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The European Deposit Insurance Scheme: Assessing risk absorption via SYMBOL

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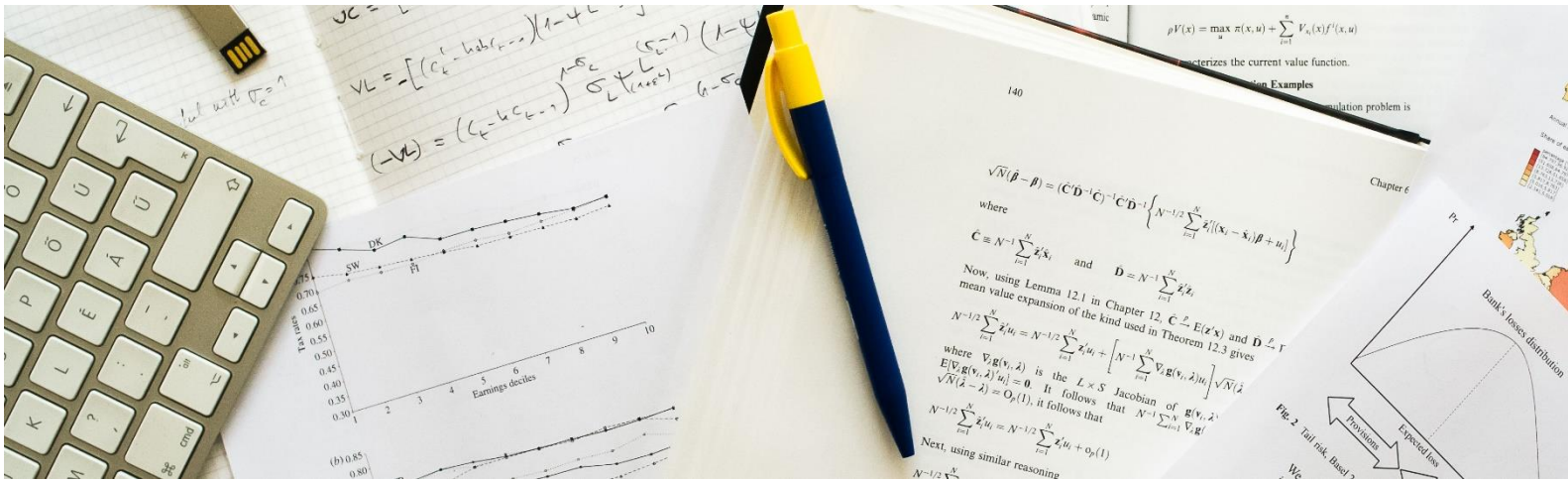

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Abstract
In November 2015, the European Commission adopted a legislative proposal to set up a European Deposit Insurance Scheme (EDIS), a single deposit insurance system for all bank deposits in the Banking Union. JRC was requested to quantitatively assess the effectiveness of introducing a single deposit insurance scheme and to compare it with other alternative options for the set-up of such insurance at European level. JRC compared national Deposit Guarantee Schemes and EDIS based on their respective ability to cover insured deposits in the face of a banking crisis. Analyses are based upon the results of the SYMBOL model simulation of banks' failures. Results show that the fully mutualised fund grants greater protection than the other two options, both in the short term and in the medium/long term, after the recovery procedure and the collection of ex-post extraordinary contributions.
The comparison between the mandatory reinsurance and the mandatory lending schemes demonstrates that the former is more effective than the latter, provided that the central body be granted sufficient funds. The performance of the mandatory lending scheme strongly depends upon the amount of resources provided to the central body and the caps on its intervention.

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1 Introduction

Deposit Guarantee Schemes (DGS) are institutions with the main purpose of reimbursing depositors whenever their bank goes into default. If a credit institution fails, DGS intervene and pay back the bank deposits up to pre-defined limit, currently fixed at 100,000 €.

DGS are in place in all EU member states. Their main features and their functioning have been partly harmonized by Directives 94/19/EC[1], the amending Directive 2009/14/EC[2], and the more recent Directive 2014/49/EC[3]. However, some aspects are still left at the discretion of the national regulation.

In November 2015, the European Commission adopted a legislative proposal to set up a European Deposit Insurance Scheme (EDIS), i.e. a single deposit insurance system for all bank deposits in the Banking Union.[4] In line with the Five-Presidents report (Juncker et al (2015)), the introduction of the European Deposit Insurance Scheme is regarded of as one of the pillars of the Banking Union, with the aim of increasing the resilience of the European banking system against future crises.

The Directorate-General for Financial Stability, Financial Services and Capital Markets Union (DG FISMA) asked the JRC to quantitatively assess the effectiveness of introducing a single deposit insurance scheme as per the Commission proposal and to compare it with other alternative options for the set-up of deposit insurance at the European level. In particular, JRC compared DGS and EDIS based on their respective ability to provide depositor protection in the face of a banking crisis. To do so, we have checked whether DGS and EDIS funds would be sufficient to cover insured deposits held at failing banks, should a banking crisis occur. Such analysis has been carried out by considering banking crises simulations based on the SYMBOL model. The analysis presented in this report is also included in the *effect analysis on EDIS* published by the EC in autumn 2016.[5] Moreover, the JRC has also assessed the effectiveness of EDIS during the transitional period, i.e. the phase where national DGS will be gradually complemented by EDIS.

The report is organized as follows. Section 2 summarizes the policy background, the main features of the functioning of EDIS as foreseen by the Commission proposal and the alternative policy options against which EDIS is evaluated in this report. Section 3 describes how the different policy options are designed for this analysis and the main working hypotheses and Section 4 presents the simulations and the results. Section 5 analyses the transition period foreseen by the Commission proposal to set-up a fully mutualized insurance scheme. Section 6 concludes. Two Annexes accompany the present report: Annex I describes in details the functioning of the SYMBOL model and Annex II reports additional charts complementing the results discussed in Section 4. A list of definitions at the end of the report provides a short definition of the key terms used in the present work.

[1] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31994L0019&from=EN
[2] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0014&from=EN
[3] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0049&from=EN
[4] See https://ec.europa.eu/info/publications/commission-proposal-european-deposit-insurance-scheme-edis_en
[5] See https://ec.europa.eu/info/publications/effects-analysis-european-deposit-insurance-scheme-edis_en
The EC report also includes some analyses, performed by the JRC, which are not reported in this document.

2 The policy background

The main objective of a Deposit Guarantee Scheme is to refund depositors whose bank has failed. According to Directive 2014/49/EC, all EU DGS must, among the other things, guarantee their depositors with a level of coverage equal to 100,000 € and the reimbursement period cannot exceed seven working days.

Pursuant to Directive 2014/49/EC, depositors thus benefit from a timely protection of a substantially large share of their wealth from bank failures. This commitment is beneficial to the stability of the financial system, as it prevents depositors from making panic withdrawals from their bank, which would bring about severe economic consequences.

By 2024 all EU DGS must set aside a fund (target fund) equal to 0.8% of their covered deposits; the fund is financed by banks' ex-ante contributions to the DGS. In case of need, the Directive 2014/49/EC permits DGS to collect additional ex-post contributions, not exceeding 0.5% of the covered deposits on a yearly basis.

In the event of a bank failure, DGS are called to intervene twice. First, DGS must immediately reimburse covered deposits of the failed bank, thus acting as a liquidity provider and substituting depositors as creditors of the failing institution. To meet its pay-out commitments, the DGS make use of their available funds and of the ex-post contributions that can be raised in the few days following the crisis. Later, when the failing bank enters the resolution/insolvency procedure, DGS are regarded of as senior creditors and they may recover (at least part of) the funds used to reimburse depositors in the short term. The amount that is not recovered represents a loss for the DGS. The quantitative analyses developed in this report will reflect both the ability to finance the immediate pay-out and the subsequent potential exposure to losses.

The fully mutualized insurance system, foreseen by the Commission's proposal reflects the third pillar of a fully-fledged Banking Union, alongside bank supervision and resolution (as stated in the Five Presidents' Report, see Juncker et al, 2015).

The rationale for introducing EDIS in the Banking Union is to ensure a level playing field for banks: the vulnerability of national DGS to large local shocks would be reduced, the link between banks and their national sovereigns would further be weakened and depositor confidence would be boosted.

According to the Commission proposal, EDIS will not be immediately introduced, but it will follow a phase-in procedure, where EDIS will gradually complement the national DGS. The legislative proposal envisages two stages for the phase-in: the reinsurance stage during the first three years and the co-insurance stage in a subsequent period of four years. Full mutualisation will be in place from the eighth year onward. Section 5 will describe these phases more in depth and will assess their effectiveness in dealing with bank failures.

2.1 Policy options for EDIS design

The present report aims at evaluating the effectiveness of a fully mutualized insurance scheme (i.e. the steady state deposit insurance scheme under the EDIS proposal) compared to two alternative steady state arrangements.

The options are the following:

- Mandatory reinsurance via funding by a network of national DGS. National DGS transfer part of their funds to a Central Body (CB hereinafter); they intervene first to reimburse the pay-out and, in case they cannot fully cover it, the CB steps in to cover a share of the uncovered amount.

- Mandatory lending among Member States via a network of DGS. National DGS are obliged to lend funds each other, up to certain thresholds, in case a DGS is not able to fully handle the pay-out event
- Full mutualisation among Member States via a single entity. A single DGS is in place to reimburse all the pay-outs occurring in the participating countries until funds available are exhausted. This option represents the steady-state arrangement in the EDIS proposal.

These options reflect different levels and different combinations of risk and governance pooling.[6]

It should be noted that none of the three arrangements envisages a common fiscal backstop, which would be available if EDIS funding (including ex-post contributions by banks) proved insufficient in a crisis. For the purposes of this analysis, if funds are insufficient to fully protect depositors, the ultimate responsibility for deposit insurance is assumed to lie with the Member States concerned. It is beyond the scope of this analysis to investigate the effect of having a common fiscal backstop in place for depositors' protection.

[6] Risk pooling means that national DGS can share losses at a higher (i.e. supranational) level; governance pooling means some form of coordination among national DGS at supranational level when dealing with depositors' protection.

3 The risk absorption design

In this Section, we describe the main working hypotheses and the modelling of the three policy options described in Section 2.1.

The performance of the three systems is assessed against two risk absorption dimensions:

- the ability to cover deposits in the immediate aftermath of a banking crisis (at the pay-out); and
- the ability to cover losses in the medium-long run, i.e. after the liquidation proceeds have been collected.

First, the ability to cover deposits in the immediate aftermath of a banking crisis is measured by the amount of insured deposits that are not covered, given that the funds immediately available are insufficient. The available funds comprise the national DGS pre-funded amount, together with the liquidity made available:

- by the central body in case of the reinsurance, or
- by other DGSs in the form of mandatory loans.

Second, the ability to cover losses in the medium term is measured as the probability of not being able to fully recover the moneys used for the pay-out and the amount of losses that are ultimately borne by the national DGS and the central body in the medium-long term, computed as the difference between the initial pay-out and the funds only available at a later stage. These funds include:

- long-term extraordinary contributions that can be collected within 1 year;
- amounts recovered from banks' insolvency procedures, and
- in the case of the reinsurance scheme, the share of uncovered losses taken up by a central body.

In this analysis, it is assumed that extraordinary ex-post contributions are not raised in the short term (few days after the crisis) to repay depositors, but are available only in the long term to cover the DGS losses. Long term extraordinary contributions are set equal to 0.5% of the amount of covered deposits of the relevant Member State.

As regards the computation of the amounts recovered from banks' insolvency procedures, the recovery rate has been alternatively set equal to:

- 90% of the amount of covered deposits of the failing banks, i.e. a 30 percentage points increase over the average recovery rate in the EU,
- country-specific recovery rates, increased by 30% to reflect that DGS claims will receive priority in a resolution/insolvency procedure under the Bank Recovery and Resolution Directive (BRRD)[7].

3.1 Mandatory reinsurance

In a mandatory reinsurance system, national DGSs operate alongside an *ex-ante* funded central body (CB). National DGSs are required to reimburse pay-outs and only if there are still uncovered deposits and national funds are fully depleted, the CB intervenes. The following key assumptions underpin the reinsurance model.

- Member States have achieved on aggregate the target (0.8% of covered deposits), which is partly allocated to the CB and partly to national DGSs. *Beta (β)* is the share of funds that remains available to the national DGS. Available financial means to DGS (see the list of definitions at the end of the report) are computed as:

$$AFM = \beta * 0.8\% \sum_{i \in MS} CovDep_i$$

[7] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0059&from=EN

The complementary share (1- β) of covered deposits goes to the central body.

The analysis assesses three scenarios:

- β = 75%, (i.e. 0.2% of covered deposits sit with the CB while 0.6% of covered deposits are available in national DGSs).
- β = 50% (i.e. 0.4% of covered deposits sit with the CB with an equal amount being available at national DGSs)
- β = 25% (i.e. 0.6% of covered deposits sit with the CB with 0.2% of covered deposits being available at national DGSs).

- When necessary, the central body intervenes to provide reinsurance liquidity to cover a share *alpha* (α) of liquidity shortfalls. This is a first cap. Alpha may vary over a wide range of values, up to 100%.
- The total amount that the CB can contribute to is also capped, according to the following formula:

$$Cap = min\left\{z * [\beta * 0.8\%] * \sum_{i \in MS} CovDep_i \,;\, y * [(1-\beta) * 0.8\%] * \sum_{i \in EU} CovDep_i\right\}$$

  This cap is equal to the smallest of following:

  - On the one hand, it considers the funds available at the national DGS (equal to the share β of the total target described above), and multiplied by a factor z>1.
  - On the other hand, it considers the share of the target available at the aggregate EU-level, multiplied by a factor y<1.

  This cap applies to both the liquidity provided in the short term and the amount of losses borne by the CB in the long term.

- The DGS can call on banks to supply extraordinary contributions (0.5% of covered deposits) to cover its losses.

In order to compare different options, the mandatory reinsurance model is assessed with different combinations of parameters' values, which are summarized in Table 1.

TABLE 1: PARAMETERS USED FOR THE ANALYSIS OF MANDATORY REINSURANCE

β	α	z	y
75%	20%	10	20%
75%	20%	10	80%
75%	80%	10	20%
75%	80%	10	80%
75%	60%	10	60%
75%	100%	10	100%
50%	20%	10	20%
50%	20%	10	80%
50%	80%	10	20%
50%	80%	10	80%
50%	60%	10	60%
50%	100%	10	100%
25%	20%	10	20%
25%	20%	10	80%
25%	80%	10	20%
25%	80%	10	80%
25%	60%	10	60%
25%	100%	10	100%

Note: *β is the share of funds that remains available to the national DGS; α is the share of liquidity shortfall that can be covered by the central body; z and y are two parameters in the formula*

defining the maximum amount (cap) of the central body's funds that can be used by a single DGS: z is a multiple of a single DGS resources, y is a share of the resources of the CB.

3.2 Mandatory lending

Under the mandatory lending approach, whenever a national DGS experiences a liquidity shortfall, the other DGSs are mandated to lend money to the DGS whose available financial means have been depleted. The lending regime is subject to specific conditions:

- The AFM of each DGS correspond to the full target, as defined in the DGSD (0.8% of the total amount of covered deposits in the relevant MS);
- The total amount that can be borrowed is capped to 0.5% of the covered deposits of the borrowing DGS;
- The loan is apportioned among creditor DGSs in proportion to their size;
- Loans are assumed to be recovered at 100% and for this purpose the borrowing DGS raises the maximum amount of ex-post contributions (0.5% of covered deposits); if the loan received is lower than the ex post contributions residual resources are used to cover the losses of the DGS.

3.3 Fully mutualized fund

Under this scenario, a single deposit insurance fund at EU-28 level is established. The AFM are equal to 0.8% of covered deposits in the EU. As there is no external actor providing extra resources, there is no distinction between liquidity shortfall and liquidity retention. The fully mutualised fund can call for extraordinary contributions from participating banks (0.5% of covered deposits) to cover its losses.

4 Simulation exercise

This section tests the three policy options described in Section 3 by simulating multiple DGS pay-outs via the SYMBOL model and applying the approach developed by Cariboni et al (2015a).[8] The SYMBOL model (SYstemic Model of Bank Originated Losses, originating from De Lisa et al, 2011, see Annex I for a description of the model) is a micro-simulation portfolio model. It implements the Basel risk assessment framework to estimate the joint distribution of bank losses at EU level and uses the unconsolidated balance sheet data of individual European banks to calculate the probabilities of default. For each bank in each simulation run, SYMBOL determines whether it fails or not. In the current analyses, a bank failure happens when simulated gross losses exceed the total actual capital. These cases trigger the DGS intervention to reimburse the amount of covered deposits of the failed banks.[9] For the purpose of the present exercise, each Monte Carlo simulation ends when 100,000 runs with at least one bank failure are obtained. Results are then aggregated at the EU level. The same set of underlying simulated banks' failures is used to assess the performance of the three policy options.

After simulating banks' shocks, the model calculates aggregate shortfalls, i.e. losses not covered by national DGSs and by the different European solutions, and compares them between the three models to establish which one minimises the shortfall for the national and EU DGSs. In other words, it estimates the absorption capacity of the three models discussed above, when the banking system suffers an asymmetric shock.

4.1 Sample description

The banks data used for the present exercise is as of 2013. The data provider is Bankscope, a proprietary database of banks' financial statements produced by Bureau van Dijk. The dataset covers a sample of around 3,400 banks from the EU28, representing 99.86% of EU28 banks' total assets.[10] Pursuant to the Commission proposal, EDIS is foreseen for the banks and countries joining the Banking Union. Since in principle the Banking Union is open to all MS willing to join it, the analysis on EDIS effectiveness at a steady state is performed assuming that all EU28 MS benefit from EDIS coverage.

Simulations run using data on total assets, risk-weighted assets and total capital and/or capital ratios, as well as customer deposits. Missing values are imputed through robust statistics (see Cannas et al (2013)).

Data on the amount of covered deposits held by each bank are not provided by Bankscope. Hence, we resort to alternative sources, namely we make use of statistics at country level elaborated by the JRC (see Cannas et al (2015) for details on the estimation techniques). We estimate the amount of customer deposits held by each bank by computing the ratio of covered deposits over customer deposits at the country level and then applying this proportion the customer deposit figures provided by Bankscope. Table 2 shows aggregated values for some selected variables of the dataset.

TABLE 2: 2013 AGGREGATED UNCONSOLIDATED AMOUNT OF SELECTED VARIABLES FOR THE BANKS IN THE SAMPLE

	Number of banks	**Total assets bn€**	**RWA bn€**	**Covered deposits bn€**	**Capital bn€**
2013	3,359	38,144	14,635	6,474	1,939

[8] Note that Cariboni et al. (2015a) run simulations country by country independently. Instead, we first simulate losses jointly for all EU 28 banks, then distribute them across countries. This simulation approach is the same applied in Cariboni et al (2015b).

[9] The model also allows running the analysis by assuming that larger banks would be resolved while only the smaller banks would go into insolvency.

[10] We use the amount of total assets in the banking sector excluding branches as provided by ECB as reference for the population.

Data are corrected to reflect the Basel III definitions of capital and risk weighted assets. Corrections are based on the European Banking Authority and the Committee of European Banking Supervisors yearly exercises (Quantitative Impact Study, QIS), assessing and monitoring the impact of the new capital standards on European banks' balance sheet data[11]. In particular, the studies estimate what would be the average correction factor to move from reported capital and risk-weighted assets to a framework compliant with the new rules. For clarity purposes, Table 3 shows the adjustments applied to the 2013 balance sheet data.

TABLE 3: CORRECTION FACTORS APPLIED TO CAPITAL AND RWA

	G1 banks Tier1 K > 3bn€	**G2 banks** Tier1 K < 3bn€	**G2 banks Medium** 1.5bn€ < Tier1 K < 3bn€	**G2 banks Small** Tier1 K < 1.5bn€
Capital correction	0.8	0.86	0.85	0.87
RWA correction	1.1	1.11	1.12	1.05

Data on recovery rates at country level come from the World Bank Doing Business report (World Bank, 2016). These data have been increased by 30% to reflect the new BRRD seniority of DGS claims in the insolvency procedure.

4.2 Key Results

We use the outcome of SYMBOL simulations and model the three policy options as described in Section 3. We compare the three options as follows:

- Fully mutualised fund against mandatory lending
- Fully mutualised fund against mandatory reinsurance
- Mandatory reinsurance against mandatory lending

In each case, both the short term (uncovered liquidity shortfall) and the medium-long term performance (uncovered loss) are evaluated. The reported charts and figures refer to rather extreme crisis scenarios, involving simulations where at least one of the two compared schemes yields uncovered liquidity shortfall or loss. In less extreme scenarios (some 90% of the simulations), the alternative schemes are obviously equivalent.

All charts presented in this section focus on the worst 1% of simulations (i.e. percentiles from 99th to 100th on the x-axis), corresponding to banking crises of increasing severity. In all charts, the severity of the crisis increases moving from the left to the right.

4.2.1 The fully mutualised fund against mandatory lending

Figure 1 shows the distribution of uncovered liquidity shortfall associated with each SYMBOL simulation. Points on the far right of the curve represent more severe crisis scenarios, and are indeed associated with larger amounts of uncovered liquidity shortfall. The curve representing uncovered liquidity shortfall under mandatory lending (dotted) is always above the curve representing uncovered liquidity shortfall under the mutualised fund (solid). Though the latter is not a proper distribution, it allows comparing events belonging to the same simulation run. Results show that in none of the simulations mandatory lending is able to deliver a smaller amount of uncovered liquidity shortfall than a fully mutualised fund. This is because loans are capped at 0.5% of the covered deposits of the borrowing DGS under mandatory lending, while under fully mutualised fund a larger amount of liquidity is available.

Figure 2 shows the distribution of medium-long term uncovered losses associated with each SYMBOL simulation. Results demonstrate that full mutualisation again turns out to

[11] See European Banking Authority (2014) for 2013 data.

be superior to mandatory lending in terms of uncovered losses for national DGS. Indeed, the curve representing uncovered losses under mandatory lending (dotted) is always above the curve representing uncovered losses under full mutualisation (solid). In other words, uncovered losses under full mutualisation are always smaller than under mandatory lending. This is due to the fact that under mandatory lending, extraordinary contributions raised by the DGS and amounts recovered from insolvency procedures are devoted to repay the loans instead of being used to cover the DGS losses.

FIGURE 1: AGGREGATE UNCOVERED LIQUIDITY SHORTFALL UNDER MANDATORY LENDING (DOTTED LINE) AND FULLY MUTUALISED FUND (SOLID LINE), EU28.

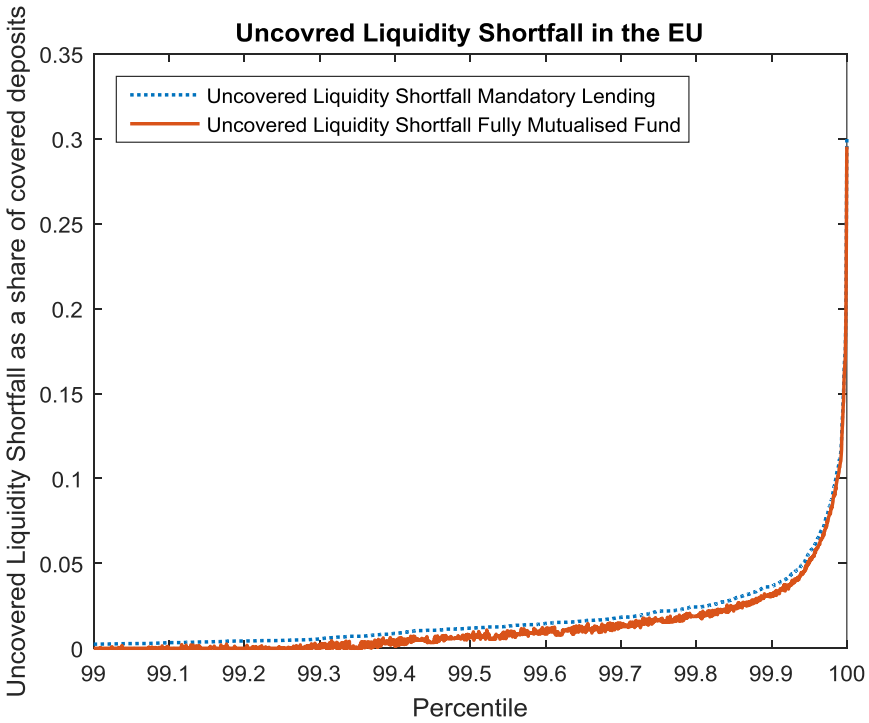
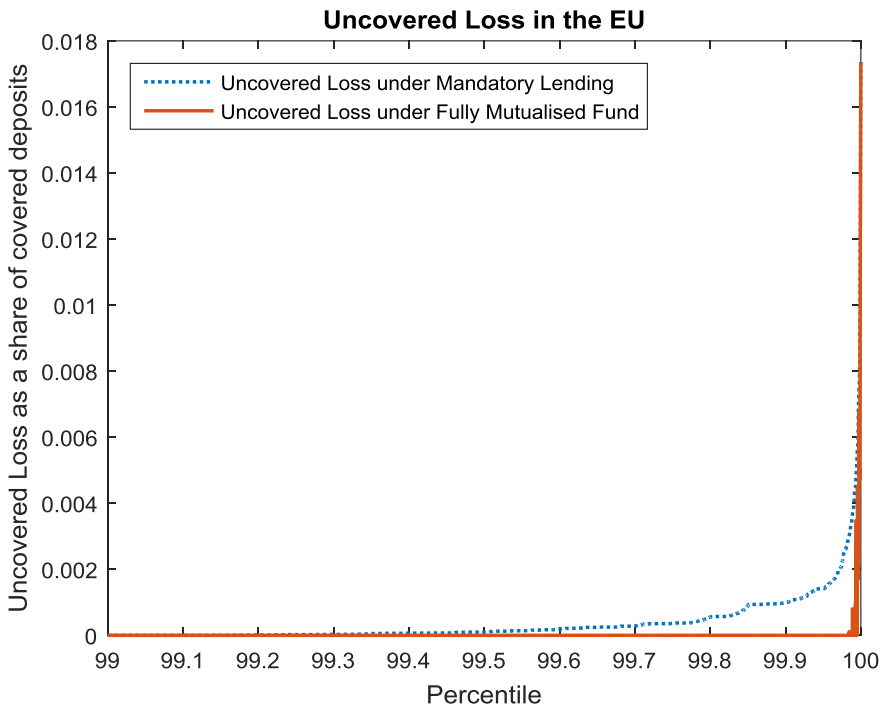


FIGURE 2: AGGREGATE UNCOVERED LOSSES UNDER MANDATORY LENDING (DOTTED LINE) AND UNDER FULLY MUTUALISED FUND (SOLID LINE), EU28



4.2.2 The fully mutualised fund against mandatory reinsurance

The fully mutualised fund offers greater absorption capacity than mandatory re-insurance for short term uncovered liquidity needs in all the simulations. This is because more funds are available to the national DGS under a fully mutualised fund than under mandatory re-insurance, where various caps are foreseen. Figure 3 shows how the curve associated with the fully mutualised fund (solid) is always below the curve associated with the mandatory re-insurance scheme (dotted), when β equals 50%, and α and y are both set at 100%.

The difference between the two curves becomes clearer when looking at the absolute amounts: the average additional support provided by a fully mutualized fund along the relevant simulations is around 10.6 billion € and it can increase up to 45 billion €. To illustrate this in more detail, one could consider the median size of deposits per household in the EU, which is 5,900 €[12]. This means, on average, that a fully mutualized fund would cover 1.8 million of households more than a re-insurance scheme with β equals 50%, and α and y are both set at 100%. Considering that the average household in the EU covers 2.3 people[13], EDIS could protect additional 4.1 million people, which is roughly the population of Ireland. When considering the maximum difference between both options, i.e. 45 billion €, the additional support would be correspondingly higher[14].

Results similar to those shown in Figure 3 hold for other combinations of parameters (see Annex II).

A fully mutualised fund offers greater absorption capacity than mandatory re-insurance also for medium-long term uncovered losses. As the amount of losses borne by the central body is capped under mandatory reinsurance, the central body can bear losses

[12] See ECB statistics: https://www.ecb.europa.eu/pub/pdf/scpsps/ecbsp18.en.pdf?d2911394a25c444cd8d3db4b77e8891a%20
[13] See http://ec.europa.eu/eurostat/statistics-explained/index.php/Household_composition_statistics
[14] 7.6 million of households corresponding to 17.5 million people.

until its funds are depleted under the fully mutualised fund. As suggested in Figure **4**, the amount of uncovered losses is larger under reinsurance than under full mutualisation in every SYMBOL simulation.

FIGURE 3: AGGREGATE UNCOVERED LIQUIDITY UNDER MANDATORY REINSURANCE (DOTTED LINE) AND UNDER FULLY MUTUALISED FUND (SOLID LINE), EU28. β EQUALS 50%, α AND Y ARE BOTH SET AT 100%.

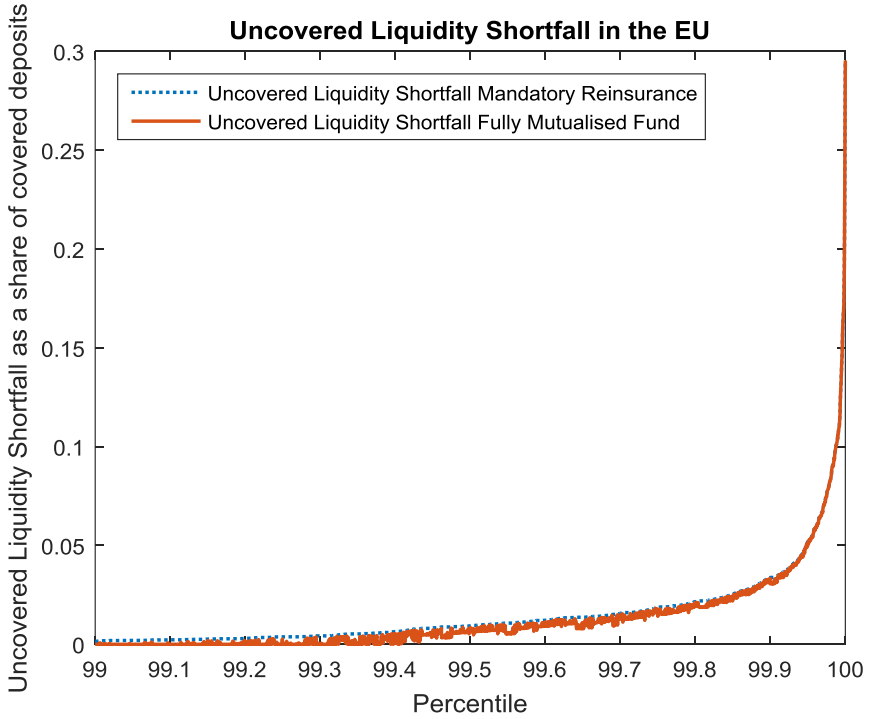
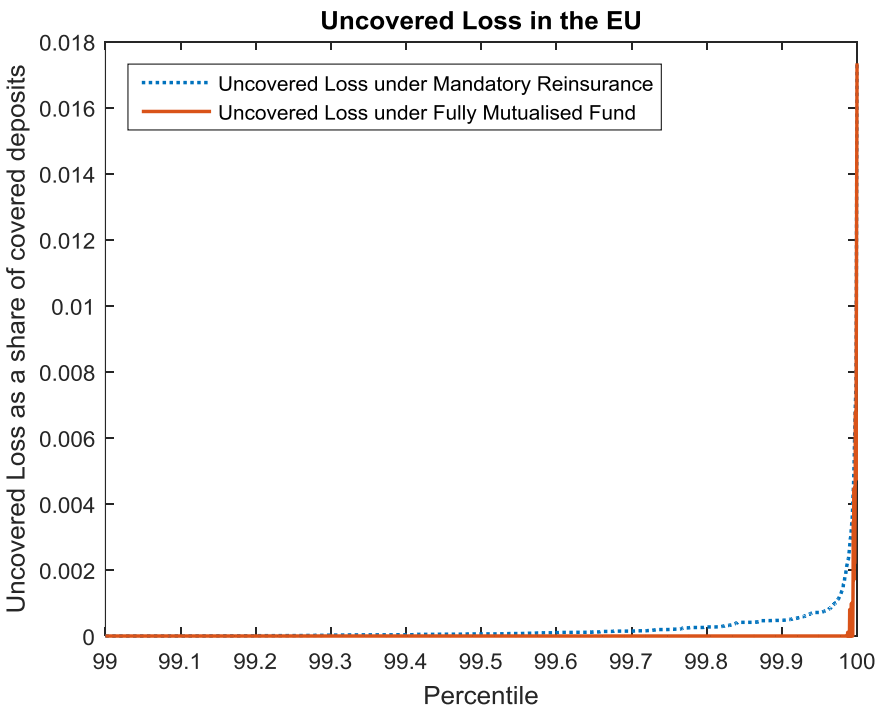


FIGURE 4: AGGREGATE UNCOVERED LOSSES UNDER MANDATORY REINSURANCE (DOTTED LINE) AND UNDER FULLY MUTUALISED FUND (SOLID LINE), EU28. β EQUALS 50%, α AND Y ARE BOTH SET AT 100%.



4.2.3 Mandatory reinsurance against mandatory lending

As regards comparing mandatory reinsurance and mandatory lending, additional statistics are provided. Table 4 shows how the two models perform in terms of uncovered liquidity shortfall and uncovered losses. The table reports the share of simulations in which the better arrangement yields lower uncovered liquidity and uncovered losses.

The relative performance of the two schemes with respect to uncovered liquidity shortfall and uncovered losses crucially depends on the parameters underlying the mandatory reinsurance scheme. As expected, parameters with lower caps of available reinsurance funds are associated with a worse performance of the mandatory reinsurance scheme compared to mandatory lending in the short (uncovered liquidity shortfall) and in the long run (uncovered losses). However, when mandatory reinsurance caps are high, the mandatory reinsurance delivers a better coverage than mandatory lending of short term liquidity and long-term loss cover needs.

As regards the combination of the two caps, raising the share α of liquidity shortfall that can be re-insured from 20% to 80%, while keeping y (cap on the coverage) at 20%, improves the performance of the reinsurance arrangement so that mandatory reinsurance becomes broadly comparable to mandatory lending. When y is set at 80%, raising α from 20% to 80% makes re-insurance the preferred arrangement over mandatory lending. The above results are valid both under a balanced split of funds between the central body and the national DGS (β=50%) and under an unbalanced split (β =75% or 25%). Analogously to what happens when varying α, the performance of re-insurance improves under larger y. However, even with y=80%, α needs to be set at a larger value for reinsurance to outperform mandatory lending. In general, if either α or y are set too low, no matter how large the other parameter is, mandatory lending will turn out to be preferable under current arrangements.

Moreover, while mandatory reinsurance prevails for higher caps in most of the runs, there are also two cases in which the mandatory reinsurance arrangement is strictly superior to the mandatory lending arrangement, i.e. the latter is outperformed in 100% of the simulations. This occurs if the CB is allocated half (β =50%) or ¾ (β =25%) of the funds, with caps on uncovered liquidity shortfall (α) and uncovered loss (y) at 100% (i.e., full cover).

For long-term uncovered losses, the re-insurance arrangement turns out to be generally preferable for higher caps of loss cover (for α at least equal to 60% or to 80% in case national DGSs are allocated ¼ of the resources), when the recovery rate is set at 90% for all the countries (see Table 5). This is in line with the fact that increasing the amount of resources available at European level makes the reinsurance arrangement absorb more losses. However, if the simulation uses recovery rates of individual Member States (with an increase of 30% to take into account the BRRD priority for DGS claims), the mandatory reinsurance arrangement performs better even with higher caps of loss coverage only (see Table 4). This might be due to the fact that banks with more distressed balance sheets tend to be in countries where the legal framework is more uncertain.

TABLE 4: MANDATORY REINSURANCE VS MANDATORY LENDING WITH INDIVIDUAL MSS' RECOVERY RATE (INCREASED BY 30% TO FACTOR IN THE BRRD PRIORITY FOR DGSS' CLAIMS)

Re-insurance parametrization		Liquidity		Loss	
		Preferred scheme	Share of simulations in which the preferred scheme outperforms the competitor	Preferred scheme	Share of simulations in which the preferred scheme outperforms the competitor
beta = 75% (0.6% to DGS - 0.2% to CB)	alpha = 20%, y = 20%	ML	68%	R	73%
	alpha = 20%, y = 80%	ML	57%	R	73%
	alpha = 80%, y = 20%	R	52%	R	97%
	alpha = 80%, y = 80%	R	73%	R	97%
	alpha = 60%, y = 60%	R	59%	R	93%
	alpha = 100%, y = 100%	R	98%	R	100%
beta = 50% (0.4% to DGS - 0.4% to CB)	alpha = 20%, y = 20%	ML	74%	R	52%
	alpha = 20%, y = 80%	ML	66%	R	52%
	alpha = 80%, y = 20%	R	50%	R	85%
	alpha = 80%, y = 80%	R	66%	R	85%
	alpha = 60%, y = 60%	R	57%	R	81%
	alpha = 100%, y = 100%	R	100%	R	100%
beta = 25% (0.2% to DGS - 0.6% to CB)	alpha = 20%, y = 20%	ML	82%	ML	65%
	alpha = 20%, y = 80%	ML	77%	ML	65%
	alpha = 80%, y = 20%	ML	62%	R	74%
	alpha = 80%, y = 80%	ML	51%	R	74%
	alpha = 60%, y = 60%	ML	59%	R	66%
	alpha = 100%, y = 100%	R	100%	R	100%

TABLE 5: MANDATORY REINSURANCE VS MANDATORY LENDING WITH RECOVERY RATE = 90%

Re-insurance parametrization		Liquidity		Loss	
		Preferred scheme	Share of simulations in which the preferred scheme outperforms the competitor	Preferred scheme	Share of simulations in which the preferred scheme outperforms the competitor
beta = 75% (0.6% to DGS - 0.2% to CB)	alpha = 20%, y = 20%	ML	68%	ML	55%
	alpha = 20%, y = 80%	ML	57%	ML	55%
	alpha = 80%, y = 20%	R	52%	R	88%
	alpha = 80%, y = 80%	R	73%	R	88%
	alpha = 60%, y = 60%	R	59%	R	84%
	alpha = 100%, y = 100%	R	98%	R	100%
beta = 50% (0.4% to DGS - 0.4% to CB)	alpha = 20%, y = 20%	ML	74%	ML	84%
	alpha = 20%, y = 80%	ML	66%	ML	84%
	alpha = 80%, y = 20%	R	50%	R	73%
	alpha = 80%, y = 80%	R	66%	R	73%
	alpha = 60%, y = 60%	R	57%	R	67%
	alpha = 100%, y = 100%	R	100%	R	100%
beta = 25% (0.2% to DGS - 0.6% to CB)	alpha = 20%, y = 20%	ML	82%	ML	97%
	alpha = 20%, y = 80%	ML	77%	ML	97%
	alpha = 80%, y = 20%	ML	62%	R	55%
	alpha = 80%, y = 80%	ML	51%	R	56%
	alpha = 60%, y = 60%	ML	59%	ML	53%
	alpha = 100%, y = 100%	R	100%	R	100%

It should be noted that if losses are very small, the share borne by the CB under re-insurance may turn out to be lower than the funds initially contributed by the national DGS to the central fund. In line with any insurance mechanism, the insurance premium

may turn out to be larger than the payout, if the event triggering coverage is associated with a small enough loss.

5 Analysis of uncovered liquidity and uncovered losses in the transitional period

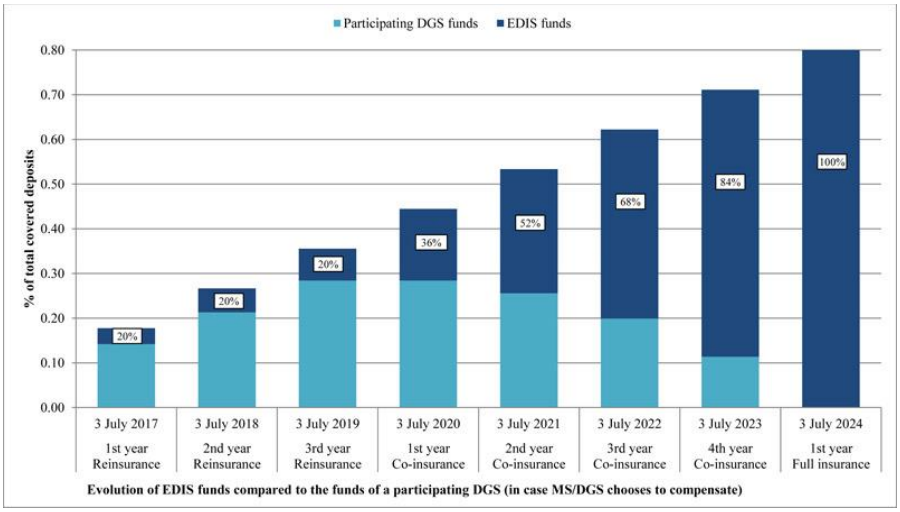
As already mentioned, the introduction of a fully mutualized fund to protect depositors will not be immediate, but it will follow a phase-in procedure characterised by an increasing degree of mutualisation in terms of funds and interventions. The phase-in procedure is expected to last 7 years and it is divided into three phases, namely **reinsurance, co-insurance** and, starting from the 8th year, **full mutualilzation**. Over the whole transition period, the AFM at the disposal of a given national DGS are a share $\beta(t)$ of the target fund collected up to time *t*, while the complementary share is transferred to the EDIS. Technically:

$$AFM^{DGS} = \beta(t) \cdot target(t)$$

$$AFM^{EDIS} = (1 - \beta(t)) \cdot target(t)$$

where $\beta(t)$ and *target(t)* are defined according to Figure 5 ($\beta(t)$ corresponds to the light blue part and *target(t)* is the overall height of the bars).

FIGURE 5: EVOLUTION OF EDIS FUNDS COMPARED TO THE FUNDS OF A PARTICIPATING DGS



Source: DG FISMA, https://ec.europa.eu/info/system/files/graph-15112014_en.pdf

In this Section, we detail the functioning of the first two phases only (being full mutualisation already analysed) and we assess their effectiveness in providing depositors protection.

5.1 Reinsurance phase

During this phase, national DGSs are first called to reimburse pay-outs. If the DGS is not able to fully cover the pay-out, EDIS steps in and it covers a share α_r of the amount that remains uncovered by the national DGS (liquidity shortfall). In formulas (for simplicity we suppress the reference to the time *t*):

$$Liq\ shortfall^{DGS} = Covered\ deposits^{DGS} - AFM^{DGS} - SC^{DGS}$$

$$Reinsurance_{liquidity} = \alpha_r \cdot Liq\ shortfall^{DGS}$$

$$Liq\ retention^{DGS} = (1 - \alpha_r) \cdot Liq\ shortfall^{DGS}$$

In other words, the national DGS, using its AFM and raising short-term extraordinary contributions (SC), is called upon to reimburse the covered deposits of the distressed banks. What is left, if any, is partially transferred to the EDIS, which uses the funds at its disposal to cover such shortfall.

$$Liq\ retention^{EDIS} = \sum_i Reinsurance_{liquidity}{}^{DGS_i} - AFM^{EDIS}$$

The remaining part, i.e. the amount of deposits that neither the national DGS nor EDIS is able to cover, is called *uncovered liquidity shortfall.*

Failed banks enter an insolvency procedure, which lasts much longer than the few days in which liquidity must be provided to reimburse covered deposits. During this phase, national DGSs and the EDIS are treated as senior creditors and may recover an amount *R*. Moreover, the DGS can call long-term extraordinary contributions (*EC*). *R* and *EC* can be used to cover the liquidity shortfall. The amount of deposits that remains uncovered after recovery and *EC* is called *excess loss*:

$$ExcLoss^{DGS} = Liq\ shortfall^{DGS} - R - EC^{DGS}$$

The second function of the European reinsurance scheme is to cover a share α_r of the excess loss:

$$Reinsurance_{loss} = \alpha_r \cdot ExcLoss^{DGS}$$

$$Loss\ retention^{DGS} = (1 - \alpha_r) \cdot ExcLoss^{DGS}$$

$$Loss\ retention^{EDIS} = \sum_i Reinsurance_{loss}{}^{DGS_i} - AFM^{EDIS}$$

Over time the reinsurance scheme would have constant coverage, i.e. α_r is time-independent.

Both the short-term funding provided by EDIS ($Reinsurance_{liquidity}$) and the amount of losses that is in the end borne by EDIS ($Reinsurance_{Loss}$) are capped according to the following formulas:

$$Cap_{liquidity} = min\left\{z * 0.8\% * \sum_{i \in MS} CovDep_i\,; y * 20\% * \frac{(t+1)}{9} * 0.8\% * \sum_{i \in EuroArea} CovDep_i\right\}$$

$$Cap_{losses} = min\left\{z * 0.8\% * \sum_{i \in MS} CovDep_i\,; y * 20\% * \frac{(t+1)}{9} * 0.8\% * \sum_{i \in EuroArea} CovDep_i\right\}$$

where *t*=1,2,3 (*t*=1 corresponding to 2017 and *t*=3 corresponding to 2020) and z and y are the parameters already discussed in Section 3.1.

5.2 Co-insurance phase

In the co-insurance regime, the EDIS contributes a share α_c to each pay-out starting from the first Euro. This share increases over time (e.g., linearly rising from 20% to 100% over five years). At the same time, AFM of the national DGS shrink over time, as funds are increasingly transferred to the EDIS (see Figure 5).

$$Coinsurance_{liquidity} = \alpha_c \cdot Covered\ Deposits^{DGS}$$

$$Liq\ retention^{DGS} = (1 - \alpha_c) \cdot Covered\ Deposits^{DGS} - AFM^{DGS} - SC^{DGS}$$

$$Liq\ retention^{EDIS} = \alpha_c \cdot \sum_i Covered\ Deposits^{DGS_i} - AFM^{EDIS}$$

The excess loss remaining once the insolvency procedure is over and long-term ex-post contributions have been called is computed as follows:

$$Coinsurance_{loss} = \alpha_c \cdot (Covered\ Deposits^{DGS} - R)$$

$$Loss\ retention^{DGS} = (1 - \alpha_c) \cdot (Covered\ Deposits^{DGS} - R) - AFM^{DGS} - EC^{DGS}$$

$$Loss\ retention^{EDIS} = \alpha_c \cdot \sum_i (Covered\ Deposits^{DGS_i} - R) - AFM^{EDIS}$$

5.3 Assessment of the reinsurance and co-insurance phases

The assessment of the reinsurance and co-insurance phases in EDIS is based on the SYMBOL model and follows the same approach described in Section 4. This piece of analysis covers banks in the Banking Union.

The simulations presented in this section are based on end-of-year unconsolidated banks' balance sheet data gathered through Bankscope. The dataset covers a sample of around 2,900 Euro Area banks as of 2013. Table 6 shows aggregated values for some selected variables.

TABLE 6: 2013 AGGREGATED UNCONSOLIDATED AMOUNT OF SELECTED VARIABLES FOR THE EURO AREA BANKS IN THE SAMPLE

	Number of banks	**Total assets bn€**	**RWA bn€**	**Covered deposits bn€**	**Capital bn€**
2013	2,885	25,267	9,505	4,774	1,627

Following the procedure already describe for the EU28 sample in Section 4.1, missing values are imputed through robust statistics and data are corrected to reflect the Basel III definitions of capital and risk weighted assets.

The analysis uses the following working hypotheses:

- Short-term extraordinary contributions are set equal to 0, while long-term extraordinary contributions are fixed at 0.5% of the amount of covered deposits of the relevant MS;
- The recovery rate from insolvency procedures is set equal to 60% of the amount of covered deposits of the failing banks;
- The set of parameters tested is summarised in Table 7 and Table 8 for the reinsurance and the co-insurance phases respectively.

TABLE 7: PARAMETERS USED FOR THE ANALYSIS OF THE REINSURANCE PHASE

T	$\boldsymbol{\beta(t)}$	$\boldsymbol{\alpha_r}$	**z**	**y**
1	80%	20%	10	20%
2	80%	20%	10	20%
3	80%	20%	10	20%
1	80%	40%	10	40%
2	80%	40%	10	40%
3	80%	40%	10	40%

Note: *β is the share of funds that remains available to the national DGS; α is the share of liquidity shortfall that can be covered by EDIS; z and y are two parameters in the formula defining the maximum amount (cap) of EDIS's funds that can be used by a single DGS: z is a multiple of a single DGS resources, y is a share of the resources of EDIS.*

TABLE 8: PARAMETERS USED FOR THE ANALYSIS OF THE CO-INSURANCE PHASE

T	$\boldsymbol{\beta(t)}$	$\boldsymbol{\alpha_c}$
4	64%	20%
5	48%	40%
6	32%	60%
7	16%	80%

Note: *β is the share of funds that remains available to the national DGS; α is the share of liquidity shortfall that can be covered by EDIS; z and y are two parameters in the formula defining the maximum amount (cap) of EDIS's funds that can be used by a single DGS: z is a multiple of a single DGS resources, y is a share of the resources of EDIS.*

Key results of the SYMBOL analysis are reported in in Table 9 (fully national system versus reinsurance) and Table 10 (fully national system versus coinsurance). Considering the co-insurance phase and going towards full mutualisation, uncovered liquidity and uncovered losses are smaller than under a fully national system, i.e. the performance of EDIS is increasing from the start of co-insurance.

Uncovered liquidity and uncovered losses are similar under the re-insurance phase and under a fully national system.

As shown in Table 9 and Table 10, the percentage of simulations in which a fully national system is better able to cover liquidity needs and losses is never above 50%, i.e. re-insurance as well as co-insurance are superior independent of the assumed parameters. Re-insurance (as transitional stage) would have weaknesses in particular as the financial capacity of the EDIS fund is very limited in its start-up phase and because the liquidity and the funding provided by EDIS in the reinsurance phase are strictly capped. The results are analogous both for uncovered liquidity and uncovered losses.

TABLE 9: SIMULATED RUNS WHERE THE NATIONAL SYSTEM OUTPERFORMS REINSURANCE AND AVERAGE SIZE OF THE UNCOVERED LIQUIDITY SHORTFALL OR LOSS COVERED BY NATIONAL DGS (% OF COVERED DEPOSITS)

T	$\boldsymbol{\beta(t)}$	α_r	**z**	y	**Liquidity**		**Loss**	
					Share	**Average**	**Share**	**Average**
1	80%	20%	10	20%	48%	0.003%	23%	0.002%
2	80%	20%	10	20%	45%	0.005%	27%	0.003%
3	80%	20%	10	20%	43%	0.006%	27%	0.004%
1	80%	40%	10	40%	14%	0.002%	5%	0.002%
2	80%	40%	10	40%	15%	0.003%	6%	0.002%
3	80%	40%	10	40%	13%	0.004%	10%	0.002%

TABLE 10: SIMULATED RUNS WHERE THE NATIONAL SYSTEM OUTPERFORMS COINSURANCE AND AVERAGE SIZE OF THE UNCOVERED LIQUIDITY SHORTFALL OR LOSS COVERED BY NATIONAL DGS (% OF COVERED DEPOSITS)

T	$\beta(t)$	α_c	**Liquidity**		**Loss**	
			Share	**Average**	**Share**	**Average**
4	64%	20%	23%	0.007%	0%	0.000%
5	48%	40%	14%	0.007%	1%	0.015%
6	32%	60%	10%	0.004%	2%	0.027%
7	16%	80%	7%	0.002%	3%	0.054%

6 Conclusions

The European Commission adopted in November 2015 a legislative proposal to set up a European Deposit Insurance Scheme (EDIS). EDIS would move into a fully mutualized insurance system for all banks in the Banking Union by 2024. JRC supported DG FISMA in the preparation of the effects analysis on EDIS complementing the legislative proposal.

The scope of the analysis run by the JRC was to assess the effectiveness of such new system in reimbursing the depositors of failing banks and to compare EDIS with other policy options identified by DG FISMA. These alternative options were: (i) a mandatory reinsurance system, where national DGS were complemented by a central body covering a share of the pay-out in case DGS funds were insufficient, with a cap on the maximum amount for the intervention; (ii) a mandatory lending system where DGS were obliged to lend money, up to a certain limit, to DGS unable to fully cover the pay-out.

JRC compared DGS and EDIS target funds with the simulated amount of liquidity demands and losses potentially affecting a DGS in the event of a banking crisis. Banking crisis scenarios were based on the SYMBOL model.

Results demonstrated that the fully mutualised fund grants greater protection than the other two options, both in the short term and in the medium/long term, after the recovery procedure and the collection of ex-post extraordinary contributions.

The comparison between the mandatory reinsurance and the mandatory lending schemes demonstrates that the former is more effective than the latter, provided that the central body be granted sufficient funds. The performance of the mandatory lending scheme strongly depends upon the amount of resources provided to the central body and the caps on its intervention.

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List of definitions

Available Financial Means (AFM): amount of funds at the disposal of a DGS.

Covered deposits (or **guaranteed** or **reimbursable** or **repayable**): deposits obtained from eligible deposits when applying the level of coverage.

Extraordinary Contributions (EC): long-term extraordinary contributions that can be raised by the DGS in need within 1 year. These contributions are equal to 0.5% of the amount of covered deposits of the relevant Member State.

Level of coverage: level of protection granted in the event of deposits being unavailable. According to EU Directive it is fixed at 100,000 €.

Liquidity shortfall (LS): amount of covered deposits in the failing bank that exceeds the total available financial means in the DGS.

Loss retention (LR): loss that still needs to be covered after the failing banks enters an insolvency procedure and the DGS receives long-term extraordinary contributions from the banks, but before the additional funding is made available by supranational agreements.

Pay-out: the amount of covered deposits that a DGS is required to cover as a consequence of bank failures.

Recovery rate (R): the amount that can be recovered during insolvency proceedings.

Uncovered liquidity shortfall (ULS): amount of covered deposits in the failing bank that cannot be covered either by AFM or through additional funding made available via a supranational arrangement.[15]

Uncovered loss (UL): loss that the national DGS or the Member State has to bear after collecting insolvency proceeds, long-term extraordinary contributions from banks at national level and after receiving additional funding made available via a supranational arrangements.

[15] The concept of "uncovered liquidity" does not mean that the national DGS would become free of its obligations to reimburse depositors according to Art. 8(1) of Directive 2014/49/EC, instead the DGS would have to obtain alternative funding as required by Art. 10(9) of Directive 2014/49/EC.

ANNEX I. Brief description of SYMBOL

The Systemic Model of Banking Originated Losses model (SYMBOL, see De Lisa et al, 2011[16]) has been developed by JRC in cooperation with members of academia and representatives of DG FISMA. 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.[17] 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;[18] (c) all risks in the bank can be represented as a single portfolio of credit risks.[19] It is then possible to use publicly available data on total regulatory capital, risk weighted assets and total assets to obtain parameters representing the average riskiness of each bank's portfolio of assets.[20]

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.[21] 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 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 total assets held.[22]

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 statistical distribution of losses for resolution tools and/or public interventions), or the

[16] Please note that at the time of submission the acronym SYMBOL was not employed yet.

[17] 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.

[18] 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.

[19] 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.

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

[21] 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.

[22] 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.

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).[23]

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.[24] 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 Total Assets (TA).

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 Resolution fund 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 total assets, which can be derived from the balance sheet data. We present a brief overview of the main ingredients below. Benczur et al (2015) offers some additional details and discussion.

[23] 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.

[24] 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.

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[25] over a time horizon of one year, with a specific confidence level equal to 99.9% (see Figure **6**):

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

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

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

with obligor size *S* =50.

Here LGD is the loss given default[26] and $\mathrm{M}(\mathrm{PD_{i,l}})$ is an adjustment term, defined as

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

with $\mathrm{b_{i,l}} = \left(0.11856 - 0.05478 \cdot \ln(\mathrm{PD_{i,l}})\right)^2$ 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 risk-weighted assets, and the total assets of the bank. Note that capital and RWA are QIS-adjusted, as detailed in Section 4.1.

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.[27] 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,…,N_0, losses for bank *i* are simulated as:

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

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

[25] 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.

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

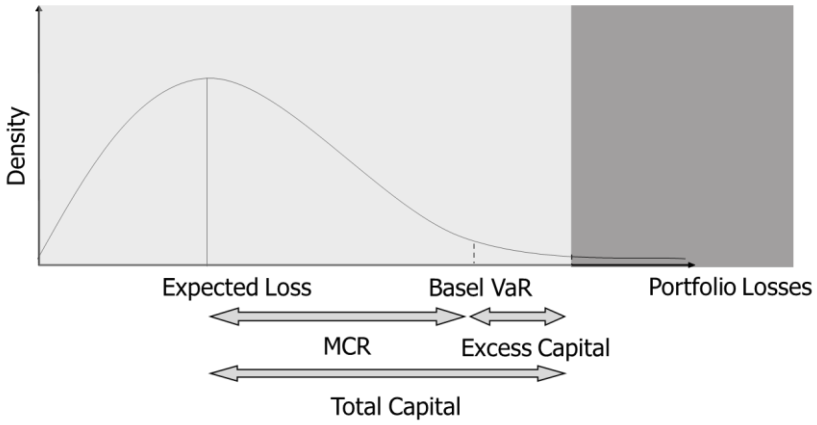
[27] The asset value of each bank's debtors evolves according to $X_{A,k} = \sqrt{R_A}\left(\sqrt{\rho}\beta + \sqrt{1-\rho}\beta_A\right) + \sqrt{1-R_A}Z_{A,k}$. Here $Z_{A,k}$ is the idiosyncratic shock to the debtor, β_A is the bank specific shock, while β is a common component. The parameter *ρ*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

STEP 3: Determination of bank failure.

Given the matrix of correlated losses, SYMBOL determines which banks fail. As illustrated in Figure 6, 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 :

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

FIGURE 6: INDIVIDUAL BANK LOSS PROBABILITY DENSITY FUNCTION



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

The light grey area in Figure 6 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.

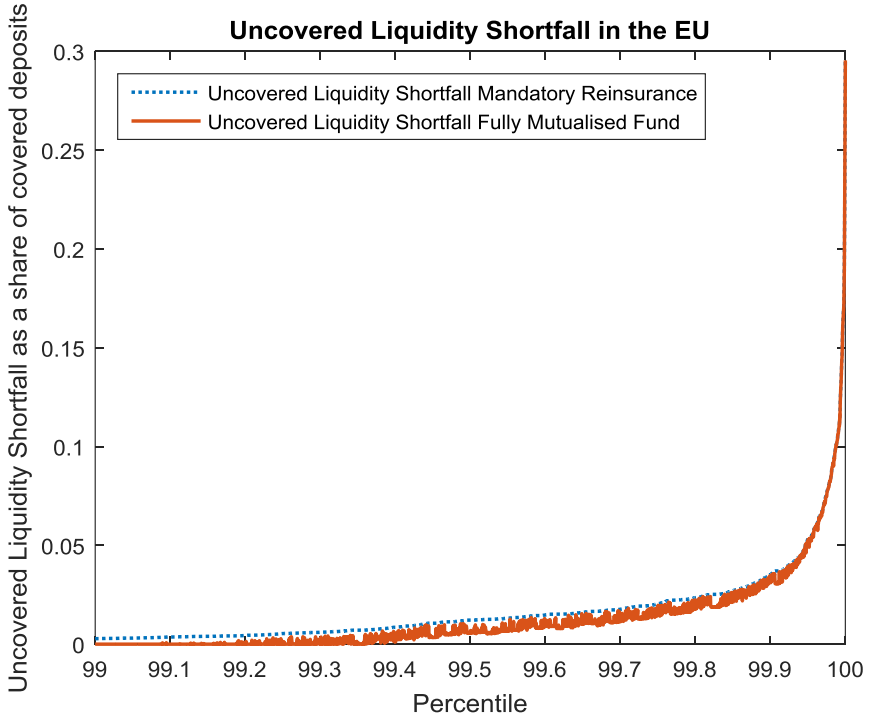
STEP 4: Aggregate distribution of losses for the whole system.

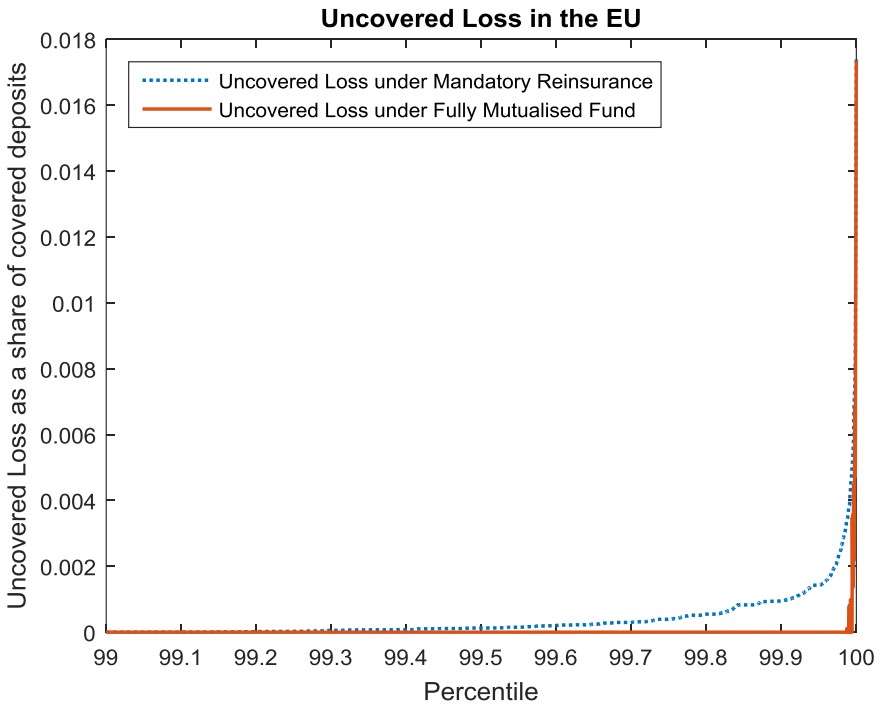
Aggregate losses are obtained by summing losses in excess of capital of all distressed banks in the system in each simulation run.

ANNEX II. Outputs on pay-out analysis via SYMBOL

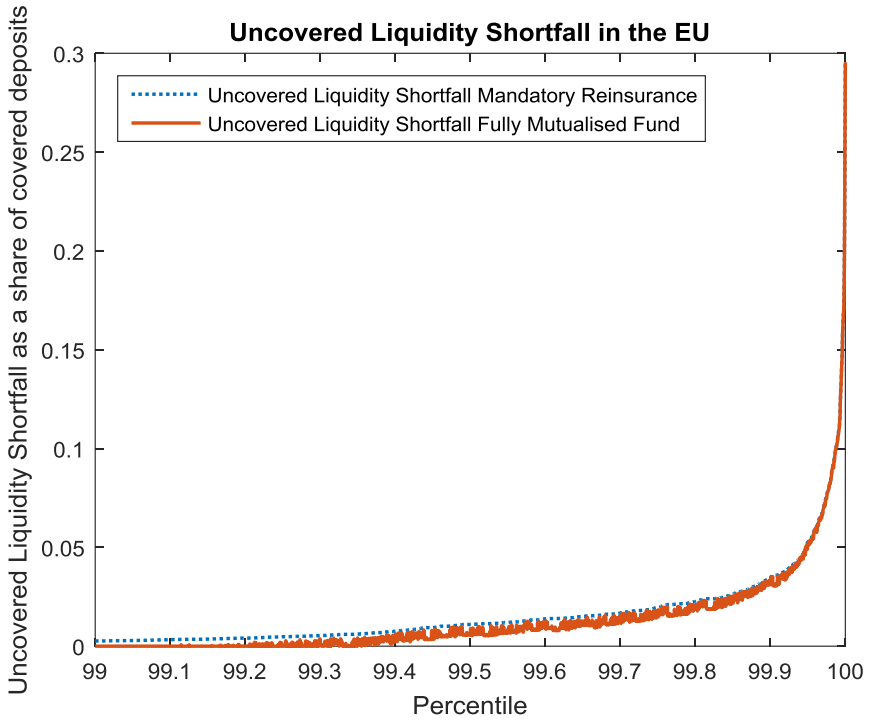
Uncovered Liquidity Shortfall and Uncovered Losses under mandatory reinsurance and mutualised fund (different parameters)

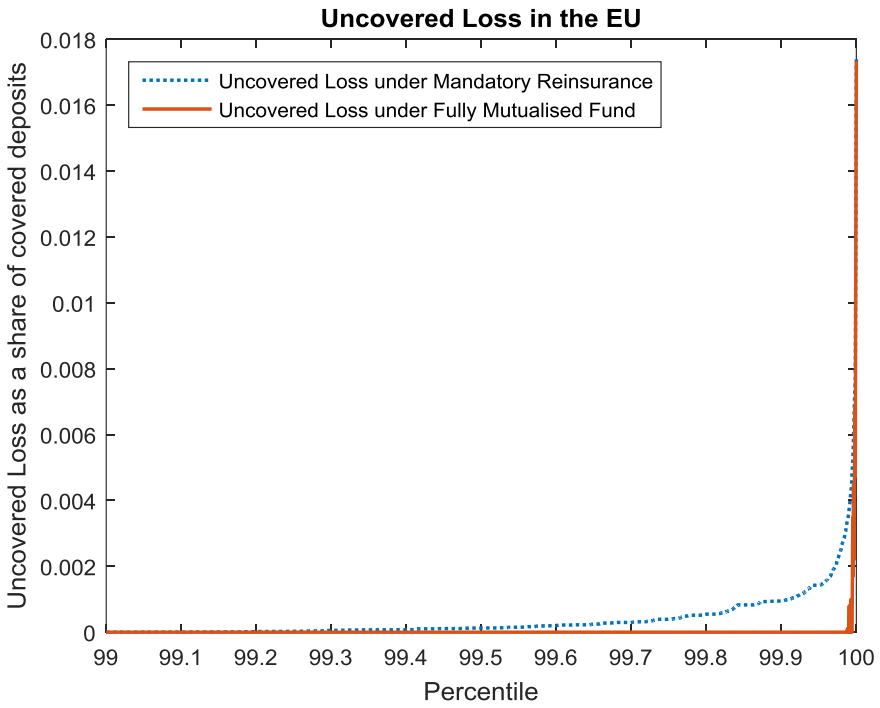
β = 75%, α = 20%, y = 20%



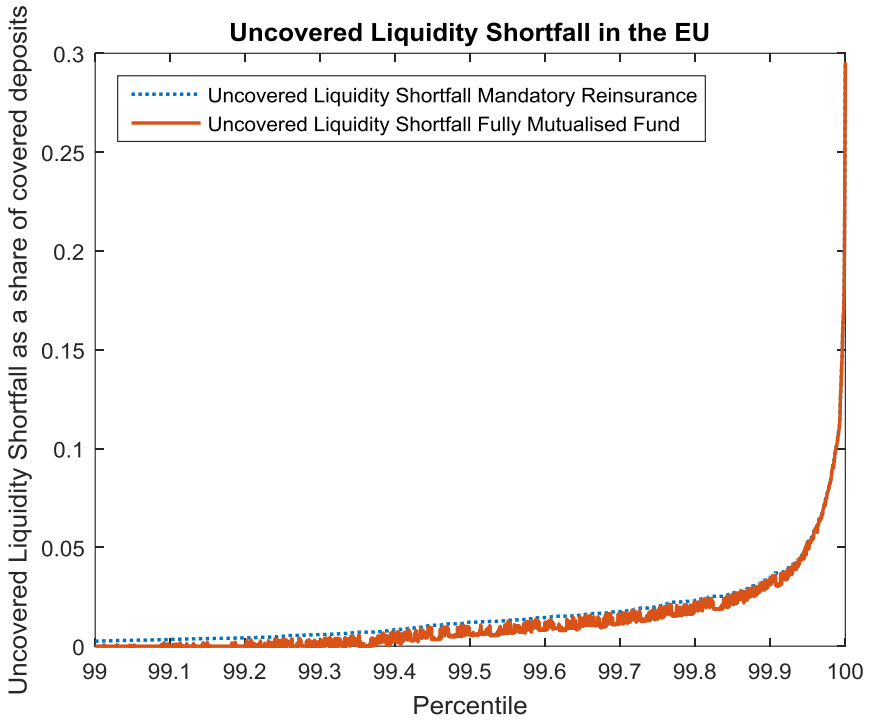


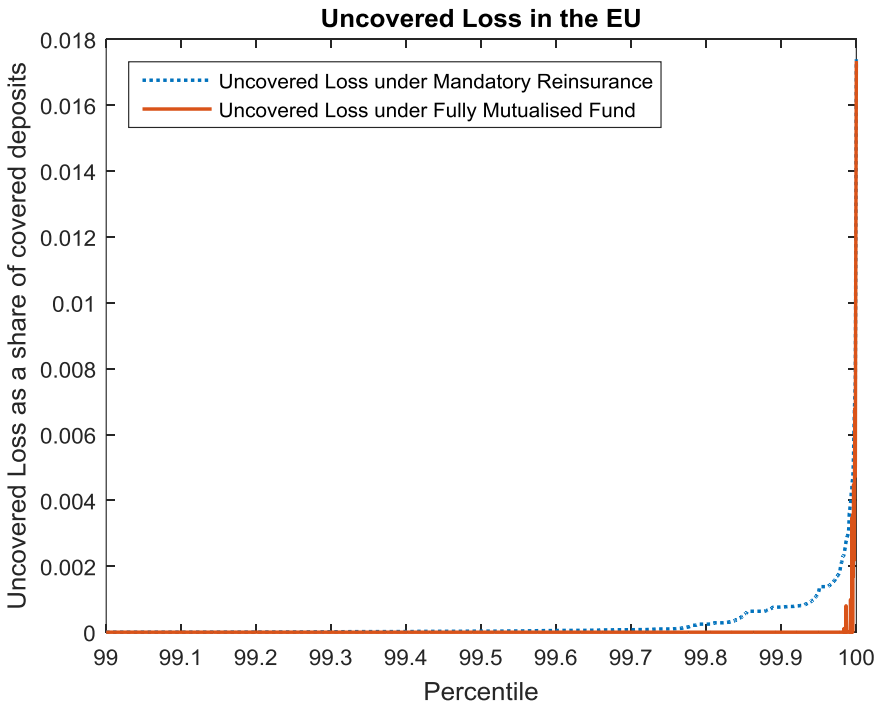
β = 75%, α = 20%, y = 80%



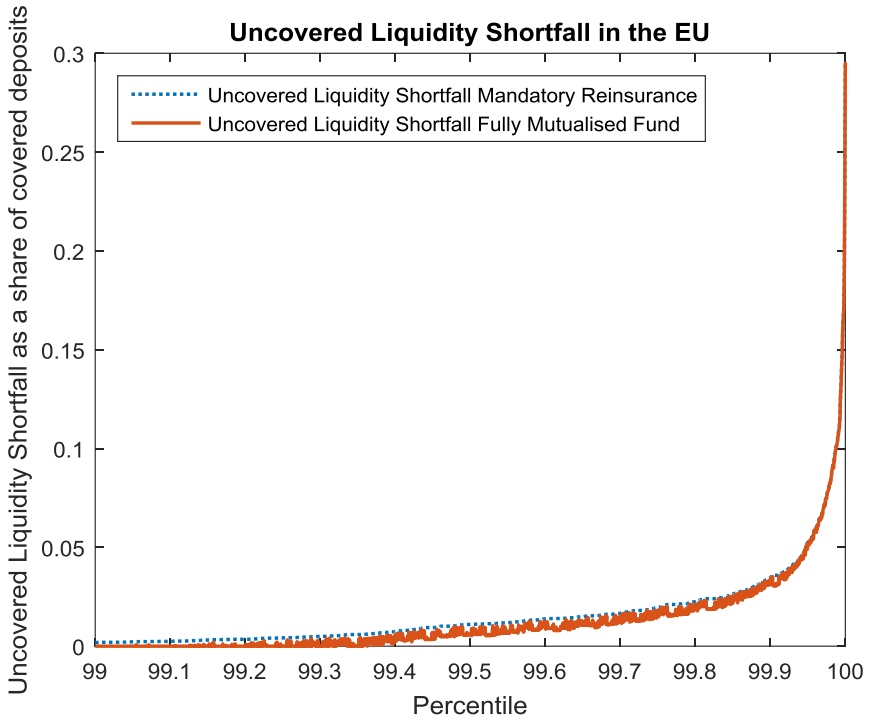


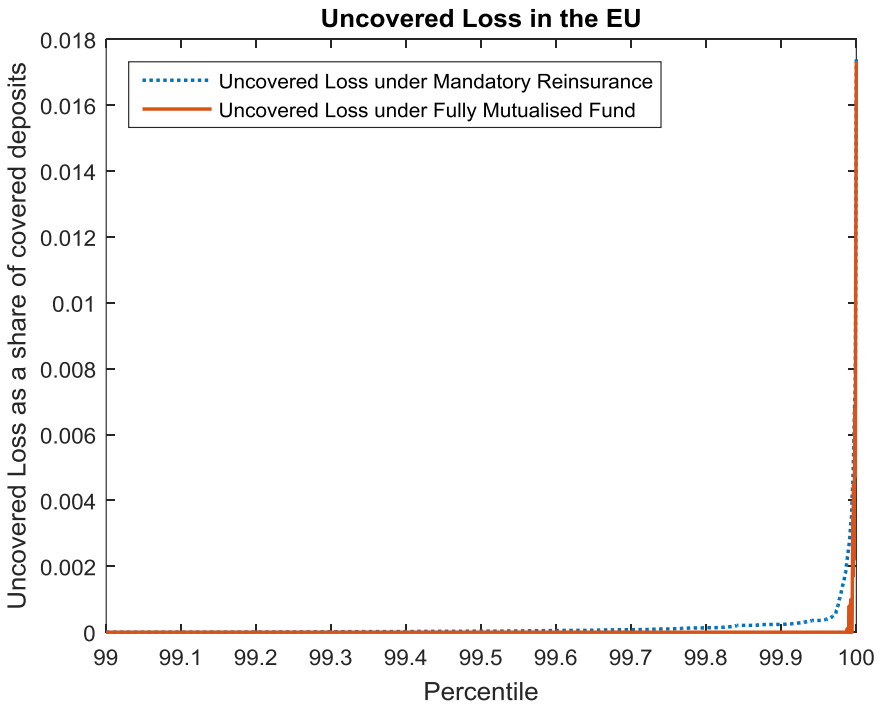
β = 75%, α = 80%, y = 20%



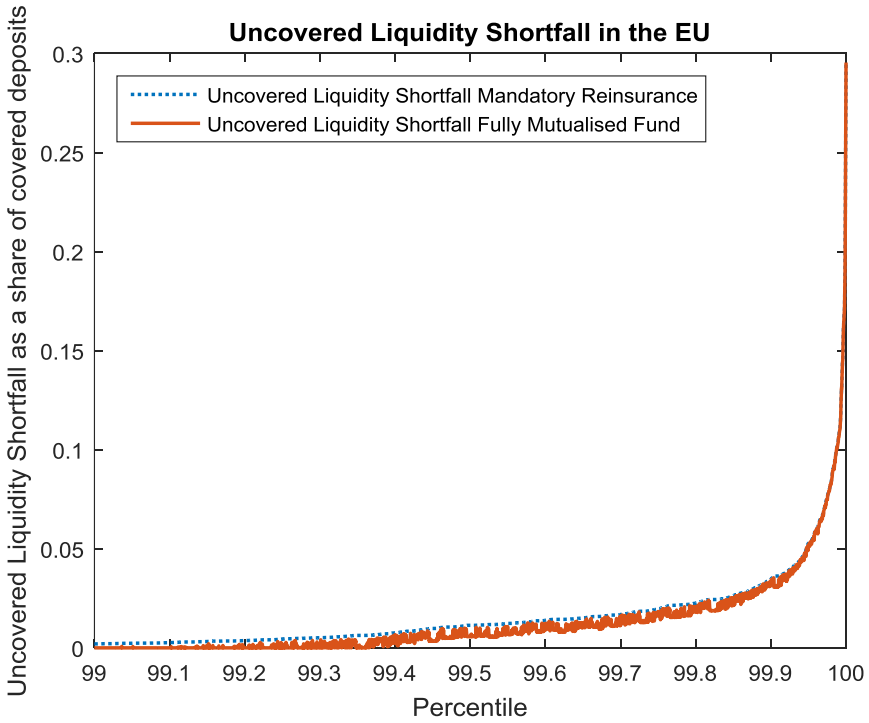


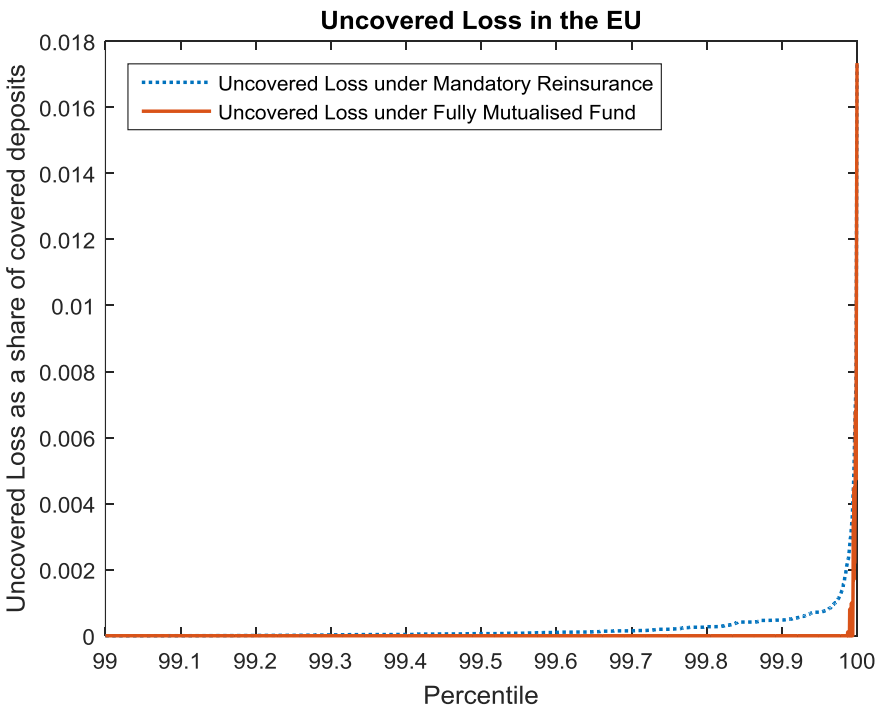
β = 75%, α = 80%, y = 80%



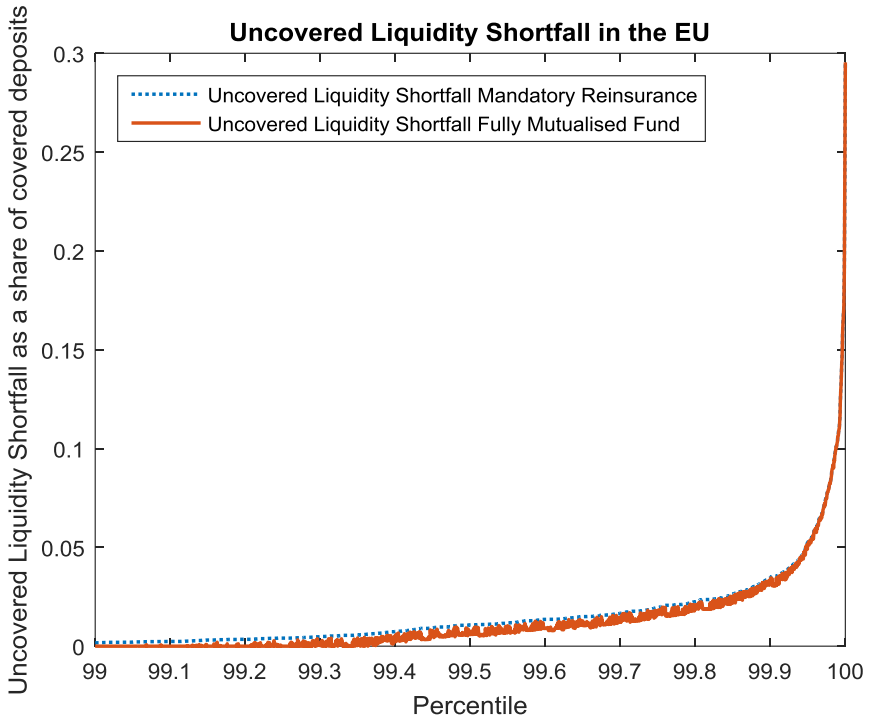


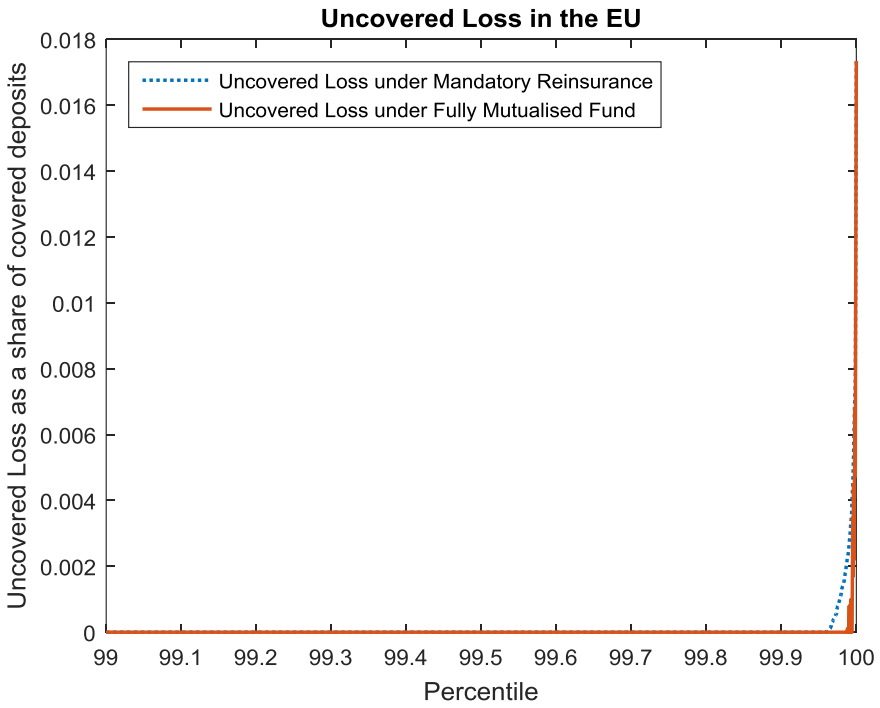
β = 75%, α = 60%, y = 60%



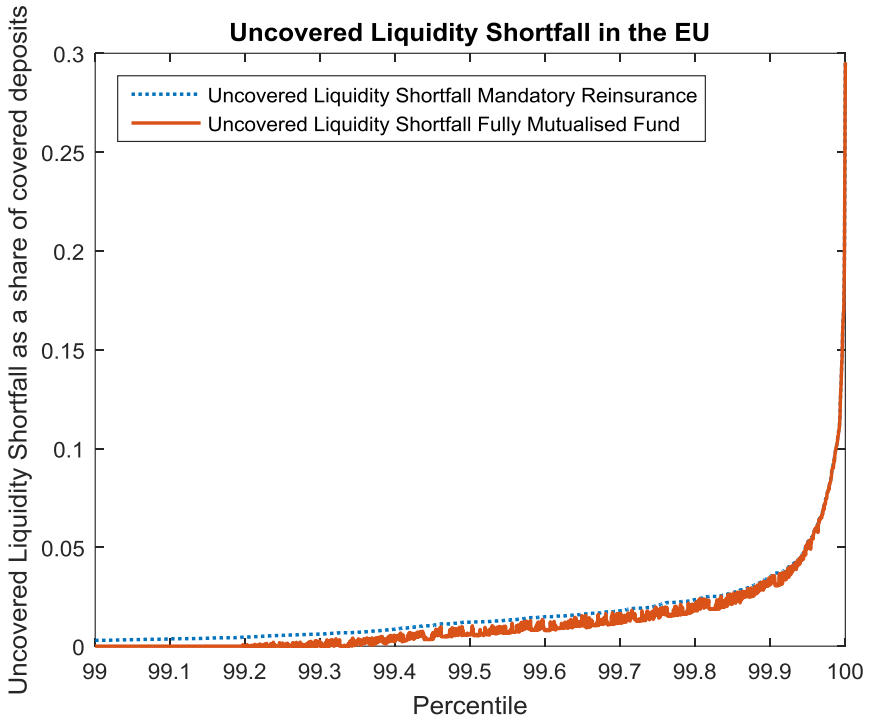


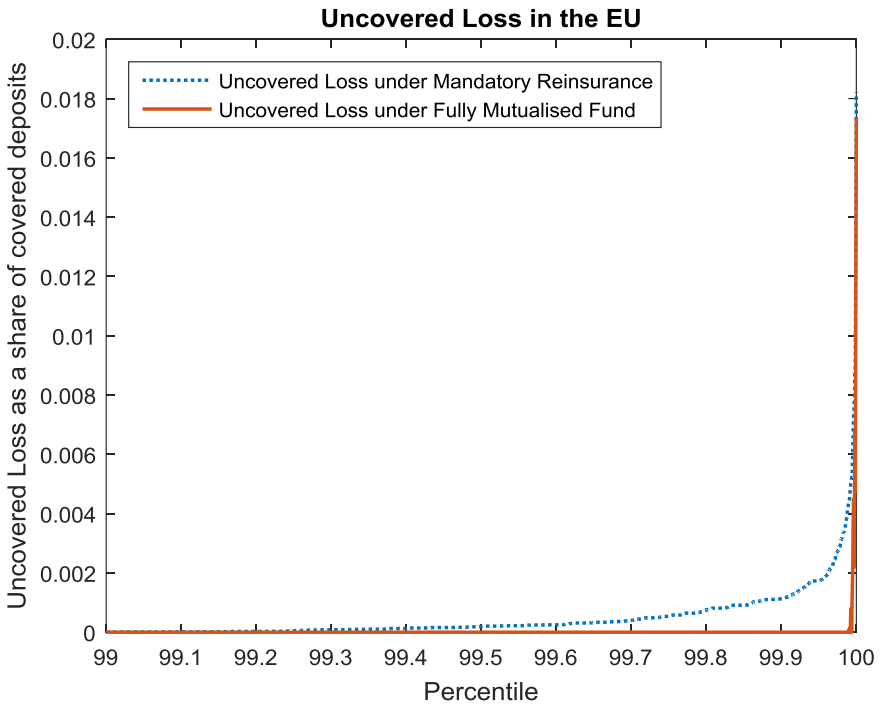
β = 75%, α = 100%, y = 100%



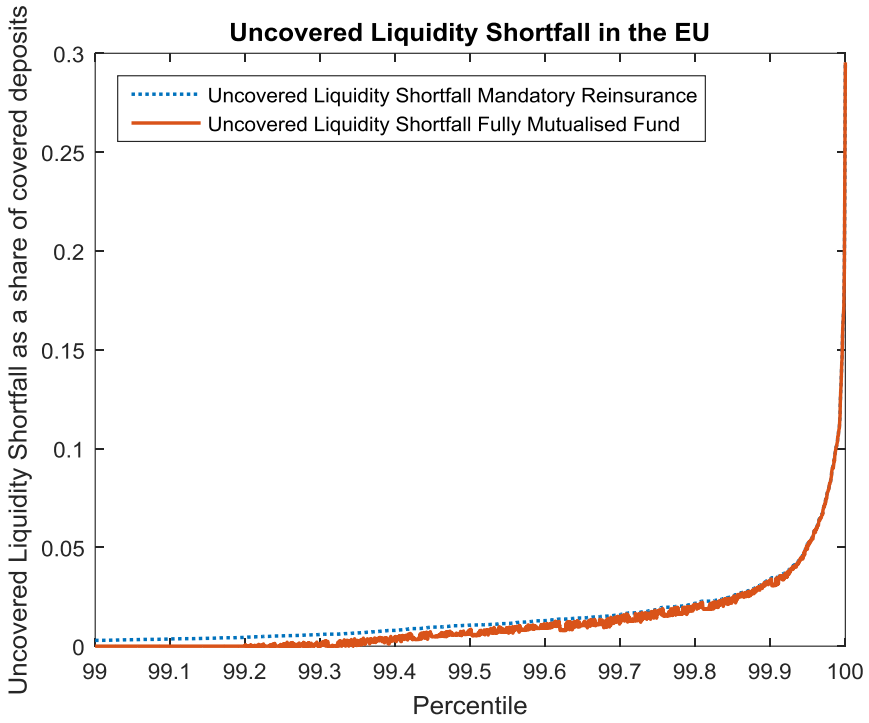


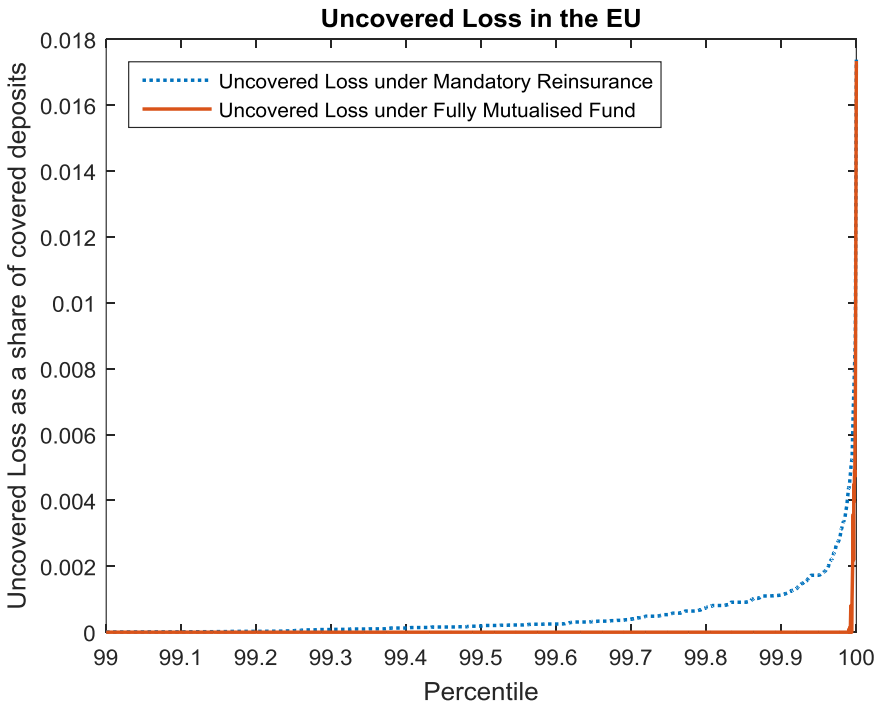
β = 50%, α = 20%, y = 20%





β = 50%, α = 20%, y = 80%





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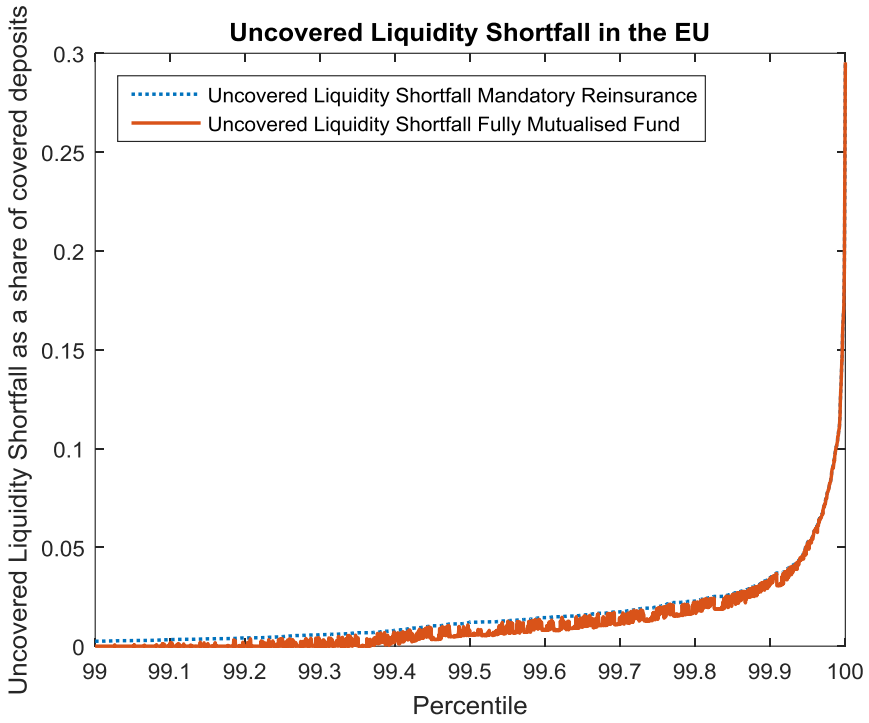

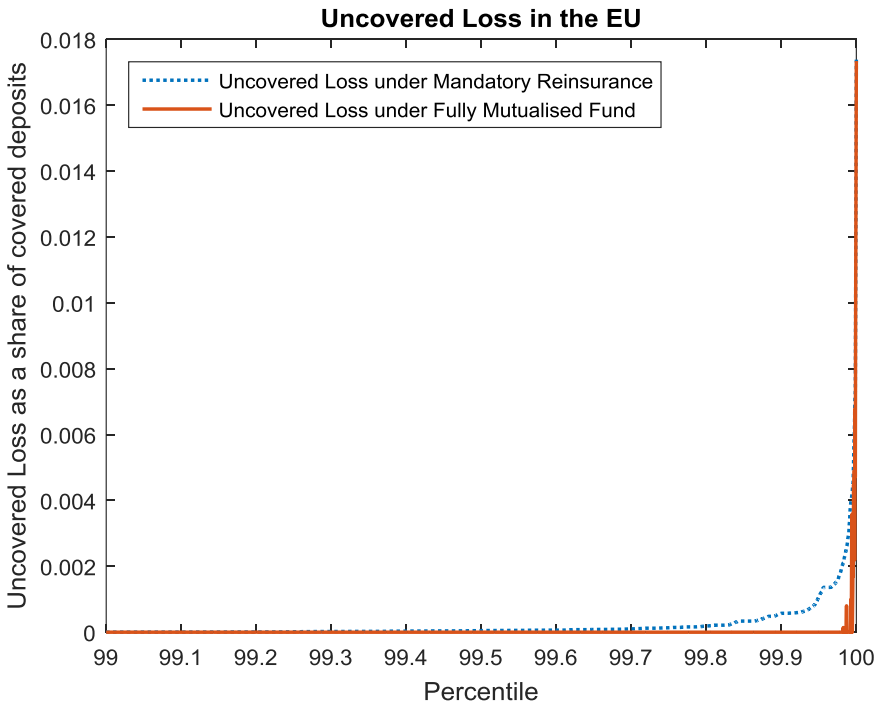

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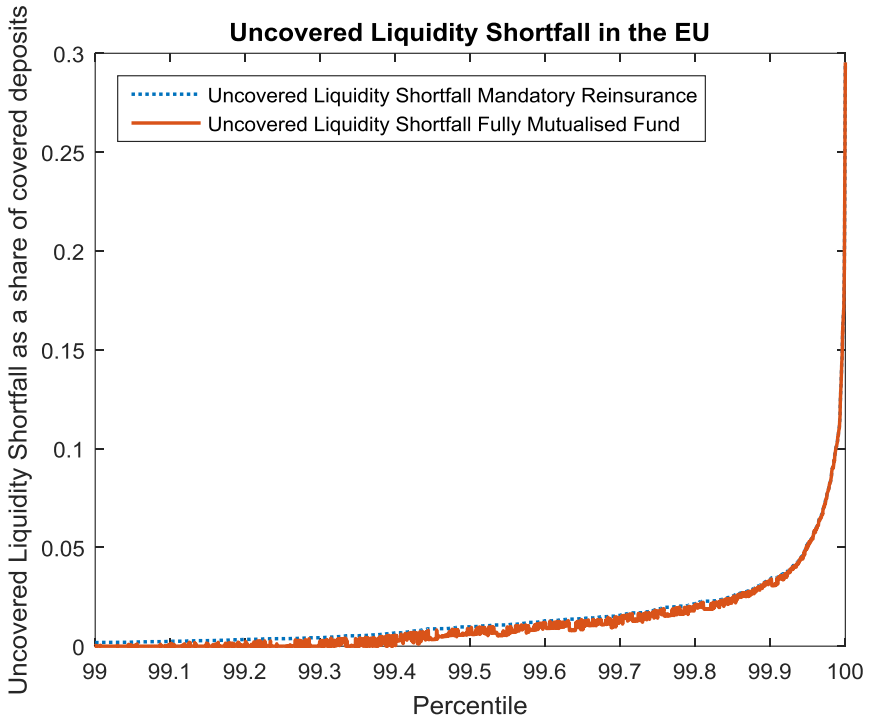

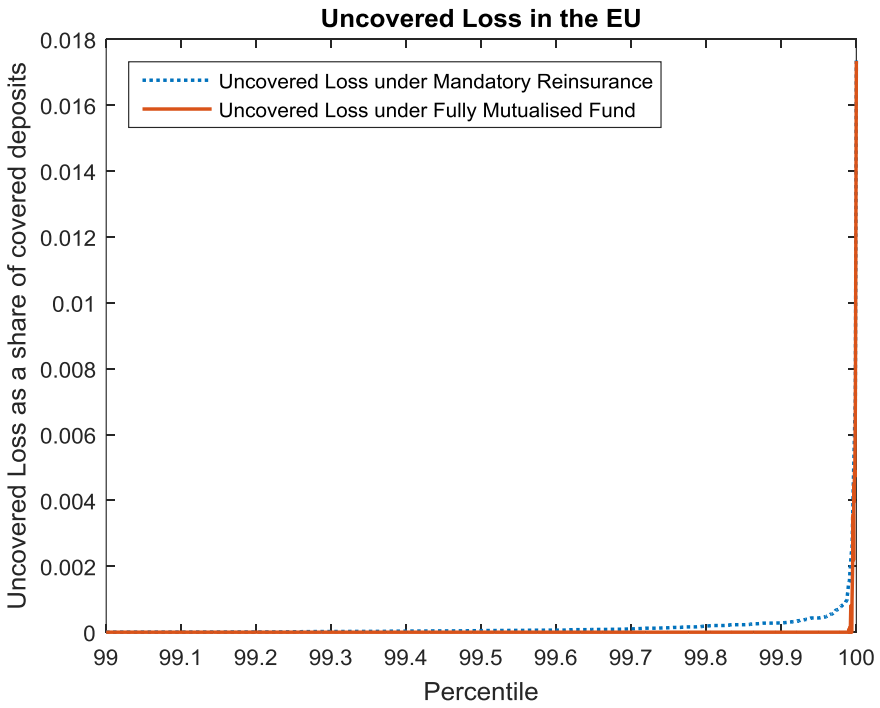

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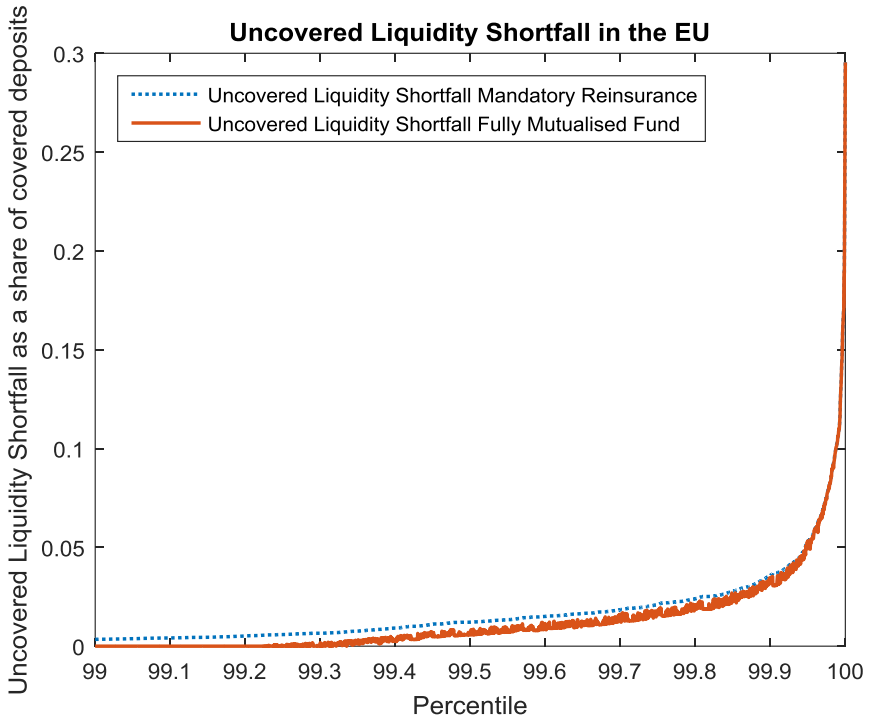
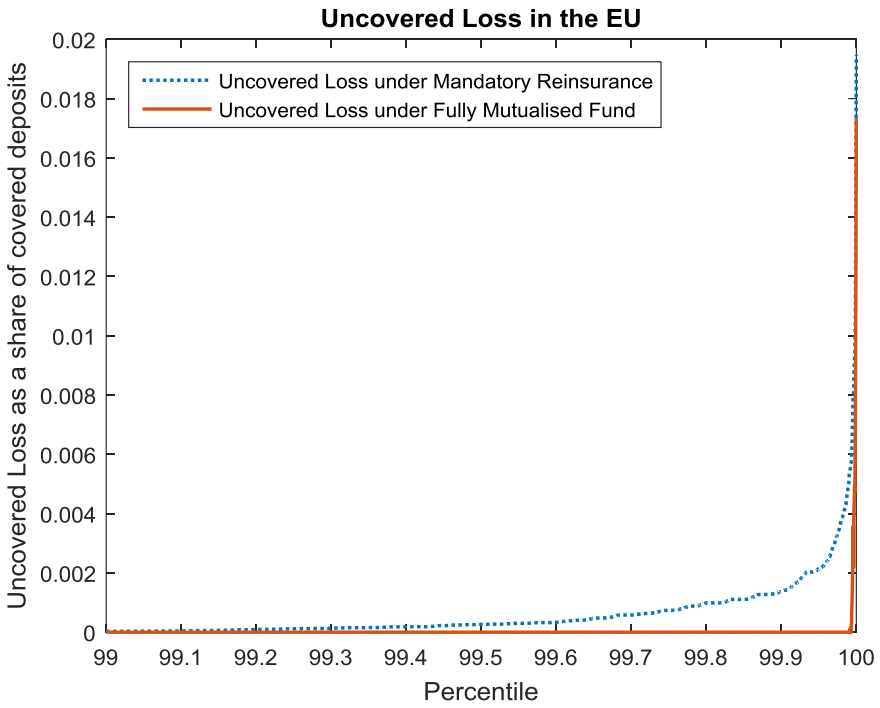
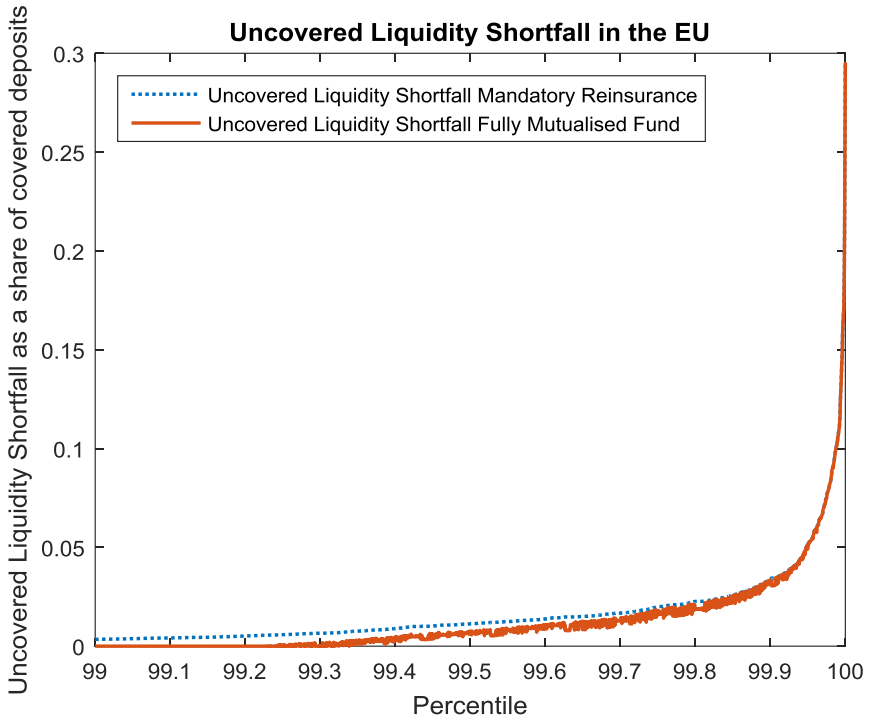
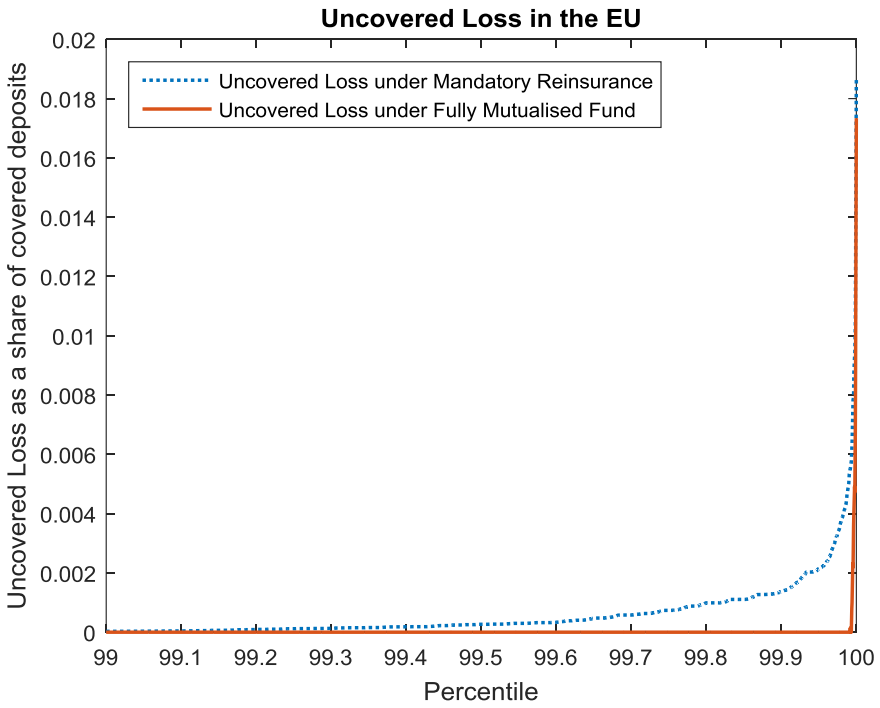




β = 25%, α = 20%, y = 80%





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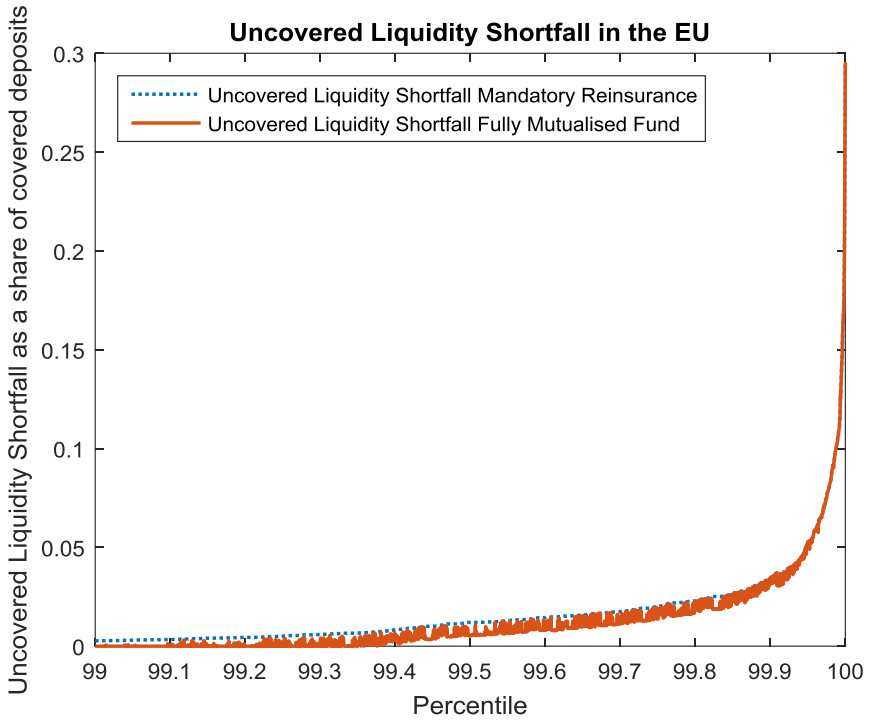

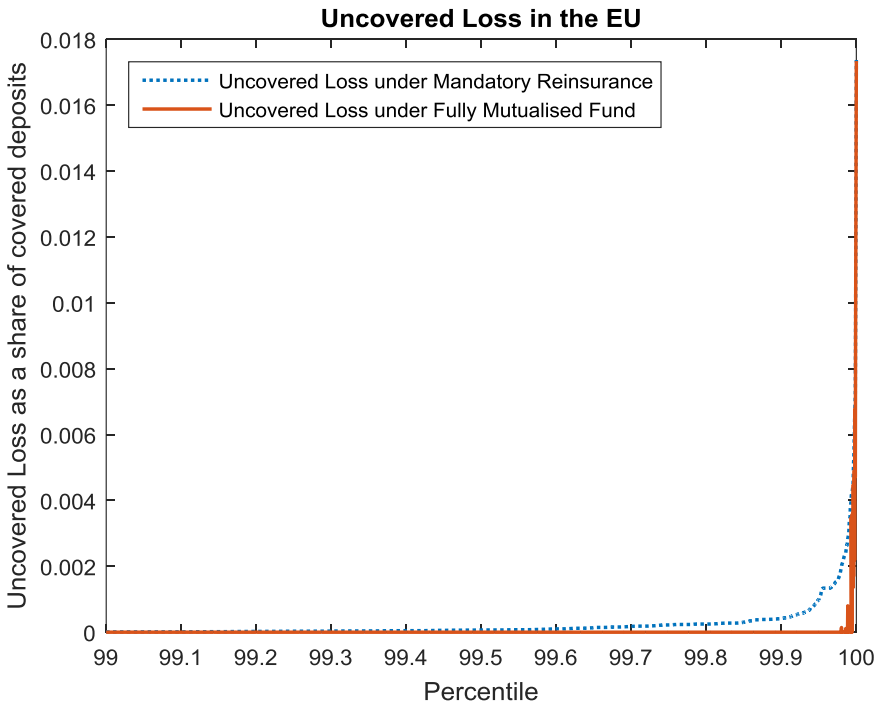

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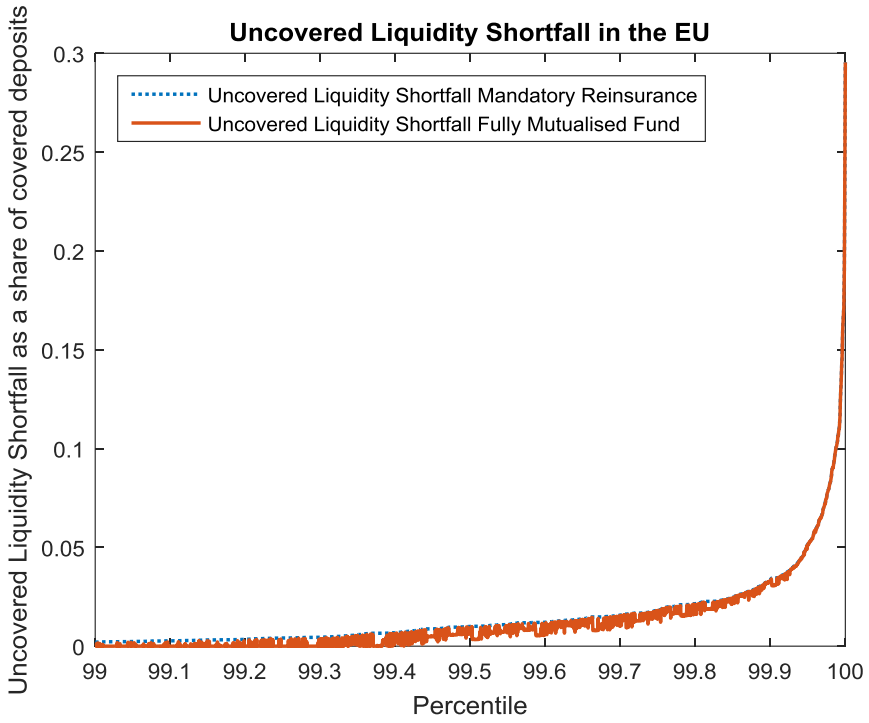

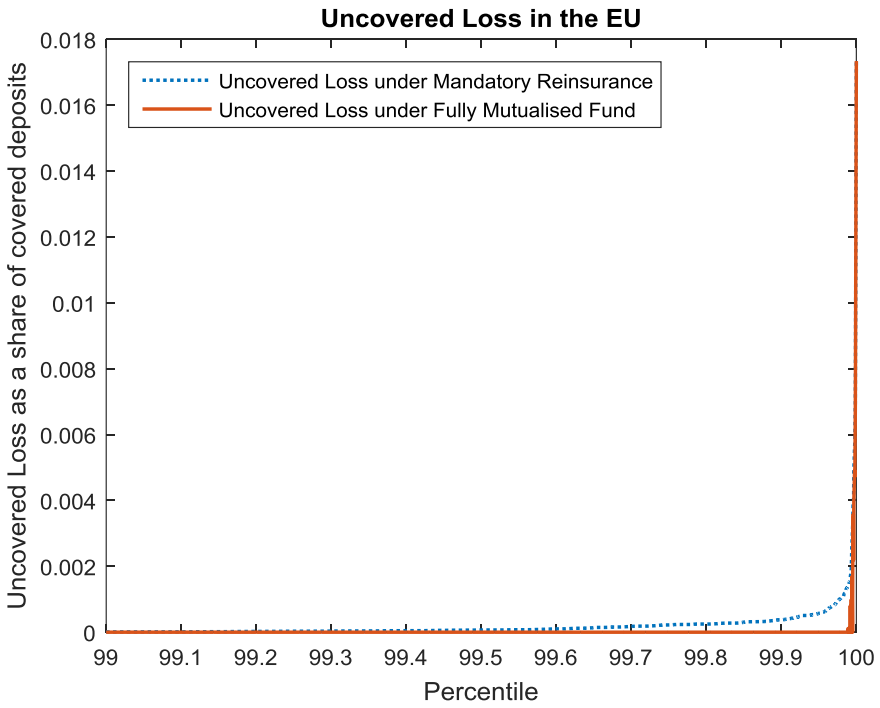

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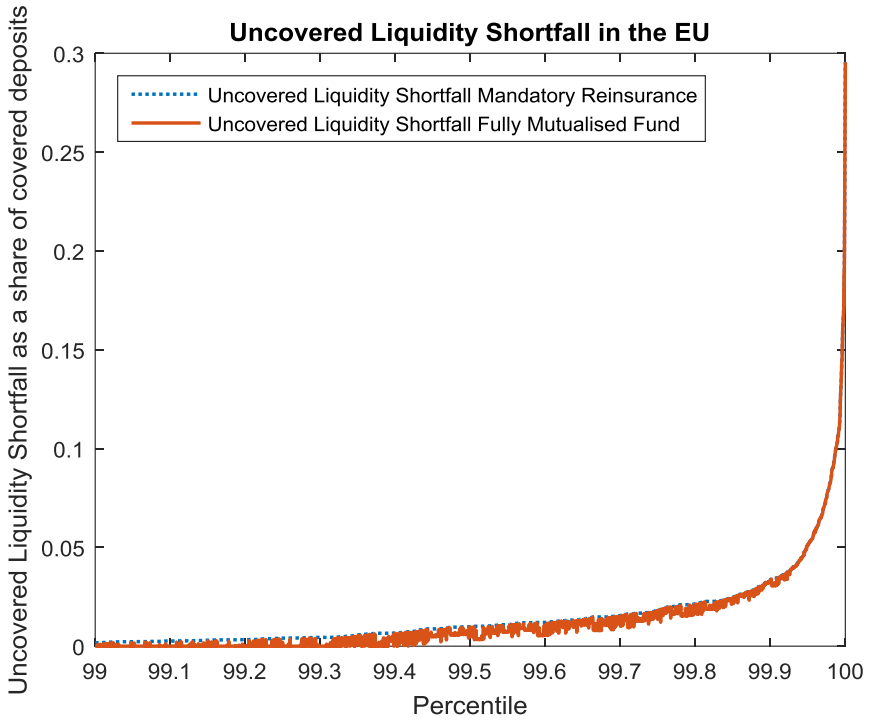

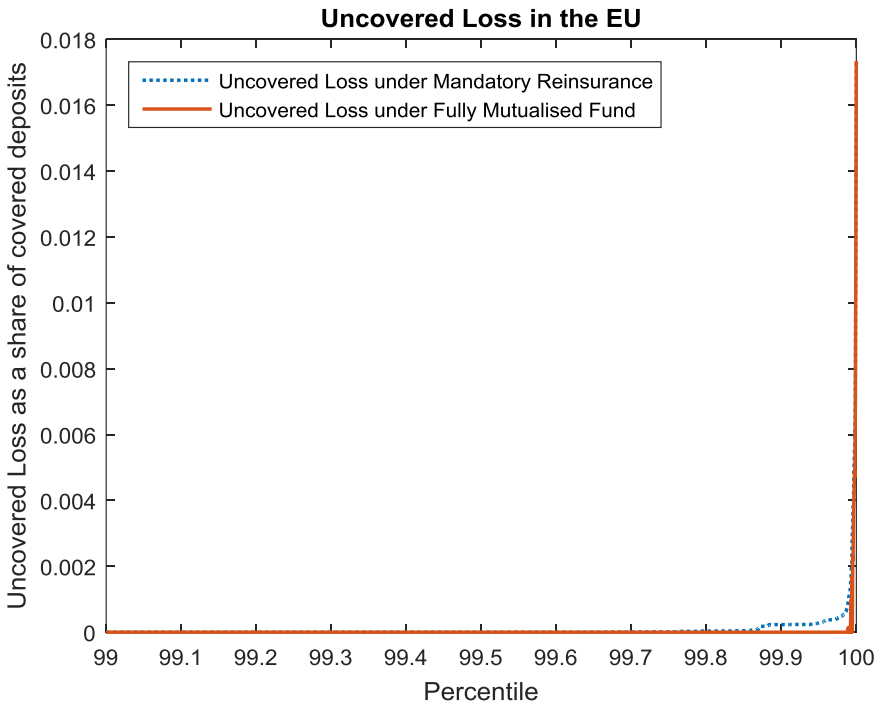

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