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Network Valuation in Euro Area Syndicated and Interbank Loan Markets

Andre Oliveira Santos

WP/26/61

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Network Valuation in Euro Area Syndicated and Interbank Loan Markets

Prepared by Andre Oliveira Santos*

Authorized for distribution by Allison Holland
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ABSTRACT: The objective of this paper is to assess the impact of single-name and widespread markdowns in syndicated leveraged loans on systemic risk in the euro area. Systemic risk implications of markdowns are simulated with network valuation models (as in Bardoscia et al. (2016)) and extended to accommodate recapitalization of systemically important banks. Key results indicate that, while the impact of single-name and widespread markdowns in syndicated leveraged loans on banks' equity is not significant under a strong confidence in the banking system, their impact could be devastating if confidence is low. This could be mitigated by timely and calibrated recapitalization of systemically important banks.

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WORKING PAPERS

Network Valuation in Euro Area Syndicated and Interbank Loan Markets

Prepared by Andre Oliveira Santos[1]

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Glossary

EBA: European Banking Authority

ECB: European Central Bank

ESRB: European Systemic Risk Board

FSAP: Financial Sector Assessment Program

EU: European Union

GFC: Global Financial Crisis

GLP: Green Loan Principles

GSIBs: Global Systemically Important Banks

LBOs: Leveraged Buyouts

MPOs: Monetary Policy Operations

MREL: Minimum Requirement for Own Funds and Eligible Liabilities

SLLPs: Sustainability-Linked Loan Principles

SSM: Single Supervisory Mechanism

Executive Summary[1]

During the acute phase of the pandemic in 2020, the risk of widespread corporate defaults arising from the containment measures was the main source of systemic risk in Europe. Public support measures, including accommodative monetary, fiscal, and financial sector policies, helped the corporate sector navigate through the pandemic. However, the pandemic left nonfinancial corporates with higher debt levels as they resorted to credit markets to strengthen their liquidity buffers. In a scenario of negative growth, higher debt levels could become a source of distress for the corporate sector.

Since the GFC, contagion models have incorporated different transmission mechanisms. During the GFC, interconnectedness and complexity came to the forefront as large parts of the U.S. and European banking systems were increasingly under distress. In the wake of the GFC, a vast array of contagion models has included different transmission channels in which default, distress, fire sales, and funding propagate shocks across the financial system. Barucca et al. (2020) and Veraart (2020) consider models in which a deterioration in bank's equity resulting from adverse shocks to assets can trigger distress contagion by increasing the likelihood that its interbank loans are not fully repaid. Lending banks providing interbank loans will mark down their loans to the distressed bank, reducing their own equity. The shock will then propagate fast through the network of interbank assets and liabilities, dying out as it spreads to lower levels. The cycle of mark-to-market losses and equity reductions would eventually converge to a halt with no further changes in equity under certain conditions.

The objective of this paper is to assess the impact of single-name and widespread markdowns in syndicated leverage loans on systemic risk in the euro area. This is important given the large volume of leveraged loans originated over the last few years—a key financial stability concern for the ECB Supervision as expressed in its key supervisory priorities for 2022-24. This paper reviews key trends in syndicated and interbank loan markets and suggests a methodology based on the literature and market practices to assess outstanding bilateral syndicated loan exposures while using the Minimum Density Estimation approach as in Anand et al. (2015) to estimate outstanding bilateral interbank exposures. Systemic risk implications of euro area syndicated loan markdowns are then simulated with non-linear network valuation models—as in Bardoscia et al. (2016) —and extended to accommodate bankruptcy costs and recapitalization of systemically important banks.

Key results in this paper indicate that single-name and widespread markdowns in syndicated leveraged loans would not have a significant impact on euro area banks' equity as long as confidence in the banking system to recover from losses remains strong. Under scenarios with low confidence, single-name and widespread markdowns in leveraged loans could have a strong impact, wiping out a large percentage of banks' equity as the initial markdown shock propagates through the interbank market. However, these losses can be mitigated by "circuit breakers" such as timely and calibrated capital injections that not only directly recapitalize distressed systemically important banks but also indirectly restore equity in other banks exposed to distressed banks by reversing partially or fully revaluation losses associated with their exposures to distressed banks. This causes a positive contagion and is equivalent to an indirect recapitalization of the financial system that goes much beyond the initial recapitalization of distressed systemically important banks. Finally, when resources to

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recapitalize systemically important banks are limited, distressed banks would need to be ranked according to some criteria to qualify for the recapitalization.

Introduction[2]

During the acute phase of the pandemic in 2020, the containment measures had the potential to trigger widespread defaults in Europe. As a result, the General Board of the European Systemic Risk Board (ESRB) considered the risk of widespread corporate defaults and their impact on the financial system as the main source of systemic risk in Europe. However, public support measures, including accommodative monetary, fiscal, and financial sector policies, helped the corporate sector navigate through the pandemic. While the systemic risk from widespread corporate defaults declined in the second half-2020, the pandemic left nonfinancial corporates with higher debt levels. This stemmed from nonfinancial corporates resorting to credit markets to strengthen their liquidity buffers during the pandemic. In a scenario of negative growth, the higher debt levels could become a source of distress for the corporate sector.

Since the GFC, contagion models have considered different transmission mechanisms. As the GFC unfolded, interconnectedness and complexity came to the forefront, with the financial system in the U.S. and Europe increasingly under stress. Some financial institutions were allowed to fail while others were deemed systemically important and bailed out to prevent the further buildup of systemic risk. The widespread default of large systemically important institutions would have impaired a large part of the financial system, with possible adverse effects on the real economy.[3] Since then, a vast array of models—including those reviewed in Glasserman and Young (2016), Caccioli et al. (2018), and Jackson and Pernoud (2021)—have considered different transmission channels in which default, distress, fire sales, and funding propagate shocks across the financial system.

Of particular interest have been valuation network models as in Barucca et al. (2020) and Veraart (2020) in which a deterioration in bank's equity can trigger distress contagion. For instance, a decline in a bank's equity arising from corporate exposure losses implies that its interbank loans are less likely to be fully repaid (Figure 1). Lending banks providing interbank loans will then mark down their loans to the bank with declining equity, reducing their own equity. The shock will then propagate fast through the network of interbank assets and liabilities, dying out as it spreads to lower levels of a tree as in a directed acyclic graph (DAG). However, if there are cycles (or circularities) in which a bank could be hit more than once by a shock as in a directed cyclic graph (DCG), the reduction in lending banks' equity would be accompanied by a new round of mark-to-market losses and equity reductions. The cycle of mark-to-market losses and equity reductions would eventually converge to a halt with no further changes in equity under certain conditions, but convergence is slower than otherwise and can cause large losses and a high number of defaults.

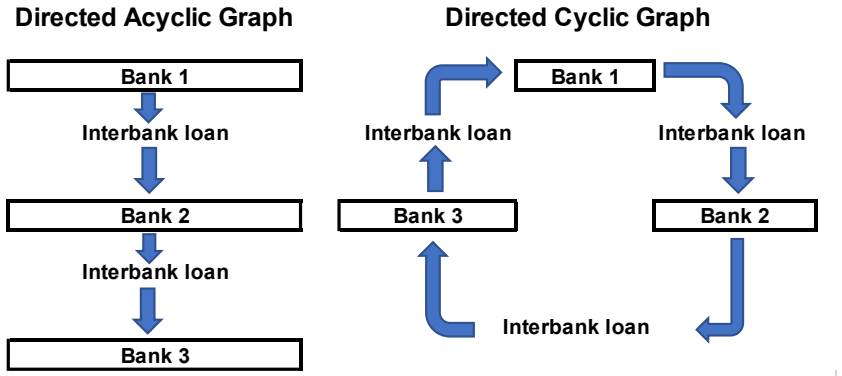
The objective of this paper is to assess the impact of single-name and widespread euro area syndicated loan markdowns on systemic risk in the euro area and the role that the recapitalization of systemically important banks could have in reversing losses from markdowns. This is important given the large volume of leveraged loans originated over the last few years—a key financial stability concern by the ECB Supervision as expressed

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[3] Barry Johnston et al (2009) outline the concept of systemically important financial institutions, markets, and instruments.

in its key supervisory priorities for 2022-24. This paper reviews key trends in syndicated and interbank loan markets and suggests a methodology based on the literature and market practices to estimate outstanding bilateral syndicated loan exposures while using the Minimum Density Estimation approach as in Anand et al. (2015) to estimate outstanding bilateral interbank exposures. Systemic risk implications of euro area syndicated loan markdowns are then simulated with non-linear network valuation models—as Bardoscia et al. (2016)—and extended to accommodate bankruptcy costs and recapitalization of systemically important banks, including timely and calibrated capital increases.

Figure 1. Acyclic and Cyclic Graphs



Key results in this paper indicate that the impact of syndicated loan markdowns on systemic risk depends jointly on size of the shock, the number of affected firms, and the confidence enjoyed by banks to recover from equity losses.[4] While the impact of single-name and widespread markdowns in syndicated leveraged loans on the euro area banks enjoying strong confidence to recover from equity losses is not significant, their impact under a low confidence scenario could be devastating, wiping out a large percentage of banks' equity as the initial markdown shock is propagated through the interbank market. In this case, bankruptcy costs could further exacerbate equity losses by reducing the default trigger. However, these losses can be mitigated by "circuit breakers" such as timely and calibrated bank recapitalization that not only directly recapitalize distressed systemically important banks with a conversion of liabilities into equity and an injection of resources from outside the institution but also indirectly restore equity in other banks exposed to distressed banks by allowing them to reverse partially or fully mark-to-market losses on their exposures to distressed banks. This causes a positive contagion and is equivalent to an indirect recapitalization of the banking system that goes much beyond the initial recapitalization of distressed systemically important banks. Finally, in the case when resources to recapitalize systemically important banks are limited, distressed banks would need to be ranked according to some criteria to qualify for the recapitalization.

Incorporating evergreening incentives, endogenous recovery rates, and bankruptcy costs in the analysis would affect some of the key results outlined above. The models in the paper assume that syndicated loan markdowns directly imply equity losses. However, there exist regulatory incentives for banks not to report underwater loans, which have been extensively documented by the literature on evergreening and zombie loans.[5] These would lower the negative impact of syndicated loan markdowns on equity. On the other hand,

[4] Confidence in the banking sector to recover equity losses is given by a parameter in a nonlinear valuation model.
[5] See Blattner et al. (2023) for a discussion on evergreening.

endogenous bankruptcy costs would amplify the adverse effect of syndicated loan markdowns on equity as courts could become congested in periods of financial distress and delay liquidation of banks, increasing the associated costs.

The paper is organized in 6 sections. Section II contains stylized facts associated with syndicated loan origination and interbank markets in the euro area. Section III initially reviews the literature on network valuation models and follows with a discussion on a network valuation model containing bankruptcy costs and recapitalization of systemically important banks. Section IV provides details on the sources of syndicated and interbank loan exposures for the loan networks included in the simulations. Section V describes the syndicated loan exposures and assesses the impact of single-name and widespread corporate defaults on euro area banks, including with recapitalization of systemically important banks. Finally, the conclusion summarizes key results in the paper.

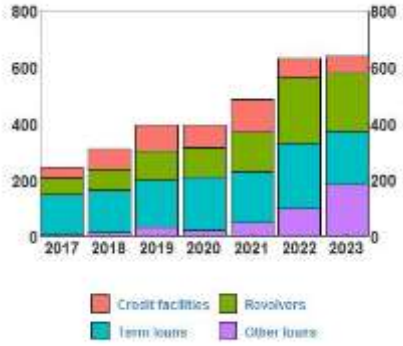
Recent Developments in Euro Area Syndicated and Interbank Loan Markets

After declining volumes following the GFC, syndicated loan origination to euro area corporates has more than recovered the previous lost ground. Figure 2, Panel A shows that annual volumes continued to grow after the pandemic, with the loan origination volumes in 2022 and 2023 at a record €690 billion and €630 billion (5.1 and 4.4 percent of euro area GDP), respectively. Among the many loan instruments, term loans and revolvers (revolving loans) have been the most common, though growth in other instruments has gathered pace. Green credentials of syndicated loans have also increased, with loans issued under the Sustainability-Linked Loan Principles (SLLPs) on the rise as indicated by Figure 2, Panel B, while syndicated loans under Green Loan Principles (GLPs) have remained more limited. While syndicates of banks and nonbanks have provided most of the loans, clubs of banks have also originated large volumes of syndicated loans as shown in Figure 2, Panel C. Finally, foreign banks have been large lenders to euro area corporates, granting 43 percent of syndicated loans over the last five years, while French, German, Spanish, Italian, and Dutch bank lent about 20 percent, 10 percent, 8 percent, 8 percent, and 5 percent of the total amount over the same period, respectively.

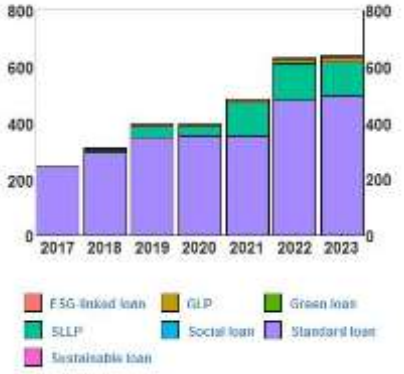
Syndicated loans have been an important instrument in the corporate sector's capital structure. They are an attractive alternative to bilateral loans or corporate bonds as: (i) they are more tailored to the borrower's financing needs than it would be the case in the bond market that requires, for instance, ratings, and detailed documentation; and (ii) they also help borrowers and lenders to address market failures (market matching, information asymmetry and moral hazard), which are particularly severe for unrated and private borrowers with no publicly disclosed financial information. Figure 3, Panel A indicates that large volumes of syndicated loans have been granted for refinancing and liquidity management (general corporate purposes) since 2020. Moreover, syndicated loans have also played an important role in financing the wave of acquisitions and leveraged buyouts. As a result, banks have arranged larger volumes of not only investment grade loans but also of leveraged loans (Figure 3, Panel B). In particular, corporates in (i) manufacturing, (ii) electricity, gas, steam, and air conditioning supply, (iii) wholesale and retail trade, repair of motor vehicles and motorcycles, and (iv) real estate activities with a domicile in France, Germany, and the Netherlands have benefited the most from the larger volumes of syndicated loans (Figure 3, Panels C and D)

Figure 2. Euro Area: Loan Syndications by Instruments, Green Credentials, Types, and Bank Domiciles

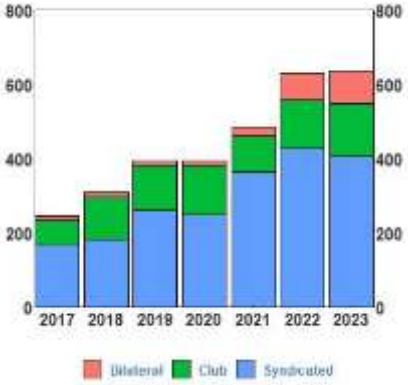
A-Syndicated Loan Volumes and Instruments (€ billion)



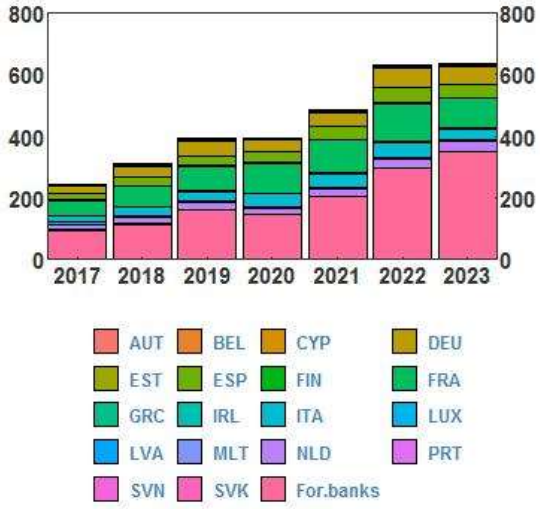
B- Green Syndicated Loans 1/ (€ billion)



C-Banks Originating Syndicated Loans (€ billion)



D- Domicile of Banks Originating Syndications (€ billion)

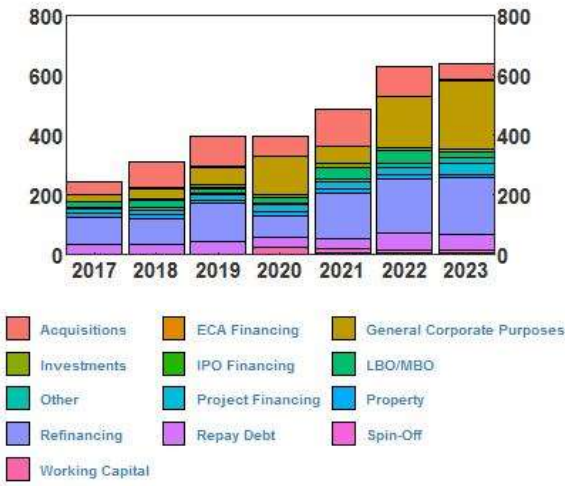


Sources: Dealogic ION and author's calculations.

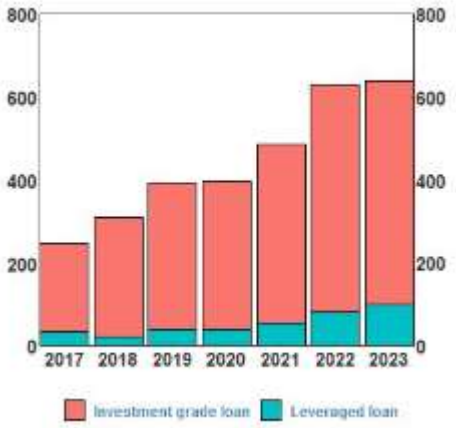
1/ SLLP and GLP stand for Sustainability-Linked Loan Principles and Green Loan Principles

Figure 3. Euro Area: Loan Syndications by Use of Proceeds, Leverage, Sector, and Corporate Domicile

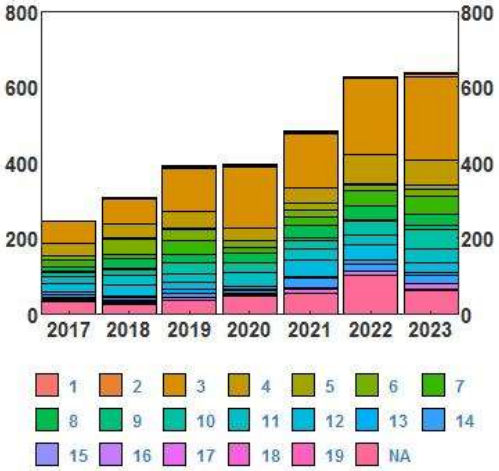
A-Use of Syndicated Loan Proceeds
(€ Billion)



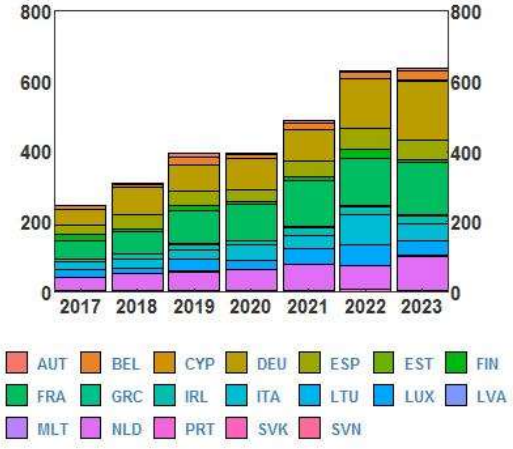
B- Syndicated Loan Types
(€ Billion)



C- Sectoral Composition 1/
(€ billion)



D-Corporate Domicile
(€ Billion)

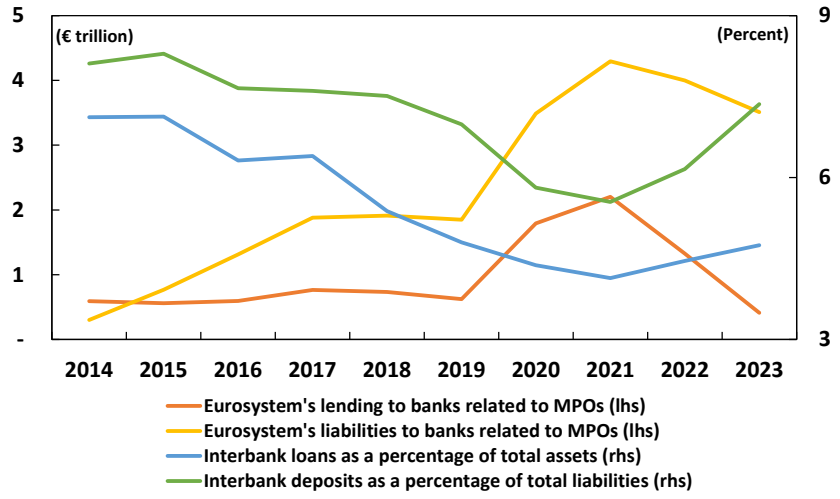


Sources: Dealogic ION and author's calculations.
1/ Sectors include: (1) Agriculture, forestry, and fishing; (2) Mining and quarrying; (3) manufacturing; (4) electricity, gas, steam, and air conditioning supply; (5) water supply, sewerage, waste management, remediation activities; (6) construction; (7) wholesale and retail trade, repair of motor vehicles and motorcycles; (8) transportation and storage; (9) accommodation and food services activities; (10) information and communication; (11) financial and insurance activities; (12) real estate activities; (13) professional, scientific; and technical activities; (14) administrative and support service activities; (15) public administration and defense, compulsory social security; (16) education; (17) human health and social work activities; (18) arts, entertainment, and recreation; and (19) other service activities.

While the role of the euro area interbank loan market in intermediating excess liquidity declined in tandem with the looser monetary policy during the 2010s, the change in monetary policy since 2021 has led to a partial

resumption of its role. Figure 4 shows that interbank loans as percentage of both total assets and liabilities steadily fell during 2014-21 in tandem with the more accommodative monetary policy. The Eurosystem's lending and liabilities to banks related to monetary policy operations (MPO) rose to €2.2 trillion and €4.3 trillion at end 2021 from €0.6 trillion and €0.3 trillion at end 2014 but have declined since then to €0.4 trillion and €3.5 trillion, respectively, at end-2023. At the same time, interbank loans and deposits declined to 4.1 percent of total assets and 5.5 percent of total liabilities in 2021 from 7.1 percent and 8.1 percent in 2014, respectively. After the start of monetary policy tightening in 2022, interbank loans and deposits increased to 4.7 percent of total assets and 7.4 percent of total liabilities, respectively, at end-2023.

Figure 4. Eurosystem Lending and Liabilities to Banks and Interbank Loans



Source: European Central Bank.

Network Valuation Models

Literature Review

Since the GFC, the literature on contagion models has attracted substantial attention. Glasserman and Young (2016), Caccioli et al. (2018), and Jackson and Pernoud (2021) provide an extensive literature review of contagion models. Among the many contagion models, network models are appealing and intuitive as distress in one bank propagates to others mostly through mark-to-market valuations in bank balance sheets. In particular, the original DebtRank valuation model proposed by Battiston et al. (2012) assumes that cumulative equity losses reflect *changes* in valuations of interbank loans, which are a linear function of the respective cumulative equity losses in other banks. As a result, shocks to banks' balance sheets are linearly propagated through the interbank market. This implies a propagation mechanism of shocks that includes both bank distress

and default. However, the linear assumption yields a propagation mechanism that is sensitive even to small shocks and overestimates equity losses. While the first impact is relatively small, mark-to-market losses substantially increase after banks propagate shocks more than once in cycles, resulting in large impairments.

New network models based on nonlinear propagation mechanisms have generated lower marked-to-market losses. Barucca et al. (2020) and Veraart (2020) introduce general frameworks for valuation networks that incorporate different models in the literature as particular cases, including Einsenberg and Noe (2001), Furfine (2003), Battiston et. al. (2012), and Rogers and Veraart (2013), for instance. These valuation models reflect balance sheet interrelationships among banks resulting from counterparty credit risk assessments and incorporate information on equity levels in probabilities of default with different specifications. For instance, Ferracci and Cimini (2022) incorporate nonlinear probabilities of default—as proposed in Bardoscia et al. (2016)—in the network valuation model. These nonlinear probabilities of default are an interpolation between the linear DebtRank and the default driven Furfine (2003) valuation models. Veraart (2020) suggests a probability of default based on the Beta distribution that can also yield simpler specifications, including a linear or a quadratic probability of default while Bardoscia et al. (2019) propose a network valuation with forward-looking probabilities of default. Though nonlinear probabilities of default reduce the mark-to-market losses propagated through the network, bankruptcy costs add a layer of mark-to-market losses as shown in Veraart (2020). Bankruptcy costs—as a deadweight loss—exacerbate contagion in the banking system by reducing the default threshold and wiping out a bank's equity at an earlier stage.

Once contagion through mark-to-market losses is triggered, loss mitigation becomes critical. This should be welfare enhancing, but limits to interventions lead to second bests. Mikhail (2019) analyzes optimal government interventions and finds that: (i) the faster the speed of contagion, the earlier the interventions should take place; and (ii) the more costly and/or the lower the welfare contribution, the less immediate or the less likely the intervention. Along the same lines, Fukker and Kok (2019) also obtain that: (i) the benefit from intervening in the case of severe fire sales triggered by a large shock to external assets is higher than no intervention; and (ii) government budget constraints lower the benefit from intervention, resulting in some banks being excluded from the recapitalization.

Prevention is also important, with stress tests shedding light on vulnerabilities. Incorporating shocks to the corporate sector in contagion models has been important to illustrate the systemic importance of large exposures. Battiston et al. (2016) suggest that stress tests in a DebtRank context would incorporate second round effects arising from contagion through the interbank channel after an initial corporate sector shock. Battiston et al (2016) consider that not only is the absolute size of corporate exposures important for contagion but also their relative size to that of banks' equity. Poledna et al. (2018) incorporate corporate loans and deposits as part of the financial sector network, with both corporate deposits and loans deemed defaultable liabilities and with feedback effects from bank distress to the corporate sector. Roncoroni et al. (2019) propose a methodology to assess the systemic importance of sectoral exposures, accounting for both first- and second-round effects of losses propagated through the European banking system.

Network Valuation Model

Banks' equity valuation in interbank networks relies on estimating expected losses on interbank exposures as indicated in Barucca et al. (2020) and Veraart (2020). This valuation is key to spillovers through interbank

markets triggered by an initial external shock, for instance, to their corporate loan exposures. Adjusting banks' balance sheet identity to incorporate banks' expected losses on their interbank exposures yields:

$$E_i(t) = A_i^e(t) + A_i^o(0) - L_i^e(0) + \sum_{j=1}^{N} A_{ij}\,(t) V_{ij}\big(O_i(t)\big) - \sum_{j=1}^{N} L_{ij}\,(0) \tag{1}$$

where, following the same notation as in Barucca et al. (2020), *N* stands for the total number of banks in the interbank network, $E_i(t)$ for bank *i*'s equity at time *t*, $A_i^e(t)$ for its external assets consisting of other exposures than interbank loans, $L_i^e(t)$ for its external liabilities consisting of other liabilities than interbank deposits, $A_{ij}(t)$ for the nominal value of its interbank loans provided to bank *j*, $V_{ij}(.)$ for the valuation of its interbank loans provided to bank *j*—with $0 \leq V_{ij}(.) \leq 1$— as a function of the information set $O_i(t)$ available to it at time *t*, $L_{ij}(0)$ for the interbank loans provided by bank *j* to *i* that remain constant during the simulation, and $A_i^o(t)$ for other assets consisting of cash and deposits with the central bank. Bank *i* is considered in default when its total assets are equal or less than its liabilities—that is, $E_i(t) \leq 0$.

The valuation term above can also be rewritten with the information set $O_i(t)$ further split between information about equity values $E_i(t)$ and the other information $O_i'(t)$ that is publicly available:

$$O_i = O_i' \cup \{E(t)\} \tag{2}$$

This allows equation (1) above to be rewritten with the valuation term $V_{ij}(.)$ as a function of equity values $E(t)$:

$$E_i(t) = A_i^e(t) + A_i^o(0) - L_i^e(0) + \sum_{j=1}^{N} A_{ij}(t)\, V_{ij}\big(E(t)\big|O_i'(t)\big) - \sum_{j=1}^{N} L_{ij}(0) \tag{3}$$

The valuation of interbank loans $V_{ij}\big(E(t)|O_i'(t)\big)$ is assumed to be equal to the expected value given by the sum of the survival probability and the product of the recovery rate and the probability of default:

$$V_{ij}\big(E(t)\big|O_i'(t)\big) = \Big[1 - PD_{ij}\left(E_j(t)\right)\Big] + \rho PD_{ij}\left(E_j(t)\right) \tag{4}$$

where $PD_{ij}(.)$ stands for probability of default related to bank *j* estimated by bank *i* and ρ for the recovery rate $(0 \leq \rho \leq 1)$. Assuming a zero-recovery rate ρ, bank *i*'s equity at time *t*+1 is driven by other banks' survival probabilities—that is, $1 - PD_{ij}\left(E_j(t)\right)$:

$$E_i(t) = A_i^e(t) + A_i^o(0) - L_i^e(0) + \sum_{j=1}^{N} A_{ij}(t)\Big[1 - PD_{ij}\left(E_j(t)\right)\Big] - \sum_{j=1}^{N} L_{ij}(0), \tag{5}$$

where the matrix $\mathrm{A}_{ij}(t)$ is given by:

$$\mathrm{A}_{ij}(t) = \begin{cases} A_{ij}(t-1) & if\ j \in \Lambda(t-1) \\ 0 & f\ j \notin \Lambda(t-1) \end{cases}, \tag{6}$$

and where the set of solvent banks $\Lambda(t-1)$ up to time t-1 is defined as:

$$\Lambda(t-1) = \{j: E_j(t-1) > 0\}. \quad (7)$$

Different specifications for the probability of default are possible. The nonlinear one in Bardoscia et al. (2016) is an interpolation between the probabilities of default in the linear Debtrank and the Furfine (2003) valuation models.

$$PD_{ij}\left(h_j(t)\right) = h_j(t)e^{\alpha\left(h_j(t)-1\right)} \quad (8)$$

where $h_j(t)$ stands for the cumulative equity losses:

$$h_j(t) = \frac{E_j(0) - E_j(t)}{E_j(0)} \quad (9)$$

and where $E_i(t) \leq E_i(0)$.[6] This specification can also be interpreted as the probability of default derived from the cumulative accuracy profile (CAP) curve as in Van Der Burgt (2008), with the denominator adjusted to map $h_i(t) = 1$ into $PD(h(t) = 1) = 1$.

The effects of corporate distress on banks can be easily incorporated in the network valuation model by assuming that external assets consist of corporate loans CL_{ik} (including syndicated loans) provided by bank *i* to corporate *k*. These external assets $A_i^e(1)$ are marked down by:

$$A_i^e(1) = (1-\lambda)\sum_{k\epsilon\Gamma(0)} CL_{ik}, \quad (10)$$

where $\Gamma(0)$ is a set of corporates that are not under default at time 0 and λ is the size of the markdown (in percent of the total exposure) without any asset recovery value. Alternatively, λ can also be calibrated to reflect the effect of incomplete or delayed reporting of syndicated loan markdowns.

Initial equity losses at time 1 from syndicated loan markdowns are then equivalent to (as a percentage of the initial equity $E_i(0)$):

$$h_i(1) = \frac{E_i(0) - \lambda\sum_{k\epsilon\Gamma(0)} CL_{ik}}{E_i(0)} \quad (11)$$

while the cumulative equity losses at time t are as following:

$$h_i(t) = \frac{E_i(0) - E_i(t)}{E_i(0)} \quad (12)$$

[6] As an alternative to the probability of default specification in Bardoscia et al. (2016), Carro and Stupariu (2024) propose a logit specification that smooths the transition between states of low and high probabilities of default.

which reflects the cumulative equity losses at time t arising from all propagation after the initial leveraged loan markdowns. For easier visualization, cumulative equity losses are displayed as a percentage of the N banks' initial equity:

$$h_i'(t) = \frac{E_i(0) - E_i(t)}{\sum_{i=1}^{N} E_i(0)}. \quad (13)$$

which can be considered as a proxy for bank i's systemic importance. Similarly, the total number of defaults is given by the number of banks with cumulative equity losses greater or equal one:

$$ND = \sum_{i=1}^{N} I^D_{h_i(t)\geq 1}, \quad (14)$$

where $I^D_{h_i(t)\geq 1}$ is an indicator function that tracks default—or whenever equity losses $h_i(t)$ for bank *i* is greater or equal to one.

Incorporating Bankruptcy Costs

Bankruptcy costs add an extra layer of losses to equity. They are the cost associated with going bankrupt, including recovery expenses, and are equivalent to deadweight losses. They not only increase overall costs but also result in equity dropping to zero at an earlier stage in the network valuation model. If the bankruptcy costs amount to μ percent of the initial equity $E_i(0)$, equity $E_i(t)$ at time t would drop to zero from above once it approaches the default threshold $\mu E_i(0)$:

$$E_i(t) = \begin{cases} 0 & if \;\; A_i^e(t) + A_i^o(0) - L_i^e(0) + \sum_{j=1}^{N} A_{ij}(t)\, V_{ij}\big(E(t)\big|O_i'(t)\big) - \sum_{j=1}^{N} L_{ij} \leq \mu E_i(0) \\ A_i^e(t) + A_i^o(0) - L_i^e(0) + \sum_{j=1}^{N} A_{ij}(t)\, V_{ij}\big(E(t)\big|O_i'(t)\big) - \sum_{j=1}^{N} L_{ij}(0) & if \;\; otherwise \end{cases}. \quad (15)$$

where external assets $A_i^e(t)$ are given by equation (11). Finally, to capture the effect of several simultaneous bank defaults during periods of financial stress, the bankruptcy cost parameter μ can be calibrated to reflect congestion in courts associated with a larger number of failing banks.

Incorporating Recapitalization

Finally, recapitalization of systemically important banks works as "circuit breaker" that interrupts losses in the network valuation model. For instance, when the systemically important bank i 's equity $E_i(t)$ is lower than a recapitalization threshold and the bank is immediately recapitalized, its equity $E_i(t)$ would be reset to a level either equal to $E_i(0)$ or higher as long as: (i) the bank is supervised by the SSM; (ii) it has not been recapitalized more than once either; (iii) there are enough convertible liabilities in the bank; and (iv) there are sufficient private or public resources to recapitalize it:

$$E_i(t) = \begin{cases} \beta E_i(0) & if\ \ A_i^e(t) + A_i^o(0) - L_i^e(0) + \sum_{j=1}^{N} A_{ij}(t)\, V_{ij}\big(E(t)\big|O_i'(t)\big) - \sum_{j=1}^{N} L_{ij}(0) \le \gamma E_i(0), \\ & i \in \{SSM\ banks\},\ I_i^R(t) \le 1,\ \sum_{i=1}^{M \le N} I_i^R(t) E_i(0) \le R(t),\ and\ L_i^e(0) - \delta\beta E_i(0) \ge 0 \\ A_i^e(t) + A_i^o(0)\ \ - L_i^e(0) + \sum_{j=1}^{N} A_{ij}(t)\, V_{ij}\big(E(t)\big|O_i'(t)\big) - \sum_{j=1}^{N} L_{ij}(0) & if\ \ otherwise \end{cases} \quad (16)$$

where $I_i^R(t)$ is an indicator that tracks whether the systemically important bank *i* has been recapitalized and limits recapitalization to a maximum of one,[7] $\beta \ge 1$ and $0 \le \gamma \le 1$ are parameters depicting the scale and the timing of the recapitalization, respectively, and $0 \le \delta \le 1$ is a parameter capturing the conversion of external liabilities into equity.[8] Under limited available resources $R(t)$ for recapitalization, systemically important banks are ranked according to specific criteria and only *M* of them are selected to prevent total recapitalizations from exceeding available resources—that is, $\sum_{i=1}^{M \le N} I_i^R(t) E_i(0) \le R(t)$.

If required by the recapitalization scheme, a systemically important bank would record a reduction in other external liabilities:

$$L_i^e(t) = L_i^e(0) - \delta\beta E_i(0) \ge 0, \quad (17)$$

arising from its partial conversion into equity equivalent to $\beta E_i(0) \ge 0$. It would also book a simultaneous increase in other assets $A_i^o(t)$:

$$A_i^o(t) = A_i^o(0) + (1 - \delta)\beta E_i(0) \quad (18)$$

to match the net recapitalization $(1 - \delta)E_i(0) \ge 0$ provided by the available outside recapitalization resources. Finally, the balance of available recapitalization resources $R(t)$ would also reflect all recapitalizations of systemically important banks:

$$R(t) = R(0) - \delta \sum_{i=1}^{M \le N} I_i^R(t) \beta E_i\,(0). \quad (19)$$

Any recapitalization scheme of systemically important banks with limited resources would need to weigh the costs and benefits from different recapitalization options. One option would involve some criteria to rank the banks, for instance, according to the impact of their default on other banks. This would restrict the recapitalizations to an amount lower than available funds, implying that some systemically important banks would be allowed to default if there are not enough resources to recapitalize all of them. Another option would be to recapitalize all defaulting banks at each point in time if and only the sum of their recapitalization needs is

[7] In principle, banks could be recapitalized more than once.

[8] Alternatively, the recapitalization threshold can also be set in terms of a minimum capital ratio. Moreover, recapitalization is set above the initial equity level to prevent further contagion in the network. Finally, the restriction that each bank can only be recapitalized once prevents additional recapitalizations throughout contagion cycles.

lower than the available recapitalization resources, implying an approach in which no more systemically important bank would be recapitalized after available recapitalization resources are exhausted.

The recapitalization of systemically important banks as shown above would then set a positive contagion in motion. Equity in lending banks exposed to the defaulting systemically important bank would rise in tandem with the recapitalization. The latter would trigger a reversal of mark-to-market losses in lending banks and would be equivalent to their indirect and partial recapitalization.

Convergence and Stability Properties of Cumulative Equity Losses

Barucca et al. (2020) show that the solution to the equity valuation equation (6) above is a fixed point. The system of equations consisting of all equity valuations can be solved iteratively by selecting a starting point for the equity valuations and solving the equations repeatedly until equity valuation changes are lower than an arbitrary low number. In particular, if the valuation $V_{ij}\big(E(t)|O_i'(t)\big)$ of interbank loans is a feasible solution with $0 \leq V_{ij}\big(E(t)|O_i'(t)\big) \leq 1$, non-decreasing function of the equity valuation $E(t)$ with $V_{ij}\big(E(t)|O_i'(t)\big) \leq V_{ij}\big(E'(t)|O_i'(t)\big)$ when $E(t) \leq E'(t)$, and continuous from below, the solution is simultaneously optimal for all banks. Moreover, when the initial equity book values are the starting points for the iterations, the optimal solution is the greatest solution that minimizes individual and total losses.

However, though the equity valuation equation (6) might have the greatest solution, the latter can still lead to unstable equity losses when cycles can be found in the interbank asset matrix $A_{ij}(t)$. Barucca et al. (2020) also indicate that the solution to the equity valuation equation (6) is unique and that convergence takes a finite number of iterations when the interbank asset matrix $A_{ij}(t)$ is an adjacency matrix of a directed acyclic graph (DAG). When the interbank asset matrix $A_{ij}(t)$ is an adjacency matrix of a directed cyclic graph (DCG), convergence is slower, with some outcomes associated with large individual and/or total equity losses. In particular, this would be the case if the maximum eigenvalue $e^{-\alpha}\lambda_{max}$ associated with the adjusted interbank leverage matrix $e^{-\alpha}\Lambda(0)$ is greater than one. As shown in Annex 1, the cumulative equity losses can be substantially reduced if α is calibrated to yield a maximum eigenvalue $e^{-\alpha}\lambda_{max}$ that is lower than one.

Corporate and Interbank Exposures

The network valuation model requires detailed information on outstanding bilateral syndicated and interbank loan exposures. While this information is not publicly available, information on syndicated loan origination and total interbank assets and liabilities can be obtained from financial services platforms. For instance, Dealogic ION contains information on syndicated loans, banks' annual reports and Fitch Connect on banks' financials, S&P Capital IQ on corporate ratings. As a result, the estimation of bilateral syndicated and interbank loans exposures based on information on syndicated loan origination and total interbank assets and liabilities require simplifying working assumptions. Firstly, the scope of the analysis is limited to mandated syndicated loans originated by euro area banks to euro area corporates before December 31, 2023, with maturity dates extending beyond January 1, 2024. Secondly, originated syndicated loans are grouped into three broad categories according to Cerruti et al. (2014). These reflect whether they are retained or sold to investors:

- *Term loans*. Type A term loans are considered as fully retained by banks while Type B to F term loans are assumed to be mostly sold to investors (Standard and Poor's, 2020), with only 5 percent retained by banks. Any institutional investor other than a bank that is part of the syndicate is excluded.

- *Credit lines*. These include revolving loans, reducing revolving, over-draft facility, bridge facility, credit facility, multiple facility, and commitment line. These are assumed to be unfunded and originated by banks. Only drawn amounts are considered as outstanding and retained by banks (Standard and Poor's, 2020).

- *Miscellaneous*. All other types of loans, including supplier and buyer credit, construction loan, commercial paper facility, lease facility loans, are considered as originated and retained by banks.

Thirdly, syndicated loans are consolidated at the parent level both for corporates and banks.[9] This reduces the number of nodes in the bank-corporate network and makes the resulting bilateral exposures comparable with the large exposure regime. While some corporates are consolidated in holding companies, others are owned by private equity firms with no publicly disclosed information. As a result, consolidation is not straight forward and requires the following simplifying assumptions for non-active corporates:

- *Ceased, liquidated, or merged corporates*. Only syndicated loans to active or inactive but with disclosed parent company as reported by Dealogic ION are considered as outstanding.

- *Merged, resolved, or liquidated banks*. Syndicated loans originated by merged, resolved, or liquidated banks are considered as outstanding when they are transferred to an acquiring bank. Loans that are transferred to an asset management company are not considered in the network.

Fourth, syndicated loans are allocated on a pro-rata basis (loan amount divided by the number of lenders in the syndication). Dealogic ION provides information only on the total amount originated by the syndicate of banks without any other detail on their allocation. Though exposure limits set the maximum amount banks can hold of a syndicated loan, some bank exposures might be under- or over-estimated. This could marginally affect the impact of syndicated loan markdowns on bank equity under high confidence scenarios in banks to recover from equity losses. However, this effect would be diluted under the low confidence scenario in which even small markdowns would trigger large cumulative equity losses resulting from the propagation of the initial markdown shock that only dyes out slowly through the interbank market.

Finally, unclassified term loans in Dealogic ION are grouped based on market practices and the literature as follows:

- *Type A term loans*. Those loans with a grace period, originated by a club of banks (Standard and Poor's, 2020), bilaterally, or as liquidity support (COVID loans). Outstanding amounts are obtained with principal amounts linearly adjusted for amortization with information on grace period.

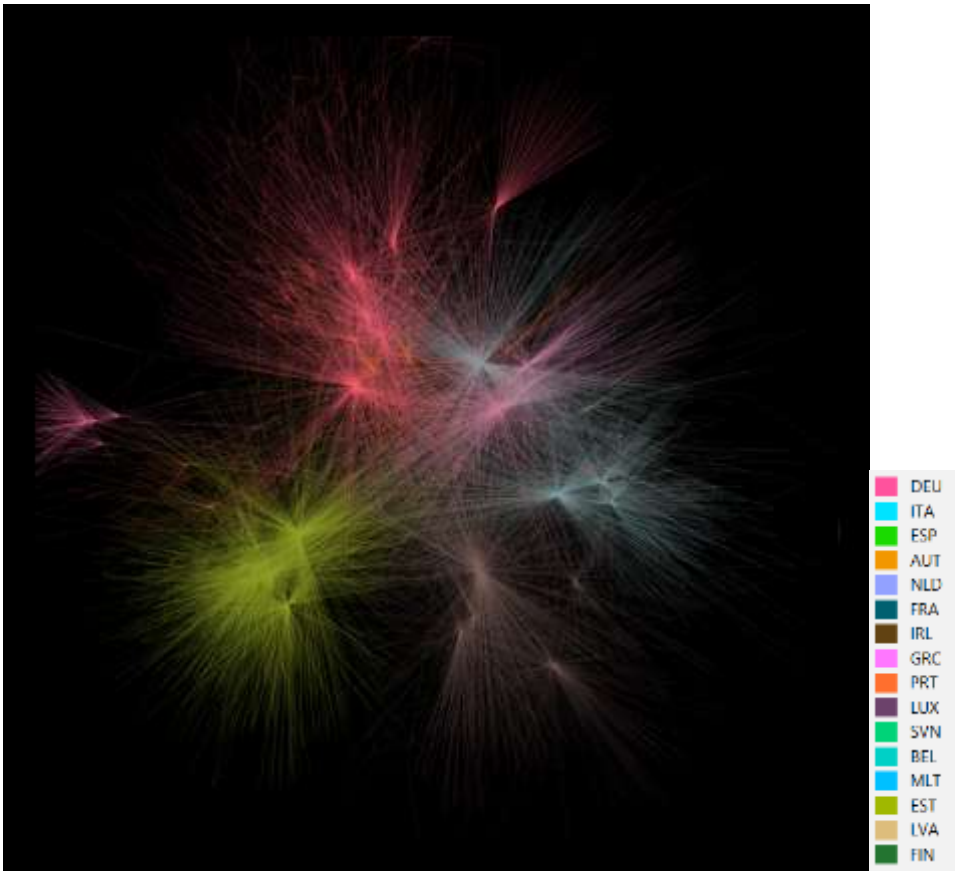
- *Type B term loans*. Those with bullet payments (Standard and Poor's, 2020), low amortization installments (e.g., 1 percent; Marsh and Virmani, 2021), private placement (NN Investment Partners,

[9] Consolidation implicitly assumes that both parent banks and corporates would bail out their subsidiaries.

2017), and oversubscribed (Standard and Poor's, 2020). The residual loans that cannot be grouped according to any of the previous criteria are considered as type B loans with only a bullet payment on the maturity date.

The obtained syndicated loan exposure network contains intricate linkages among banks and corporates. After group consolidation, loan reclassification, and principal adjustment, outstanding syndicated loan exposures to corporates are obtained by adding all loans granted by a specific bank group to a specific corporate group. The resulting network consists of 11,144 syndicated loan exposures to 4,012 parent corporates by 256 parent banks. Figure 5 plots the network, with nodes representing either banks or corporates while edges are proportional to the syndicated loan exposure amounts obtained with the graph visualization platform *Gelphi*. Corporates are located on the head side while banks are on the opposite side, mostly where the edges converge to vertexes. Figure 5 shows that markdowns to some corporates, in particular those in the middle of the network, can simultaneously affect a large number of banks' equity. Finally, the estimated syndicated loan exposures at end-2023 totaled €849.5 billion, which is lower than the €946.5 billion total amount of syndicated loans compiled by the ECB.

Figure 5. Estimated Euro Area Syndicated Loan Network

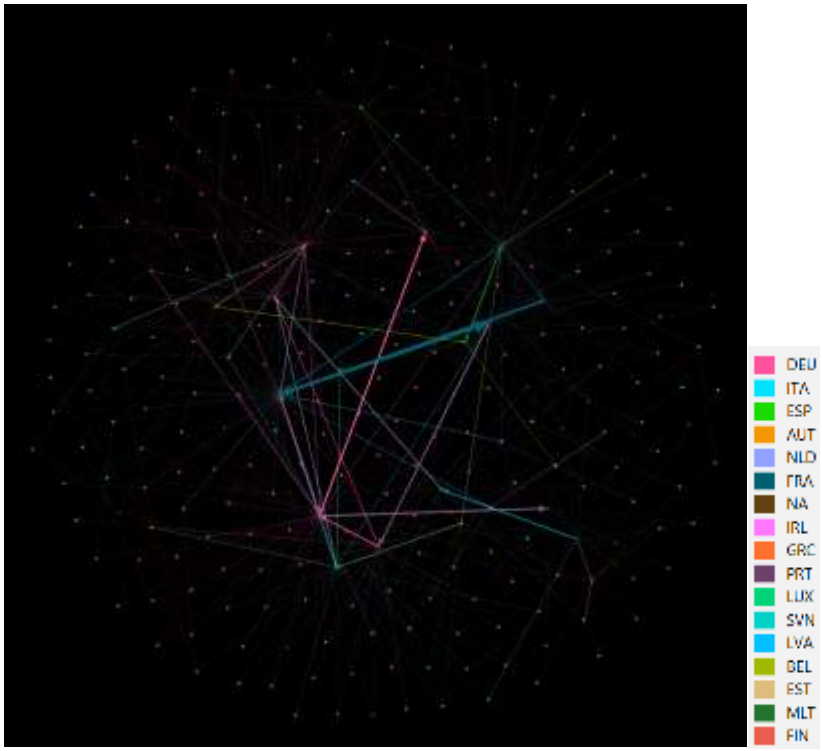


Sources: Dealogic ION and author's calculations.

Shocks in valuation network models are propagated through the interbank market. Other contagion channels could exist, such as through corporate bonds and derivatives. Information on bilateral interbank exposures is collected by the ECB as part of their supervisory activities and is not made publicly available. However, banks'

annual report, complemented by S&P Market Intelligence and Fitch Connect, only contain total loans and advances due to and deposits from banks. These can be used in the estimation of a bilateral interbank exposure matrix at a bank group level with the Minimum Density Estimation method (Anand et al, 2015) in the R library *NetworkRiskMeasures*.[10] This method minimizes the links needed for assigning a given volume of interbank loans, resulting in a sparse interbank loan exposure matrix, while reducing false positive errors associated with incorporating lending relationships when they are not part of the network, as described by Anand et al. (2017). Figure 6 displays the resulting matrix where 516 edges are proportional to the interbank loan exposures while 256 nodes represent banks, with borrowing banks located on the head side and lending banks located on the opposite side.[11] German, Italian, and Spanish banks have the largest number of edges.

Figure 6. Estimated Euro Area Interbank Loan Network



Sources: Banks' annual reports, S&P Market Intelligence, Fitch Connect, and author's calculations.

The estimated bilateral consolidated interbank exposure matrix by banking groups is characterized by a larger share of cross-border interbank exposures (68 percent of total interbank exposures) than of domestic interbank exposures (32 percent). However, this characterization can still be consistent with a larger share of unconsolidated domestic interbank exposures (67 percent) than the share of unconsolidated cross-border interbank exposures (32 percent) in the euro area as published in European Central Bank (2024). Firstly, the universe of institutions covered by the ECB is larger and includes not only deposit-taking institutions but also money market funds. Secondly, while the estimated consolidated balance sheet excludes intra-group

[10] Both Interbank loans and deposits exclude reverse repos and repos, respectively.

[11] As the sum of interbank loans across different bank groups was greater than the sum of their interbank deposits at end-2023, each bank's interbank loans were normalized by the ratio the sum of interbank loans to the sum of interbank deposits. This ensures that the sum of interbank loans is equal to the sum of interbank deposits.

exposures, loans by monetary financial institutions to other monetary financial institutions in the ECB publication would consider intra-group exposures. As a result, the inclusion of intra-group loans to and deposits—specially in cooperative bank groups in Finland, France, Italy, and Spain—would substantially change the characterization of the estimated bilateral interbank exposure matrix. For instance, Credit Agricole Group reported outstanding intra-group current accounts and term deposits amounting to €89.6 billion at end-2023 while inter-group current accounts and term deposits from were lower at €85.6 billion—which is considered in the estimation of the bilateral interbank matrix.[12]

Results

Estimating the Syndicated Loan Exposures

Grouping syndicated loan exposures according to different bank and corporate attributes can help shed light on their systemic importance. Figure 7 plots bidimensional histograms in which the horizontal axis shows the distribution of syndicated loan exposures according to their absolute size (in buckets) and as a percentage of bank capital (a proxy for their degree of systemic risk) while the vertical axis displays the distribution of syndicated loan exposures according to bank headquarters, their supervisors, and ratings. The different bidimensional histograms indicate that most bilateral exposures are within prudential large exposure limits set by the EBA, including below the 25 percent of Tier I capital and the €150 million thresholds:[13]

- *Bank headquarters*. Banks in France, Germany, Italy, the Netherlands, and Spain held most of the exposures under €100 million as of end-2023 (Figure 7, Panel A). Though some exposures, as a percentage of total equity, by banks located in Germany and Spain seemed to be above the prudential large exposure limits, compliance with these limits needs to consider netting out any public guarantees associated with these exposures.

- *Bank supervisors*. While the largest bank groups supervised by the ECB held a significant number of the smaller and larger exposures (Figure 7, Panel B), the largest ones as a percentage of banks' equity were held by some smaller banks under the supervision of the German and Spanish national supervisory authorities.

- *Bank ratings*. Investment grade banks (above BBB-) also held a sizeable number of exposures (Figure 7, Panel C). However, some non-rated banks held exposures that represented a large share of their equity.

Moreover, concentration exposure in certain credit risk segments can also be a source of vulnerability. Figure 8 also displays a bidimensional histogram with the distribution of syndicated loan exposures according to

[12] The gap on the asset side is even larger at end-2023 for Credit Agricole Group where intra-group loans and receivables due from credit institutions amounted to €418.6 billion while loans and receivables due from other external credit institutions were lower at €136.7 billion.

[13] In the Europe, the EBA has set prudential large exposure limits to a client or a group of connected clients to prevent banks from incurring large concentration risk in their books. These require large exposures not to exceed more than: (i) 25 percent of the institution's Tier 1 capital (or 15 percent for global systemically important institutions to other global systemically important institution) after accounting for credit risk mitigants; and (ii) either 25 percent of the institution's Tier 1 capital or EUR150 million, whichever is higher, for connected parties.

absolute and relative sizes of exposures on the horizontal axis and the distribution of syndicated loan exposures according to corporate headquarters, sector, and leverage on the vertical axis. It depicts a low concentration of syndicated loan exposures in risky segments as follows:

- *Corporate headquarters*. Most syndicated loans were provided to corporates with headquarters in Germany, France, Italy, the Netherlands, and Spain as of end-2023 (Figure 8, Panel A).

- *Sectoral exposures*. Euro area banks' exposures were concentrated mostly in the energy, finance manufacturing, and transportation sectors (Figure 8, Panel B). Some large exposures to energy and administrative and support service sectors as a percentage of total equity seemed to be higher than the prudential large exposure limits.

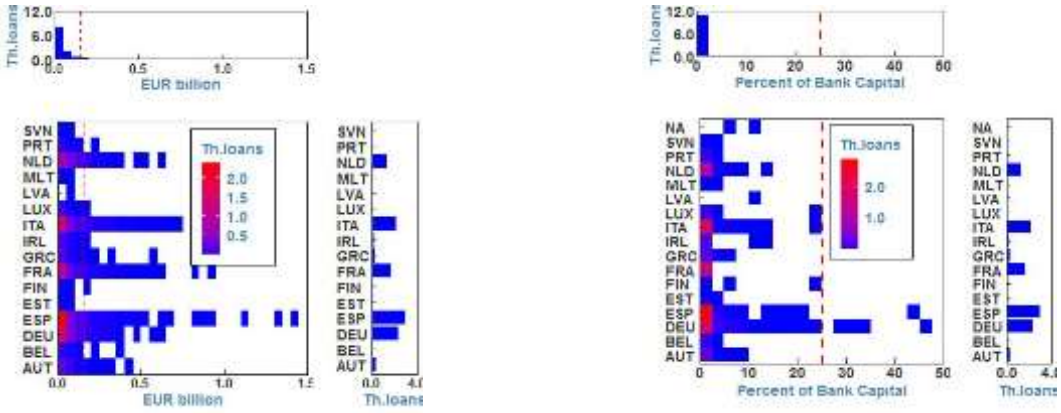
- *Corporate ratings*. More than 50 percent of the exposures were granted to investment grade corporates at the origination (Figure 8, Panel C). Some exposures to leveraged corporates represented a large share of banks' total equity.

The low size of most syndicated loan exposures suggests that the immediate impact of euro area corporate defaults on euro area banks' equity may be limited. However, shocks originated from widespread corporate distress can be substantially amplified when banks spread shocks more than once in cycles, as simulated in the next section.

Figure 7. Estimated Outstanding Syndicated Loan Exposures by Euro Area Banks, End-2020 1/

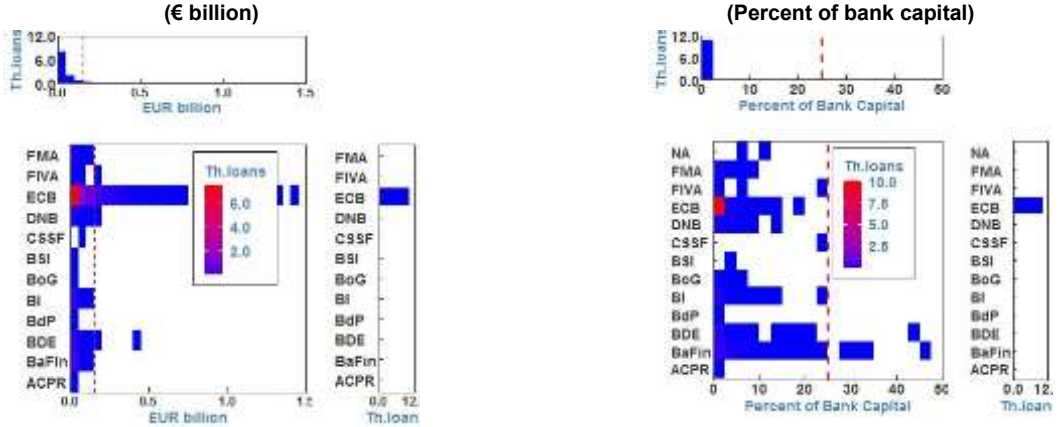
A-Exposures by Bank Headquarters

(€ billion) **(Percent of bank capital)**



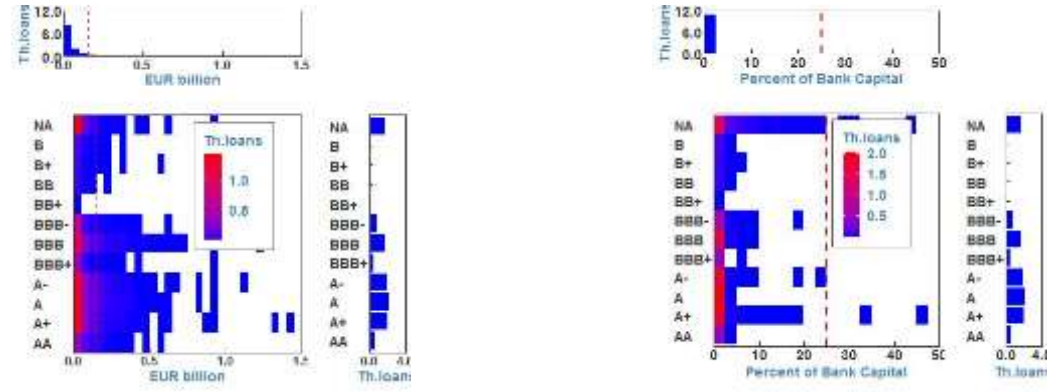
B-Exposures by Bank Supervisor

(€ billion) **(Percent of bank capital)**



C-Exposures by Bank Ratings

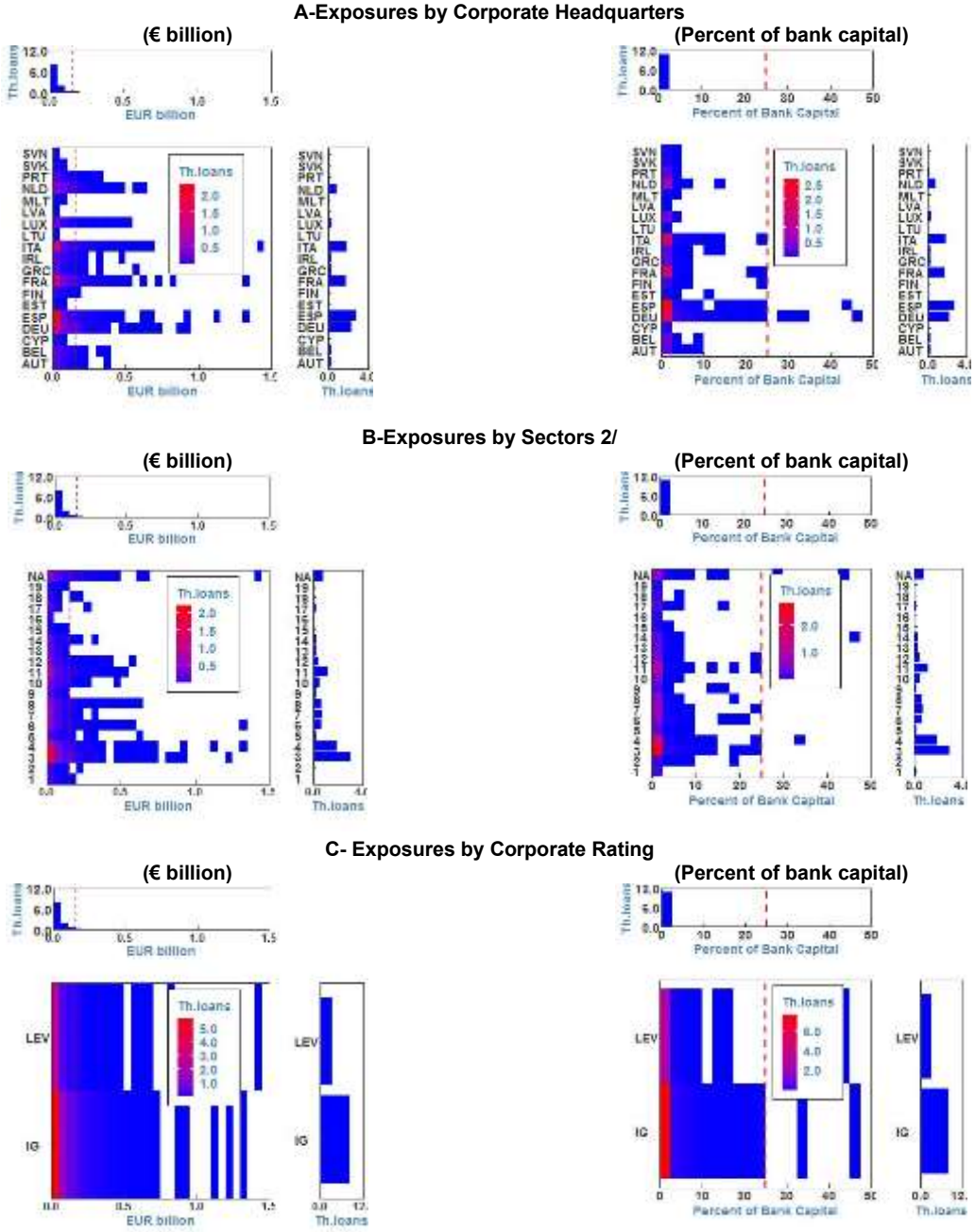
(€ billion) **(Percent of bank capital)**



Sources: Dealogic ION, banks' annual reports, S&P Market Intelligence, Fitch Connect, ECB, and author's calculations.

1/ Bi-dimensional histograms and marginals with the x axis displaying the distribution of syndicated loan exposures according to their absolute size (bins of €50 million) and as a percentage of bank capital (bins of 2.5 percent) while the vertical axis displays the distribution of syndicated loan exposures according to bank headquarters, their supervisors, and ratings. Prudential large exposure limits are shown as dashed vertical lines.

Figure 8. Estimated Outstanding Syndicated Loan Exposures to Euro Area Corporates, End-2020 1/



Sources: Dealogic ION, banks' annual reports, S&P Market Intelligence, Fitch Connect, ECB, and author's calculations.

1/ Bi-dimensional histograms and marginals with the x axis displaying the distribution of syndicated loan exposures according to their absolute size (bins of €50 million) and as a percentage of bank capital (bins of 2.5 percent) while the vertical axis displays the distribution of syndicated loan exposures according to corporate headquarters, sectors, and ratings. Prudential large exposure limits are shown as dashed vertical lines.
2/ Sectors include: (1) Agriculture, forestry, and fishing; (2) Mining and quarrying; (3) manufacturing; (4) electricity, gas, steam, and air conditioning supply; (5) water supply, sewerage, waste management, remediation activities; (6) construction; (7) wholesale and retail trade, repair of motor vehicles and motorcycles; (8) transportation and storage; (9) accommodation and food services activities; (10) information and communication; (11) financial and insurance activities; (12) real estate activities; (13) professional, scientific; and technical activities; (14) administrative and support service activities; (15) public administration and defense, compulsory social security; (16) education; (17) human health and social work activities; (18) arts, entertainment, and recreation; and (19) other service activities.

Simulating Spillovers

The syndicated and interbank loan networks described in the last section can be a useful tool to analyze the impact of single-name and widespread corporate distress on financial stability. The markdown of syndicated loans by banks retaining them in their loan book is also equivalent to a shock to holdings of syndicated loans arising from fire-sales. Moreover, as equity is written down due to markdowns, the loan distress is spread to other banks through revaluation of interbank loans. As a result, though the low size and concentration of syndicated loan exposures suggest that the immediate impact of euro area corporate distress on euro area banks' equity may be limited, shocks originated from corporate distress can be amplified in the interbank loan network when banks spread shocks more than once in revaluation cycles.

The shock amplification in the interbank network largely depends on the stability properties of the interbank network matrix. The Minimum Density Estimation approach by Anand et al. (2015) generates a bilateral interbank network $A_{ij}(0)$ with a low edge density (0.007). This is consistent with the pos-GFC interbank network with lower densities as highlighted by Ramadiah et al. (2022). If the maximum eigenvalue $e^{-\alpha}\lambda_{max}$ associated with the equity-adjusted interbank leverage matrix $\Lambda(0)$ is greater than one, cumulative equity losses and bank defaults are unstable. In the case of the interbank leverage matrix $e^{-\alpha}\Lambda(0)$, its estimated maximum eigenvalue is 2.02. As a result, a coefficient *α* that is higher than 0.703 would dampen the estimated maximum eigenvalue of the adjusted interbank leverage matrix $e^{-\alpha}\Lambda(0)$ to a value lower than one, resulting in stable cumulative equity losses and bank defaults. Ramadiah et al. (2022) consider the combination between network density and the *α* coefficient as an indication whether confidence is high or low in the capacity of banks to recover from equity losses. In the case of the results below, the high and low confidence environment is associated with *α* coefficients that are higher or lower than 0.703, respectively.

The impact of corporate distress on systemic risk depends jointly on the size of the shock, the number of affected firms, and the confidence enjoyed by banks to recover from equity losses. Figure 9, Panel A displays density estimates (ridgelines) from total cumulative losses triggered by 4,012 single-name syndicated leveraged loan markdowns as a function of the markdown—ranging from 10 percent to 100 percent, with steps of 10 percent—when banks enjoy strong confidence to recover from their equity losses; that is, when the coefficient *α* is equal to 3 (left chart) and 1.5 (right chart).Similarly, Figure 9, Panel B plots cumulative losses from widespread syndicated leveraged loan markdowns in the manufacturing, energy, and finance sectors—with markdowns ranging from 1 percent to 100 percent, with steps of 1 percent—under the same confidence environments. Both panels show that single-name and widespread syndicated leveraged loan markdowns (even a full markdown) do not trigger systemic risk when there is high confidence in banks to recover from equity losses. This is not surprising, given past large corporate insolvencies. In particular, the collapse of Wirecard (a single-name exposure), for instance, in June 2020 resulting from extensive fraud was not followed by contagion among banks, though some banks booked substantial provisions associated with their direct exposures to Wirecard.[14] Finally, if bankruptcy costs were incorporated in the nonlinear network valuation model, they would further increase bank distress, worsening cumulative equity losses.

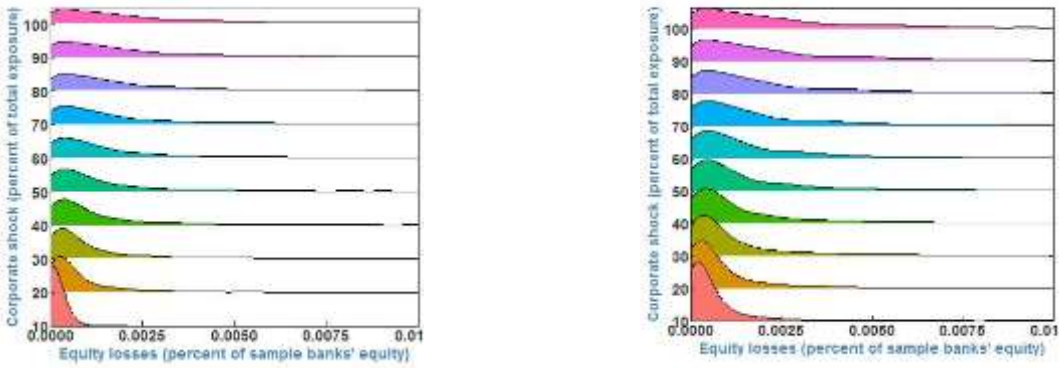
[14] Wall Street Journal reported on August 5, 2020 that 15 banks lent €1.75 billion to Wirecard under a revolving credit facility in June 2018. In particular, Commerzbank disclosed on August 5, 2020 that it had booked €175 million in provisions associated with a "single case."

Figure 9. Simulations of Bank Distress Triggered by Leveraged Loan Markdowns Under Full Confidence

(Percent of sample bank's equity)

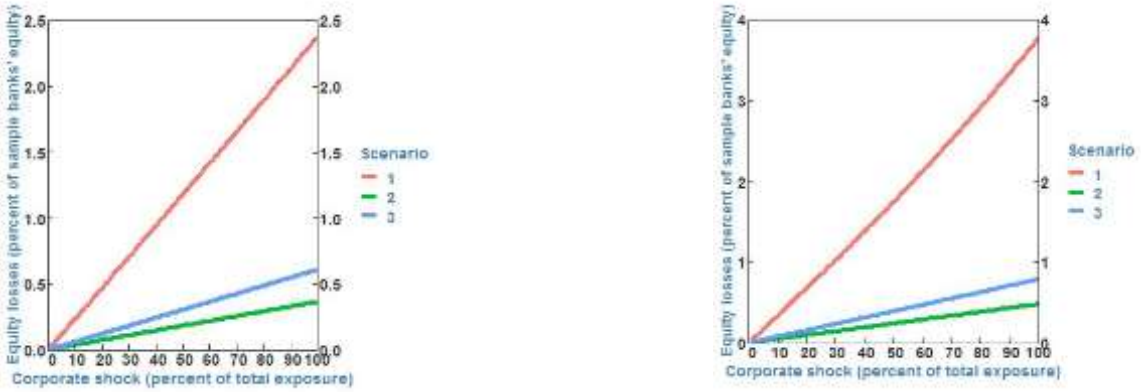
Panel A: Single-Name Markdowns

α = 3 **α = 1.5**



Panel B: Widespread Markdowns 1/

α = 3 **α = 1.5**



Sources: Dealogic ION, banks' annual reports, S&P market Intelligence, Fitch Ratings, and author's calculations.

1/ Scenarios include syndicated loan markdowns to the following sectors: (1) manufacturing; (2) energy, and (3) finance.

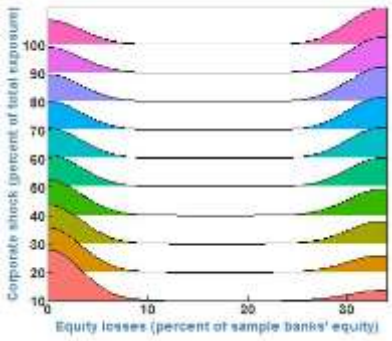
On the other hand, single-name and widespread distress in syndicated leveraged loans could trigger large equity losses and bank defaults under a scenario of low confidence. Figure 10 plots total cumulative equity losses arising, respectively, from single-name and widespread syndicated leveraged loan markdowns in the manufacturing, energy, and finance sectors as a function of markdowns when α is equal to 0.703.[15] Figure 10, Chart A shows bimodal density estimates (ridgelines) from equity losses arising from different single-name syndicated loan markdowns. The different density estimates imply that mounting markdowns under the low confidence scenario would trigger increasingly larger cumulative equity losses—above 33 percent of the sample banks' total equity—as cycles in the interbank asset matrix lead to rounds of propagation of the initial

[15] Based on NACE classification.

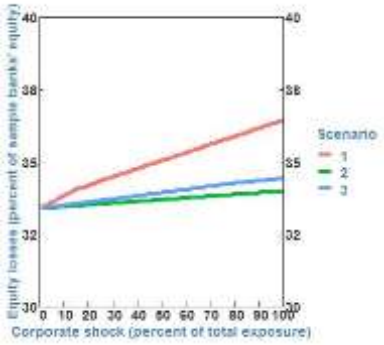
markdown shock that only dyes out slowly. However, a scenario of low confidence in the banking system with large cumulative equity losses triggered by a single-name syndicated leveraged loan markdowns would likely be accompanied by simultaneous and widespread markdowns in other syndicated leveraged loan exposures, for instance, in one or several other sectors. Figure 10, Chart B indicates that widespread syndicated leveraged loan markdowns in the manufacturing, energy, and finance sectors would spark large total cumulative equity losses, representing at most 36 percent of the sample banks' equity, under the low confidence scenario in the capacity of banks to recover their equity losses.[16]

Figure 10. Simulations of Bank Distress Triggered by Leveraged Loan Markdowns Under No Confidence (α = 0.703)
(Percent of sample bank's equity)

A. Single-Name Markdowns



B. Widespread Markdowns 1/



Sources: Dealogic ION, banks' annual reports, S&P market Intelligence, Fitch Ratings, and author's calculations.

1/ Scenarios include syndicated loan markdowns to the following sectors: (1) manufacturing; (2) energy, and (3) finance.

Working as circuit breakers, calibrated and timely recapitalization of systemically important banks substantially reduces the effect of widespread syndicated leveraged loan markdowns on total cumulative equity losses under the low confidence scenario. Figure 11 shows the effects of a recapitalization scheme for systemically important banks supervised by the SSM that: (i) is triggered when equity falls below $E_i(t) \leq \gamma E_i(0)$, with γ restricted to either 0 or 0.2; (ii) limits the number of recapitalizations to one per bank; (iii) ranks systemically important banks by their degree, or number of edges, leaving some of them not recapitalized if the total resource envelope of €146 billion for recapitalization is exhausted;[17] (iv) recapitalizes banks to $E_i(t) = \beta E_i(0)$, where β is constrained to either 1 or 1.2; and (v) matches the recapitalization with a reduction of $\delta\beta E_i(0)$ in other external liabilities and an increase of $(1-\delta)\beta E_i(0)$ in other external assets, where δ is set equal to 8 percent, as long as there are enough other liabilities to be converted into equity. Figure 11 indicates that the recapitalization scheme would significantly limit total cumulative equity losses from widespread syndicated leveraged loan markdowns under a low confidence environment. These would range between:

[16] Equity losses and bank defaults from single-name markdowns under the low confidence scenario sets the floor for the ones under the high confidence scenario.

[17] The resources available for the recapitalization of systemically important banks amounted to EUR78 billion at end-2023 as reported by the Single Resolution Fund. An additional EUR68 billion will be available in a backstop from the ESM to the SRB whenever all countries ratify the ESM reforms.

(i) 2 percent and 30 percent of sample banks' equity (Figure 11, Panel A, left chart) when equity is fully depleted (γ constrained to 0) and recapitalization restores initial equity levels (β equal to 1). In this case, available recapitalization resources would drop from €146 billion to a range between €50 billion and €104 billion (Figure 11, Panel A, right chart). The many peaks in the left chart correspond to large net equity losses in one or several systemically important banks before recapitalization.

(ii) 3 percent and 7 percent of the sample banks' equity (Figure 11, Panel B, left chart) when equity is fully depleted (γ is equal to 0) and banks are recapitalized 20 percent above the initial equity levels (β equal to 1.2). Available recapitalization resources would decline from €146 billion to a range between €39 billion and €93 billion (Figure 11, Panel B, right chart); and

(iii) 1 percent and 7 percent of the sample banks' equity (Figure 11, Panel C, left chart) when a recapitalization of 20 percent above initial equity levels (β equal to 1.2) is triggered after equity drops to below 20 percent of the initial equity level (γ is equal to 0.2). Available recapitalization resources would decline from €146 billion to a range between €64 billion and €104 billion (Figure 11, Panel C, right chart).

The larger use of available recapitalization resources in the case of a 20 percent recapitalization above initial equity when the latter is fully depleted should not come as a surprise. As a result, an earlier 20 percent recapitalization above initial equity when the latter drops by more than 80 percent (to below 20 percent) would require less use of available recapitalization resources. Except in a few cases, an earlier recapitalization to restore equity to its initial value would also prevent contagion triggered by widespread syndicated loan markdowns. An optimum recapitalization strategy would need to strike a balance—in terms of costs and benefits—between its size and timeliness. In particular, well-calibrated recapitalization would provide additional buffers to lean against propagation cycles while minimizing the use of available recapitalization resources. In most cases, failing systemically important institutions would be recapitalized without fully wiping out available recapitalization resources. Finally, though these results seem compelling, they are sensitive to the estimated network of bilateral exposures. Different networks could imply stronger or milder propagation of shock, net equity losses, and recapitalization needs.

Figure 11. Simulations of Bank Distress Triggered by Widespread Leveraged Loan Markdowns 1/

(Percent of sample bank's equity and € billion)

Panel A: α=0.703, γ=0, and β=1

Net Equity Losses **Available Recapitalization Resources**



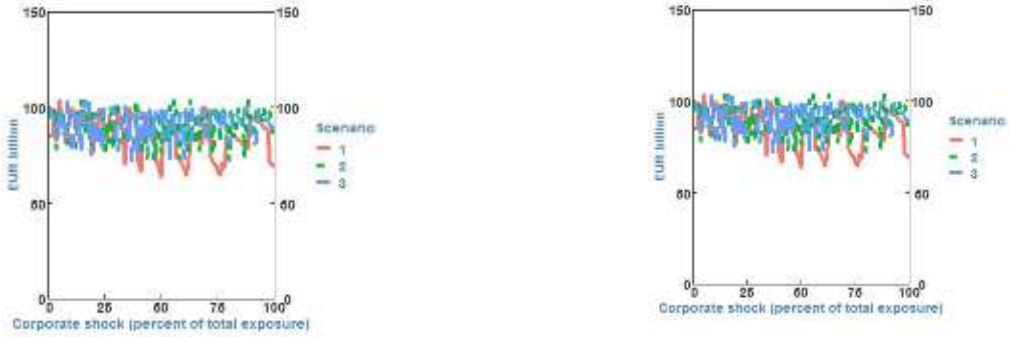
Panel B: α=0.703, γ=0, and β=1.2

Net Equity Losses **Available Recapitalization Resources**



Panel C: α=0.703, γ=0.2, and β=1.2

Net Equity Losses **Available Recapitalization Resources**



Sources: Dealogic ION, banks' annual reports, S&P market Intelligence, Fitch Ratings, and author's calculations.

1/ Scenarios include syndicated loan markdowns to the following sectors: (1) manufacturing; (2) energy, and (3) finance.

Conclusion

While syndicated loan origination in the euro area continued to grow after the pandemic in 2020, the change in monetary policy since 2021 has implied an increasing role of interbank loans in intermediating excess banking liquidity. Origination of syndicated loans to euro area corporates reached record volumes in 2022 and 2023 at €690 billion and €630 billion (5.1 and 4.4 percent of euro area GDP), respectively. After the start of monetary policy tightening in 2022, interbank loans and deposits increased to 4.7 percent of total assets and 7.4 percent of total liabilities, respectively, at end-2023. On average, the estimated outstanding bilateral syndicated loan exposures by euro area banks to euro area corporates were less than €100 million, within the prudential single-name exposure limits set by the EBA. Finally, the estimated matrix of bilateral interbank exposures assumed a minimum number of links among euro area banks for a given volume of interbank loans, minimizing false positive errors.

Considered as a source of systemic risk, widespread corporate defaults had the potential to trigger spillovers in the euro area banking system during the pandemic. The simulations based on the valuation network model—as in Barucca et al. (2020) and Veraart (2020)—indicate that the systemic risk implications of single-name and widespread corporate defaults in the euro area would depend on the size of the shock, the number of affected firms, and the degree of confidence enjoyed by banks to recover from equity losses. While shock propagation through interbank loans triggered by single-name and widespread markdowns in euro area syndicated leveraged loans would be low under a scenario of high confidence in euro area banks to recover their equity losses, markdowns would lead to large total cumulative equity losses when confidence to recover from equity losses is low. While bankruptcy costs would worsen the effect of single-name and widespread markdown on total cumulative equity losses, these can be interrupted by a timely and calibrated recapitalization of systemically important banks. However, limited available resources for recapitalization would make crisis management more challenging as systemically important banks would need to be ranked according to some criteria to quality for recapitalization.

Finally, the analysis in this paper underscores the role played by public policies in preventing, containing, and mitigating systemic risk in the banking system. This was no more evident than during the peak of the COVID containment measures when regulatory, fiscal, and monetary policies prevented widespread corporate defaults from triggering systemic risk across the euro area banking system. The minimum effect of some large corporate defaults on the banks during the peak of the COVID containment measures also illustrates the role played by prudential single-name exposure limits and large capital buffers available to absorb credit losses. The analysis also highlights the need for sufficient resources in the resolution fund to help recapitalize failing systemically important banks and prevent contagion in the euro area banking system.

Annex I. Stability Conditions

Nonlinear Debt Rank Model

This section relies on Bardoscia et al. (2017). After some algebraic manipulation, equation (6) above can be rewritten as an expression for the cumulative equity losses $h_i(t)$:

$$h_i(t) = h_i(t-1) + \sum_{j=1}^{N} \Lambda_{ij}(t) \left[PD_{ij}\left(h_j(t)\right) - PD_{ij}\left(h_j(t-1)\right) \right]. \tag{I. 1}$$

At time 1, $h_i(1)$ is just equal to the markdown in syndicated loans. At time 2, $h_2(t)$ would be equal to:

$$h_i(2) = h_i(1) + \sum_{j=1}^{N} \Lambda_{ij}(2) PD_{ij}\left(h_j(2)\right). \tag{I. 2}$$

Iteration until time *t* yields the following expression:

$$h_i(t) = h_i(1) + \sum_{j=1}^{N} \Lambda_{ij}(t) PD_{ij}\left(h_j(t)\right). \tag{I. 3}$$

For a fixed point $\bar{h}_i$, the expression above can also be rewritten as:

$$\bar{h}_i = h_i(1) + \sum_{j=1}^{N} \Lambda_{ij}(t) PD_{ij}\left(\bar{h}_j\right). \tag{I. 4}$$

A perturbation around $h_i(t)$, would be equivalent to:

$$\begin{aligned}
h_i(t) - \bar{h}_i &= h_i(1) + \sum_{j=1}^{N} \Lambda_{ij}(t) PD_{ij}\left(h_j(t)\right) - \bar{h}_i \\
h_i(t) - \bar{h}_i &= h_i(1) + \sum_{j=1}^{N} \Lambda_{ij}(t) PD_{ij}\left(h_j(t) + \bar{h}_j - \bar{h}_j\right) - \bar{h}_i \\
h_i(t) - \bar{h}_i &= h_i(1) + \sum_{j=1}^{N} \Lambda_{ij}(t) \left(\bar{h}_j + PD'_{ij}\left(\bar{h}_j\right)\left(h_j(t) - \bar{h}_j\right) \right) - \bar{h}_i \\
h_i(t) - \bar{h}_i &= \sum_{j=1}^{N} \Lambda_{ij}(t) PD'_{ij}\left(\bar{h}_j\right)\left(h_j(t) - \bar{h}_j\right),
\end{aligned} \tag{I. 5}$$

where the fourth row uses the definition of $h_i(t)$. Matrix notation implies that the expression above can be written as:

$$h(t) - \bar{h} = \Lambda(t) PD'\left(\bar{h}\right)\left(h(t) - \bar{h}\right) \tag{I. 6}$$

The dynamics for cumulative equity losses is only stable if the largest eigenvalue of the matrix $\Lambda(t)PD'(\bar{h})$ is larger than one. Given that:

$$PD(h(t)) = h(t)e^{\alpha(h(t)-1)} \tag{I. 7}$$

is a convex function, its derivative is equal to:

$$PD'(h(t)) = (1 + \alpha h(t))e^{\alpha(h(t)-1)}. \tag{I. 8}$$

and is an increasing function of cumulative equity losses $h(t)$. This implies that the largest eigenvalue of $e^{-\alpha}\Lambda(0)$ is smaller or equal than the largest eigenvalue of $(1 + \alpha h(t))e^{\alpha h(t)}e^{-\alpha}\Lambda(t)$. As a result, if the largest eigenvalue of $e^{-\alpha}\Lambda(0)$ is larger than one, then all fixed points would be unstable.

The coefficient α in the probability of default could be set so that:

$$\lambda_{max}e^{-\alpha} < 1 \tag{I. 9}$$

implying that:

$$\alpha > log(\lambda_{max}) \tag{I. 10}$$

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