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Macroprudential Consolidation Policy in Interbank Networks

Gaffeo E. · **Molinari M.**

Abstract Can consolidation policy be made consistent with macro-prudential supervision? In this study, we seek to provide new insights on this key-question using a network approach. We study how the resilience of a banking network evolves as we shock an initially homogenous competitive market with a sequence of M&A activities that significantly alter the topology of the network. We study how different M&A treatments impact on the structural vulnerabilities that can propagate through the system and we show that the severity of contagion and default dynamics depends on the chosen treatment. The desirability of alternative competitive settings (such as hub-centered market or a more concentrated and yet symmetric market) are assessed against an homogenous benchmark case and we show that the choice depends crucially on the size of the interbank market and the level of bank capitalization. The existence of a large highly connected hub is beneficial in a capitalized network with a well-developed interbank market but it can significantly weaken the system resilience in a poorly capitalized market. Antitrust and competition authorities shall adopt a state-contingent approach to M&A activities according to the market conditions in which banks operate.

Keywords Consolidation Policy · Macroprudential Regulation · Interbank Networks.

JEL Codes: D85 · G21 · G34 · L40

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1 Introduction

The Global Financial Crises (GFC) of 2007-08 has put to the fore an additional dimension to the established trend of consolidation in the banking sector registered worldwide during the last three decades. Urged by compelling considerations of systemic stability, regulators thoroughly arranged - and in some cases forced - the acquisition of troubled banks by in-market competitors as a crisis-management tool to be added to traditional resolution procedures and state-supported bailouts. While this occurred repeatedly in the USA (see e.g. the acquisitions occurred between April and October 2008 of Bear Sterns by JP Morgan Chase, of Wachovia by Wells Fargo, and of Countrywide Financial and Merrill Lynch by Bank of America), in the UK (where HBOS was taken over by Lloyds TSB in September 2008) and in the Euro area (where BNP Paribas acquired a 75% stake in Fortis in September 2008, and a brand new institution called Bankia was created in Spain from the integration of seven regional cajas in December 2010)[1], very little is known on what consequences these actions may have on the financial soundness of the newly created legal entities on the one hand, and on the stability of the banking system as a whole on the other one.

Regardless of whether banking consolidation occurs through unassisted transactions under standard market conditions or as emergency actions orchestrated by regulators as a means of resolving a banking crisis, antitrust authorities and central bankers have the opportunity to shape the structure of the industry by exercising their authority to recommend, approve or block any single merger. Our starting point is that M&A activities alter the topology of a network of interbank lending-borrowing obligations for three reasons: 1) large players are formed that did not exist before (i.e., the size distribution of nodes changes); 2) the total number of active banks decrease (i.e., the total number of nodes changes); 3) larger banks typically have more borrowing-lending relationships than smaller banks (i.e., the degree distribution of the network changes). Hence, in addition to affecting the competitive environment in which banks operate, different strategic approaches followed by regulators in managing consolidation processes (let just one very big bank to form by allowing it to acquire a large number of smaller banks; or limit the size of each merger to just two small units at once) lead to different interbank network topologies, which could in principle be characterized by different degrees of resilience to shocks and vulnerability to financial contagion. If this is the case, banking consolidation policy can be conceived as an additional tool for macroprudential regulation aimed at preventing or taming systemic crises.

In this paper we employ agent-based techniques to study the issues of the resilience to shocks and the unfolding of systemic risk in an evolving interbank network, where we explicitly account for the possibility that banks can be merged or forced to be separated (for instance, in terms of business lines) over time. By developing a flexible computational platform, we perform a set of simulation experiments aimed at assessing the potential for contagion associated to alternative M&A regulations. In particular, moving from a benchmark structure with a given number of banks which are homogeneous both in terms of size and of interbank connectivity, we compare three different network-changing M&A licensing policies in order to evaluate their effect on the resilience of the system to an idiosyncratic shock causing the insolvency of a node. In a first treatment, a single bank is allowed to expand its business and grow in size by acquiring from time to time its smaller competitors. In the other two treatments we assume that a bank can be dissembled and its activities evenly distributed to all other operating institutions, and that a merger can be admitted only between two equally-sized banks, respectively.

Our results suggest that the systemic properties of the interbank topologies emerging from different approaches to drive market consolidation are not all alike, since they depend on key characteristics of the system. For instance, the creation of a large highly interconnected bank operating as a hub turns out to decrease systemic risk if institutions are well capitalized and interbank obligations represent a sufficiently high share of banks' total assets, but its effect

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[1] A similar approach was adopted by local regulators during the 1997-98 Asian financial crisis (Shih (2003)).

on resilience is reversed in a poorly capitalized market. The clear policy implication is that when deciding on how to manage the consolidation of the banking sector a regulator shall closely monitor the evolution over time of the interbank network that ensues from the deal, its interactions with capital requirements, and the structural funding policies followed by all banks participating to the market.

The ideas in this paper are related to several strands of earlier work. One branch of the literature has extensively used mean-field approximation and simulation techniques to assess the issue of contagion in banking systems (Nier et al (2007); May and Arinaminpathy (2010); Gai et al (2011); Battiston et al (2012) and Krause and Giansante (2012)). One key finding is the existence of a non-monotonic (inverted M or U-shape) relation between the degree of connectivity and the number of defaults due to failure cascades occurring in a network of mutual financial obligations. Connectivity acts first as a means to increase the contagion effect, but beyond a certain threshold it contributes to enhance risk-sharing and eventually the resilience of the system. Although contagion dynamics is central to our story as well, we differ from these other works by explicitly exploring how the propagation of idiosyncratic shocks may be affected by different regulations aimed at altering the topology of the network through M&A transactions. Furthermore, we add to the literature balancing the ”stability” and the ”fragility” views on how market structure and competition policies in the banking sector affect financial stability (Beck (2008); Berger et al (2009); Vives (2011)) a perspective focused on how the complex web of balance-sheet interdependencies among financial institutions can be altered to tame systemic risks, thus reinforcing the case for a macroprudential approach to bank consolidation policy (Ratnovski (2013)). Finally, we extend previous work analyzing bank merger decisions in stressed financial networks (Leitner (2005); Rogers and Veraart (2013)) by adopting an ex-ante approach. Without an a-priori knowledge of which bank will fail, merge or will be acquired by one another during a future crisis, a regulator aimed at deploying a consolidation emergency plan should compare alternative approaches to consolidation policies, in order to gauge which one has superior properties in terms of macroprudential objectives.

The structure of the paper is as follows. Section 2 introduces a model of the banking system and shows how idiosyncratic shocks can propagate through the network of interbank obligations. Section 3 discusses the design of the three treatments we use to simulate alternative M&A rules, and describes how different consolidation policies alter the topology of the network. Section 4 presents the results we obtain from Monte Carlo simulations. Section 5 concludes with some final remarks.

2 The Model Set-Up

The network generating process and the shock propagation mechanism used in this paper draw upon Gaffeo and Molinari (2013). Hence here we only outline their basic features and the interested reader may refer to it for further details. Consider a banking network populated by n banks. Each bank $i \in n$ is assumed to have a balance-sheet as the one depicted in Table 1. Bank Assets comprise interbank assets (IA_i) and a broad category labeled external assets (EA_i) that capture the sum of all non-interbank assets such as loans to firms and households, treasury bonds and other risk-free assets, cash-reserves etc. The liabilities are made up by core liabilities (see Hahm et al (2013)) in the form of retail deposits (D_i), and interbank liabilities (IL_i) as an additional source of funding. In our model the "interbank market" is just a short-cut for a set of instruments comprising overnight transactions, short-term and long-term interbank debt and wholesale funding. The accounting identity between assets and liabilities is ensured by the bank equity or net-worth (NW_i).

Table 1 Bank i's Balance Sheet

Assets	Liabilities
	NW_i
EA_i	D_i
IA_i	IL_i

Each entry of each bank's balance-sheet is retrieved in the following way. First, we create a weighted liability matrix X^l of mutual exposures.

$$X^l_{n,n} = \begin{bmatrix} x_{1,1} & x_{1,2} & \cdots & x_{1,j} & x_{1,n} \\ x_{2,1} & x_{2,2} & \cdots & \cdots & x_{2,n} \\ \vdots & \vdots & \ddots & x_{i,j} & \vdots \\ x_{n,1} & x_{n,2} & \cdots & \cdots & x_{n,n} \end{bmatrix}$$

Each element x^l_{ij} reads the interbank fund borrowed by bank i from bank j. By construction, this is equal to the amount lent by bank j to bank i. We use a random Erdös-Rényi model in which each element x_{ij} takes up a positive value with a given independent probability p.

Once the liability matrix is specified, the interbank liabilities IL_i of each bank are computed as:

$$IL_i = \sum_{j=1}^{n} x^l_{ij} \tag{1}$$

and the interbank assets IA_i as:

$$IA_i = \sum_{i=1}^{n} x^l_{ji} \tag{2}$$

It follows that the deepness of the interbank market is given by:

$$IB = \sum_{i=1}^{n} IA_i = \sum_{i=1}^{n} IL_i \tag{3}$$

External assets are imputed as a fixed proportion of interbank assets $EA = \alpha IB$. The capital buffer is assumed to be homogenous across all banks and is governed by the parameter β that defines the equity ratio with respect to total assets: $NW_i = \beta[EA_i + IA_i]$.

As it will become clearer later, interbank liabilities of a troubled institution act in our model as the channel through which financial distress can spread to affect other healthy nodes. This is the reason why we want to have perfect control over the size of interbank liabilities. To this end, we need to make some adjustments to the weighted liability matrix in order to constrain the elements of each row to sum up to the same amount. This implies that all banks borrow the same interbank amount and we let interbank assets be determined endogenously in a fashion similar to Gai and Kapadia (2010) or Gai et al (2011). As a consequence some banks will be net borrowers and some will be net lenders in the interbank market. In order to achieve this result, we set *ex-ante* the value of non-zero elements but then we divide this number by the number of links that each bank has in each realization of the network. In this way, IL_i is given for each bank and it is evenly distributed across all creditors but the size of the single interbank loan is not fixed *ex-ante* and may vary across banks.

Following the literature (see Nier et al (2007); Gai and Kapadia (2010) and others), we trigger contagion at time $t = 1$ with a targeted shock (γ_i) that wipes out the external assets of one bank in the system. Large idiosyncratic shocks are unlikely although possible (e.g. fraud) or one can think of it as a simplified scenario in which there is a common shock that results in a loss for one institution so severe as to force it into default.

The propagation of losses throughout the network works as follows: whenever a bank i is buffeted, it fails if it does not have enough capital to cope with the shock. Bank distress is managed under a bail-in scheme whose main purpose is that of avoiding the premature closure of the financial institution in order to preserve specific know-how and asset value. The authority with a bail-in power forces a recapitalization of the bank at the expense of the creditors and a conversion of external debt into equity allows to restore a minimum viability threshold, which allows an ordered resolution.[2]

The dynamic adjustment works as follows: if $NW_i - \gamma_i < 0$ then bank i will not be able to honor part of its liabilities and will hence be declared insolvent. Supposed that at time t=1, we set into default the a random bank i by exogenously mark down do zero its external assets. In the following time-round, t+1 each bank j holding interbank claims against that failing institutions will be required to bail-in and some (or all) of their interbank assets will be written off. We define as non-distressed claims those interbank assets that are not marked down for bail-in purposes. Starting from the initial weighted liability matrix, we build a new matrix of non-distressed claims (NDC) updated according to the following rule of motion of interbank exposures:

$$NDC_{ji}(t+1) = [1 - \theta_i(t)]NDC_{ji}(t) \tag{4}$$

where $NDC_{ji}(t)$ is the value of the outstanding loan at time t made from bank j to bank i and θ is loss-given-default.[3]

The total value of interbank (non-distressed) assets for each bank j at each time-round t is simply computed as:

$$NDC_j(t) = \sum_{i \neq j} NDC_{ji}(t) \tag{5}$$

and:

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[2] See Gaffeo and Molinari (2013) for a more in-depth explanation of this scheme.

[3] Let us assume that the exogenous shock is given to bank i at time $t = 1$. This means that $NDC_{ji}(1) = X^l_{ij}\ \forall\, i, j$. The rule of motion as in equation 1 allows us to fill in the matrix of non-distressed loans ($NDC_{ji}(t)$) for $t > 1$) at each time-round during the contagion process.

$$1-\theta_i(t) = \begin{cases} 1-\frac{max(\gamma_i(t)-NW_i(t),0)}{IL_i(t)} & \text{if } IL_i(t)-[max(\gamma_i(t)-NW_i(t),0)]>0 \\ 0 & \text{if } IL_i(t)-[max(\gamma_i(t)-NW_i(t),0)]<0 \end{cases} \tag{6}$$

$1-\theta_i(t)$ is the share of non-distressed loans made to bank i at each time-round during the contagion process and one can think of it the recovery rate at time t for the banks connected to the failing bank i. $1-\theta_i(t)$ is bank-specific, time-varying and consistent with a *par condicio creditorum* principle. Those neighbor banks that suffer a residual loss larger than their equity base will enter a bail-in scheme and contagion will spread to their creditors.[4]Higher-order default avalanches can unravel through the network and contagion stops when $1-\theta_i(t)$ equals one for all banks at a given time t+k.

This set-up is now modified to embed the possibility to alter the structure of the network *via* a series of M&A shocks and the next section provides an accurate description of these experiments.

3 Treatments Design

In our view, competition policy should be explicitly recognized as part of the macroprudential toolkit to safeguard the banking system, for reasons which go far beyond crisis-management purposes. The extensive microprudential regulation to which banks are submitted (Basel I-II, plus national legislations) - in terms of codes of conduct, laws, rules, standards as well as capital and liquidity requirements - implies severe compliance costs Elliehausen (1998). Since a large part of compliance costs are fixed costs, there are huge economies of scale to be exploited. A further increase of compliance costs associated with new regulatory reforms due to be applied in the next few years (Basel III) could force (especially small) banks (for instance, cooperative and savings&loans banks) to merge for reasons different from the pursue of efficiency in lending and borrowing activities. Since mergers among banks are scrutinized and approved by antitrust authorities and central banks, these latter have the opportunity to design the structure of the industry by choosing how banks are allowed to merge.

We design a flexible network platform that allows us to measure how the resilience of an interbank network changes as we implement three different types of M&A treatments. We define *Vertical Merge Process* (henceforth VMP) one in which there is only one big bank in the system and such bank is the only one allowed to acquire other banks so that it becomes larger and larger; a pure *Horizontal Merge Process* (henceforth HMP) as one in which, a bank is disassembled and its shares are evenly distributed to all other surviving institutions. And finally an intermediate or semi-horizontal (SHMP) case in which a merge is only allowed between two small banks. For exposition purposes, we present the as SHMP treatment I, the VMP as treatment II and the HMP as treatment III.

Our starting point, equal for the three treatments, consists of a symmetric banking system populated by N=25 homogeneous small banks characterized by the same probability $P = 0.2$ of forming a link between one another.[5] Haldane (2013) provides evidence that most modern banking systems exhibit high levels of concentration that have also increased for the last 20 years. The top 3 banks account for a market share of 40 (US), 60 (Switzerland), 70 (Germany) up to 80 percent for the UK. Manna and Iazzetta (2009) report that the top 20 banking groups in Italy account for 80 percent of the market and the top 5 groups have a share higher than 55 percent in 2007. Gai et al (2011) show the network of large exposure between UK banks in 2008 and their network comprises 24 banks. With these trends in mind, we feel that a network of 25 financial institution is a reasonable choice to start with.

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[4] The residual loss for any bank j $\gamma_j(t+k)$ for any k is defined a $\gamma_j(t+k) = \sum_{i\neq j} NDC_{ji}(t+k-1) - \sum_{i\neq j} NDC_{ji}(t+k)$

[5] We call this a symmetric system because banks belong to the same size-class and share the same probability of being connected to one another.

Our experiments are based on 9 "merge-rounds". The benchmark banking network just described is found at merge-round 1 and we simulate one merge at each of the following 8 merge-rounds. From merge round 2 onwards, links are formed with probabilities that are adjusted in order to keep the expected number of links constant. In such a way, we can perform our *resilience-analysis* in a controlled environment in which the aggregate size of the network, that of the interbank market and the aggregate level of net-worth (which can be taken as a proxy for absorbing capacity net of network effects) are kept fixed for any given level of interconnectedness. To the extent that M&A shock vary the number of channels trough which contagion can diffuse or the aggregate quantity of net-worth available as shock-absorbing buffer, our experiments would by construction alter the ex-ante degree of resilience. Here we shall want to keep that constant and we check instead the ex-post resilience which only depends on the within-network distribution of such links and equity.

Let us define P_s as the probability of forming a borrowing link for a small bank. When large banks are formed, each one of them is assumed to have a borrowing probability $P_l > P_s$ to be connected to other banks. As an illustrative example, let us consider the vertical merge process. Let N=25 be the total number of banks in the homogenous case. The expected number of links in this case is equal to $E(L) = PN(N-1)$. In merge round 2, we now have 24 banks, out of which 23 will be small banks and 1 large bank, whose interbank liabilities will be twice as large as those of the other small banks. In the third round there will be 23 banks, out of which 22 will be small and one with interbank liabilities three times as large. Let N_s be number of small banks and N_l the number of large banks in the asymmetric network. The aggregate assets(S) remain unchanged $S = N_s S_s + N_l S_l$ (where S_s is the value of assets of a small bank and S_l is the value of assets for a large one.) and so does the aggregate net-worth. In order to keep $E(L)$ constant, the following condition must be satisfied at all merge rounds:

$$PN(N-1) = P_s N_s(N_s-1) + P_l N_l(N_l-1) + P_s(N_s N_l) + P_l(N_s N_l) \tag{7}$$

One important remark is in order: P_s and P_l are the probabilities of borrowing for a small bank and a large one respectively. In the homogenous network P is also the probability of lending but in asymmetric networks the lending probabilities are endogenously determined and no longer coincide with the borrowing probabilities.[6]

Let us point out that the treatments impact on two dimensions: on the one hand, we alter concentration level in the market. As shown in figure 1, the Herfindahl index is increasing at each round (see figure 1). Let us point out that we tried to work with sensible concentration levels that resemble values observed across Europe.[7] On the other hand, the treatments have an impact on the degree of asymmetry of the network. The asymmetry can be measured along three different dimensions: the difference in size (between large and small banks), the difference in the number of large and small banks, and the difference in interconnectedness. Let us note that neither aggregate assets nor the number of expected links are affected by the treatments.

The difference in size is captured by the size adjustment coefficient $\Phi(R)$ that we use at each merge round R to determine the size of interbank liabilities of large banks relative to that of small banks and external assets are adjusted accordingly. Table 2 sums up how each treatment impact on these dimensions of the network's asymmetry and Table 3 provides a summary of the main variables, parameters and acronyms used in the paper.

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[6] Let us define the probability of lending for a small bank P_s^L and P_l^L the probability of borrowing for a large bank. These probabilities are computed as: $P_s^L = [P_l N_l + P_s(N_s-1)](N_s+N_l-1)^{-1}$ and $P_l^L = [P_l(N_l-1) + P_s N_s](N_s+N_l-1)^{-1}$.

[7] The ECB report on banking structures ECB (2010) reports information on the Herfindahl index for most EU countries from 2005 to 2009. The average is around 11 percent but there is a great deal of cross-country heterogeneity. Italy (along with Germany and Luxembourg) stands out as a market with low concentration with values increasing from 2.3 percent in 2005 to 3.53 in 2009. The Netherlands (or even more Finland) appear at the other end of the spectrum with a market concentration starting at 17 percent in 2005 up to 20 percent in 2009.

Fig. 1 Herfindahl Index

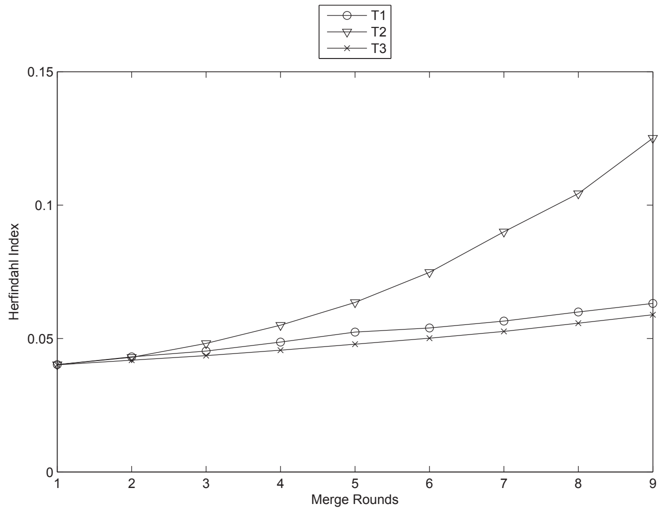

Table 2 Summary table of the treatments

Merge Rounds R	Φ			N_s			N_l			P_s			P_l		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
1	1	1	1	25	25	25	0	0	0	0.2	0.2	0.2	na	na	na
2	2	2	1.0417	23	23	24	1	1	0	0.2	0.2	0.218	0.617	0.617	na
3	2	3	1.0870	21	22	23	2	1	0	0.2	0.205	0.237	0.627	1	na
4	2	4	1.1364	19	21	22	3	1	0	0.2	0.224	0.260	0.638	1	na
5	2	5	1.1905	17	20	21	4	1	0	0.2	0.250	0.286	0.650	1	na
6	2	6	1.2500	15	19	20	5	1	0	0.2	0.280	0.316	0.663	1	na
7	2	7	1.3158	13	18	19	6	1	0	0.2	0.315	0.351	0.677	1	na
8	2	8	1.3889	11	17	18	7	1	0	0.2	0.356	0.392	0.694	1	na
9	2	9	1.4706	9	16	17	8	1	0	0.2	0.406	0.441	0.712	1	na

$N_sS_s + N_lS_l = 1500$ ∀ Merge Rounds and Treatments

Average Number of Links=120 ∀ Merge Rounds and Treatments

4 Contagion Simulations

In this Section we present the simulation results of our paper. In what follows, we measure the resilience of the system to an exogenous idiosyncratic disturbance that randomly hits one bank. Let us stress that the size of the shock does not change as we implement the three treatments and it does not depend on the size of the buffeted bank. In the benchmark case we randomly pick one small bank, whereas along each M&A treatment we concentrate on shocking a large institution because this is where the mutation of the network is most visible and hence where new structural vulnerabilities or additional resilience are likely to develop. We consider three different alternative scenarios for the banking system: a robust environment characterized by a 4 percent level of bank capitalization ($\beta = 0.04$)) and interbank market that attracts 16 percent of the the banking system's assets ($\alpha = 5$). A second case in which we expand the size of the interbank assets up to about one third of total assets ($\alpha = 2$) and keep aggregate net-worth still at 4 percent. At last, we investigate the properties of a more fragile environment in which banks are undercapitalized ($\beta = 0.01$).

Table 3 Summary Table of Network Variables, Parameters and Acronyms

Banking Network	
N	Number of Nodes/Banks (Benchmark Case)
N_l	Number of Large Nodes (Banks)
N_s	Number of Small Nodes (Banks)
P	Interbank-borrowing-link Probability (Benchmark Case)
P_l	Interbank-borrowing-link Probability for a Large Bank
P_s	Interbank-borrowing-link Probability for a Small Bank
Parameters	
α	Interbank Deepness
β	Equity Ratio
Φ	Size-Adjustment Coefficient
γ	Initial Trigger Shock
Balance-sheet Items	
IL	Interbank Liabilities
IA	Interbank Assets
NW	Net-Worth (Capital Buffer)
EA	External Assets
D	Costumer Deposits
M&A Treatments	
$SHMP$	Semi-Horizontal Merge Process (Treatment I)
VMP	Vertical Merge Process (Treatment II)
HMP	Horizontal Merge Process (Treatment III)
Network Matrices	
$X^l_{n,n}$	Weighted Liability Matrix
$NDC_{n,n}$	Non-Distressed Claim Matrix
Interbank Contagion	
CD	Contagion Dynamics
DD	Default Dynamics

Figure 2 displays the average *contagion multiplier* computed as the (averaged over 100 Monte Carlo runs) ratio between dislocated assets (at the end of the default cascade) and the initial exogenous shock. Contagion Multipliers do not always provide the full story and there is more to the picture. A more detailed analysis is instead presented in Figures 3, 4 and 5. In these plots, one can appreciate the aggregate value of the banking network (i.e. the sum of total assets of all banks) at several time-rounds for each Monte Carlo run. The pre-shock status is captured at time-round 1 (red line). At time-round 2 (green line), the system takes an exogenous idiosyncratic shock and the aggregate value falls by the size of this shock. At time-round 3 (black line) the residual loss (if any) is transmitted to other institutions connected to the first bank and this is what we call contagion dynamics (henceforth CD). At time-round 4 (blue line), we capture the first round of default dynamics (henceforth DD). In fact, at time-round 4 there are two possible scenarios. In one case, neighbor banks that carry the residual loss at time-round 3, do withstand the shock and survive. Hence no default dynamics are triggered and, if so, the blue and black line completely overlap. Or else, they do not have enough net-worth to absorb the shock and hence they also fail. Shall this be the case, further losses sweep through the network and the blue line sets below the black one. Let us point out that the randomness of the network generating process is only visible at time-round 4 onwards when DD start to kick in. We also display the final time-round at the end of the adjustment process, when the spread of default is finished. The more severe (higher-order) default dynamics are, the lower this line will be.

An interesting result is that in a robust environment (i.e. one in which banks comply with the minimum 4 percent of capital and interbank assets only account for 16 percent of

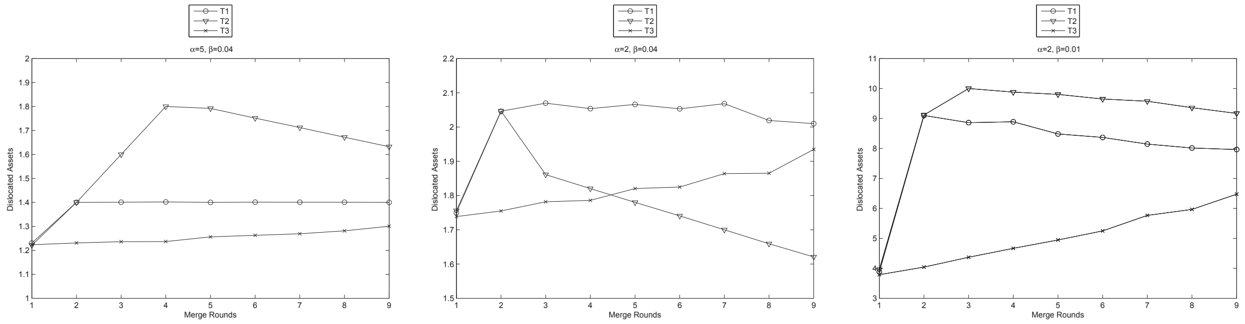

Fig. 2 Contagion Multipliers - Treatment I (SHMP), II (VMP) and III (HMP)

total assets) (Figures 3, 4 and 5 top panels) we observe that the M&A treatments make the system more prone to contagion dynamics but less subject to default dynamics and this is true regardless the chosen treatment. Note that this is not visible by simply looking at the contagion multipliers shown in Figure 2. For brevity we only show results at M&A round 1 (benchmark case - homogenous system of 25 small banks), 4 and 9. In the benchmark case (Figures 3, 4 and 5 top left panels), we see that the contagion dynamics are present and default dynamics follow suit in some cases. Moving on to the right panels, one can appreciate how the severity of contagion dynamics becomes stronger (the black line is now lower than where it was in M&A round 1) and yet default dynamics are almost fully neutralized. Indeed, the black line is almost not visible because it is fully overlapped by the blue line at time-round 4. One could argue that in this scenario the HMP (treatment III) performs best. Although we observe default cascades at M&A round 4 and 9, they are rather rare and small in magnitude. Even though default dynamics disappear under the SHMP and VMP, contagion dynamics are much stronger and contribute to a greater aggregate loss. This is so because as the large bank size increases, so does its interbank borrowing and thus its strength as a shock-spreader. Of course, it is possible for a bank to become so large that its role of shock-spreader is diminished by the enhanced value of its network. Indeed this is precisely what we observe in treatment 2. With this treatment, from merge round 4 onwards (see the left panel in Figure 2) one can fully appreciate how the shock-absorbing capacity of the large bank more than offsets its strength as a shock-spreading unit so that the contagion multiplier starts to fall.

A number of interesting remarks are worth making. First, a more concentrated market is generally more stable even though contagion multipliers are higher than in the benchmark case at M&A round 1. Second, a concentrated and yet symmetric market does a better job at curtailing CD. An HMP is hence to be preferred ex-ante to other consolidation rules consistent with the creation of a more asymmetric network. Nonetheless, if the market is already dominated by a large bank, the regulator shall favor the formation of a big hub that could keep contagion multipliers under control.

The upside of having a hub can be even greater with a deep interbank market (see Figure 2 middle panel). In this case, the shock absorbing capacity of the hub becomes so strong that its presence enhances the resilience of the system to the point where contagion multipliers become smaller than that observed in the benchmark case. Given the topological structure induced by each treatment, we can analytically derive an expected value for the magnitude of contagion and first-order default dynamics. We compute CD and first-order DD for each treatment as explained below and Figure 6 columns 2 and 3 display the results. One can directly compare them with the contagion multipliers shown in column 1, here reported again for ease of comparison.

- *Semi-Horizontal Merge Process* (Treatment I):

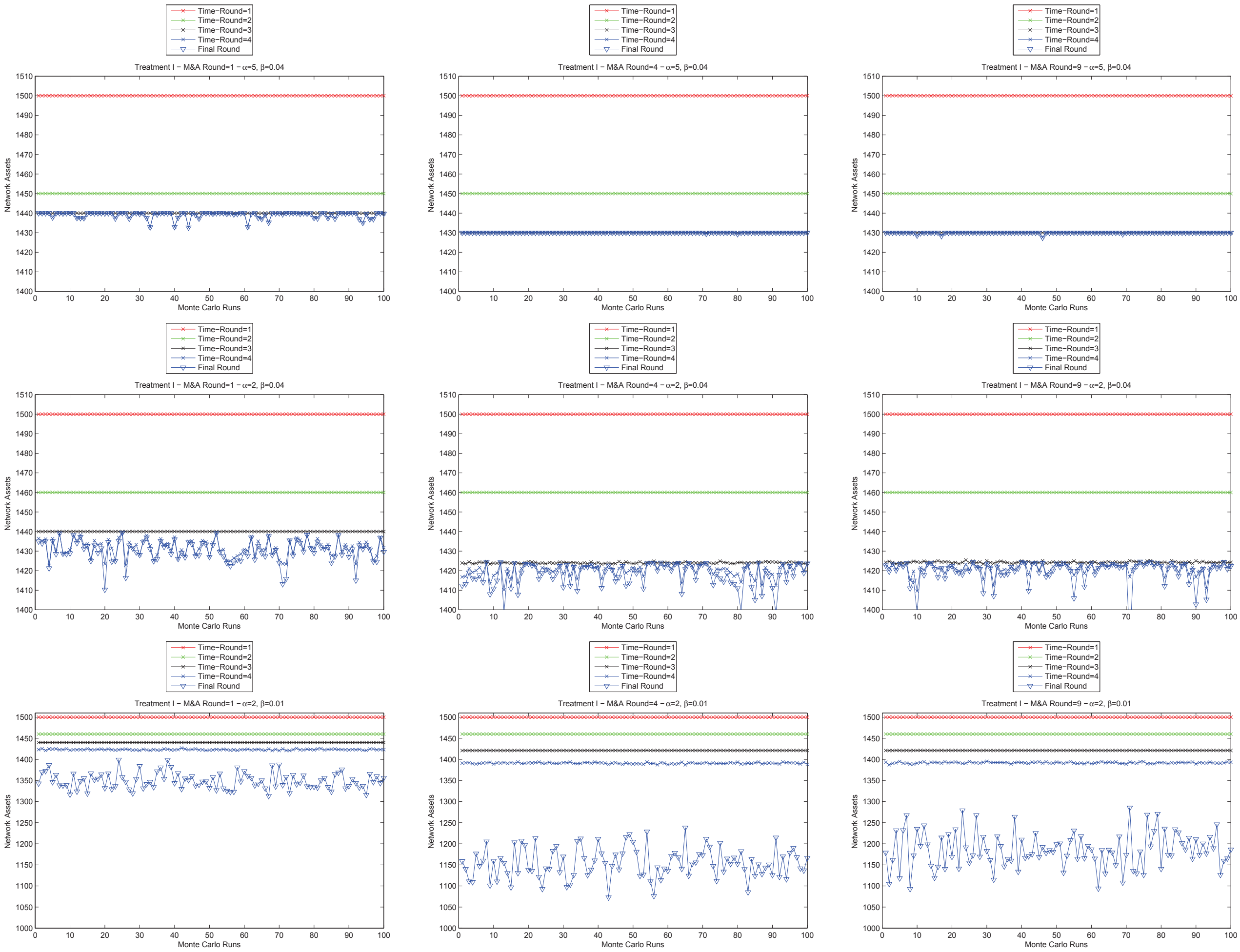

Fig. 3 Network Assets - Treatment I

$$CD = min(\Phi(R)IL(R=1), \gamma - \Phi(R)S_s\beta) = \Phi(R)IL(R=1) \quad (8)$$

with $\Phi(R=1)=1$ and $\Phi(R)=2$ for $R=2\dots 9$. $IL(R=1)$ captures total interbank liabilities of each bank in the benchmark case at merge round $R=1$

$$DD^{1^{st}} = max[P_l(N_l-1)\frac{\Phi(R)IL(R=1)}{P_l(N_l+N_s-1)} - P_l(N_l-1)S_s\Phi\beta, 0] + max[P_l(N_s)\frac{\Phi(R)IL(R=1)}{P_l(N_l+N_s-1)} - P_l(N_s)S_s\beta, 0] \quad (9)$$

- *Vertical Merge Process* (Treatment II):

$$CD = min(\Phi(R)IL(R=1), \gamma - \Phi(R)S_s\beta) \quad (10)$$

with $\Phi(R=1)=1$ and $\Phi(R)=R$ for $R=2\dots 9$

$$DD^{1^{st}} = max[P_l(N_s)\frac{min(\Phi(R)IL(R=1), \gamma - \Phi(R)S_s\beta)}{P_l(N_s)} - P_l(N_l)S_s\Phi\beta, 0] \quad (11)$$

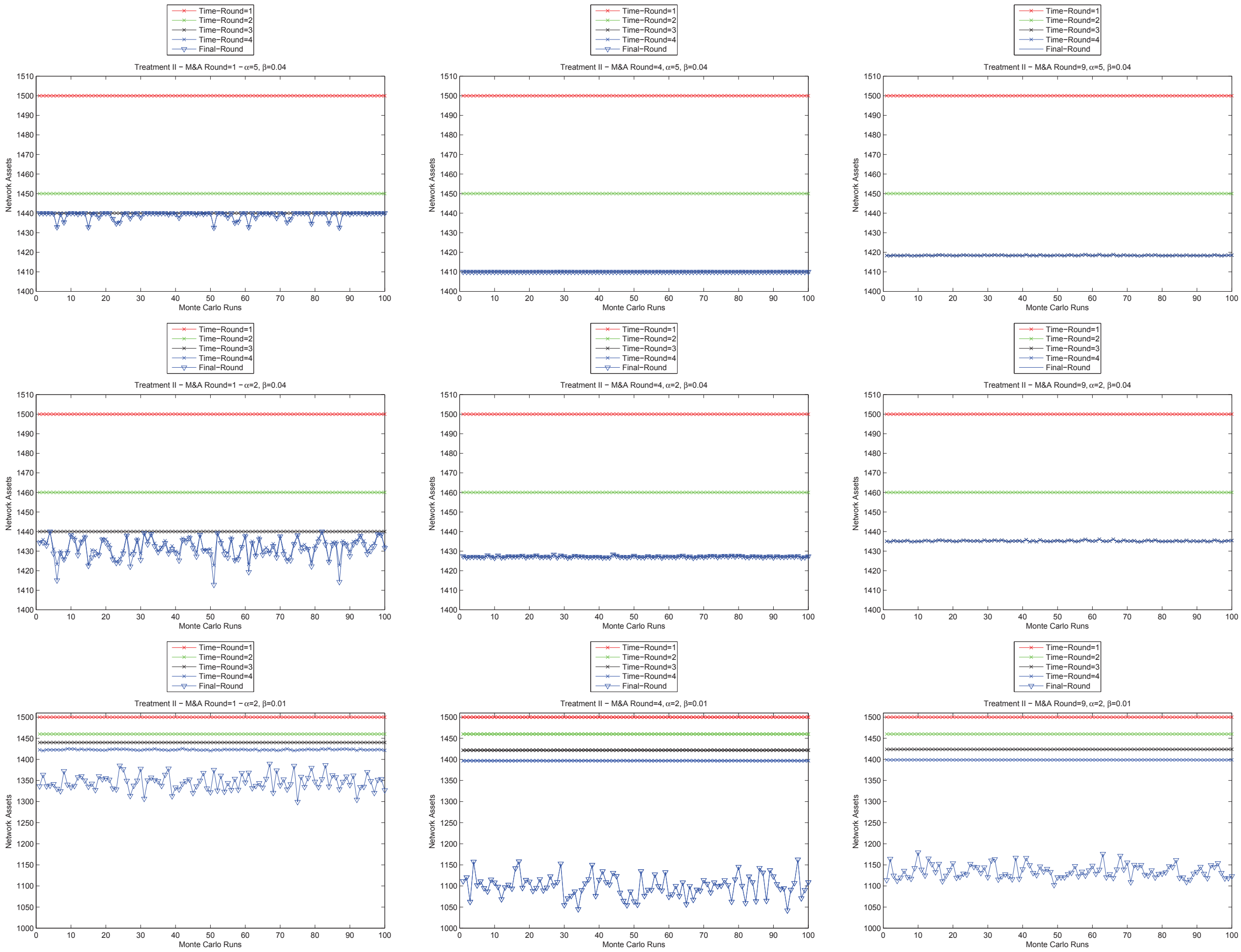

Fig. 4 Network Assets - Treatment II

- *Horizontal Merge Process* (Treatment III):

$$CD = min(\Phi(R)IL(R=1), \gamma - \Phi(R)S_s\beta) = \Phi(R)IL(R=1) \tag{12}$$

with $\Phi(R=1)=1$ and $\Phi(R)=N(1)/N(R)$ for $R=2\dots9$ where N is the total number of banks at Merge Round R and

$$DD^{1^{st}} = max[\Phi(R)IL(R=1) - P_m(N_m-1)S_s\Phi\beta, 0] \tag{13}$$

Even if the expected pool of networth of neighbor banks (given by $P_l(N_l)S_s\Phi\beta$ in eq. 11) decline at each Merge Round (see Figure 8, bottom right panel) the shock-absorbing capacity of the large bank is so large that it guarantees that the residual shock passed on to these other banks (given by $P_l(N_s)\frac{min(\Phi(R)IB,\gamma-\Phi(R)S_s\beta)}{P_l(N_s)}$ in eq. 11) is smaller than their reduced equity base. Hence no default dynamics are set in motion (See the analytical results on CD and DD presented in Figure 6). In such an environment ($\alpha=2$, $\beta=0.04$), the policymaker should have a preference for a hub-centered market.

This is no longer the case when the banking system is weakly capitalized. Here we present results obtained with a deep interbank bank ($\alpha=2$). As one can appreciate from Figure

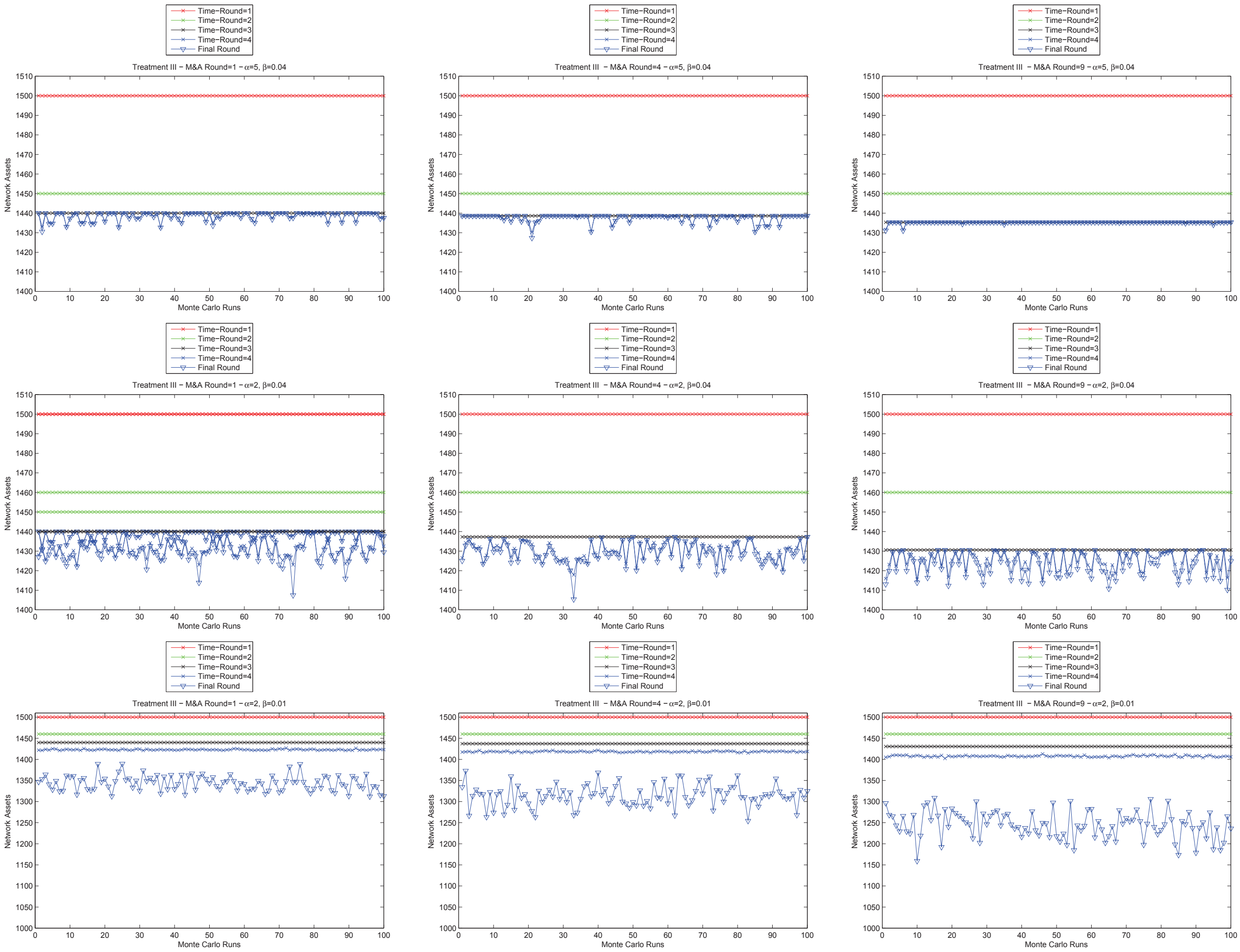

Fig. 5 Network Asset - Treatment III

4 bottom panels, the hub is now working as a market de-stabilizer. Even though contagion dynamics and 1^{st} order default dynamics are weaker than those observed with SHMP (T1) (see Figure 6 bottom middle and right panel), contagion multipliers are higher with T2. This is due to a stronger effect of complex higher-order default dynamics (which we do not model analytically). As one can see, Figure 7 shows how first-order default dynamics (at time round 4) are weaker with VMP (T2) but fifth-order losses (time round 8) and higher order losses are stronger with VPM. Higher order losses are quantitatively important in a fragile environment as that depicted in Figure 2 right panel and Figure6 bottom panels. In this environment, it is clear that policy makers should not encourage mergers or the creation of larger institutions. If necessary at all, unassisted horizontal mergers do provide a better alternative to other forms of $M\&A$. Let us stress that HMP is better able to curb higher-order default dynamics. The disruption brought about by higher-order default dynamics clearly depends on the probability of being jointly hit by multiple shocks, while VMP and SHMP are characterized by a higher level of interconnectedness and this significantly amplifies the chances of a bank taking on losses from multiple counterparts. Under these circumstances, it follows that a low-interconnected competitive banking system maximizes the resilience of the system to higher-order distress so that authorities should carefully ponder the desirability of any takeover, merges or acquisition that could significantly alter the topology of the network.

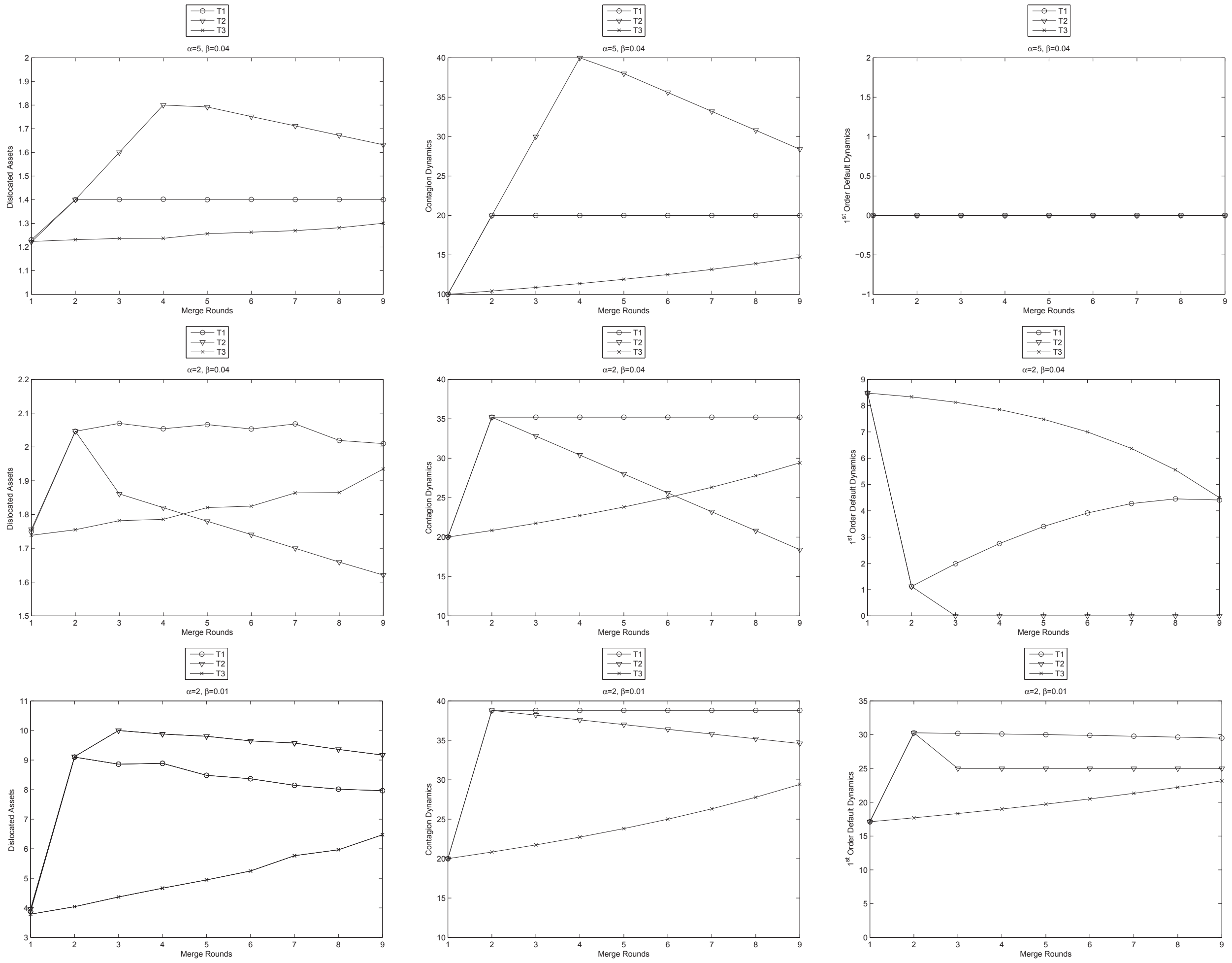

Fig. 6 Contagion Multipliers, Contagion Dynamics and 1^{st} order Default Dynamics

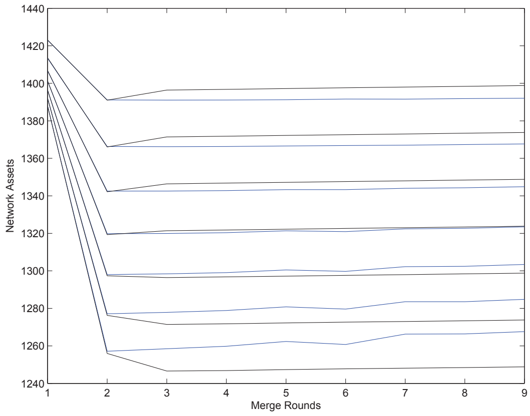

Fig. 7 Network Assets: Black Line - SHMP(T1), Blue Line - VMP(T2) for Time-Round 4,5,6,7,8,9,10

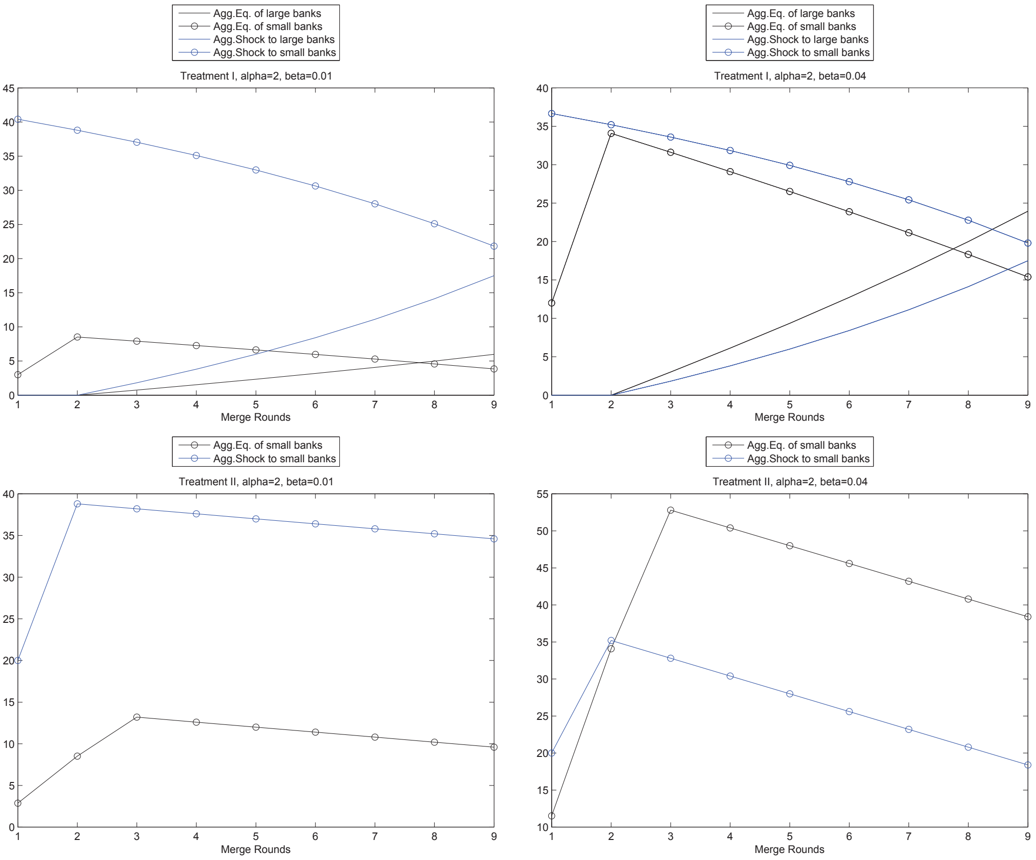

Fig. 8 Residual Shock and Absorbing Capacity

5 Concluding Remarks

In this paper we have aimed at shedding lights on the channels through which different competitive settings can fuel default/contagion throughout an interbank network, in order to draw some conclusions towards the provision of macroprudential-oriented consolidation policy rules.

Some remarks on the limitations of our analysis are in place, however. First, here we have focused exclusively on a resolution mechanism assimilable to a bail-in scheme Gaffeo and Molinari (2013). When studying an homogenous network, the value of dislocated assets and the number of defaults during a contagion spiral tend to move hand in hand and hence the number of default is taken as a sufficient statistics for network resilience. When the size can vary across banks though, the this may no longer be the case and this is why we focus on dislocated assets. Let us also note that we have defined dislocated assets as those assets that are wasted during the contagion process and the bail-in mechanism is consistent with this idea. Other resolution mechanisms are not as suitable. If, for example, a failed bank is liquidated, some of its assets will be destroyed during the process (due to the initial shocks or further fire-sales) and yet some assets are not lost as such but simply transferred outside the banking system (like the assets used to pay back depositors). The simple measure of assets available to the banking system is in this case an upward biased measure of contagion-induced stress. Under a bail-in scheme, the value of dislocated assets provides an unbiased measure of distress because the assets wiped out of the banking system during the episode of contagion are also lost by the economic system as a whole. Second, we have only studied the propagation of a shock via interbank liabilities and we have provided an inspection of the role of large banks as shock-spreader through this channel. In real network this may not necessarily be the case. Indeed, structural vulnerabilities could also develop and propagate through interbank assets (rather than liabilities) and these dynamics would be captured with a liquidation mechanism in which interbank assets can be called back in and hence trigger a funding shock to neighbor debtors. These could of course amplify the dynamics discussed in this paper and further research is certainly needed to fully shed light on this aspect.

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