407.93	54.10	11.75
99.995	460.12	76.09	20.70	475.27	78.92	22.11	547.75	90.67	28.29	514.54	77.51	21.06
99.999	812.21	188.98	114.68	831.77	194.61	119.64	928.45	220.01	142.77	890.80	196.09	121.18
100	954.52	237.53	158.09	975.69	244.27	164.47	1,080.96	275.28	194.53	1,041.86	247.01	167.19

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List of abbreviations and definitions

AFS: Available for sale assets excluding loans

AIRB: Advanced internal rating based approach

AMZ: Total assets held at amortized cost excluding loans to banks and customers held at amortized cost

BCBS Basel Committee on Banking Supervision

BIS: Bank for International Settlements

CCB: Capital conservation buffer

CRD: Capital Requirement Directive

CRR: Capital Requirement Regulation

DA+DL: Derivatives held for trading (volume in assets and liabilities side)

DGS: Deposit guarantee schemes

DHV: Derivatives held for hedging purposes (volume in assets and liabilities side)

DSGE: Dynamic Stochastic General Equilibrium

EBA: European Banking Authority

EL: Expected losses

EU: European Union

FN: Financial needs

FIRB: Foundation internal rating based approach

FRTB: Fundamental review of the trading

FV: Assets held at fair value excluding loans

GDP: Gross domestic product

HTM: Securities held to maturity

IOPD: Implied obligor probability of default

IRB: Internal rating based approach

K: Regulatory capital

LB: Net loans to banks

LCR: Liquidity coverage ratio

LR: Leverage ratio

MCR: Minimum capital requirement

NCL: Net loans to customers

NSFR: Net stable funding ratio

PCA: Prompt corrective action

RF: Resolution fund

SME: Small medium enterprises

TCE: Tangible Common Equity

RWA: Risk weighted assets

SYMBOL: Systemic Model of Banking Originated Losses

TSA + TSL: Securities held for trading excl. derivatives (volume in assets and liabilities side)

VAR: Value at Risk

VECM: Vector Error Correction Model

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doi:10.2791/988150

ISBN 978-92-79-64119-0