

Credit Enhancement Techniques and Banks Connectivity

Julien BARRE* Alain RAYBAUT†
Dominique TORRE†

December 2008

Abstract

We present a dynamic model capturing three distinctive features of the recent subprime crisis and the related consequences on the stability of the banking system. The first feature is the network form of the management and mutualization of risk by the way of vehicles of credit enhancement (CDOs, SIVs and conduits). The second is the distortion of risk appreciation entailed by these risk management practices. In an analytical model, we introduce rational banks able to choose their levels of risk, of return and their net position according to fundamentals, regulatory devices and the existence of credit enhancement vehicles which are considered as ways of mutualizing risk. The dynamics of the model deals with the network structure associated with the misperception for a bank of the role of the credit enhancement vehicles. We find that a highly connected network corresponding to a given bank can generate destabilizing forces. We also find that the heterogeneity of the network corresponding to each bank can explain that a given crisis does not extend uniformly among the financial system as a whole.

JEL Classification: G01, G2.

Keywords: Credit enhancement techniques, networks, subprimes crisis.

*University Nice - Sophia Antipolis - Laboratoire Dieudonné - CNRS. E-mail: julien.barre@unice.fr

†University Nice Sophia-Antipolis - GREDEG (DEMOS) - CNRS. E-mail: alain.raybaut@gredeg.cnrs.fr, dominique.torre@gredeg.cnrs.fr

1 Introduction

During the nineties, new financial instruments and techniques have emerged to manage credit risk. These techniques have many properties: they enhance the return of credit issuers, they improve the performance of portfolios holders, they diffuse idiosyncratic credit risks among the financial system as a whole and they increase the number of the funded project without - at least apparently - increasing the risk of the financial system taken as a whole. Whereas the skills of risk managers have grown rapidly, credit derivatives and other sophisticated vehicles have irrigated up to the smallest funds and diffused to the balance sheet of the most conservative provincial banking institution. The Credit Default Swap (CDS) which, against the benefit of a premium, engages the seller to compensate the buyer of the amount of the losses generated by the underlying credit contract, has known a spectacular boom between 2003 and 2007 (see N. Rey, 2008 and Fitch annual evaluations). During the same years, even more complex products as Collateral Debt Obligations (CDO) or Commercial Mortgage-Backed Securities (CMBS) prove also an incredible success .

The design of these techniques was supposed to combine four advantages: (i) a capacity to enhance the evaluation of a given risky position, (ii) a power to divide, slice and recombine different risks, (iii) the advantage to exploit the diversity of interacting intermediaries, (iv) the use of attractive assets and derivatives, able to transfer easily from hand to hand protection and return, even far from the origin of the risk.

(i) In the case of a CDS issuance, the dissociation of the origin of the risk (generally an unrated household or a badly rated company) and of its legal owner (generally a highly rated financial intermediary) is a formal way to enhance the quality of the position of the buyer when this last is a bank submitted to Basel I prudential norms. Another advantage for CDO holders is derived from the rating practices for CDO. The unrated (but risky) equity tranches are generally neglected to evaluate the risk of these structured products: the evaluation only considers the weighted average rating of the senior and mezzanine security tranches. The same credit derivative can then enhance simultaneously and more or less artificially the quality of the position or two or more intermediaries.

(ii) When a given risk is initially backed by a large set of securities, convertibles and equities, these different assets can be stripped for providing counterparts of different derivatives. The resulting tranches can be sold separately and sooner or later recombined with other slices to constitute standardized asset. When the correlation of risks is low, this recombination plays in the default risk area the usual role of diversification in portfolio manage-

ment. When this correlation is not negligible, this recombination presents however no real objective advantage for the owners of the CDO except to generate a too optimistic evaluation of the risk of the derivative.

(iii) The association of different intermediaries is an important aspect of these techniques. Specialized financial intermediaries can generate the initial credit and the associated risk. Special Purpose entities (SPV) issue the credit derivatives able to hedge the initial risk. Banks, pension funds and other intermediaries buy those CDS, tranches and CDO as a source of revenue or in order to realize a value-added in a further resell. Hedge funds have an important role at this stage, given their uncontrolled possibilities to exploit leverage effects by issuing bonds as a way of financing their investment in CDO.

(iv) The transferability of the risk far from its origin is also a property of these techniques. This dissemination proves the efficiency of secondary markets of credit derivatives. It also underlines the capacity of financial intermediaries to combine those assets in adapted structured investment vehicles (SIV and conduits) and to issue new hedges and derivatives able to extend without apparent limits the area of risk sharing.

The developments of the subprime collapse have exhibited the dark side of these financial innovations. The diffusion of the crisis far from its origin has proved credit derivatives less secure and positions less uncorrelated than expected. Far from having prevented the crash of the specialized mortgage loans institutions, the CDS, CDO and other SIV seem to have spuriously encouraged them to increase their exposition to highly correlated risks (Dodd, 2007; Muromachi, 2007; Shao and Yeager, 2007; Rey, 2008; Eichengreen, 2008; Mah-Hui Lim, 2008)¹. The Credit Scoring Agencies over evaluation of the derivatives has induced from the assets owners a bad perception of their levels of exposition (Crouhy and Turnbull, 2007/08). The size of leverage positions accumulated by the hedge funds was certainly too large to be realized in case of need by those funds without spillovers on other intermediaries (Cartapanis and Teiletche, 2008; Aglietta and Rigot, 2008). At least, their ability to evaluate the nature and the risks of the products accumulated in portfolios everywhere in the system has not increased at the same rhythm than the diffusion of these risks in the economy (Bernanke, 2007).

All these causes of the credit derivatives crash have been examined in the recent literature². This paper will not aim discriminating between them. It

¹see also the premonitory arguments of Morrison on the way credit derivatives reduce banks' incentives to monitor their loan portfolios (Morrison, 2005).

²Ashcraft and Schuermann have identified seven kinds of frictions - each one able to be formulated in terms of information asymmetry - to characterize the interactions of the

only proposes new arguments to rationalize the over evaluation issue. Our working assumption is that, with the generalization of the use of credit enhancement techniques, the bad perception of the risk by financial intermediaries can explain by itself the propagation of the crisis as soon as there is a sufficient level of interactions between intermediaries.

The model we propose in the rest of the paper illustrates the way by which the level of connectivity of financial intermediaries can alter their perception of risks and eventually generate a financial crisis. An important feature of our setting is that the mere existence of thick relations between banks and financial intermediaries could generate for each financial agent the feeling that the connectivity of the banks network is an advantage to disseminate risk. It is also crucial that this connectivity of the banking networks would be only partial (there is no clearing house for risk management practices inside the banking networks) in such a way that the level of risk of each bank could not be only determined by systemic variables. Lastly, it is necessary that credit derivatives allow banks and funds to develop with their environment credit enhancement practices. The evaluation bias generated by the Credit Scoring Agencies can increase the negative consequences of the idiosyncratic risk transfer practices. But other circumstances related to the financial agents environment - for instance an insufficient information about the nature of the hedging assets or a shortsighted perception of the consequences of hedging - could similarly generate an over-issue of credit enhancement assets and create new sources of collapse for the whole system. In all cases, the necessary conditions are only and always (i) that techniques of credit enhancement would be available for all financial agents and (ii) that there exists thick but incomplete inter bank connections able to diffuse - but not perfectly - individual risks among the system.

The paper is organized as follows. Section 2 presents the assumptions of the model. We then derive the resulting stationary equilibria of this setting and instability conditions in the case of homogeneous agents. Section 3 comments and concludes.

2 The analytical model

Let us consider a set of n banks i with $i = 1, \dots, n$. We suppose that all banks have the same payoff function $W(x_i, \rho_i, y_i, \bar{y}_i)$ where W is continuous and C^2 in its arguments. The first variable, x_i , measures the value of the bank's net position in terms of risky investments. We assume that due to regulation policy, notably to capital requirements, W is not monotonously

different intermediaries during the genesis of the crisis.

increasing in x_i . The second variable ρ_i refers to the rate of return and the third one y_i to the individual level of risks associated with the bank's investment choices, with $W'_\rho > 0$, $W''_\rho \leq 0$, $W'_y < 0$ and $W''_y \leq 0$.

Finally, the fourth variable \bar{y} measures the perception by the bank of the global effect of the use of the techniques of credit enhancement. At each time, the bank i considers \bar{y}_i as given, whereas \bar{y}_i changes during time according to the level of risk of all banks. \bar{y}_i captures the fact that each bank is embedded in a financial system characterized by the development of a network of management and mutualization of risk by the way of vehicles of credit enhancement. This mutualization is frequently considered as having a positive effect on the capacity of each element in the system to tolerate a given level of risk. We assume that \bar{y}_i is computed by each bank i as an average over its neighbors on the interaction graph in formula:

$$\bar{y}_i = \frac{1}{k_i + 1} \sum_{j=1}^n g_{ij} y_j \quad (1)$$

In this last equation, k_i is the connectivity of agent i (her number of neighbors), and g is the adjacency matrix of the interaction graph: $g_{ij} = 1$ if i and j are neighbors, $g_{ij} = 0$ otherwise. We use the convention $g_{ii} = 1$, amounting to consider that each bank consider its own risk as one index component - among other - of the level of risk of the system

Let us assume that it exists an increasing continuous concave relation $\rho_i = h(y_i)$ between return and risk, then the payoff function writes in a compact way $W(x_i, y_i, \bar{y}_i)$, where W is continuous, C^2 and concave in its two first arguments.

The objective of a bank is to choose the optimal combination (x_i, y_i) maximizing W . The properties of W guarantee the existence of an optimal solution in the simplest static and symmetric case. In a dynamic perspective, we assume that each bank i updates the two variables x_i and y_i according to the simple dynamics

$$\dot{x}_i = \frac{1}{\tau_x} \partial_1 W(x_i, y_i, \bar{y}_i) \quad (2)$$

$$\dot{y}_i = \frac{1}{\tau_y} \partial_2 W(x_i, y_i, \bar{y}_i) \quad (3)$$

where $\partial_1 W = \frac{\partial W}{\partial x}$ and $\partial_2 W = \frac{\partial W}{\partial y}$. τ_x and τ_y are characteristic times for the adjustment of quantities x and y by the agents. Without the coupling induced by the variables \bar{y}_i 's, each agent would evolve toward a stable equilibrium,

the same for everyone if W has a single maximum. It is natural to study the existence and stability of such homogeneous equilibria in the presence of interactions. This type of stationary solution verifies $x_1 = \dots = x_n = x^*$ and $y_1 = \dots = y_n = y^*$. x^* and y^* are solutions of

$$\partial_1 W(x^*, y^*, y^*) = 0 ; \partial_2 W(x^*, y^*, y^*) = 0 \quad (4)$$

since in this case $\bar{y}_i = y^*$, according to Eq. (1).

We now suppose we have found a homogeneous stationary solution x^*, y^* . Without coupling, such a solution would obviously be stable³. It is thus interesting to investigate the influence of coupling on the linear stability. In this perspective, we will proceed in two steps. We will first suppose that the bank immediately adjusts its portofolio to its optimal value, given the level of idiosyncratic risk (small τ_x limit case). Then we will consider the general case in which the two control variables adjust simultaneously.

2.1 Small τ_x limit

We first concentrate on the $\tau_x \ll \tau_y$ limit; in this case, according to eq. (3), each bank immediately adjusts its variable x_i to its optimal value, given y_i and her environment \bar{y}_i . We call this optimal value $x^{opt}(y_i, \bar{y}_i)$. From this definition, we have

$$\partial_1 W(x^{opt}(y, \bar{y}), y, \bar{y}) = 0 \quad (5)$$

Differentiating with respect to y and \bar{y} , we get:

$$\partial_{11} W \partial_1 x^{opt} + \partial_{12} W = 0 \text{ and } \partial_{11} W \partial_2 x^{opt} + \partial_{13} W = 0 \quad (6)$$

The interesting dynamics is on the variable y_i , and reads:

$$\dot{y}_i = \partial_2 W(x^{opt}(y_i, \bar{y}_i), y_i, \bar{y}_i) \quad (7)$$

where we have used τ_y as time unit. We linearize the dynamics around the homogeneous equilibrium and study the evolution of a perturbation v_i :

$$\dot{v}_i = [\partial_{22} W + \partial_{21} W \partial_1 x^{opt}] v_i + [\partial_{21} W \partial_2 x^{opt} + \partial_{23} W] \sum_j \frac{g_{ij}}{k_i + 1} v_j \quad (8)$$

In this equation, all partial derivatives are taken at the point $(x^* = x^{opt}(y^*, y^*), y^*, y^*)$. Using equation (6), this relation may be rewritten as

$$\dot{v}_i = \frac{1}{\partial_{11} W} \left[(\partial_{22} W \partial_{11} W - (\partial_{12} W)^2) v_i + (-\partial_{12} W \partial_{13} W + \partial_{23} W \partial_{11} W) \sum_j \frac{g_{ij}}{k_i + 1} v_j \right] \quad (9)$$

³Indeed, by assumption the stationary solution (x^*, y^*) is a local maximum of W . Then, the second order conditions imply that this solution is linear stable for this dynamics

Using the notations

$$\alpha = \frac{\partial_{22}W \partial_{11}W - (\partial_{12}W)^2}{\partial_{11}W}, \quad \beta = \frac{\partial_{23}W \partial_{11}W - \partial_{12}W \partial_{13}W}{\partial_{11}W} \quad (10)$$

We rewrite vectorially the equation for the v_i 's:

$$\dot{\vec{v}} = \alpha I \vec{v} + \beta B \vec{v} \quad (11)$$

where I is the $n \times n$ identity matrix, and $B = (b_{ij})_{i,j=1}^n$ is the graph connectivity matrix normalized to 1 line by line: $b_{ij} = g_{ij}/(k_i + 1)$. We now need to study the eigenvalues and eigenvectors of the matrix $\alpha I + \beta B$.

From this standpoint, we will first consider a complete graph configuration in which each agent is connected to all others; then we will discuss the case of an arbitrary connection graph.

2.1.1 The complete graph

If each agent is connected to all others, we simply have $b_{ij} = 1/n$. In this case, the eigenvalues of B are 1 (multiplicity 1), and 0 (multiplicity $n-1$). The eigenvalues of the matrix $\alpha I + \beta B$ are then $\alpha + \beta$ (multiplicity 1) and α (multiplicity $n-1$), and the corresponding eigenvectors are those of the matrix B . Thus, a homogeneous stationary solution is stable if and only if $\alpha + \beta < 0$. Note that if (x^*, y^*) is a maximum of W at fixed $\bar{y} = y^*$, then $\alpha < 0$. α has a stabilizing effect, and the potential destabilization comes from β which contains the coupling between agents. If an increase of \bar{y} can be considered as least locally as an increased mutualization of risks in the system, the second order derivatives components of β can make it positive and create destabilizing forces.

The most unstable eigenvector is

$$\vec{w}_1 = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix} \quad (12)$$

all other eigenvectors being stable. Consequently, starting close to the unstable solution, one may expect a collective dynamics of all agents in the same direction. The intuition behind this result is therefore that the generalization of the new financial technologies, based notably on the implementation of a network of management and mutualization of risks will likely result in an increased instability of the system.

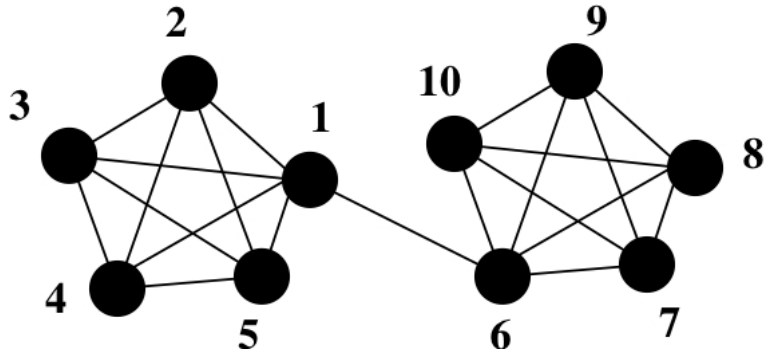


Figure 1: An example of a graph with two well connected clusters, loosely connected one with the other.

2.1.2 An arbitrary graph

For an arbitrary connection graph, we still know that \vec{w}_1 is an eigenvector of B , associated with eigenvalue 1 (this is because B is normalized to 1 line by line). In addition B is a matrix with non negative entries; if it is primitive, we can apply the Perron-Frobenius theorem, and conclude that 1 is a dominant eigenvalue of B , and is simple. Thus, $\alpha + \beta < 0$ is again a necessary and sufficient condition for stability in this case. Let us note finally that B is primitive if and only if the graph of the agents is connected (this is true only if we use the convention that an agent is connected with herself, that is $b_{ii} > 0$ for all i).

In this case, the most unstable eigenvector is still \vec{w}_1 . However, other eigenvectors, corresponding to different evolutions for different agents, may also be unstable. This is to be expected for instance if the graph possesses strongly connected clusters of agents, with loose connections between clusters. See Figs. 1 and 2 for an example; in this case, the consequences of instability are not the same for all agents.

We note finally that the conclusions for an arbitrary unweighted graph are easily extended to weighted graphs, which correspond to the more realistic case where the influence of each neighbor is given a weight.

2.2 The general case

We do not assume any more that $\tau_x \ll \tau_y$. For simplicity, we take $\tau_x = \tau_y$ and use them as time unit. The evolution of a perturbation $x_i = x^* + u_i$,

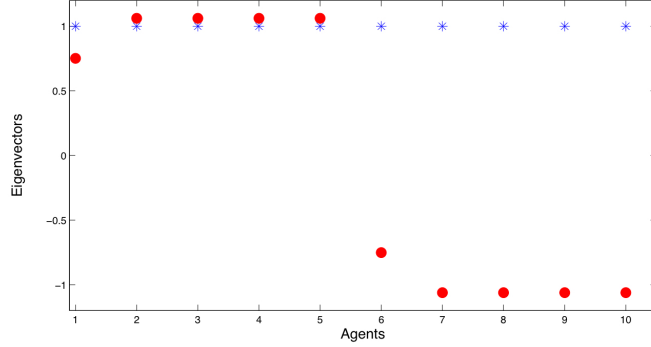


Figure 2: The first eigenvector of the connectivity matrix B of the graph on the left (stars), corresponding to eigenvalue $\lambda_1 = 1$, and the second eigenvector (circles), corresponding to eigenvalue $\lambda_2 = 0.942$.

$y_i = y^* + v_i$ is given by

$$\dot{u}_i = \partial_{11}W(x^*, y^*, y^*)u_i + \partial_{12}W(x^*, y^*, y^*)v_i + \sum_j \partial_{13}W \frac{g_{ij}}{k_i + 1} v_j \quad (13)$$

$$\dot{v}_i = \partial_{11}W(x^*, y^*, y^*) + \partial_{22}W(x^*, y^*, y^*)v_i + \sum_j \partial_{23}W \frac{g_{ij}}{k_i + 1} v_j \quad (14)$$

We may rewrite vectorially the above equations:

$$\begin{pmatrix} \dot{u}_1 \\ \dot{v}_1 \\ \vdots \\ \dot{u}_n \\ \dot{v}_n \end{pmatrix} = \begin{pmatrix} \partial_{11}W & \partial_{12}W & 0 & 0 & \cdots \\ \partial_{12}W & \partial_{22}W & 0 & 0 & \cdots \\ 0 & 0 & \partial_{11}W & \partial_{12}W & \cdots \\ 0 & 0 & \partial_{12}W & \partial_{22}W & \cdots \\ \cdots & & & & \end{pmatrix} \begin{pmatrix} u_1 \\ v_1 \\ \vdots \\ u_n \\ v_n \end{pmatrix} + \begin{pmatrix} 0 & b_{11}\partial_{13}W & 0 & b_{12}\partial_{13}W & \cdots \\ 0 & b_{11}\partial_{23}W & 0 & b_{12}\partial_{23}W & \cdots \\ 0 & b_{21}\partial_{13}W & 0 & b_{22}\partial_{13}W & \cdots \\ 0 & b_{21}\partial_{23}W & 0 & b_{22}\partial_{23}W & \cdots \\ \cdots & & & & \end{pmatrix} \begin{pmatrix} u_1 \\ v_1 \\ \vdots \\ u_n \\ v_n \end{pmatrix}$$

As above, the first part tends to stabilize the homogeneous solution; the second part tends to destabilize it. The eigenvalues of the first matrix are the eigenvalues of the Hessian around the maximum $\lambda_1 < 0$ and $\lambda_2 < 0$, each with multiplicity n . The second matrix has obviously the eigenvalue 0, with multiplicity n . From the Perron Frobenius theorem, we know that

if $\partial_{13}W > 0$ and $\partial_{23}W > 0$, its largest eigenvalue in modulus is $\partial_{23}W$: it corresponds to the positive eigenvector $u_1 = \dots = u_n = \partial_{13}W$, $v_1 = \dots = v_n = \partial_{23}W$. As the two matrices do not commute, we cannot provide in this case a simple necessary and sufficient condition for instability as above. However, the qualitative result is the same: for large enough $\partial_{13}W$ and $\partial_{23}W$, the homogeneous solution is unstable, for small enough $\partial_{13}W$ and $\partial_{23}W$, it is stable.

3 Conclusion

The simple model we develop in this paper illustrates the way in which the perception of the mutualizing effects of credit enhancement vehicles can destabilize a financial system in which the usual forces generated by risk, return and banking prudential regulation generate stabilizing effects. The network effects that we have considered in this setting give an important role to the ‘local’ perception of the environment by the banks. This environment could be defined by the partners of each bank. It could be as well generated by a belief component (the observation of the credit enhancement practices of the more influent financial institutions of the market). As each bank has also its own effective partnership network and overall its own way to observe its environment, the destabilizing forces could be very unequally distributed in the banking system as a whole. The spillovers can be large in a part of the system and quite small in another one.

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