Paper Draft No XX/2022

Effects of Consolidation on Network Models of the Financial System*

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Abstract

The banking industry has been facing a consolidation trend over the past years, the impact of which is not yet well understood. Since the financial crisis, there is an ongoing research that aims to better understand how the stability of the financial system can be assessed and supported. In this context, network models have proven an effective tool to simulate hypothetical situations and analyse the consequences. In our study, we aim to analyze the effect of mergers and acquisitions onto the stability of financial network models from a theoretical point of view. We use different well-established network models and analyse a wide variety of model assumptions, concerning e.g. connectivity, contagion channel and merge process. Our main finding is that merging activities can stabilize or destabilize the model financial network, depending on various details such as the connectivity of the network and the assumed merge process. Merging activities can increase diversification of single banks and support their resilience to shocks. However, merging activities can also decrease stability, if e.g. the network is driven into the contagion window or unsufficiently stable banks emerge in key positions in the network.

Keywords: Financial network model, Mergers and Acquisitions, Financial Stability, Contagion

JEL classification: G01, G21.

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1 Introduction

The global financial system has seen a consolidation trend for four decades now DeYoung, Evanoff, and Molyneux (2009). The number of banks is declining globally, the German financial system not being the exception. It is noteworthy that during the global financial crisis of 2007/08 the decrease rate was even higher. Some authors assume that in the aftermath of the COVID-19 crisis it is likely that the consolidation trend will, similar to 2007/08, continue at an increased rate for some period of time Wójcik and Ioannou (2020). Motives for banks to participate in mergers and acquisitions (M&A) activity can be diverse. Mergers can be stockholder value enhancing, cause efficiency improvements, can lead to higher diversification, may be motivated by managers' hopes for higher compensation post merger or the goal to become a systemically relevant institution DeYoung et al. (2009). A further aspect are regulatory interventions, as authorities might enforce the acquisition of a troubled institution by its more stable competitors Gaffeo and Molinari (2016). This might also increase consolidation rates upon crisis.

While consolidation is an ongoing process in the banking sector, the effects of the consolidation trend on the stability of the financial system as a whole is not well understood. While some literature reviewing the topic from an empirical point of view exists (see for example Uhde and Heimeshoff (2009); De Nicolo and Kwast (2002); De Nicolò, Bartholomew, Zaman, and Zephirin (2004); Baele, De Jonghe, and Vander Vennet (2007)), the literature employing network tools to investigate the effects of mergers and acquisitions on the stability of the financial system is sparse and focuses on specific cases (Rogers and Veraart (2013); Gaffeo and Molinari (2016)). A selection of related literature will be detailed in Sec. 2. Gaining more knowledge in this area would be desirable for several reasons: As mergers are an omnipresent feature of the interbank market, closely investigating the effects of M&A activity onto the financial network, i.e. the changing bank numbers, the changing size distributions and the change in network structure are key to a better understanding of the development of the banking sector. Furthermore, a sound understanding of the effects of mergers could enable the authorities to have a sound basis for decisions related to mergers, which ultimately may positively influence financial stability.

Modeling the banking system as a network appears very natural. In modern financial systems, banks and other financial institutions, such as hedge funds and insurance companies, are highly interconnected directly through a web of claims and obligations Gai and Kapadia (2010) and indirectly through commonly held assets. A network approach has been widely used, in particular to evaluate systemic risk and the stability of the system Hüser (2016). Credit exposures on the interbank market can be conveniently represented as links in a network of financial intermediaries. A frequently used approach (e.g. Gai and Kapadia (2010); Gaffeo and Molinari (2015); Elliott, Golub, and Jackson (2014)) is to externally impose an initial failure on the interbank market, which implies that other institutions, directly exposed towards a failed bank, suffer losses. As a consequence, these banks might be unable to meet their interbank obligations, leading to further failures. This mechanism can enable losses to spread via the network of direct interbank exposures. This is commonly referred to as the *direct contagion channel* Hüser (2016); Bluhm, Faia, and Krahnen (2014). The *indirect channel* on the other hand, captures more subtle links between financial institutions. The main mechanism for contagion via the indirect channel is through fire sales of common assets (e.g. Caccioli, Shrestha, Moore, and Farmer (2014)). When a troubled institution is forced to sell assets, the asset prices might be quickly depressed which can impact other institutions, holding the same asset, to suffer losses Hüser (2016). These channels are not independent of each other: A bank might be tempted to sell illiquid assets as a result of losses, or the fear of losses, via the direct contagion channel or might be unable to meet its liabilities due to losses via the indirect channel Hüser (2016); Glasserman and Young (2015). While the literature (see e.g. Upper (2011)) suggests that contagion via the direct channel alone is unlikely, it is still worthwhile to investigate this channel due to its connection to other channels of contagion.

In this paper we will investigate the effect of mergers on common simplified financial network models, considering both the direct and the indirect channel. The basis of our investigations will be simple network models, namely the financial contagion model by Gai and Kapadia (GK model) Gai and Kapadia (2010) for the direct channel and the model introduced in Caccioli et al. (2014) for the indirect channel.

To model how the consolidation trend affects the stability of the interbank network model, we will introduce M&A into the model. The merger of two institutions is implemented in a very natural way. Quantities external to the interbank market are simply added, while claims and obligations on the interbank market are consolidated. We investigate different methods to select banks for merging and compare a random selection of merging banks with a process that favors larger institutions to take part in the merge process. We also perform several robustness checks to validate our results.

The structure of this paper is as follows. In the next section we review the relevant literature, where we focus on stability analysis on interbank network models and on literature related to merging activities. Then, the network models are introduced and the merge process is specified. We then show our results on how merging activities influence the stabilitiy of the network models and discuss them with respect to other literature.

2 Related Literature

In this section we give a brief overview over the most important literature related to the subject.

While it has been a research topic for several decades, there is still a deep need for understanding and an ongoing debate on the roots of systemic risk and financial contagion, e.g. Allen and Gale (2000); Eisenberg and Noe (2001); Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015); Glasserman and Young (2015). In this context, modelling the interbank market and banks' exposure to common assets as directed networks is today a widespread technique that has proven an efficient tool to gain a better understanding of financial systems and potential systemic risk factors, e.g. Elliott et al. (2014); Hüser (2016); Neveu (2018).

In their seminal work, Gai and Kapadia introduced a simple interbank network model (GK model), where banks (nodes) with stylized balance sheets are connected via randomly chosen claims (links) against each other. In their model, if a bank fails, it defaults on all its interbank liabilities and thus can induce further defaults, potentially leading to system-wide cascades. The authors showed that this simple model exhibits a robust-yet-fragile tendency, which constitutes the basis for many subsequent analyses.

As an example, since the assumption of a random network is not backed by empirical observation, in Caccioli, Catanach, and Farmer (2012), the GK model is investigated on different topologies and asset distributions. They find that a scale-free topology, which has been reported for several banking systems (see e.g. Hüser (2016); Boss, Elsinger, Summer, and Thurner 4 (2004)) has a positive effect on the stability of the system if the initially shocked bank is chosen at random, but a drastical worsening of the stability if a highly connected bank is chosen. For a heterogeneous (power law) asset distribution, the contagion window is wider than for the homogenous distribution. Similar results are also found in Guan and Pollak (2016).

The GK model focuses on the interbank channel, which is often referred to as the Direct Channel of Contagion (DCC). However, there are also network approaches to model cascades that arise through common asset holdings, which are believed to have been the primary vector of contagion in the 2007/08 financial crisis Upper (2011); Caccioli et al. (2014)

In Caccioli, Farmer, Foti, and Rockmore (2015), the authors extend the GK model by introducing a single common asset of which all banks hold some fraction in their balance sheets. Once a bank fails it fire sells all its illiquid assets, which causes a devaluation of the common asset. The extended model therefore allows to investigate the interplay of the DCC and the Indirect Channel of Contagion (ICC). The authors find that the considered networks are relatively stable if only the DCC is present, however, the combination of the two channels greatly amplifies cascades.

Other studies focus solely on the ICC, e.g. in Caccioli et al. (2014), a bipartite network model of overlapping portfolios is introduced by modeling banks and assets as nodes, and links are established between banks and assets, representing an investment of a bank into a certain asset. Upon default of a bank it fire sells its portfolio. As a consequence, the value of every asset in the bank's portfolio declines which affects other banks invested in the same asset. In the study, the authors investigate the stability of the network as a function of parameters such as market crowding and diversification, and pinpoint the parameter space where cascades predominantly occur.

While network models are commonly used to analyse the stability of the financial system, to our knowledge, there are only few studies considering the impact of M&A in this context. One study (Rogers and Veraart (2013)) focuses on the direct interbank network and tries to grasp under which conditions other banks have an incentive to rescue a troubled institution. The authors set up a framework for this research question and establish conditions in which cases a rescue consortium exists. They also discuss a few explicit toy examples such as a ring network. In Gaffeo and Molinari (2016), a small network of banks connected via the DCC is considered. Contagion is spread via a bail-in mechanism. The authors include three different topology altering processes: vertical merge (one large bank acquires smaller counterparties), horizontal merge (one bank is disassembled, and its shares are evenly distributed over other institutions) and semi-horizontal merge (merge can only happen between two small banks). Claims on the interbank market are rearranged after every merge round using rules sensitive to banks size. In this setup, the authors find for a certain range of capitalization that the stability of the system increases under a vertical merge process.

In another study Cheng and Zhao (2019), a model for the interbank market similar to the GK model is analysed, where the authors discuss forced mergers as a possible intervention policy. The merging institutions are chosen by different micro- and macroprudential regulation frameworks. They find that mergers are, within a certain regime of connectivity, a viable intervention policy, i.e. increase stability compared to the unmerged network.

While the mentioned former models study the impact of mergers on the stability of the system, they only consider direct connections between banks. Furthermore, these works consider special cases such as small networks or random topologies, and assume specific merge processes. In our study, we will try to fill those gaps: we additionally study different merge processes on networks where financial intermediaries are indirectly connected, and check the validity of our results also on the potentially more realistic scale-free topologies.

While our analysis is purely theoretical, there are also empirical analyses related to the effect of mergers on the stability of a financial system. In Uhde and Heimeshoff (2009), the authors find that a more concentrated market has a negative impact on the stability of the system. A similar result was found in De Nicolo and Kwast (2002), however the authors claim that factors other than consolidation might have been responsible for the systemic risk increase.

A separate strand of literature focuses on the question why banks participate in merging activities, a question which can also turn relevant for model setup. Recent literature provides different motives DeYoung et al. (2009). Studies on M&A activity inside and outside the U.S. find evidence that mergers are stockholder value enhancing and cause efficiency improvements. On the other hand, another study (Craig and Dinger (2008)) showed that mergers can lead to decreasing checking account rates and thus may negatively impact conditions for customers. Further, studies have shown that cost-efficient banks tend to acquire more inefficient counterparts Hannan and Pilloff (2009). Studies examining large U.S. bank mergers have found that CEO compensation benefits post merger Anderson, Becher, and Campbell II (2004) which might be an incentive for bank managers. Last, mergers can enable a bank to increase its diversification, i.e. lead to bank portfolios that cover a wider range of geographies and types of products and investments Berger, Buch, DeLong, and DeYoung (2004).

The literature is inconclusive how M&A activity and thus higher banking market concentration affects financial stability and whether the *concentration-stability* or the *concentration-fragility* view is dominant Uhde and Heimeshoff (2009). Supporters of the concentration-stability hypothesis argue that large banks may increase profits which provides higher capital buffers to counter shocks Boyd, De Nicolo, and Smith (2004). Furthermore, larger banks may increase loan portfolio diversification of the banking sector, e.g. they might be more likely to invest in foreign markets thus increasing geographical diversification, which can reduce risk Boyd and Prescott (1986). Last, a concentrated market may be easier to monitor which would decrease the risk for system-wide cascades Allen and Gale (2000).

On the other hand, supporters of the concentration-fragility hypothesis argue that the existence of large institutions systematically increases systemic risk Moch (2018). Very large banks may be tempted to take on risky investments, as they might be likely to be rescued by the government due to their systemic importance Mishkin (1999). Moreover, larger banks might demand higher loan interest rates. As a consequence, borrowers might be more likely to take on risky investments to compensate higher loan repayments Boyd and De Nicolo (2005). It is to note on this argument that other works suggest lower loan interest rates of larger banks Montoriol-Garriga (2008). Some authors also raise the concern that larger banks might be more difficult to monitor as larger banks are geographically and business wise expanded Beck, Demirgüç-Kunt, and Levine (2006). There are also empirical studies in favor of the concentration-fragility hypothesis Weiß, Neumann, and Bostandzic (2014).

In our study, we will also contribute to this debate as our results indicate that M&A activity can increase or decrease stability, depending on the exact constellation (in terms of network connectivity and the merge process) and the measure of stability.

3 Modelling Approach

Our modelling approach leverages upon well-established modeling approaches, namely, the model by Gai and Kapadia (2010) for the direct channel and a model by Caccioli et al. (2014) for the indirect channel. We furthermore adopt the setup of the merging process from Gaffeo and Molinari (2016). Our model assumptions are detailed in the following paragraphs.

Network model The financial system is represented as a multilayer network comprising a set of financial institutions (banks for brevity, but it could also comprise other financial institutions) $\mathcal{B}$ and a set of commonly held assets $\mathcal{A}$. For simplicity, we consider random network structures[1], characterized by the average bank degree z (i.e. the banks' degrees follow a Poisson distribution). The number of banks in the system is denoted by $n := |\mathcal{B}|$, the number of commonly held assets by $m := |\mathcal{A}|$. Two types of links (i.e. two network layers) are present in the network: directed links between banks $i, j \in \mathcal{B}$, weighted by $\omega^{\mathrm{IB}}_{(ij)}$, represent interbank claims and obligations[2], while undirected links between a bank $i \in \mathcal{B}$ and a commonly held asset $a \in \mathcal{A}$, weighted by $\omega^{\mathrm{CA}}_{\{ia\}}$, represent investments of a bank into a certain asset. The weight represents the amount of monetary units of the interbank claim or investment, respectively.

Each bank $i \in \mathcal{B}$ is assigned a balance sheet. Balance sheets capture the financial state of the bank, that is its total assets A^{Σ}_i and total liabilities L^{Σ}_i, as well as the amount of shock the bank is facing at time t, resulting from losses on assets via the contagion channels $\gamma_i(t)$ and the banks capital $K_i(t) := A^{\Sigma}_i - \gamma_i(t) - L^{\Sigma}_i$. The capital determines the solvency of a bank: if $K_i(t) \leq 0$, bank i is insolvent. The asset side is further subdivided into interbank assets A^{IB}_i, assets invested into the commonly held assets A^{CA}_i and external assets A^{E}_i, where the former two are given by

$$A^{\mathrm{IB}}_i := \sum_{j \in \mathcal{B}} \omega^{\mathrm{IB}}_{(ji)} \quad \text{and} \quad A^{\mathrm{CA}}_i := \sum_{a \in \mathcal{A}} \omega^{\mathrm{CA}}_{\{ia\}}$$

and A^{E}_i are not further modeled assets external to the network. The relative importance of these asset positions is characterized by two parameters $\alpha^{\mathrm{IB}} := A^{\mathrm{IB}}_i / A^{\Sigma}_i$ and $\alpha^{\mathrm{CA}} := A^{\mathrm{CA}}_i / A^{\Sigma}_i$. The liability side, on the other hand, is subdivided into interbank lia-

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[1] To note that we consider more realistic network structures as robustness checks.

[2] An outgoing link represents an obligation for a bank, i.e. money that the banks owes to a counterparty.

bilities L_i^{IB} and external liabilities L_i^{E}. Since every interbank asset is an interbank liability for a counterparty bank, the interbank liabilities are endogenously determined from the interbank assets. The capital in the banks' balance sheets is initially fixed by a parameter $\kappa_i := K_i(0) / A_i^{\Sigma}$.

We consider two different contagion channels: For the direct channel of contagion, shock is spread over the web of interbank claims and obligations. As in Gai and Kapadia (2010), we make a zero recovery assumption, i.e. assume that a defaulted bank is unable to repay any of its interbank liabilities[3]. Thus, every creditor a defaulted bank has is shocked by the full size of its loan. On the other hand, shock is spread over the indirect channel via overlapping portfolios. Each asset is assigned a price $p_j(t)$, where prices are initialized to one. Upon insolvency, a bank liquidates its asset portfolio which causes a devaluation of the liquidated assets. Devaluation is dictated by a market impact function f. For our analyses we consider two market impact functions: First, $f_1(d_j) = \phi^{d_j}$, where $\phi \in [0, 1]$ is a depreciation factor and d_j is the number of defaulted banks invested into asset j (see e.g. Sánchez (2017)). Second, $f_2(x_j) = \exp(-kx_j)$, where k is a constant and x_j is the fraction of asset j that has been liquidated (in accordance with Caccioli et al. (2014)).

We further consider two types of initial shock to the network: The perturbation is either induced by an initial bankruptcy of one bank in the network that then spreads shock via the direct and indirect channel, or via the initial devaluation of a network asset (toxic asset). Shock is then spread until the cascade terminates.

Mergers We extend the network model by allowing banks to engage in M&A. In accordance with Gaffeo and Molinari (2016), mergers are performed in separate rounds, called *merge rounds* R. This allows us to distinguish states of the system. We merge two banks in the network i and j to a new bank k by first adding the external quantities in the balance sheets[4]. Afterwards, interbank links are combined such that the merged bank has the sum of all interbank claims and obligations of the previously separated banks. However, two cases deserve special attention: First, if the merging banks share a counterparty, the links to the same counterparty are joined into one, which reduces the number of links, and second, if the merging banks have obligations between one another, these obligations are resolved at the time of the merger, which reduces the number of links and the number of total assets in the system. The investment portfolios, i.e. the links to commonly held assets, are also combined, such that the merged bank invests in the union of the two previously separate portfolios. Note that we do not explicitly account for merger costs.

To summarize, in our model, the merge process changes the network in three key ways: the number of banks decreases, the interbank assets are rearranged and the number of links and the total interbank assets may decrease through the merge process. We are aware that the reduction of merging activities to these mechanistic changes is a simplification, but we will discuss later the implications of these assumptions.

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[3] To note that we challenge this assumption as a robustness check.

[4] E.g. for liabilities $L_k^{\mathrm{E}} = L_i^{\mathrm{E}} + L_j^{\mathrm{E}}$.

Simulation To analyze the effects of mergers onto system stability, we start with an unmerged network with some initial degree $z_{R=0}$ and perform consecutive merge rounds while constantly measuring stability after each round. Our standard setup is a network of $n = 1000$ banks and a total of $R = 500$ merge rounds. For our analysis, we always consider 1000 realizations of a given network connectivity $z_{R=0}$. Stability is measured in terms of two parameters: the Contagion Frequency (CF) is the probability that a system-wide cascade, i.e. a cascade where more than 5% of network assets default, occurs. It is given by the fraction of realizations that show a system-wide cascade. The Contagion Extent (CE) on the other hand, is given by the average fraction of defaulted system assets in realizations, where a system-wide cascade occurred.

We consider two stylized processes to select banks for merging in each round: in the Random Merge Process (RMP) we choose the merging partners at random and in the Vertical Merge Process (VMP) one bank, in the following referred to as the acquiring bank (AB), is selected as the merging institution and keeps acquiring other banks which leads to the emergence of one dominating and highly interconnected bank in the system.

4 Results

We consider three different scenarios: In scenario (1) only a DCC is present ($m = 0$). We choose $\alpha^{\text{CA}} = 0$ and $\alpha^{\text{IB}} = 0.2$ in accordance with Gai and Kapadia (2010). In scenario (2) both DCC and ICC are present, i.e. $\alpha^{\text{IB}} = 0.2, \alpha^{\text{CA}} = 0.02$. For simplicity we set $m = 1$ and assume that every bank in the network invests into this asset.[5] Shock is transmitted according to f_1[6]. And finally, in scenario (3), only an ICC is present, i.e. $\alpha^{\text{IB}} = 0$ and $\alpha^{\text{CA}} = 0.8$. Shock is transmitted according to f_2[7]. Other scenarios could be discussed, but the three selected configurations already provide a rich variety of results. The capital share is always set to $\kappa = 0.04$ as in Gai and Kapadia (2010).[8]

Before turning our attention towards mergers, let us present the results for the unmerged network that have previously been found in the literature, e.g. Gai and Kapadia (2010); Caccioli et al. (2015); Sánchez (2017). In Fig. 1, the CE and CF are plotted over the average degree z.

Instability is observed within a certain window of the average degree z, the contagion window. Below this window, for small values of z, the network exhibits many small connected components. An initial shock is only spread within the respective connected component and therefore does not affect the vast majority of banks in the network. For large values of z, above the contagion window, banks diversify their assets such that they are able to withstand a few counterparty defaults, thus rendering cascades very unlikely. Towards the upper end of the contagion window, the system exhibits a robust-yet-fragile

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[5] This choice could also be interpreted as simplified mean-field approach, where every bank suffers a similar average shock through devaluation of assets.

[6] In the simplified picture, where we only consider one asset in the network (mean-field approach), we further assume that the impact on the asset deprecation is independent of the bank size, thus use the market impact function f_1. We set $\phi = 0.3$ in accordance with Sánchez (2017)

[7] As done by other authors, we set $k = 1.0536$ such that an asset losses 10% of its value when 10% of holdings have been liquidated.

[8] To note that for better comparability, the default parameter values are chosen similar to existing studies, which in turn are often inspired by corresponding values in real financial networks. In numerous robustness checks, we varied the parameter values.

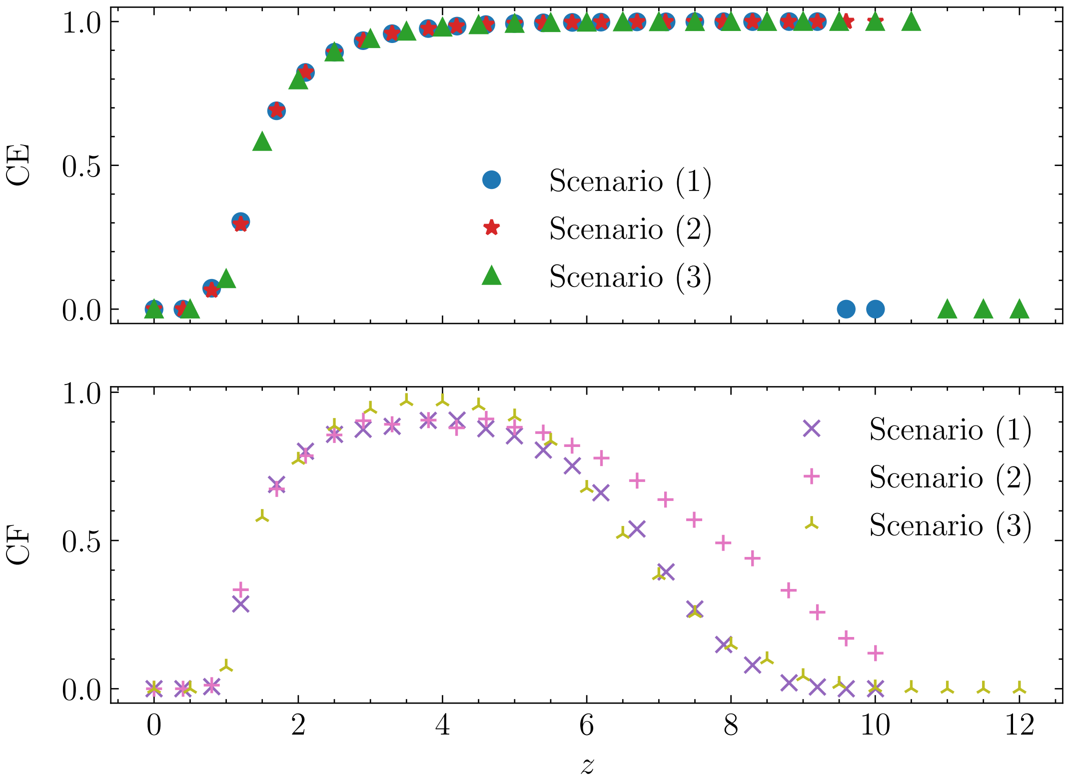

Figure 1: Contagion Extent (CE) and Contagion Frequency (CF) over average degree z for all considered scenarios. For scenario (3) shock is induced via an initial bankruptcy.

tendency Gai and Kapadia (2010). System-wide cascades are very unlikely, but they cause a complete network collapse if they occur. We also note, that the interplay of a direct and indirect channel (scenario (2)) causes the most unstable networks.

We now turn to mergers in the network. In Fig. 2, the results for scenarios (1) and (2) are shown for the RMP and the VMP for two different initial connectivities which are chosen at the lower end and towards the upper end of the contagion window, respectively. We plot the CE and CF over the merge rounds R. First, consider scenario (1), where only a DCC is present. Shock is induced via the default of a randomly selected bank in the network. For the RMP, we observe that the CF decreases over the merge rounds, while the CE stays constant or increases, depending on initial connectivity. Since the network is sparse ($z \ll n$), most of the randomly selected merge partners are neither interconnected, nor share common neighbors. Therefore, mergers increase the diversification of merged banks - this is particularly the case for the initially denser network (right column of Fig. 2). Although it is possible for a bank to participate in more than one merger, this occurs only randomly under the RMP and the network prevails overall similar to the initial homogenous state[9]. The increased diversification through mergers increases the ability of merged banks to stop cascades in the early stages, hence the CF decreases. However, banks are not sufficiently diversified to stop a rolling cascade and thus the CE

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[9] Since the network remains rather similar to the homogenous state, stability trends mostly agree with the contagion window observed in the unmerged system, considering that the average degree z roughly doubles over the 500 merge rounds.

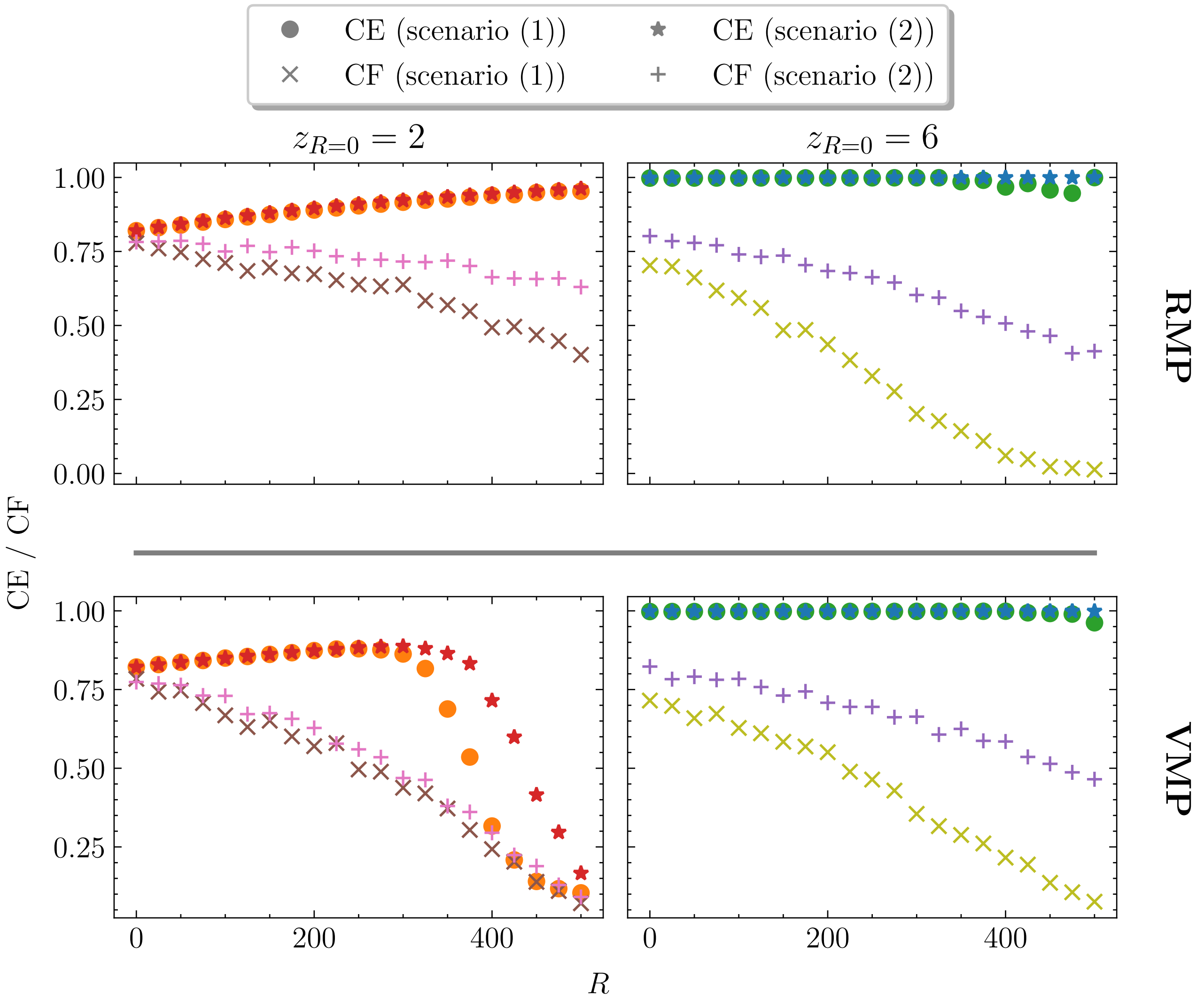

Figure 2: Results for scenarios (1) and (2). Contagion Extent (CE) and Contagion Frequency (CF) are plotted over merge rounds R for the Random Merge Process (RMP) (top row) and the Vertical Merge Process (VMP) (bottom row).

is not impacted.

For the VMP, similar to the RMP, we observe a decrease of the CF in scenario (1), but also a decrease of the CE after some merge round. These stability changes can be attributed to the AB. Through consecutive mergers, the AB becomes more and more the center point of the network. Particularly for the initially denser network, the AB is connected to almost the entire network after 500 merge rounds.[10] During this process, the AB becomes more and more stable and acts as a cascade barrier in the network. After some point, the AB becomes stable enough to even absorb larger shocks in the event of system-wide cascades, thereby stopping a system-wide cascade and decreasing the CE. The point where the AB starts to survive, even if a system-wide cascade occurs, coincides

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[10] This is of course an extreme, and extremely stylized process and should not be understood as mimicking real merging activities. Rather, the aim is to explore the ultimate impact of such extreme situations, under the assumptions as detailed above.

with the point where the CE decreases.[11]

Next, we consider the addition of an ICC, i.e. scenario (2). Shock is again induced via the random default of a bank in the network. For the RMP we observe that the CF greatly increases under the inclusion of an ICC. The effect is particularly visible for the higher connectivity. This can be understood as follows: As discussed above, the RMP stabilizes systems, at least in part, by causing increased diversification of interbank loans. Through the additional ICC banks are gradually weakened by losses on the common external asset, thus decreasing their capital, which renders banks more susceptible towards direct contagion and relativizes the benefits of increased diversification. For the VMP we observe that the CF is higher with an additional ICC, but only for the initially denser network - the $z_{R=0} = 2$ network is unaffected. Furthermore, the point where the CE decreases is pushed to higher merge rounds. The reason for the CF in the $z_{R=0} = 2$ being unaffected by the additional ICC is that in the VMP all banks except one remain unmerged. The ICC, through the market impact function, induces higher losses particularly at the start of the cascade which increases counterparty risk for otherwise sufficiently diversified banks. In the sparse $z_{R=0} = 2$ case, interbank asset diversification is weak anyway and banks are typically vulnerable towards a single counterparty default, thus the effect of the additional ICC onto the CF is weak. For the initially denser network, however, banks are more diversified and can typically (without the ICC) withstand counterparty defaults, thus here we observe an effect through the ICC. To sum up the results from scenario (2), the introduction of an additional contagion channel can, compared to the original network, naturally only decrease stability. It depends, however, on the network structure in terms of connectivity and on the merge process whether the ICC impacts stability or whether stability is unchanged.

To further investigate the additional instabilities of the ICC, we now consider the results for scenario (3), where only an ICC is present, in Fig. 3. The top row shows the stability metrics over R for the RMP, the bottom row for the VMP. In this scenario, as the relevant links in the network are established between banks and assets, but we do not model direct links between banks, we distinguish between two different mechanisms to induce shock: either via a defaulted bank or via a toxic asset.[12]

We first focus on the top row, where the results for the RMP are detailed. For both initial connectivities, we observe a net decrease of the CF, however, the effect of mergers seems to be stronger if shock is induced via a toxic asset in the system. The CE increases or is unaffected by the mergers. The reason for the net decrease of the CF is again the increased diversification caused by the RMP. Through the mergers, the investment portfolios of the merged banks increase in size, which reduces the importance of a single asset. On the other hand, merged banks pose a greater risk for the system if they are troubled. The RMP typically increases portfolio sizes and investment volumes, which are associated with a higher market impact risk. Since we do not see any stabilization trends in the CE, we deduce that merged banks are not capable of surviving in the event of a

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[11] Here we would like to emphasize that the setup of our analysis implies that the share of risky assets on a bank's balance sheet can only decrease through merging activities, while the share of capital may increase if interbank links are eliminated through merging activities. This may seem to introduce a bias in our analysis towards a higher stability of merged banks. However, we analyze the impact of this assumption in the robustness checks.

[12] In the toxic asset case, the initially devalued asset is chosen randomly, and its value is reduced by 35%.

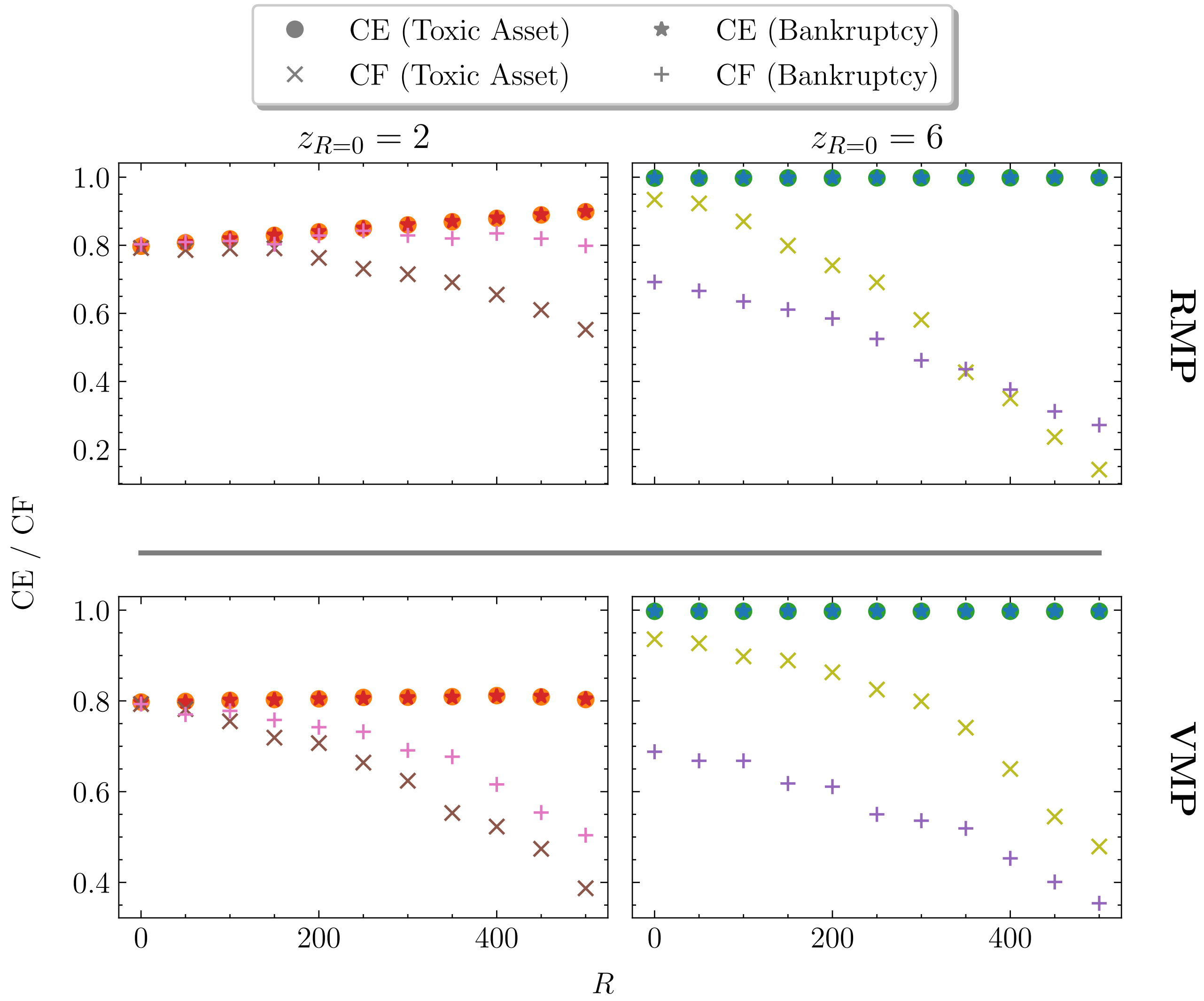

Figure 3: Results for scenario (3). The Contagion Extent (CE) and the Contagion Frequency (CF) are plotted over the merge rounds R for the Random Merge Process (RMP) (top row) and the Vertical Merge Process (VMP) (bottom row).

system-wide cascade. The reason that the effects of mergers are stronger in case of a toxic asset in the system is again related to the increased diversification. First, it must be noted that initially shocking a randomly chosen asset must not cause any defaults in the network, if banks invested into the initially shocked asset are able to absorb the depreciation. If average diversification increases, the probability that the initial depreciation is absorbed also increases. Second, while the average bank degree roughly doubles over the merge process, the average asset degree stays constant or even slightly decreases. Hence, the impact of an initial bankruptcy increases, while the impact of initial asset depreciation stays constant or decreases, and potentially might be absorbed by diversified banks.

Next, we focus on the VMP, i.e. the bottom row in Fig. 3. Again, we observe a stabilization trend in the CF over the merge rounds. The CE is mostly unaffected. Through the VMP, the AB heavily increases its portfolio size (number of different assets in the portfolio) as well as the average investment per asset in the portfolio. In consequence, the AB concentrates a high market impact, through the large investment volumes, and additionally excels at absorbing shocks, thanks to its strong diversification. This can, in this stylized setting, reduce the risk of system-wide cascades. If, however, a cascade does break out, the AB is almost always pushed into default, which then has catastrophic consequences for the rest of the system. Therefore, we see a destabilization trend in the CE. Again we observe that the network is more stable if shock is induced via a toxic asset in the network. Reasons for this have already been discussed above.

4.1 Robustness checks

As noted above, due to the simplicity of the used models, the results can in general not be easily transferred to concrete, real financial systems, but should rather be seen as general theoretical insights into possible mechanics of merging activities onto financial networks. In this section, to challenge the generality of our theoretical results, in our modelling approach, there are several assumptions that should be challenged.

As a first robustness check, we vary the numeric parrameters of the model. The initial model setup contains a choice for different parameter values which could of course be changed. A variation of the relevant parameters (e.g. portion of interbank assets, capital) has also been performed in previous studies (e.g. Gai and Kapadia (2010)) and we see similar trends here, which is why we summarize them in brief: An increase in capital in general increases stability, while an increase in the risky assets decreases stability. These observations appear very natural and even mechanistic. However, we checked that the main results of our study relating to the impact of merging activities on stability remain unchanged to a variation of these parameters if kept in a meaningful range.

A second robustness check concerns the topology: One assumption in the network models presented above is that of a random network structure. However, to note that the GK model is very flexible regarding the underlying network structure and has also been used to explore the impact of different topologies (e.g. Caccioli et al. (2012)). There are studies reporting real interbank markets to have a scale-free degree distribution, e.g. Boss et al. (2004); Bech and Atalay (2010). Thus, to challenge the dependency on the network structure, we repeat the simulations with a scale-free topology. For this, we use Chung-Lu scale-free networks (scale-free networks) Chung and Lu (2002), a more realistic topology Boss et al. (2004); Bech and Atalay (2010). We find that the scale-free topology benefits stability compared to the random topology if the bank initially defaulted is selected randomly, however, if we instead apply a targeted shock to a hub-bank, system stability worsens drastically.[13] The general stability implications of mergers, we saw in random networks, remain the same in scale-free networks. Here, we would like to state that while the structure of a scale-free network may appear more realistic, we chose to present our main results based on the random network structure. This is mainly because the scale-free network contains initially already a few hub banks which makes interpretation of the role of these banks a bit more complicated. In random networks, these hub banks only emerge and show their particular role in the merging process in the random network.

A further robustness check concerns the zero recovery assumption and the assumption of permanent asset devaluation: In the DCC, a bank defaults on all of its interbank

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[13] For unmerged networks this has previously been found e.g. in Caccioli et al. (2012)

liabilities and in the ICC, any asset devaluation is considered to be permanent. While these assumptions seem simplistic and rather strong, a relaxation does not provide any surprising insights - this conclusion has previously been drawn from a similar analysis that has been done in the original paper Gai and Kapadia (2010). We repeated our simulations with a relaxed assumption: If banks can recover part of their claims against a defaulted bank, the stability naturally increases. However, this is similar to decreasing the portion of interbank assets present on the banks' balance sheets (i.e. changing $\alpha = 0.2$ to a smaller value). Similarly, by allowing a devaluated asset to increase its value would be equivalent to reducing the effect of the market impact function or to reduce the portion of external common assets.

A less obvious assumption to challenge is the development of interbank assets and capital in the DCC. As described above, through the mechanic merge process, interbank claims can disappear if two banks connected by a link merge. In this case, the (risky) interbank assets are reduced while the remaining balance sheet is unchanged. This implies that merged banks may have a comparative advantage over unmerged banks, as the ratio between their capital and their total assets may (mechanically) increase, if their total assets decrease through the described process. To challenge this assumption, we performed additional simulations where we correct, after each merge round, for the potentially lost interbank assets, such that the ratio between capital and interbank assets stays constant. The stability trends are identical to the results shown above, such that we are confident that this detail does not influence our conclusions.

It could further be perceived as restriction of our study that we only consider two merge processes, namely the random and the vertical merge process. Here, to note that we performed additional selective analyses with the semi-horizontal merge process, which was analyzed in Gaffeo and Molinari (2016) and in which only unmerged parties are selected for merging - this process could thus in some sense be considered as opposite of the VMP. However, given that in our setup, the merge process starts with a network of 1000 banks of size 1 and ends up with a network of 500 banks of size 2, the results were of limited interest for the analysis of real merge processes.

Last, to mention that our network size (1000 banks) is to some extent arbitrary, but of a meaningful size (e.g. the number of German banks lies between 1000 and 2000 Bankenverband (2020)). The number of merge rounds (500) is also arbitrary, but should allow to get a significant change of the network structure (by decreasing the number of banks to one half of the initial size which is not unrealistic given the developments of the banking sector over the last years).

5 Discussion

To analyze how the stability of the banking system can be affected by the consolidation trend, we consider different well-established network models of the financial system and extend them with M&A. We also consider qualitatively different merge processes, where the processes differ by the selection of merge partners. Despite these models being extremely stylized, they allow for valuable insight into how stability may be altered by the modeled M&A activity.

Our goal is to capture the key channels of contagion in financial systems as well as their interplay: the Direct Channel of Contagion (DCC) and the Indirect Channel of

Contagion (ICC). The DCC refers to losses on the interbank market due to defaults on loans and therefore captures counterparty risk for the banks in the system. For the indirect channel, one key connection are overlapping portfolios Upper (2011).

Our main result is that the impact of merging activities onto system stability is diverse and depends on several aspects. In some constellations, mergers can benefit stability, while in others, it is detrimental. Particularly for the RMP, stability outcomes show a sensitive dependence to the initial connectivity; while for highly connected systems the increased diversification caused by the mergers leads to more stable systems, weakly connected systems tend to show a destabilization trend. For the VMP we find a stabilization trend in cascade probability, independent of the initial connectivity. The cascade extent, on the other hand, is unaffected or increases initially but then may decrease for large merge rounds. This dramatically changes if the dominating bank, formed through consecutive vertical mergers, is attacked. Its default leads to a sudden system breakdown. We find that these results hold true both for a random and a scale-free network topology. Our results regarding the partially stabilizing effect of mergers agrees with the related literature. In Gaffeo and Molinari (2016), the authors also find a stabilizing effect of vertical mergers. Although the authors in Cheng and Zhao (2019) consider different merge processes, they also find a stabilizing effect of mergers in some range of the connectivity.

The literature suggests that indirect connections between banks are of particular importance for the stability of the system Upper (2011). In our simulations, we find that particularly the stability of networks resistant to shocks through diversification via the direct channel are negatively impacted by this additional channel and that the effect is even stronger in (the more realistic) scale-free networks than in random networks. For both considered merge processes, the RMP and the VMP, the additional indirect channel decreases the partial positive effects of mergers on stability. This shows the importance to consider different contagion channels. However, mergers can still increase the stability against the unmerged system under some circumstances.

For a network subject solely to the ICC, we find that mergers generally can benefit stability, however the effect is weaker than in the GK model. For the RMP the stability outcome is again more sensitive to initial connectivity than for the VMP. We further find that in merged systems, the initial idiosyncratic default of a bank is potentially more harmful to the system than a toxic asset that suddenly suffers devaluation. However, as discussed above, this is also partly due to the assumptions employed in the present model. Nevertheless, we think it is worth mentioning that the source of the initial shock (either one initially defaulting bank, which is a huge shock on one single bank, or a devaluated asset, leading to a less intense shock on several banks) may impact different networks differently.

In the scope of our rather stylized modeling approaches we can formulate the following results that are common to our different modeling approaches: First, mergers generally seem to increase stability of financial systems under certain circumstances and may thus potentially be an effective intervention policy. The mergers of small and medium-sized banks can benefit stability, but only for certain network topologies. The acquisition of smaller banks by its larger competitors, that lead to an increased market share of the acquiring bank, might increase stability, but only if the survival of the larger bank is ensured. In this sense, the merger of a small troubled institution with a stable (larger) bank in the system could be considered a viable resolution strategy. However, our results show that in this case the robustness of the larger bank is key, which also supports existing measures as the G-SII/OSRI buffers which are aimed to ensure a sound capital basis of large banks.

While our analysis is able to give some model-based insights into the effects of mergers, thereby extending the sparse literature on the effects of M&A on systemic stability, we are also well aware of limitations and shortcomings of the current approach.

While we base our analysis on random and scale-free topologies, there is also some evidence that real interbank markets may exhibit a core-periphery structure Fricke and Lux (2015). In a core-periphery network, banks are partitioned into two sets based on their relations with each other. Core banks are connected to each other and to periphery banks, but periphery banks are not connected to each other Hüser (2016). An investigation of the effects of M&A on a core-periphery network could be an interesting extension to our investigations. In particular, we think it might be useful to analyze the vertical merge process, when considering a couple of core banks in the role of the acquiring bank(s), and potentially incorporating contagion dynamics between them. Additionally, it could be valuable to explore the impact of different types of mergers, namely core-core, core-periphery or periphery-periphery bank mergers.

While we did investigate the interaction of the direct and indirect channel, we limited ourselves to a rather simplistic case. We would expect, however, that the destabilization trend compared to only directly linked networks, which we saw from our simplistic approach, would occur in a similar way. Furthermore, we would expect that the stabilizing effects through diversification, but also the (de)stabilizing effects through centralization would be observed in a similar way. Nevertheless, it might deserve a separate study to explore the possible interactions between the ICC and the DCC in more detail.

Another detail is that we neither explicitly accounted for merger costs nor increasing efficiencies through mergers. This is on the one hand due to keep a simplistic model - merger costs/benefits would introduce additional parameters that would need to be estimated and set in a reasonable range. On the other hand, we think that due to the simple nature of the models, introducing these features would not yield any surprising results: Merging activities would be systematically more stabilizing or destabilizing, depending on the choice of parameters. However, we acknowledge that this feature is not present in our analysis.

While we analysed different merge processes, the implementation of merging activities contains to a large extent a random element - in particular, we did not attempt to merge banks for which a merger is e.g. optimal in a specific sense (apart from the assumption that the acquiring bank in the VMP attempts to get larger). This modeling choice could be interpreted such that banks do not have any information to decide whether a merger is favorable for them (or for the network). It would certainly be an interesting extension to analyse strategic mergers where merging partners are chosen under certain selection rules (e.g. Rogers and Veraart (2013)).

A common feature of all models considered in this work is that they are static with regard to the network structure. The reasoning behind this assumption is simplicity, but also the idea that merging banks continue to pursue their activities similarly to their pre-merger business. This would e.g. be a reasonable assumption for banks that intend a strategic portfolio extension with their merger. Another interpretation would be that we assume that banks do not have time to rebalance their portfolio before failing. These points motivate that banks neither react to mergers, nor to defaults. It could be an interesting yet more complex addition, however, to allow banks to rebalance their asset portfolio and interbank market connections as a reaction to defaults and mergers. However, to note that this requires additional assumptions on how the merged bank (and possibly all other banks) will reallocate their exposures among their potential counterparts. It is not clear that these additional assumptions will finally be more realistic than the static assumption, but we acknowledge that our results are certainly influenced by this assumption.

Other than that, we note that despite our efforts to motivate our parameter choices with empirical data and the choices in previous studies, the various model parameters would further allow for possible calibration to concrete real-world financial systems (e.g. size distribution of banks, number of counterparties/external assets per bank etc.), to some extent. While this could be an interesting extension, we think that such investigations would wrongfully suggest a non-existent similarity of the analyzed models with real financial networks. A representative study would require large data sets over sufficient observation periods. In contrast, we are convinced that the more general analysis performed in this work makes the best advantage of the simplified stylized models and allows for an easy and meaningful interpretation.

Finally, it must be noted that all results in this work are purely theoretical. The use of stylized models in general is a strong simplification, which can yet provide interesting insights into possible mechanisms. As we have seen in these simplified systems, mergers can improve or worsen system stability, depending on the connectivity and size of the merge partners, the overall size and degree distribution of the network and the contagion source and channel. These general insights can provide a basis for additional, more targeted research to support or contradict the observed features in more elaborated models or in real financial systems.

6 Conclusion

In this work, motivated by the ongoing consolidation trend in the banking sector on the one hand, and the high importance of network models for analyzing financial systems on the other hand, we aim to shed light on the effects of mergers on financial network models, with a focus on their stability. A sound understanding of the effects of mergers onto the stability of the financial system can provide important additional information to market participants and supervisors, and might support decision processes of authorities supervising the financial sector and monitoring the M&A activity.

Using different well-established network models of the financial system enriched with M&A, we find that in the stylized models under consideration, mergers can improve or worsen system stability, depending on a variety of details such as the connectivity and size of the merge partners, the overall size and degree distribution of the network and the contagion source and channel. This rich variety which was observed already in simplified models should be understood as first step and motivation to gain a deeper understanding of the impact of merging activities onto the financial system.

References

Acemoglu, D., A. Ozdaglar, and A. Tahbaz-Salehi (2015). Systemic risk and stability in financial networks. *AMERICAN ECONOMIC REVIEW 105*, 564–608.

Allen, F. and D. Gale (2000). Financial contagion. *Journal of political economy 108*(1), 1–33.

Anderson, C. W., D. A. Becher, and T. L. Campbell II (2004). Bank mergers, the market for bank ceos, and managerial incentives. *Journal of Financial Intermediation 13*(1), 6–27.

Baele, L., O. De Jonghe, and R. Vander Vennet (2007). Does the stock market value bank diversification? *Journal of Banking & Finance 31*(7), 1999–2023.

Bankenverband (2020). Die Entwicklung der Anzahl verschiedener Kreditinstitute in Deutschland von 2004 bis 2019.

Bech, M. L. and E. Atalay (2010). The topology of the federal funds market. *Physica A: Statistical Mechanics and its Applications 389*(22), 5223–5246.

Beck, T., A. Demirgüç-Kunt, and R. Levine (2006). Bank concentration, competition, and crises: First results. *Journal of banking & finance 30*(5), 1581–1603.

Berger, A. N., C. M. Buch, G. DeLong, and R. DeYoung (2004). Exporting financial institutions management via foreign direct investment mergers and acquisitions. *Journal of International money and Finance 23*(3), 333–366.

Bluhm, M., E. Faia, and J. P. Krahnen (2014). Monetary policy implementation in an interbank network: Effects on systemic risk. *SAFE Working Paper*.

Boss, M., H. Elsinger, M. Summer, and S. Thurner 4 (2004). Network topology of the interbank market. *Quantitative finance 4*(6), 677–684.

Boyd, J. H. and G. De Nicolo (2005). The theory of bank risk taking and competition revisited. *The Journal of finance 60*(3), 1329–1343.

Boyd, J. H., G. De Nicolo, and B. D. Smith (2004). Crises in competitive versus monopolistic banking systems. *Journal of Money, Credit and Banking*, 487–506.

Boyd, J. H. and E. C. Prescott (1986). Financial intermediary-coalitions. *Journal of Economic theory 38*(2), 211–232.

Caccioli, F., T. A. Catanach, and J. D. Farmer (2012). Heterogeneity, correlations and financial contagion. *Advances in Complex Systems 15*(supp02), 1250058.

Caccioli, F., J. D. Farmer, N. Foti, and D. Rockmore (2015). Overlapping portfolios, contagion, and financial stability. *Journal of Economic Dynamics and Control 51*, 50–63.

Caccioli, F., M. Shrestha, C. Moore, and J. D. Farmer (2014). Stability analysis of financial contagion due to overlapping portfolios. *Journal of Banking & Finance 46*, 233–245.

Cheng, X. and H. Zhao (2019). Modeling, analysis and mitigation of contagion in financial systems. *Economic Modelling 76*, 281–292.

Chung, F. and L. Lu (2002). Connected components in random graphs with given expected degree sequences. *Annals of combinatorics 6*(2), 125–145.

Craig, B. R. and V. Dinger (2008). Bank mergers and the dynamics of deposit interest rates. *Bundesbank Discussion Paper 2*, 1–28.

De Nicolò, G., P. Bartholomew, J. Zaman, and M. Zephirin (2004). Bank consolidation, internationalization, and conglomeration: Trends and implications for financial risk. *Internationalization, and Conglomeration: Trends and Implications for Financial Risk*.

De Nicolo, G. and M. L. Kwast (2002). Systemic risk and financial consolidation: Are they related? *Journal of Banking & Finance 26*(5), 861–880.

DeYoung, R., D. D. Evanoff, and P. Molyneux (2009). Mergers and acquisitions of financial institutions: A review of the post-2000 literature. *Journal of Financial services research 36*(2-3), 87–110.

Eisenberg, L. and T. H. Noe (2001). Systemic risk in financial systems. *Management Science 47*(2), 236–249.

Elliott, M., B. Golub, and M. O. Jackson (2014). Financial networks and contagion. *American Economic Review 104*(10), 3115–53.

Fricke, D. and T. Lux (2015). Core–periphery structure in the overnight money market: evidence from the e-mid trading platform. *Computational Economics 45*(3), 359–395.

Gaffeo, E. and M. Molinari (2015). Interbank contagion and resolution procedures: inspecting the mechanism. *Quantitative Finance 15*(4), 637–652.

Gaffeo, E. and M. Molinari (2016). Macroprudential consolidation policy in interbank networks. *Journal of Evolutionary Economics 26*(1), 77–99.

Gai, P. and S. Kapadia (2010). Contagion in financial networks. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 466*(2120), 2401–2423.

Glasserman, P. and H. P. Young (2015). How likely is contagion in financial networks? *Journal of Banking & Finance 50*, 383–399.

Guan, Y. and M. Pollak (2016). Contagion in heterogeneous financial networks. *Advances in Complex Systems 19*(01n02), 1650001.

Hannan, T. H. and S. J. Pilloff (2009). Acquisition targets and motives in the banking industry. *Journal of Money, Credit and Banking 41*(6), 1167–1187.

Hüser, A.-C. (2016). Too interconnected to fail: A survey of the interbank networks literature. Technical report, Leibniz Institute for Financial Research SAFE.

Mishkin, F. S. (1999). Financial consolidation: Dangers and opportunities. *Journal of Banking & Finance 23*(2-4), 675–691.

Moch, N. (2018). The contribution of large banking institutions to systemic risk: What do we know? a literature review. *Review of Economics 69*, 231–257.

Montoriol-Garriga, J. (2008). Bank mergers and lending relationships. *ECB Working Paper* (934).

Neveu, A. R. (2018). A survey of network-based analysis and systemic risk measurement. *Journal of Economic Interaction and Coordination 13*, 241–281.

Rogers, L. C. G. and L. A. M. Veraart (2013). Failure and rescue in an interbank network. *Management Science 59*, 882–898.

Sánchez, P. C. (2017). Financial contagion in the interbank market.

Uhde, A. and U. Heimeshoff (2009). Consolidation in banking and financial stability in europe: Empirical evidence. *Journal of Banking & Finance 33*(7), 1299–1311.

Upper, C. (2011). Simulation methods to assess the danger of contagion in interbank markets. *Journal of Financial Stability 7*(3), 111–125.

Weiß, G. N., S. Neumann, and D. Bostandzic (2014). Systemic risk and bank consolidation: International evidence. *Journal of Banking & Finance 40*, 165–181.

Wójcik, D. and S. Ioannou (2020). Covid-19 and finance: Market developments so far and potential impacts on the financial sector and centres. *Tijdschrift voor economische en sociale geografie 111*(3), 387–400.