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# Does CRDIV Provide an Efficient Way to Deal with Banks' Simultaneous Defaults?



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## Abstract

The Capital Requirement Directive IV issues detailed rules on the new global regulatory standards for bank capital adequacy. For instance, it requires all instruments in the additional Tier 1 layer of a credit institution to be written down or converted into equity as soon as the Common Equity Tier 1 capital falls below 5.125% of risk weighted assets. Whether or not the new framework has made the banking sector more resilient, there is still one issue that regulators have never dealt with. The Basel accord imposes a regulatory minimum capital on each bank that is meant to cover unexpected losses, as if the banks were isolated entities. In reality however, banks are exposed to common borrowers. The present study performs a quantitative assessment where banks are part of a shared economic environment. Through a micro simulation portfolio model we estimate the aggregate distribution of bank losses assuming banks are interconnected via a correlation structure and, possibly, a contagion network. Our results show that systemic loss in the presence of a correlation across banks is 5% higher than what the system may experience without such correlation. The increase increases to 40% when adding secondary effects. Hence, a modelling framework has been developed to assess how different rules for allocating extra capital are able to cancel out the losses due to commonalities. We show that the regulatory rule, namely requiring extra capital as soon as the common equity falls below 5.125% of risk weighted assets, is more efficient than asking Global Systemically Important Banks (GSIBs) or all banks to increase their Common Equity Tier 1. Results provide evidence that allowing debt instruments that can be converted into equity into the additional Tier 1 may be an efficient macro-prudential tool to face banks' simultaneous defaults and this would help to deal with a key missing piece in the Basel framework.

**Keywords:** Banking Regulation; Capital Requirements; CoCo Bonds; Basel III; Banking Crisis.

**JEL Codes:** C15; G01; G21; G28.

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## 1 Introduction

The recent financial crisis has unveiled a number of shortcomings associated with the Basel II framework. Though Basel II provides clear rules for banks to increase their

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capital requirements, a number of papers and actual events have showed how the capital set aside did not fulfil the role it was designed for. Indeed, this led to the occurrence of several bail-outs (see Blanchard, 2009; Claessens, 2010; Laeven, 2013). The new framework, known as Basel III (and transposed into the Capital Requirement Directive IV, CRR/CRD IV), tackles the problem both at the micro and macro-prudential levels (see EP, 2013a; 2013b). The macro-prudential dimension has mostly been added to deal with the endogenous risk embedded in the financial system (see BCBS, 2010a; 2010b). On one side, a conservation buffer of 2.5% of risk weighted assets (RWA) has been imposed above the minimum capital requirement (set at 8% by Basel II). On the other side, Basel III introduces rules for: (1) counter cyclical capital buffers built up to provide additional protection; (2) capital surcharge for the global systemically important banks (GSIBs); (3) automatic recapitalisation of banks in time of financial distress. The counter cyclical capital buffers (fully effective from January 2019) are intended to protect banks while reducing the amplitude of the business cycle in the financial sector. The idea is to impose extra capital constraints during boom period, and release this requirement during busts (see BCBS, 2010c)<sup>1</sup>. The rationale behind the extra capital buffer for GSIBs is quite clear, since banks identified as systemically important need extra protection because their failure might trigger a global financial crisis. Lastly, Basel III (and consequently CRDIV, at the European scale) has also introduced a mechanism to set up an automatic recapitalization to overcome the difficulty of raising new capital during a crisis. In particular, all additional Tier 1 debt instruments would be written down, or converted into Common Equity Tier 1 (CET1), as soon as the CET1 ratio falls below 5.125% of RWA. The contingent convertible bonds (CoCos) feed the discussion as they are loss absorbing hybrid instruments with such characteristics. Along with the analysis on the efficiency of such hybrid instruments to cope with systemic crises, we focus on another aspect which has been scarcely addressed by regulation: banks are part of a common economic environment and they share exposures to similar borrowers. Even Basel III seems to neglect these commonalities in the banking sector. Regulatory capital, as it is designed in the regulation, is meant to cover unexpected losses arising in banks as individual entities, not taking into account that several banks might fail simultaneously. When common exposures are considered, losses are spread over a larger number of banks and the banking sector will be forced to raise extra capital to avoid systemic crises. In other words, common exposure changes the shape of the loss distribution, «fattening» the tail. This opens the discussion to a vast stream of literature linked to systemic risk, for example as discussed in Brownless (2012). So far, both the efficiency of hybrid capital and the role of commonalities in systemic crises have only been broadly discussed in the literature.

<sup>1</sup> «The primary aim of the counter cyclical capital buffer regime is to use a buffer of capital to achieve the broader macro-prudential goal of protecting the banking sector from periods of excess aggregate credit growth that have often been associated with the build up of system wide risk. Protecting the banking sector in this context is not simply ensuring that individual banks remain solvent through a period of stress, as the minimum capital requirement and capital conservation buffer are together designed to fulfil this objective. Rather, the aim is to ensure that the banking sector in aggregate has the capital on hand to help maintain the flow of credit in the economy without its solvency being questioned, when the broader financial system experiences stress after a period of excess credit growth. This should help to reduce the risk of the supply of credit being constrained by regulatory capital requirements that could undermine the performance of the real economy and result in additional credit losses in the banking system» (BCBS, 2010c).

Therefore in our paper, we investigate considering that there is correlation among banks, to what extent the conversion to equity of the hybrid debt instruments in the additional Tier 1 layer is able to avoid systemic crises.

On a dataset of 78 EU banks that make up part of the list that underwent the European Banking Authority (EBA) stress tests in 2015, we use a micro simulation portfolio model (see e.g. DeLisa, 2011; Benczur, 2017)<sup>2</sup>, which implements the Basel risk assessment framework, to estimate the joint distribution of bank losses.

The model is compliant with the Basel framework in terms of default rate per bank which is around 0.1% even if commonalities are considered. On the other hand, if one looks at the distribution of defaults, we see that while the Basel assumption (zero correlation) produces a very similar number of bank defaults per simulation, the distribution of defaults by simulation is realistically more skewed and affected by extreme events in the right tail when commonality among banks is imposed.

In terms of aggregate losses in a severe financial crisis, we observe an increase of 5% with respect to the baseline when correlation is considered. Contagion makes the situation even worse, generating a further 40% increase in losses due to secondary effects. Such extra losses are what the new capital is designed to cover. To this purpose, we measure the efficiency of different rules to allocate additional capital used to cover losses caused by correlation (and secondary effects). In particular, the CRDIV rule calls for extra capital as soon as the CET1 falls below 5.125% of RWA which is what CRDIV states. Results show that this is more efficient than asking GSIBs, or even all banks, to increase their CET1. Moreover, the CRDIV rule identifies a set of problematic banks quite similar to those examined in the 2014 EBA Stress Tests. Finally, we show that the CRDIV rule performs better than the others even with regard to reducing the entire aggregate losses distribution. These results provide evidence that the CRDIV rule may help to deal with a missing piece in the Basel framework, by providing an efficient way to cope with banks' simultaneous defaults.

The paper is organised as follows. Section 2 presents an overview of the literature and Section 3 describes the dataset. Section 4 introduces the scenarios: one mirroring the Basel III theoretical framework (banks as individual entities), and the second representing a more realistic situation where banks are correlated. Moreover, section 4 also presents the set of different rules implemented in the paper (to impose a capital increase). In Section 5, we introduce the modelling framework. Section 6 presents the results: we first show the model compliant with the Basel framework, discuss the efficiency of the different rules, and then perform a series of robustness checks. Section 7 concludes the paper.

<sup>2</sup> This model, which is referred to as SYMBOL (Systemic Model of Bank Originated Losses), has been developed by the European Commission by banking sector experts to assess the impact of different legislative proposals, such as the increase in the minimum capital requirement, the size of funds for resolution purposes (see e.g. EC, 2012b), the cumulative evaluation of the entire financial regulation agenda (see e.g. EC, 2014b), and the assessment of contingent liabilities linked to public support to the EU banking sector during the crisis (see e.g. EC, 2011; 2012c). The model provides estimates of the magnitude of systemic losses derived from banks' defaults, taking into account the Basel capital requirements, and is flexible enough to allow different correlation structures among banks and a direct interbank contagion.

## 2 Literature Review

The Basel regulatory framework has been discussed extensively in the literature, both looking at the overall impact of the financial regulatory reforms in Europe (see Elliott, 2012) and at the micro versus macro dimension of the new prudential regulation (see Brunnermeier, 2009; Ojo, 2010; FSB, 2011; IMF, 2011; BW, 2013; Claessens, 2013; Beck, 2015).

As far as micro prudential rules are concerned, several papers discuss the effect of introducing higher capital requirements. In particular, there is evidence that the benefits would outweigh the costs involved (see BoE, 2012; MAG, 2010; EC, 2012a; Jenkins, 2012; Miles, 2013). Core capital is essential for increasing banks stability and for reducing the average funding cost for banks (Toader, 2015), while another paper shows that regulatory requirements tend to affect capital ratios permanently and credit supply temporarily (see Bridges, 2014). The cost of holding equity on the balance sheet is likely to be smaller than the frictions associated with raising new equity (see Hanson, 2011).

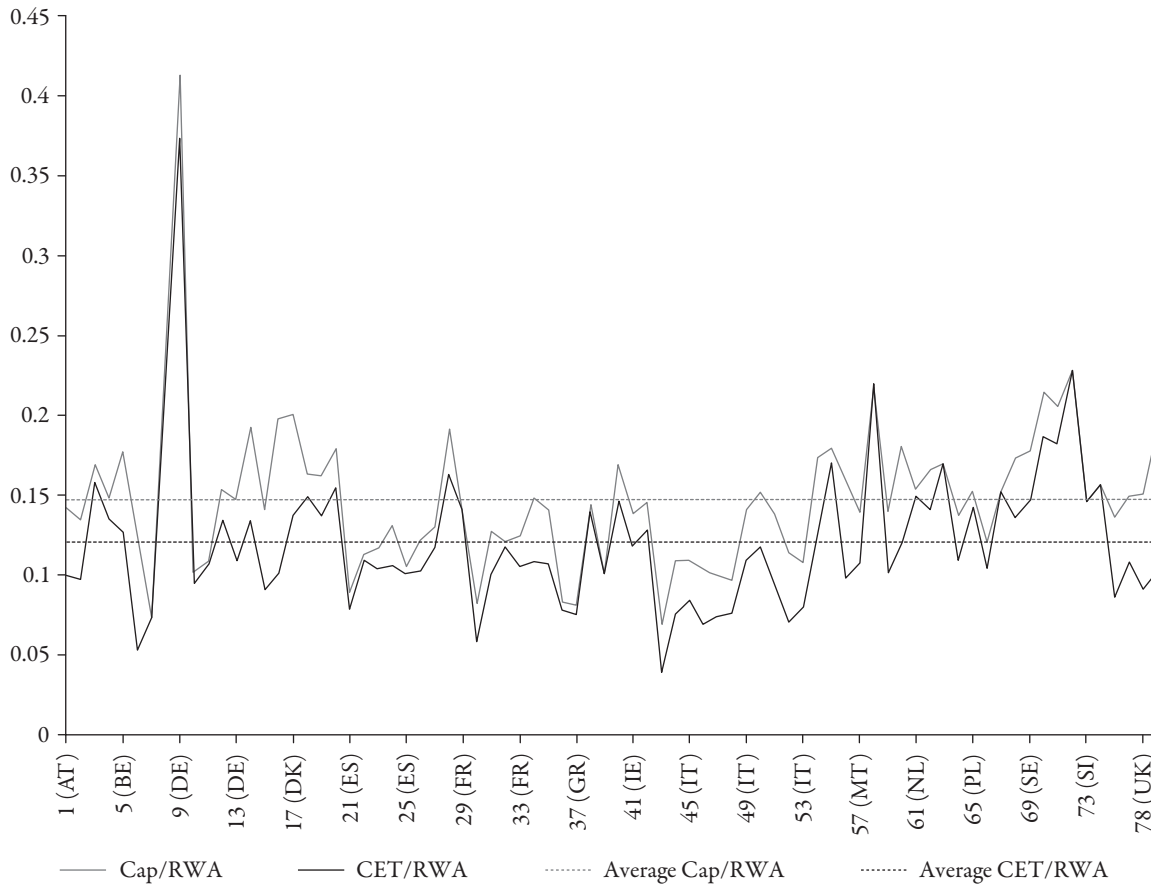
Moving on to the macro-prudential aspects of the regulation, a number of papers have performed quantitative analyses to test the effect of introducing counter cyclical capital buffers. The results do not seem to point to a clear direction. While Jiménez (Jiménez, 2017) find that counter cyclical capital buffers in Spain are useful in controlling the credit supply cycles and smoothing the downturn during recessions as in others show that the counter cyclical buffers have limited effectiveness through the cycle, and may even be counterproductive during downswings (see Repullo, 2011; Claessens *et al.*, 2013). Benefits and costs of a capital surcharge for the GSIBs has also been analysed by the Macroeconomic Assessment Group (MAG, 2011).

The research on contingent convertible bonds is also rich, in particular on how to price them according to different methods: a Merton approach (Fitch, 2011); a structural credit risk model (Pennacchi, 2011; Barucci, 2012); conic finance (Madan, 2011); using a credit derivative approach or an equity derivative pricing model which uses barrier options (Spiegeleer, 2012); a closed-form pricing formula of a CoCo (Corcuera, 2014); a Black & Scholes setting under a Heston process, and the Hull-White model for the interest rate (Di Girolamo, 2017). Another group of papers is more focused on the market reaction and the effect of using (or issuing) contingent capital bonds (see Koziol, 2012; Chen, 2013; Vallee, 2013; Chan, 2014; Hilscher, 2014; Ammann, 2015; Berg, 2015; Martynova, 2015; Schmidt, 2015; Cahn, 2016).

As a regulatory instrument, CoCos have been studied for their qualitative characteristics (see DeSpiegeleer, 2011; Maes, 2012; DeSpiegeleer, 2014; Kjell, 2014). Finally, the literature also provides a discussion on the effectiveness of imposing the conversion of CoCos to a level set as in the CRDIV, arguing that the conversion at 5.125% CET1 may be too low to prevent the failure of a financial institution (see PRA, 2013; Boermans, 2014; Cahn, 2014; ECB, 2014).

**Table 1:** Summary information on selected variables for the sample used in the analysis. Numbers are in Euro billions and refer to the end of 2013

Capital	CET1	RWA	TA
1,317	993	9,065	24,012

**Figure 1:** Capitalisation of the sample.

### 3 Dataset

We use a subset of 78 EU banks among those considered in the 2014 European Banking Authority (EBA) stress test. Data refer to the end of 2013. Our major data source is the SNL financial database that contains the data used in the EBA stress tests, and the Bureau van Dijk Orbis Bank Focus database that contains balance sheets and other bank-specific information for a large number of banks from a large variety of countries. The variables used are: Total Regulatory Capital (Capital), CET1, RWA and Total Assets (TA).

Table 1 presents some aggregate figures for the sample. The sample accounts for around 56% of the EU banking sector in terms of total TA<sup>3</sup>.

Figure 1 shows the recapitalisation levels for banks in the sample: on average the share of total capital and CET1 is 15% and 12% of RWA.

<sup>3</sup> European Central Bank (ECB) data on aggregated banks' total assets for the EU (including branches) are used as the statistical population.



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## 4 Scenarios and Rules

### 4.1 Scenarios

We implement three reference scenarios:

- *Baseline*: Basel framework, banks are considered as individual entities, hence the correlation among banks is set to zero;
- *Scenario 1*: a more realistic situation where banks face common exposures (both because of the economic cycle and similarities in assets' composition);
- *Scenario 2*: a contagion mechanism through the interbank market takes place and extra losses are added to those coming from the correlation structure alone.

### 4.2 Rules

Three different rules are defined to represent different criteria regulators may impose to banks for the capital increases able to cover losses arising from commonalities:

- *Rule 1 (CRDIV rule)*: Extra CET1 is required whenever a bank suffers from unexpected losses higher than  $\text{CET1} - 5.125\% \text{RWA}$ <sup>4</sup>;
- *Rule 2*: all banks are required to hold extra CET1;
- *Rule 3*: only the GSIBs are required to hold extra CET1.

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## 5 Modelling Framework

We have developed a modelling framework that can be divided in four parts: (1) a micro simulation model of general potential losses in the banking sector; (2) calibration of correlation among banks; (3) introduction of a contagion mechanism; (4) losses allocation.

### 5.1 Micro simulation model

The core modelling approach is the micro simulation model (SYMBOL) developed by the European Commission in collaboration with academia to estimate banking losses. The model starts by estimating the individual bank probabilities of default (PDs), using information on the minimum capital requirement (MCR) declared by banks on their balance sheets<sup>5</sup>. PDs and actual capital values are used to generate unexpected losses among

<sup>4</sup> This reflects the CRDIV criteria of triggering CoCo bonds as soon as CET1 falls below 5.125% of RWA.

<sup>5</sup> The Basel FIRB formula allows banks to calculate the minimum capital requirements they need to set aside against each exposure to cover unexpected losses at a specific confidence level of 99.9%, over a one year time period. Since the input required is the probability of default of each exposure and the MCR of a bank is known to be 8% of RWA, the probability of default of a bank can be derived by inverting this formula.

individual banks via a Monte Carlo estimation. The model assumptions are detailed in Benczur, 2017.

Let be the  $I \times J$  matrix of unexpected losses generated by SYMBOL, where  $I = 78$  refers to the number of banks in the sample, and  $J = 100,000$  is the total number of simulations for which at least one default happens<sup>6</sup>. From here on, we then define as *losses*, for each bank and each run, the unexpected losses in excess of capital plus recapitalisation needs to raise funds up to<sup>7</sup>:

$$(ExLR)_{ij} = (GL)_{ij} - Capital_i + 8\%RWA_i$$

Sample total assets are given by:

$$SystTA = \sum_{i=1}^I TA_i,$$

and the *systemic loss distribution* (referred to the sample) by:

$$(1) \quad SystLoss_j = \sum_{i=1}^I (ExLR)_{ij}.$$

Equation 1 provides the losses distribution, and different points in the distribution are associated to different levels of financial stress. To identify a systemic crisis level, we use the level of state-aids provided to the financial sector during 2008-2012 period (see EC, 2014a). The total amount of recapitalisation measures during such period amounts to 428 € bn, corresponding to roughly 1% of EU total assets. A total of about 180 € bn was also provided to the banking sector via asset reliefs. Including these, the total losses due to the crisis increases to 600 € bn, which is around 1.4% of EU total assets ECB (2014). Operationally, from the systemic loss distributions (*SystLoss*), we only keep the runs such that:

$$(2) \quad \tilde{j} = \{j \text{ such that: } 0.75\%SystTA \leq SystLoss_j \leq 1.25\%SystTA\}.$$

Individual banking losses conditional on a systemic crisis are computed by averaging the individual bank loss on the selected runs (see Equation 3). By summing them up, we derive the systemic conditional losses of the sample (Equation 4)

$$(3) \quad CondLoss_i = \mathbb{E} [(ExLR)_{ij}] : i \in \tilde{j}$$

$$(4) \quad SystCondLoss = \sum_{i=1}^I CondLoss_i.$$

<sup>6</sup> As robustness checks, the analysis has been performed using 500,000 and 1,000,000 runs and results do not change.

<sup>7</sup> 8% is the minimum capitalisation level at which a bank is considered viable.



## 5.2 Calibration of the correlation

The interconnection across banks is a consequence of their exposure to common borrowers or the shared factor, which has increased in recent years with the globalization of the banking sector in Europe. The recent crisis has shown how the high level of correlation may lead banks to face simultaneous defaults. This section aims to capture the correlation structure existing across banks using balance sheet data.

The model uses a default value for banks' correlation equal to 0.5%, but for better picturing of a more realistic situation, we have developed a new methodology to calibrate the correlation structure based on ROA, as a bank performance indicator, and GDP growth rate, at the country level as an economic indicator. The following two measures are inputs:

- *GDP growth* rate per country (1996-2013, source: Worldbank): macroeconomic indicator of the total economic activity of a country;
- *ROA per bank* (2007-2014, source: Bankscope): microeconomic indicator of the profitability of each bank.

In the literature, GDP growth is expected to have a positive effect on bank profitability, and there are numerous papers demonstrating that the ROA indicator is one of the significant inputs in predicting GDP growth. GDP growth and the ROA for banks in our sample have a Pearson correlation coefficient of 30% and a significant *p*-value. We use both measures to estimate the correlation structure in our sample, in order to capture the country and bank individual effects.

Combining these matrices into one factor is not straightforward however. We build two correlation matrices from the GDP growth of the country where banks in the sample are located, and one from the profitability of the banks:

*A*: positive defined correlation matrix of the GDP growth making use of a moving average over 4 years (see Table 2);

*B*: positive defined correlation matrix of the ROA making use of a moving average over all the years (see Table 3).

Using an approach often employed in the literature (see Numpacharoen, 2013), we build an adjusted correlation matrix using a weighted average of the two matrices above (see Table 4):

$$(5) \quad C = \frac{A\sigma_A + B\sigma_B}{\sigma_A + \sigma_B}$$

This guarantees that starting from a positive defined correlation matrix we still have a positive defined correlation matrix (see Numpacharoen, 2013). Matrix *C* is thus the bank-by-bank correlation based both on individual bank performances and country specific economic indicators, which we use through the paper. This matrix represents the real correlation in the banking sector. On average, the resulting correlation among banks is around 50% (see Mistrulli, 2011).

From Table 2, Table 3 and Table 4 one can see that matrix *C* mainly depends on matrix *A*, where matrix *B* only adjusts values in a few cases.

**Table 2:** ROA correlation matrix for the first 6 banks (matrix  $A$ )

	1	2	3	4	5	6
	AT	AT	BE	BE	BE	CY
1 AT	1	0.68	0.64	0.01	-0.70	0.95
2 AT	0.68	1	0.02	-0.35	-0.26	0.65
3 BE	0.64	0.02	1	0.69	-0.38	0.56
4 BE	0.01	-0.35	0.69	1	0.30	-0.12
5 BE	-0.70	-0.26	-0.38	0.30	1	-0.69
6 CY	0.95	0.65	0.56	-0.12	-0.69	1

**Table 3:** GDP correlation matrix for the first 6 banks (matrix  $B$ )

	1	2	3	4	5	6
	AT	AT	BE	BE	BE	CY
1 AT	1	1	0.97	0.97	-0.97	0.76
2 AT	1	1	0.97	0.97	0.97	0.76
3 BE	0.97	0.97	1	1	1	0.80
4 BE	0.97	0.97	1	1	1	0.80
5 BE	0.97	0.97	1	1	1	0.80
6 CY	0.76	0.76	0.80	0.80	0.80	1

**Table 4:** Final adjusted correlation matrix for the first 6 banks (matrix  $C$ )

	1	2	3	4	5	6
	AT	AT	BE	BE	BE	CY
1 AT	1	0.73	0.69	0.16	-0.45	0.92
2 AT	0.73	1	0.16	-0.15	-0.08	0.66
3 BE	0.69	0.16	1	0.74	-0.16	0.60
4 BE	0.16	-0.15	0.74	1	0.40	0.02
5 BE	-0.45	-0.08	0.16	0.40	1	-0.46
6 CY	0.92	0.66	0.60	0.02	-0.46	1

### 5.3 Introduction of a contagion mechanism

The SYMBOL model allows the estimation of second order losses due to the contagion effect. The model focuses on the role of the interbank lending market in causing direct contagion. We make use of this model to include a contagion mechanism in our analysis. The data required for this is the amount of interbank assets ( $IB^+$ ) and liabilities ( $IB^-$ ) for each individual bank.

$$(6) \quad (GL)_i^{contagion} = 40\%IB_i^- \frac{IB_i^+}{\sum_{b \neq i} IB_b^+}$$

The failure of a bank drives additional losses on other banks, equal to 40% of the amounts of its total interbank debts. A loss of 40% on the interbank exposure is coherent with the upper bound of economic research on this issue (see e.g. James, 1991; Upper, 2004; Mistrulli, 2007).

Since bank-to-bank (interbank) lending positions are not publicly available, an approximation is needed to build the whole matrix of interbank linkages. It is assumed that the more a bank is exposed in the interbank market as a whole, the more it will suffer

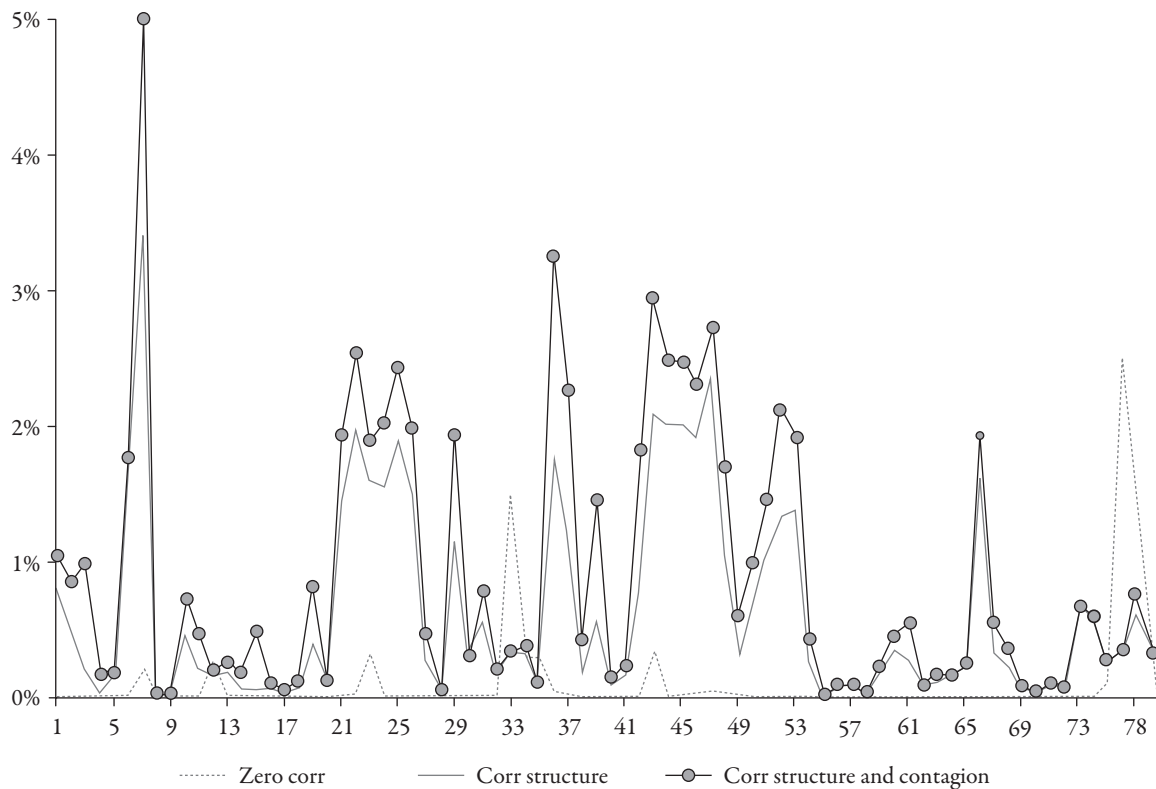


Figure 2: Bank losses conditional on a systemic crisis as share of total assets.

from a default in the system. In particular, contagion losses are apportioned to all other banks proportionally to their interbank loans.

A default driven by contagion occurs whenever these additional contagion losses ( $(GL)_i^{contagion}$ ) and losses generated via Monte Carlo ( $(GL)_i$ ) exceed the bank's available capital. This contagion mechanism stops when no additional bank defaults.

#### 5.4 Loss allocation

We run the model under different assumptions to take into account correlation and/or contagion:

$A_o$ : representing our Baseline where neither correlation nor contagion are considered;  
 $A_c$ : representing either Scenario 1 or Scenario 2 depending on the absence (Scenario 1) or presence (Scenario 2) of the contagion mechanism.

From Figure 2, we observe that in the Baseline case, only a few banks contribute to the overall losses, while in the Scenario 1 case (and Scenario 2), losses are spread across banks.

We aim to quantify the amount of extra funds (as a share of RWA) needed to (*Goal*) align the systemic conditional losses under  $A_c$  to the systemic conditional loss resulting from  $A_o$  (Basel framework). We apply the following «optimisation» procedure:

We denote by  $\alpha_i$ ,  $i = 1, \dots, I$  the extra share of RWA that each bank is required to hold to reach the Goal.

We consider a sample of  $1,024 \times I [0,1]$  uniformly quasi-random values for  $\alpha$ 's ( $\alpha_{bi}$ ). We replace  $\alpha_{bi}$  with zero if bank  $i$  is not involved according to the rules described in Section 4.2<sup>8</sup>.

For each bank  $i$  and each run  $j$ , we compute the new individual bank losses after the extra funds  $\alpha_{bi}$  have been taken into account:

$$(7) \quad (TempExLR_{ij})_b = (ExLR_c)_{ij} - \alpha_{bi}RWA$$

We average those losses over the selected runs  $\tilde{j}_c$ ; then we sum them up getting 1,024 new values for the systemic conditional loss:

$$(8) \quad TempSystCondLoss_b = \sum_{i=1}^I (TempExLR_{ij})_b : i \in \tilde{j}_c$$

These values are reported in Figure 3. The dashed horizontal line represents our benchmark (215 € bn, see Table 5).

We compare these with our benchmark and, out of the 1,024 different values, we select:

$$(9) \quad \tilde{b} = \{b \text{ such that } 99.5\%215 \leq TempSystCondLoss_b \leq 105\%215\}$$

In Figure 3 we only select those whose systemic conditional loss lies inside the two solid horizontal lines.

We calibrate the extra share of RWA that each bank is required to hold by averaging the  $\alpha_{\tilde{b}}$  obtained above:

$$(10) \quad \alpha_i \mathbb{E}_b[\alpha_{ib} : b \in \tilde{b}]$$

Finally, for each bank  $i$  and for each run  $j$ , we define the new losses as:

$$(11) \quad NExLR_{ij} = ExLR_{ij} - \alpha_i RWA$$

and consequently:

$$(12) \quad NSystLoss_j = \sum_{i=1}^I NExLR_{ij};$$

$$(13) \quad NCondLoss_i = \mathbb{E}_j[NSystLoss_j : j \in \tilde{j}];$$

and

$$(14) \quad NSystLoss_j = \sum_{i=1}^I NCondLoss_i$$

<sup>8</sup> We reiterate that according to the CRDIV rule, bank  $i$  would have an extra CET1 only if its unexpected losses ( $GL_i$ ), conditional on a systemic crisis are higher than CET1-5.125%RWA, while Rule 2 states that all banks are asked to raise additional CET1 capital.

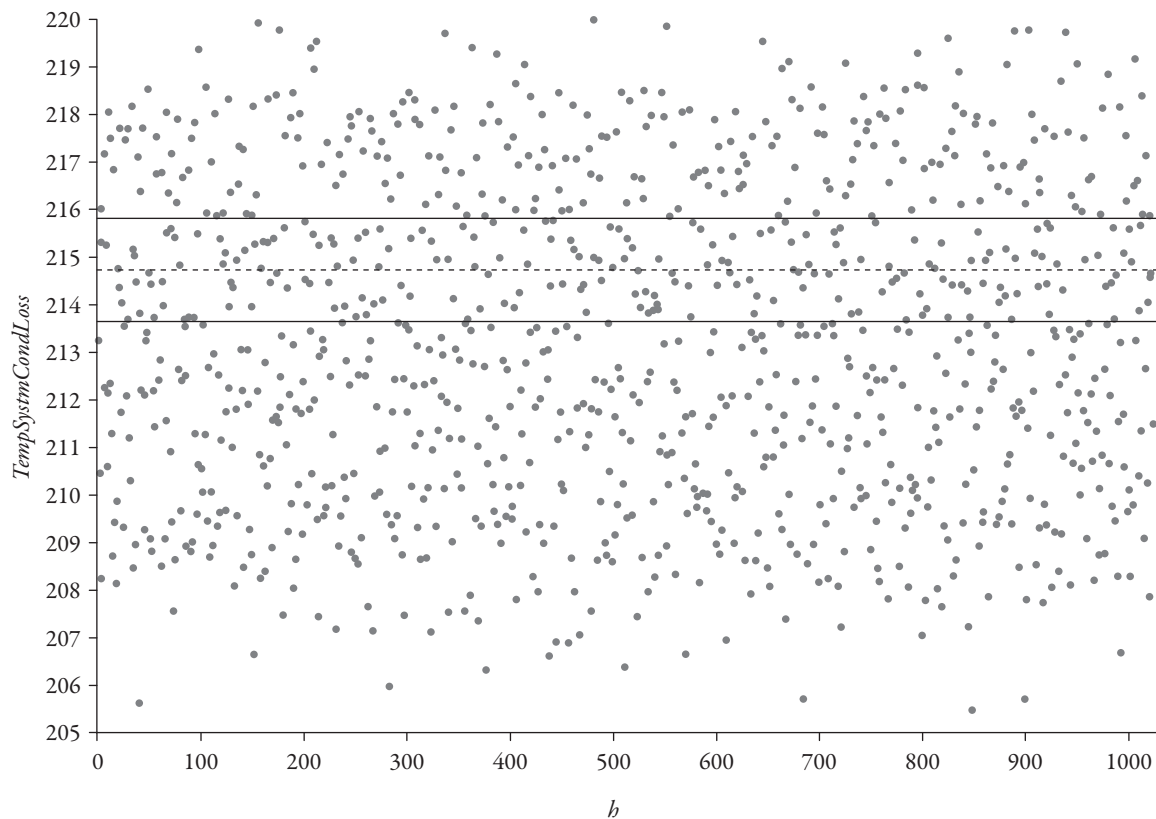


Figure 3: Example of systemic conditional loss when using different level of extra funds.

## 6 Results

### 6.1 Assessing model compliance with respect to the Basel framework

In this section we analyse the model performance with respect to the Basel framework, and we show that our model is compliant with Basel even when different levels of bank correlations are considered (contagion is not relevant here). We look at two indicators:

- estimation of the default rate per bank;
- estimation of the number of defaults per simulation.

We test four different correlation structures: no correlation, constant bank correlation equal to 50% or 90%, and the correlation matrix as estimated in Section 5. The model is run under two different levels of capitalisation: as declared in the balance sheet and fixing capital equal to 8% RWA<sup>9</sup>.

Figure 4 shows that the default rate per bank is 0.1% when capital is fixed at 8% RWA, independently of the correlation structure. This implies that our model is compliant with the Basel framework, and by varying correlation the average number of default per bank stays the same. The result holds also under the current level of capital, with a lower median value since banks usually hold extra capital buffers.

On the other hand the distribution of defaults per simulation depends on the correlation used as shown in Figure 5. Zero correlation leads to approximately the same number

<sup>9</sup> It is the minimum capital level required by Basel II to cover unexpected losses over a time horizon of one year, with a specific confidence level equal to 99.9%.

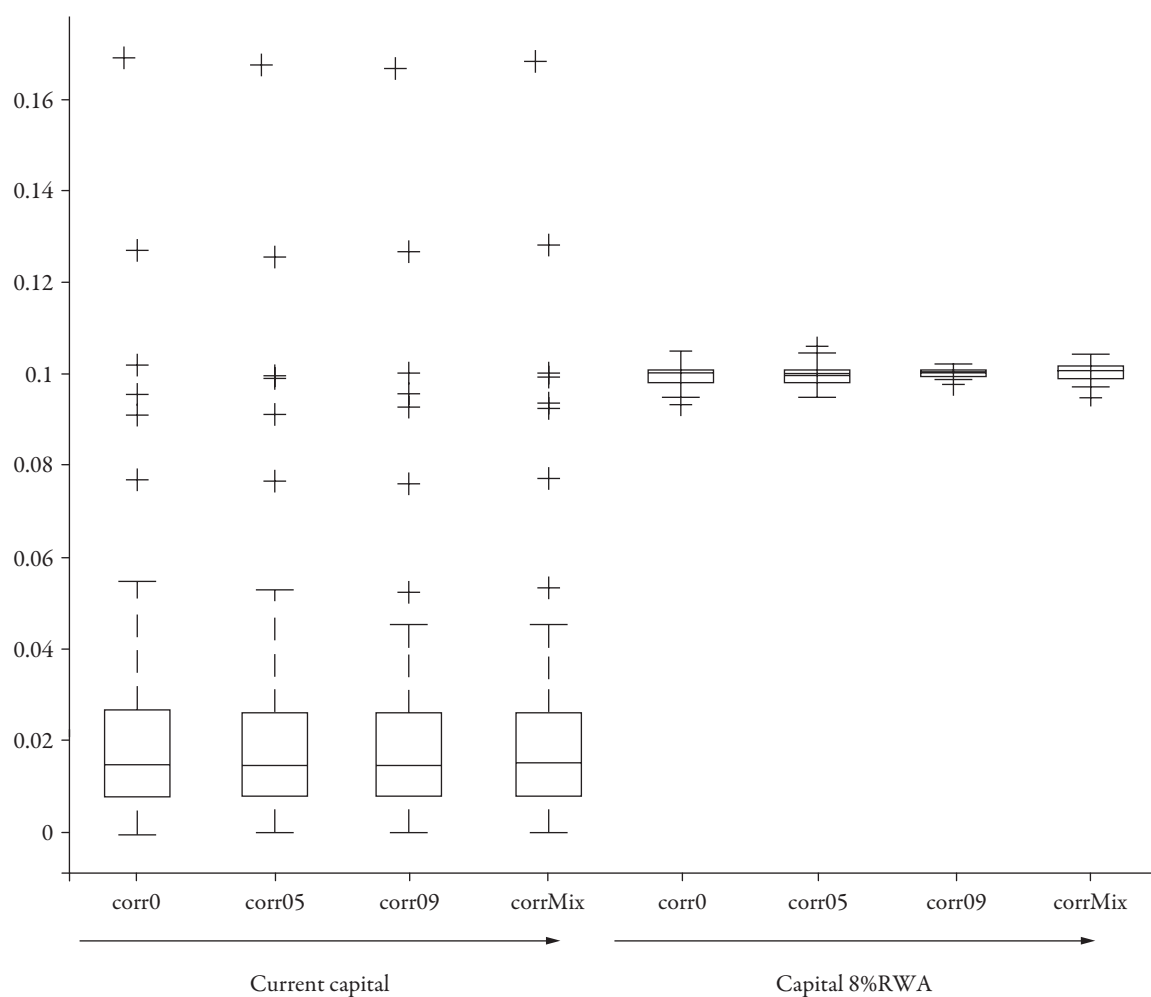


Figure 4: Compliance with Basel (a).

of defaults per simulations for all banks, which is in line with the Basel assumption that banks are deemed to be isolated from the rest of the system. Whenever correlation is considered, the distributions of defaults becomes increasingly skewed, and more and more affected by extreme events in the tail as the level of correlation increases. This result is in line with Figure 2 where we have observed that in the case of zero correlation, only a few banks contribute to the overall losses, while for the mixed correlation case, losses are spread across banks. We therefore affirm that with a zero correlation, the Basel framework does not take into account commonalities among banks which indeed exist in a more realistic situation.

## 6.2 Extra funds to deal with banks' simultaneous defaults

Following the methodology explained in Section 5, we estimate the amount of systemic conditional loss of the sample under a zero correlation (Baseline) and under more realistic scenarios (Scenario 1 and Scenario 2).

Table 5 reports the amount of systemic losses conditional to a crisis event. Scenario 1 gives rise to 5% higher losses than those estimated under the Baseline (from 215 to



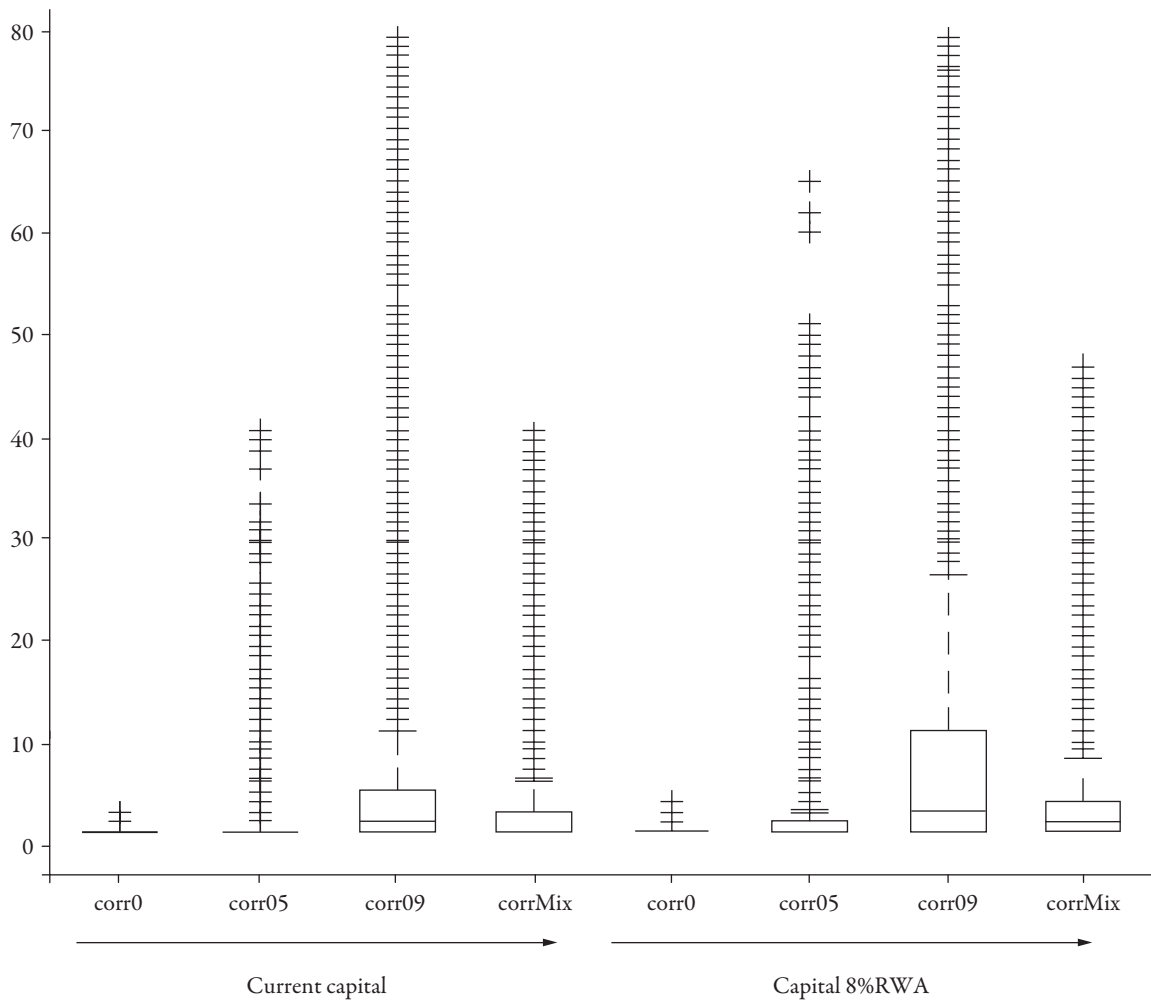


Figure 5: Compliance with Basel (b).

Table 5: Conditional losses

	Baseline	Scenario 1	Scenario 2
Systemic conditional losses (Euro billion)	215	226	298
Systemic conditional losses (shares of TA)	0.89%	0.94%	1.24%

Table 6: Total amount of extra funds

	CRDIV rule	Rule 2	Rule 3
Scenario 1 (Euro billion)	10.94	11.06	10.88
Scenario 2 (Euro billion)	84.40	145.37	173.63
Scenario 1 (share TA)	0.05%	0.05%	0.05%
Scenario 2 (share TA)	0.35%	0.61%	0.72%

226 billion). By introducing secondary round effects (contagion) losses increase by 40% (from 215 to 298 billion).

Table 6 reports additional funds needed to cancel out these extra losses, and one can see that the amount varies from 10.9 billion to 11.1 billion in Scenario 1, and from 84 billion to 173 billion in Scenario 2, depending on the rule.

**Table 7:** Aggregated extra funds raised by banks to absorb losses stemming from simultaneous defaults

	CRDIV	Rule 2	Rule 3
Scenario 1 (banks required to raise funds)	28	78	11
Scenario 2 (banks required to raise funds)	41	78	11
Scenario 1 (average share a)	0.31%	0.12%	0.21%
Scenario 2 (average share a)	1.79%	1.63%	3.30%
Scenario 1 (average reduction in losses)	2.54%	17.87%	1.90%
Scenario 2 (average reduction in losses)	24.50%	32.41%	19.89%

### 6.3 Assessment of the rules proposed

In the previous section we saw that different rules used to reduce losses have indeed led to a different effect on the amount of extra funds called for the purpose of absorbing extra losses. They also had different impacts on individual banks.

Table 7 summarises the results of each scenario under each rule. Under the CRDIV rule, we impose 28 banks in Scenario 1 and 41 banks in Scenario 2 to convert hybrid capital for an amount equal to 0.3% and 1.8% of RWA, respectively. In these cases, banks profit from additional capital to reduce losses by 2.5% under Scenario 1 and by 24.5% under Scenario 2. Rule 2 imposes an increase in funds of 0.1% (Scenario 1) and 1.6% of RWA (Scenario 2). The increase in capital is lower than before, however all banks here are highly affected, independent of their systemic riskiness. The extra share of CET1 for Rule 3 (GSIBs banks) is estimated to be 0.2% (Scenario 1) and 3% of RWA (Scenario 2). In these cases, loss reduction is 2% and 18% respectively.

Though the differences are small the CRDIV rule seems to be the best way of raising CET1, where only banks involved in a systemic crisis of magnitude (similar to the most recent crisis) are requested to hold extra funds on their balance sheet. Banks required to convert part of their hybrid capital have conditional losses larger than 3% of total assets, and as such, they are indeed less resilient to a systemic shock<sup>10</sup>.

On the contrary, other rules do not detect problematic banks, and to make matters worse, they have a huge impact on those banks which are already safe enough without any intervention from the regulator. In fact, these rules impose a huge loss reduction to German banks even when not needed. Figure 6 presents results for a sub sample of banks. The top plots show the reduction in the conditional loss, while the bottom plots depict the additional funds each bank is required to hold. The results for the full sample are available from the authors upon request.

### 6.4 Identification of the most effective rule for the allocation of extra funds

From the results presented in the previous section, it is clear that different allocation rules have different impacts both on the total amount of extra funds and on the selection of banks. Hence, we need to define a metric to evaluate which rule is the most efficient. The idea to achieve this is to define an elasticity index able to measure which rule has

<sup>10</sup> Cyprus, Spain, Greece, Italy, and Portugal.

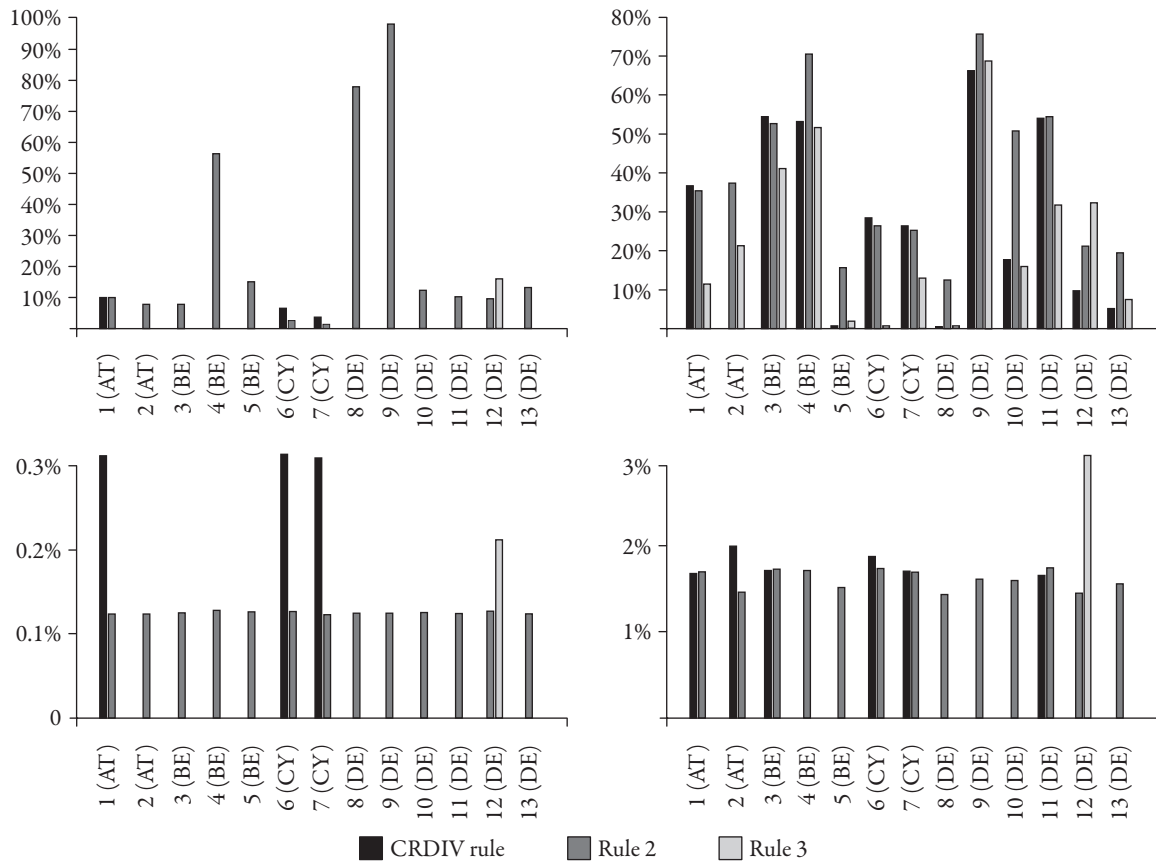


Figure 6: Top plots depict Reduction in the conditional loss as a share of total assets (left panel Scenario 1, right panel Scenario 2). Bottom plots show Extra funds as a share of risk weighted assets (left panel Scenario 1, right panel Scenario 2).

the lowest impact on capital while reducing losses to the target level (no correlation case). We do not limit ourselves to a crisis of 1% of total assets, but instead we consider different crisis levels.

In other words, we look at the whole systemic loss distribution under Scenario 1 and Scenario 2 ( $NSysLoss$ ), and we select the following runs as representatives of different crisis levels:

$$\tilde{j} = \{j \text{ such that } I_l(1) \cdot SysTA \leq NSysLoss \leq I_l(2) \cdot SysTA\}$$

where the intervals  $I_l$  have a length  $l = 0.001$  and range from 0.005 to 0.025:

$$I_l = [0.005 + 0.001(l - 1) : 0.005 + 0.001l]$$

At each crisis level, we compute individual conditional bank loss according to Equation 3 (by averaging individual bank losses over the selected runs). As in Equation 4, we sum them up to obtain the systemic loss of the sample conditional on the  $l^{th}$  crisis level. The elasticity index is then defined considering that the higher the elasticity the more effective the rule is in reducing loss:

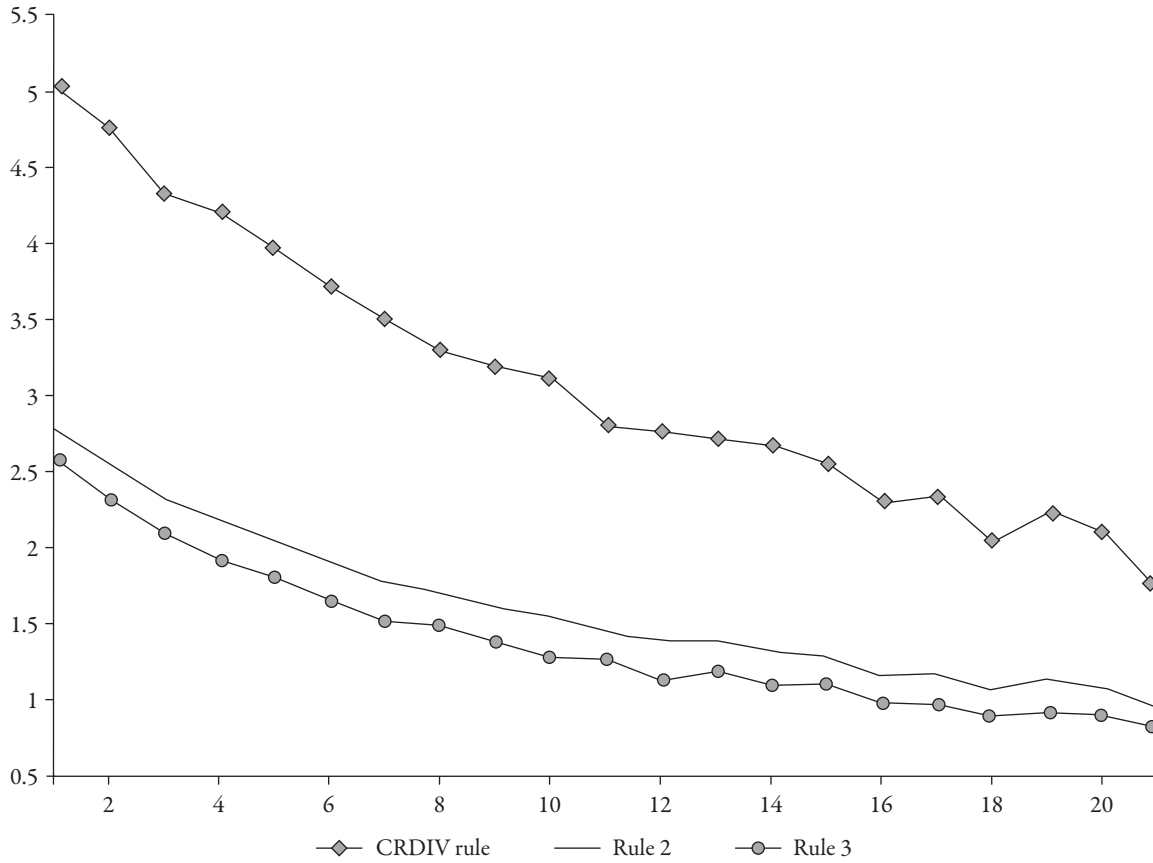


Figure 7: Elasticity index: Scenario 1.

$$Elasticity = \frac{\Delta SystCondLoss}{\Delta Capital}$$

where

$$\Delta SystCondLoss = \frac{CondSystLoss_c - NSystCondLoss}{NSystCondLoss}$$

and

$$\Delta Capital = \frac{\sum (Capital_i + \alpha_i RWA_i)}{\sum Capital_i}$$

Figure 7 shows that the CRDIV rule guarantees the highest level of elasticity under Scenario 1 with respect to Rules 2, 3. In fact, the conversion of hybrid capital whenever the CET1 falls below 5.125% of RWA requires the lower amount of additional funds to the banking sector to get the same systemic loss reduction. Results are similar under Scenario 2.

## 6.5 Robustness checks

In this section we perform three different robustness checks to test whether the CRDIV rule is the most efficient and to ensure that the number of selected banks does not drive results.

### 6.5.1 *Alternative rule (Rule 4)*

The alternative rule used in this section selects random samples of 28 (as in Scenario 1 under the CRDIV rule) and 41 (as in Scenario 2 under the CRDIV rule) banks. Average results show that the random selection of banks leads to an additional capital of 3% and 117% higher than what was found under the CRDIV rule, even if the amount of losses to be covered is the same. Figure 8 plots the confidence interval of our results under Scenario 1 when selecting several random samples of banks to increase capital. The CRDIV rule outperforms in every variation. Results are similar under Scenario 2.

### 6.5.2 *Cluster analysis on balance sheet data*

The second exercise attempts to detect systemic banks from balance sheet information. As the main drivers of the SYMBOL model are RWA, TA, and level of capital, we have clustered banks into two groups based on these two balance sheet ratios, and we have selected a group of 22 banks as candidates for increases in funds.

Figure 8 shows that the elasticity indexes under Scenario 1 for CRDIV rule and for the cluster analysis are very similar, pointing to the ability of CRDIV rule to spot banks weakness in crisis periods. Results are similar under Scenario 2.

### 6.5.3 *Comparison with EBA stress test*

The last exercise is a comparison of our results with the findings of the EBA stress test. We compare the selection of systemic banks made under the CRDIV rule with the banks failing the EBA stress test. Table 7 reports the associated contingency table. Under the CRDIV rule we identify a similar set of problematic banks as found in the 2014 EBA stress tests, with an error of 22% under Scenario 1 and 33% under Scenario 2.

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## 7 Conclusion

In recent years, European regulators have gone through a lot of effort to make the financial sector more stable. Still, the effect of banks being exposed to common macroeconomic shocks and/or to similar market actors has been only scarcely discussed. Even the Basel framework seems to underestimate this aspect.

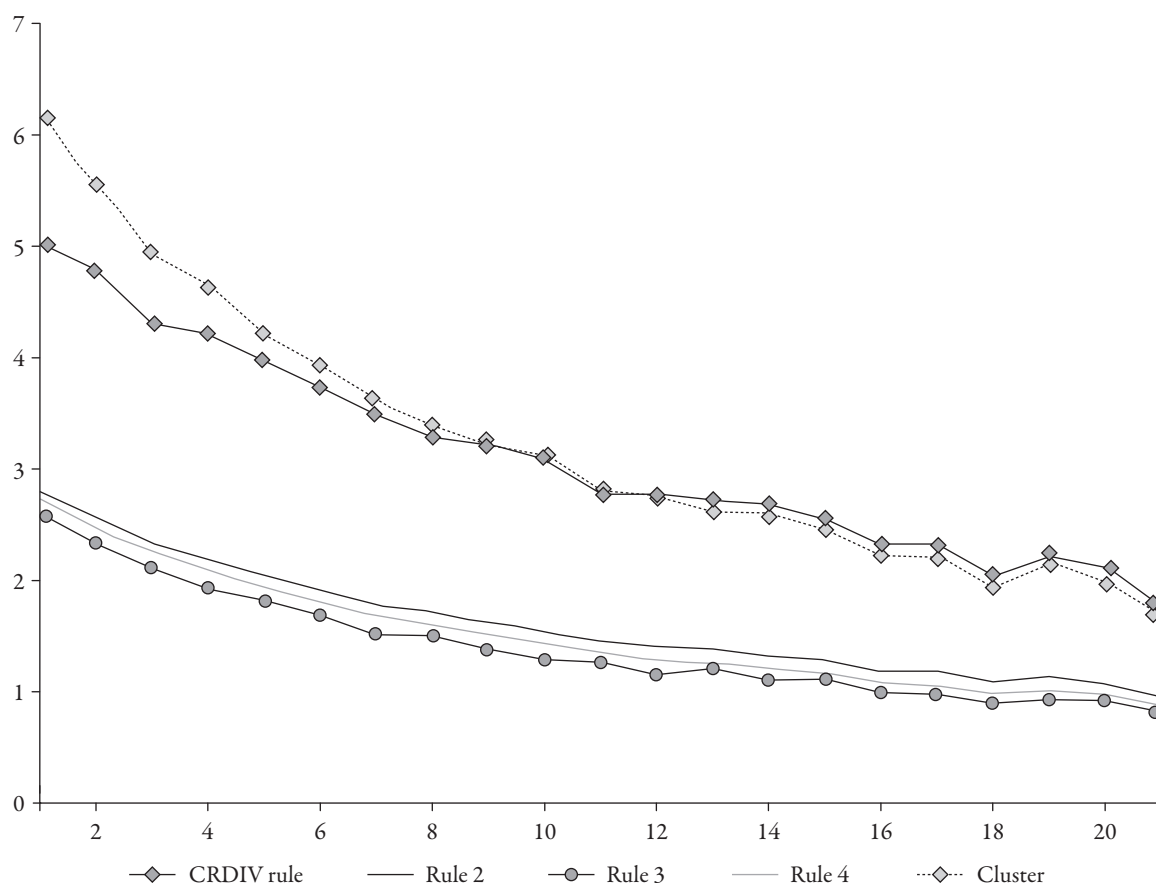


Figure 8: Elasticity index.

Table 8: Contingency table for scenario 1 and 2

		Holding CoCos			
		Scenario 1		Scenario 2	
		Yes	No	Yes	No
Failed EBA stressed test	Yes	15	4	17	2
	No	13	46	24	35

In this paper, we first estimate the amount of extra losses occurring in the banking sector when banks are considered to be part of a system rather than being isolated. Second, we investigate which is the best regulatory instrument to reduce losses to the level foreseen by Basel. In particular, we suppose that banks are interconnected via a correlation structure based on bank specific performance and country specific economic characteristics, we introduce a direct contagion through the interbank market, and we analyse to what extent the level set in legislation for mandatory writing down or conversion into equity of CoCo bonds can help in absorbing extra losses due to correlation.

Losses are generated through a micro simulation portfolio model called SYMBOL which implements the Basel risk assessment framework to estimate the joint distribution



of bank losses. Results show model compliance to the Basel framework even when correlation is considered, and in this case, one can observe a significant increase for losses with respect to the situation when banks are considered as individual entities.

More specifically focusing on the part of the aggregate losses distribution associated with a severe crisis (similar to what experienced during the last financial crisis), losses increase with respect to a baseline scenario (no banks interconnection) by 5% in the presence of a correlation across banks and they increase to 40% when adding secondary round effects.

In order to reduce the losses to the level foreseen by Basel, we propose a set of alternative rules for allocating the extra capital needed to reduce losses. By applying an optimisation procedure, we show that the regulatory rule of requiring extra capital as soon as the common equity falls below the 5.125% of risk weighted assets is more efficient than asking GSIBs (or all banks) to increase their CET1. The same rule enables the identification of a set of problematic banks very similar to what was found in the 2014 EBA stress tests. Finally, the same rule is again found to be the most efficient one to reduce the entire losses distribution.

These results provide evidence that the Capital Requirement Directive IV rule for more capital under which CoCos bonds are provisioned, provides a good way to deal with a key missing piece in the Basel framework.

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