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Default cascades: When does risk diversification increase stability?

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ABSTRACT

We explore the dynamics of default cascades in a network of credit interlink-ages in which each agent is at the same time a borrower and a lender. When some counterparties of an agent default, the loss she experiences amounts to her total exposure to those counterparties. A possible conjecture in this context is that individual risk diversification across more numerous counterparties should make also systemic defaults less likely. We show that this view is not always true. In particular, the diversification of credit risk across many borrowers has ambiguous effects on systemic risk in the presence of mechanisms of loss amplifications such as in the presence of potential runs among the short-term lenders of the agents in the network.

1. Introduction

One of the most important issues that the Global Financial Crisis (GFC) has brought to the fore concerns the effects on systemic risk of the increasing interdependence both among the main actors of financial markets and among financial markets across countries. In particular, the notion of too-big-too-fail becomes more subtle, while the regulatory mechanisms based only on a bank's own risk may fail to mitigate aggregate risk-shifting incentives, and can, in fact, accentuate systemic risk (Acharya, 2009).

Increasing interdependence of global financial markets – mainly achieved by means of liberalization of capital flows – may be supposed to lead to greater worldwide financial stability, as risks are spread around the world. Increasing interdependence of economic agents, on the other hand, allows for a better diversification of individual risk, as risks are spread around the set of connected partners: The larger the number of borrowers a lender is connected to in a network of borrowing/lending relationship, the smaller the fraction of an idiosyncratic shock (which leads to the default of a borrower) the lender has to bear. This, other things being equal and assuming idiosyncratic shocks are not correlated, i.e. they are not springing from the same source. It is reasonable to conjecture, therefore, that individual risk diversification leads to a lower systemic risk. There is at least one good and obvious reason to think that this is indeed the case. Consider a network of borrowing/lending relationships. Suppose agent i lends 1 unit to each node in a neighborhood consisting of k borrowers. When a borrower defaults (hence the idiosyncratic shock to i), the loss the lender experiences (due to the non performing loan) amounts to her relative exposure to the borrower. The relative loss amounts to $1/k$. By increasing the number of counterparties so that $chik$ tends asymptotically to infinity, the impact of a negative shock (the relative exposure to each borrower) tends to zero. Since the lender hit by an idiosyncratic shock does not feel the pinch and does not react to it, there will not be further repercussions of the shock itself. In this case, we can rule out domino effects and default cascades. Hence enhanced risk diversification through increasing network density reduces systemic risk.

The GFC has cast doubt on these conclusions. The breakdown of a relatively small segment of the US financial system has not only spread to the other segments – an obvious consequence of interdependence – but has also pushed the system on the verge of a "financial meltdown" at the time of the Lehman Brothers bankruptcy. Moreover, this event has triggered a financial crisis worldwide due to capital market integration. One legitimate

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conjecture therefore, is that increasing interdependence of agents and integration of financial markets in principle may not reduce but increase the risk of a systemic collapse.

Empirical research aimed at estimating systemic risk before the GFC found very little evidence of global vulnerability (Bartram et al., 2007), confirming the view that risk diversification had been pushed so far as to reduce systemic risk to a negligible level. A remarkable body of empirical literature on stress-testing in financial systems also confirmed the view, stating that the default of an individual institution was typically not able to trigger a domino effect (see Elsinger et al., 2006; Boss et al., 2004; Furfine, 2003). The empirical evidence accumulated during the GFC, however, has raised legitimate doubts on the adequacy of the procedure adopted to carry out these stress-tests (Haldane, 2009; Amini et al., 2010). The unraveling of the GFC has overwhelmingly shown that systemic risk is not negligible and domino effects are likely despite the recent impressive increase of risk diversification (Brunnermeier, 2008).

According to the theoretical literature, Allen and Gale (2000) is the most important contribution to the analysis of "financial contagion" through credit interlinkages among banks. They show that, given full diversification of risk at the level of the individual bank, the spread of an unexpected liquidity shock and its systemic effects depend crucially on the pattern of interconnectedness among banks. When the network is *complete* – i.e. density is at its maximum – and the amount of interbank deposits held by each bank is evenly spread over all other banks, the impact of the shock is easily mitigated. When the network is connected but incomplete, with banks only having few counterparties, the system is more fragile. When the incomplete network assumes the typical structure of a "wheel" or a "cycle", the shock may lead to a systemic collapse. In this case, in fact, the shock is toppling one bank after the other along the network cycle. In the end, therefore, given full diversification of (individual) risk, a complete network is more resilient than an incomplete one.

A recent, post-crisis strand of literature has tried to identify the conditions upon which an increase of network density – i.e. a scenario in which the topology of the network tends toward completeness – is not beneficial, i.e. does not reduce systemic risk (see Battiston et al., 2009; Stiglitz, 2010; Castiglionesi and Navarro, 2010; Allen et al., 2010; Wagner, 2010). In the present paper we contribute to this new line of research by exploring the mechanisms that, following the default of an agent, may lead to an increase of systemic risk when connectivity increases. Our approach is related to the framework put forward by (Eisenberg and Noe, 2001) in order to analyze the effects of an agent's default on the cash flows of the counterparties. Such framework has been further studied also in Gai and Kapadia (2010a) and in Cont et al. (2010), where the default of a bank decreases the value of the assets of each counterparty in the interbank market. In this approach, the representation of the agents in the credit network is stylized and based on accounting identities. Behavioural assumptions are kept to a minimum: agents neither choose their capital structure (and thus their level of financial robustness), nor the partners to be connected to. Moreover, agents do not interact strategically. This static balance sheet approach – similar in spirit to the procedure adopted to carry out stress tests on banks – may look somehow mechanical (Christian and Upper, 2011) but allows to characterize analytically the emergence of systemic risk as function of essentially two determinants: i) the fraction of defaulting counterparties of each agent and ii) the initial financial robustness of each agent (Gai and Kapadia, 2010a).

In our paper, we model a network of borrowing/lending relationships among financial institutions ("banks"). These institutions are also active on "financial markets", i.e. they trade financial obligations with agents outside the network itself. For instance, they can collect deposits from households or get short-term loans from outside investors. Each agent is represented by a stylized *balance sheet*. Balance sheets are interrelated, as the asset of one agent (lending bank) is a liability for another agent (borrowing bank). The intertwined dynamics of the individual equity ratios are the driving force of the change in the credit network. In particular we will focus on changes produced by borrowers' defaults, which weaken the financial robustness of lenders and may therefore induce further defaults. In this context, therefore, from the initial default of one or few agents may endogenously follow the default of some other agents in a full-fledged *default cascade*.

In a nutshell, we carry out the following exercise. We assume an initial allocation of assets and liabilities across agents and an initial set of defaults. We then derive a law of motion for the financial robustness – as measured by the *equity ratio* – of the agents concerned by the default of one or more counterparties. Finally, we investigate how the size of the default cascade is affected by the initial distribution of robustness and by the level of risk diversification in the network.

The core feature of our model of the credit network is the fact that balance sheets are interrelated, and therefore the dynamics of the individual equity ratios are intertwined. This fact is the source of the *externalities* which play a crucial role in the model. We introduce a distinction between two types of externalities which correspond to different properties in relations to systemic risk. With the first type, the default of an agent (borrower) has an obvious and immediate effect on the financial robustness of its counterparties (lenders) in a credit network. The non-performing loan, in fact, translates into a reduction of the lender's equity. However, there are no further effects of the default on the counterparties. Whenever the market value of total assets in the counterparty's portfolio becomes smaller than that of liabilities, the counterparty in turn defaults. If some other counterparties in turn, default on their counterparties a cascade of defaults may ensue.

In this baseline scenario, which we label as *external effect of the first type*, we find different *regimes*, in which increasing connectivity may have a beneficial role or a detrimental one (or no role at all). When financial robustness is not very different across agents (the degree of heterogeneity and therefore the variance of equity ratios is relatively small), increasing connectivity makes the system more resilient to systemic defaults. More precisely, with increasing connectivity the system remains stable even at lower values of average robustness. On the other hand, increasing network density, may stimulate systemic defaults when: the initial robustness is heterogeneous across agents (high variance), but the average robustness is low and there is an initial large enough shock. The reason why, from a systemic point of view, in such a situation it is better to concentrate risk instead of diversifying it is that spreading the losses make more agents default (since are already fragile).

We also model an *external effect of the second type* which, in contrast to the first type, involves an amplification of losses along the chain of lending relations. The ambiguous role of diversification on systemic risk is in this case much more pronounced. We suspect this second mechanism to appear in several situations, but in this paper we focus on one specific case. Namely, we show how the mechanism arises if, in addition to the ingredients of the baseline model, we assume that agents borrow also short-term and are exposed to the potential run of the short-term lenders. When the agent is hit by the default of one or more of her counterparties (for brevity, the initial default), her short-term creditors cannot rule out that other counterparties may default, because they do not know with certainty the situation of the counterparties. This means that the chances that the agent defaults have increased, although technically she is still solvent. As a result, short-term creditors have to decide whether to roll-over debt to the agent or not, taking into