Banking Crises and Institutional Arrangements

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Abstract

What is the role of interbank markets and central banks in coping with banking crises? In experiments using an agent-based framework with multiple banks and an interbank market. I found that when banks cannot interact, then runs in isolated banks occur with a higher frequency than when banks have equal market shares. That is, there are no runs escalating to systemic panics. In contrast, if one bank has a market share twice as big as the rest, runs spread. The presence of a central bank may unexpectedly increase the occurrence of bank runs. Institutional complexity helps to reduce the frequency of bank runs. Hence, decentralized institutional structures perform better than centralized ones.

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1. Introduction

When do banks emerge? Whenever *credit and monetary* transactions within firms dominate transactions within markets (Coase 1937). In other words, whenever it is cheaper to develop contracts within an organization that engages in *credit and exchange*, instead of contracting individually on a very short-time basis. Banks bring advantages of specialization and economies of scale to credit, exchange, and transfer activities (de Roover 1974, Crouzet 2001). These characteristics are what distinguish them from other firms. The activities of credit and exchange have been evolved a great deal since the twelfth century when Genoese and Venetian bankers were inventing the financial instruments and techniques that are still in use today. Monetary and insurance services are a byproducts of this evolution.

Diamond and Rajan (2001) make the case that banks are special because they provide liquidity--not just to other entrepreneurs by financing their projects, but to the bank's own creditors or depositors. Banks create liquidity on both sides of the balance sheet at the cost of a run prone financial structure. This banking contract would serve to solve the commitment problem between the depositors and the banker; that is, providing to the latter with funds at a lower cost subject to the feasibility of a run. However, in a thorough review of the theoretical and empirical literature on financial intermediation, Gorton and Winton (2002) claim that the industrial organization of banking usually includes elements of instability, but that banks per se do not[2]. The goal of this paper is to understand whether certain institutional arrangements are more prone to generate banking crises. Specifically, it focuses on the role of interbank markets and central banks in coping with banking crises.

In a study of historical experience with bank regulation in the United States and international comparisons, Calomiris (1993) observed, “The central lesson of these studies is that instability is associated with some historical examples of banking that had common characteristics; it is not an intrinsic problem of banking per se.” p. 3 He concludes that instability arises from the organization of the banking industry, not the nature of the banking contract itself. Probably, the difference between Calomiris’s empirical results and the results Diamond finds in several theoretical papers, (Diamond and Dybvig 1983, Diamond 1984, Diamond and Rajan 2001) is that Diamond reduces the actors in his models to a ‘representative’ bank or a ‘continuum’ of agents that behave as banks.

Here I present a model of a multibank system where banks and depositors are represented by discrete agents within an object-oriented computational framework (see Epstein and Axtell 1996, Weiss 2000), instead of by a representative agent or by a continuum of agents. First, I explore the effects due to *cooperative arrangements among banks* and due to banking panics. In the

[2] The liquidity that a bank à la Diamond creates is inside money, not ‘fiat money’ that is usually considered to be outside money (Selgin and White 1996: 85-6, and Mises 1980: 278-338).

model, competitive banks are not isolated; rather, they operate within webs of associations and cooperative relationships, as well as creating multi-branch structures. Since branch banking and cooperative associations such as clearinghouses accomplish much the same task regarding the maintenance of liquidity, my model work with an association from within an environment of otherwise independent banks. The rules of association generally map into risk-sharing insurance arrangements. This computational model should generate less insolvency in the presence of such clearinghouse arrangements[3].

A next extension is to include *central banking* in the model's environment. How do things differ when a central bank exists? The central bank must be described by a different rule of operation than what pertained to clearinghouses[4]. It is also necessary to pay attention to the central bank's budget constraint.

Laeven and Valencia (2008: 24-5) found that there were 124 systemic banking crises between 1970 and 2007 among 101 developed and developing countries. The fiscal costs of these crises were as high as 55.1% of GDP, but averaged 13.3%, while output losses ranged from nil to 98% of GDP. If the US savings and loans is excluded together with the 2007 onset of the recent crisis in UK and US, then there were 121 systemic banking crises in 99 countries.

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[3] One feature of such arrangements was usually controls placed on individual bank portfolios as a condition for belonging to the association. Such controls relieved some of the moral hazard that would have otherwise resulted.

[4] Gorton and Mullineaux (1987) describe how private commercial-bank clearinghouses worked originally in New York.

Low volatility of inflation and output in most developed countries save Japan between 1984 and 2006 led economists to term the period as 'the Great Moderation' (Bernanke 2004). It seemed as if banking crises and deep recessions in advanced economies were things of the past. But financial instability has occurred even in times of low price volatility and booming output, not just in the US during the Great Depression but also in other countries and times—e.g. Korea and Japan in the late 1980s and 1990s. Borio (2006) presents a compelling case for prudential policies even during these tranquil times[5].

In Romero (2009) I presented a one-bank model with multiple discrete agents as depositors. That model had three different versions but all of them were based on the canonical model of Diamond and Dybvig (1983). The most important of the three versions was the last one, which included *social networks* were included in the decision-making processes of depositors. Moving from the original banking contract à la Diamond and Dybvig to the version with depositor networks, the frequency of bank runs dropped from 42 percent to 17 percent, that is by 60 percent.

Here I will build on the modified banking contract used in the second and third versions in Romero (2009). In addition, I will introduce a multiple-bank

[5] It is not the first time that this has happened, though. Bronfenbrenner (1969) collects a series of papers from renowned economists where the title of the book reflects what was their view at that time after almost two decades of stability: *Is the Business Cycle Obsolete?* Although their answer was not an absolute negative, Bronfenbrenner (1969: vii) reported "that greater reliance by "politicians" on economic "technocrats," particularly on econometric macroeconomists, might soon render the cycle obsolete." A similar optimism was around in 1997 according to Fuhrer and Schuh (1998) just before the East Asian crisis.

setting, each bank having a distinctive clientele and constraints. Table I displays other models in the literature that deal with the specifics of an interbank market, a central bank, or financial contagion. Except for Temzelides (1997), all of those models make use of a continuum of agents. The model presented here adds to this literature a model wherein both banks and depositors are discrete and can have heterogeneous attributes and decision rules.

Table I: Selected multi-bank models

paper	Interbank Market	Central Bank	Continuum (c)/ Discrete (d)	Contagion
Allen and Gale (2000)	X	X	C	X
Bhattacharya and Gale (1987)	X		C	
Champ et. al. (1996)			C	
Rochet and Tirole (1996)	X	X	C	X
Smith (1984)		X	C	
Smith (1991)		X	C	
Temzelides (1997)	X		D	X
This paper	X	X	D	X

The paper is organized as follows. The next section presents a multibank model wherein banks can be isolated or participate within an interbank market. Section 3 adds a central bank as another agent to the environment and studies the interaction of the interbank market with some aspects of monetary policy by a central authority. Section 4 discusses some issues related to the implications of the results presented here and the methodology of the paper. The last section concludes.

2. Multibank Model

There are n depositors and m banks. Each depositor keeps track of her initial deposits, amount withdrawn, payoffs or fitness, returns for withdrawing at an early or later date, and amount left in her bank account. The payoffs for a depositor are given below and they are the same as the ones presented in the second version of the model in Romero (2009). Let the payoff for impatient agents be:

$$V_1(f_j, r_1) = \begin{cases} 1 & if \;\; f_j > f \\ c_1 & if \;\; f_j \leq f \end{cases} \tag{1}$$

and for patient ones be:

$$V_2(f_j, R) = \begin{cases} R & if \;\; f_j > f \\ R\left(\dfrac{1 - c_1 f}{1 - f}\right) & if \;\; f_j \leq f \end{cases} \tag{2}$$

where f_j is the number of depositors being served at time t, and c_1 is the efficient consumption allocation for those withdrawing at the early period. Otherwise they will consume c_2 in the next period, which is equal to second expression in the payoff for V_2. The total number of impatient depositors is f. Finally, the following relationships hold: $c_1 < c_2$, $c_1 \geq 1$, and $R > 1$.

The payoffs are the same as those in Diamond and Dybvig (1983: 415). They argued that a proportional tax levy on the wealth held at the beginning of period t = 1 can be used to finance a deposit insurance scheme (stated in their second Proposition). Deposit insurance generates incentives for patient depositors to wait until their bank's investment matures no matter what other depositors do. This result should hold even if the fraction of impatient depositors in stochastic. Nonetheless, I showed in Romero (2009) that even with these payoffs bank runs occurred in three of the 12 experiments run with the model. After explaining the attributes for each bank agent, I will describe a slight modification to this banking contract.

In the model, banks register their initial deposits, the amounts withdrawn by their depositors at every period during the simulation, how many depositors have been served, depositors' final balances, and bank's outstanding balance. A bank again will invest so long as it has a positive balance after serving the depositors who decided to withdraw at that period, and so long as the queue size (f_j) is less than or the same as the number of impatient depositors (f_{imp}). Thus, this process is given by:

$$I_t(b_{t-1}, R) = \begin{cases} R & if \ \ f_j \leq f_{\mathrm{im}p} \\ 0 & if \ f_j > f_{\mathrm{im}p} \end{cases} \tag{3}$$

where I_t is the bank's investment per period and b_{t-1} is the bank's previous positive balance, which earns a return of R—which is the same as the gross rate of return that patient depositors will receive when the investment matures. If the bank goes bankrupt and depositors cannot be served the simulation stops.

The model has four banks. Each bank has no more than ten customers. Thus, there is a banking market with four banks and forty depositors. These numbers are large enough to illustrate what happens with multiple agents, yet small enough that one can readily examine each agent's behavior. Again, impatient agents withdraw first, and then patient depositors have to decide whether to withdraw, since they are the 'strategic' agents. In this version of the model, the payoff structure was modified according to equations (1) and (2). The decisions whether to withdraw depend simply on the size of the queue, and the payoff for consuming earlier is always lower than the payoff from waiting. The extension is merely a modification of the rule under which patient agents make their decisions whether to withdraw based not just on the size of the queue, but also on whether the interest rate the bank pays on deposits exceeds the depositor's 'subjective' interest rate.

My aim here is to answer the following questions: Under what conditions can a liquidity crisis in a given bank spread or be contagious to others? How fast does this occur? To make this operational the model contains an interbank market that allows banks that lack sufficient funds to pay all customers in the withdrawal queue to borrow money from any other bank that has a positive balance. After serving its customers the bank will be required to repay the loan with interest. If the bank is unable to repay its debt and/or to serve its customers, it goes bankrupt. Customers stop withdrawing from the bank if they have consumed all of their savings from it.

Table II: Multibank Model

Model 1	No Interbank Market	Interbank Market	One Big Bank
#Patient	16	16	14
#Impatient	24	24	11
Run	Yes	None	Only big one
Time-step/ period	6	25	4

Note: Constant consumption and heterogeneous interest rates across customers and banks and with p(impatient/deposited) = 0.5. [Referential runs]

Table II shows results for three different experiments run within this version of the model. In the baseline scenario of no interbank market, each bank is isolated from the other banks and, in turn, their customers. In the second period, two of the four banks cannot keep serving their clients. In the third period, another bank 'fails;' and by the sixth period, the last bank also stop serving its clients. Thus, there is an overall bankruptcy of; i.e. a banking panic; the system that takes place gradually. This banking panic, though, is due neither to a contagion effect brought about by customers sharing information, nor from a localized bank run spreading to the whole system.

The second case (the second column in Table II) contains a basic 'interbank market' to explore how such an institutional environment can facilitate or discourage financial contagion. In the simulation, bank runs did not occur in any of the banks. This result was surprising, since I expected that ending the isolation of banks and their customers would result in contagion due to a bank’s financial fragility spreading to other banks. Each bank determines its own interest rate policy and decides whether to borrow from a more liquid bank. The decision whether to borrow depends on how many impatient versus patient agents each bank has in its queue and what are the depositors’ particular ‘subjective’ interest rates expected from trading with the bank.

In the third and last case I present an extension of the second case. Like the second case, it contains an interbank market, but it reduces the number of customers from the initial 40 to 25. Then, I allocate the customers arbitrarily to make sure that only one of them will get 10 customers and the rest only 5 per bank. By doing so, I get an interbank market with one of them twice as big in customers and liabilities (deposits) than the rest. This resulted in another unexpected result, which is a bank run at period 4 only for the bigger bank while the smaller banks were able to serve all of their customers. One interesting aspect of the extension is that before running out of liquidity the bigger bank lent money to another smaller bank that could serve its customers.

3. A New Agent as a Central Bank

Now let us add a central bank to the previous multibank model and its interbank market. The characteristics of the central bank are the following: (a) it controls the monetary base of the economy; (b) it collects the reserves from the commercial banks; (c) it establishes the legal reserve ratio; (d) it determines its policy for a discount rate; and (e) it can lend money to any of the commercial banks. Its balance is the sum of the monetary base plus the total reserves deposited by the commercial banks.

This extension of the model allow us to analyze the interaction between two important institutional features of financial systems in many countries today; a central bank and an interbank lending market. The central bank has three instruments for implementing its policies: altering the quantity of the monetary base; changing the minimum legal reserve ratio for commercial banks; or changing its discount rate below or above the fixed interbank market rate of 0.01% assumed in the previous version of the model. I develop experiments based on the different policy alternatives for the central bank and the probability of depositors being impatient. The results for the frequency of bank runs are reported in Table III.

Table III: Effects of adding a Central Bank

Model 2: Central Bank

Panel (a): Reserve ratio 2%

p(impatient)

0.5	MB		0.2	MB		0.75	MB	
CB-rate %	5	8	CB-rate %	5	8	CB-rate %	5	8
0.008	25%	0	0.008	50%	0	0.008	25%	0
0.012	25%	0	0.012	50%	0	0.012	25%	0

Pabel (b): Reserve ratio 30%

p(impatient)

0.5	MB		0.2	MB		0.75	MB	
CB-rate %	5	8	CB-rate %	5	8	CB-rate %	5	8
0.008	25%	0	0.008	0	0	0.008	0	0
0.012	25%	0	0.012	0	0	0.012	0	0

Notes: Percentages are proportions of bank runs. Runs have up to 2800 periods. The payoff structure is the same as in the multi-bank model. MB = monetary base. CB = central bank. [Referential runs]

The monetary base can be either 5 units or 8 units in a period; the central bank's interest rate can be either 0.008% (below the interbank market rate) or 0.012% (above the interbank market rate); the probability of a depositor being impatient can be 0.5, 0.2, or 0.75; and the reserve ratio is fixed across banks at 2%. The results is 2 x 2 x 3 = 12 experiments, shown as the gray boxes in panel (a) in Table III. The monetary supply with a central bank present in the model is given by adding the monetary base (5 or 8 units), and the total deposits of the banking system at any period (initially set at 40 units).

Note that with a similar reserve ratio of 2% for all the commercial banks and independently of what is the probability of a depositor being impatient, or what is the central bank's interest rate; whenever the monetary base increases from 5 to 8 units there are no bank runs at all. Thus, the central bank fulfills its role of lender of last resort.

When the monetary base is only 5 units there are bank runs but in no more than 50% of the banks. If the probability of a depositor being impatient is 0.5 or 0.75 the proportion of bank runs is the same; i.e. 25%. Why is that the proportion of bank runs does not increase when there are probably more impatient depositors in the population? Because the payoffs per depositor actually goes down, since each depositor may be withdrawing earlier and more frequently but the average withdrawal per depositor is lower. In contrast, when that probability goes down to 0.2 unexpectedly the proportion of bank runs increases up to 50% of the banking system. Precisely because of an increase in the average withdrawal per depositor now that there are more probably more patient depositors in the population. It is also important to notice that the central bank's interest rate does not play any role in affecting these results.

Panel (b) in Table III shows the results for the same 12 experiments presented in panel (a). The difference is that the reserve ratio now is fixed at 30% for all the banks. Also, in this case whenever the monetary base is increased from 5 to 8 units, bank runs do not occur. This result holds across the three different probabilities for being an impatient depositor (0.2, 0.5, and 0.75), and for the two different levels of the central bank's interest rate (either below 0.01% or above it).

A main difference in panel (b) with respect to panel (a) is that no bank runs occur when the probability of being impatient is 0.2 or 0.75 for any amount of monetary base; i.e. 5 or 8 units. Thus, when the reserve ratio increases from 2% to 30% the proportion of bank runs decreases to nil for those values of the probability of being impatient, or any value of the monetary base or the central bank's interest rate.

The results do not change, though, when the probability of being an impatient depositor is 0.5 in either panel. That is to say there is still a 25% of bank runs in the banking system when the monetary base is only 5 units.

Last but not least, why do bank runs still occur when I have a central bank and an interbank market working together? First, each commercial bank balances its accounts by deducting reserves deposited in the central bank. Secondly, each can borrow no more than 10 percent of the outstanding balance of the central bank at every period. Loans from the central bank and the interbank market are scheduled to pay in the next period plus any interest out of any remainder in banks' balances. The main difference with the previous model, which has only an interbank market and where no runs occurred, is that in this version the reserves are centralized in the central bank and are no longer at the disposal of each of the banks competing in the interbank market for funds. Banks incur debt first by borrowing in the interbank market, then they proceed to ask to the central bank for any further loans. However, if any bank still has no required funds from any other bank and does not have money to keep serving its depositors it can get the funds from the central bank anyway. Since liquidity problems also arise in a sequential fashion in the banks, the central bank who now centralizes the reserves of the system can provide funds to one bank at a time. Hence, the central bank is also subject to a sequential service constraint.

4. General Implications

I have implemented agents within a microeconomic environment and studied their statistical aggregate patterns. To some extent these patterns are 'emergent' in the sense of Epstein and Axtell (1996) because they were not imposed upon the agents' behavior. The patterns 'grow up' from the microeconomic structure in which the agents are embedded. Because the models also include interaction between depositors and banks (and in the third model in Romero (2009) among the depositors, too) they can be examples of self-organized complex systems.

In each of my models agents' interaction occur within a set of rules based on economic behavior. The rules were part of the design of the environments for each model. Can the rules themselves also be the result of an emergent process? On one hand, this can be a question answered by evolutionary computation or a more stylized agent-based model such as Axtell (1999). There Axtell shows how firms are ‘emergent’ organizations after individual workers join or leave a firm. On the other hand, one can provide a rationale for that process from an evolutionary economic point of view. I take the latter approach here.

In the model of multiple banks I experimented with a version in which there was neither an interbank market nor a central bank. The isolated banks did not pool reserves when liquidity was scarce. Their behavior was like that of primitive unit-banking system. A clearinghouse association is an organization that purports to overcome the lack of pooled reserves for a banking system. The clearinghouse and the appearance of an interbank market for loans explains the evolution towards a more integrated system that allocates reserves throughout all banks by portfolio adjustments.

How could these institutional solutions emerge? In the version of the model where banks were isolated, every time that there was a big increase in demand for withdrawals individual banks suffered important reserve losses that led to banking runs. Some banks failed while others did not. Banks with excess reserves could not increase profits by lending to other banks with lack of liquidity. It was if an opportunity for increasing business was not being exploited. Here lies the economic origin of the interbank market. The development of more institutionalized forms to cope with liquidity risks is rather the result of a trial and error process. After the banking industry suffers massive losses or panics, a group of bankers may decide to establish clearinghouse associations to reduce the transaction costs of check clearing and transfer of net balances, and, more importantly to pool reserves to improve liquidity across the banking industry.

This gives place to the distinction between members and non-members of these types of associations or private clubs that provide public goods to members. This is important for naturally test under what scheme banks may reduce the overall risk of panics. Due to a unitary banking industry all the network externalities that a branch-banking industry may offer under clearinghouses will be absent. At a localized level member banks will be covered even in a unitary system by the pooling of reserves with all the other local banks also participating of this type of associations.

In the models, I have not yet incorporated relevant industry characteristics such as branch banking. Calomiris (1992) and Ramírez (2003) present evidence for the pre-Great Depression period comparing branching regulations across the U.S. and in Virginia (which allowed branching) versus West Virginia (which did not). Their results show that banks in states that allowed branching were more resilient to agricultural or seasonal crises than banks in states that did not allow branching. An evolutionary account of banking institutions should make room for an explanation of the different industrial architectures that may flourish within different rules, and other set of institutions belonging to property rights and monetary arrangements. I leave such extensions for future work.

But even more resilient industrial architectures may not eliminate the risk of failure. Tussing (1967) presents a compelling case that fewer resources will be wasted if banks were treated like any other commercial firms when they fail. His claim is another way to argue that if bankers know that they will be bailed out during economic crises, they will have incentives for them to mis-allocate their resources.

Central banks have been established for varied reasons. The Bank of England was explicitly founded for purely fiscal reasons (White 1999: 81-3), while the Federal Reserve System was the result of a prolonged public discussion in which fiscal concerns were minor[6]. The main argument for establishing the Federal Reserve was not the frequent banking panics of the preceding system, but what was considered its ultimate cause namely the inelastic money supply (Wicker 2005: 22-41).

Some economists consider a fiat-money monetary system headed by a central bank a suboptimal solution compared to a classical gold standard or a competitive private provision of money (Hayek 1978, Mundell 1999, Klein 1974). In this vein, it is interesting how recent historical research on the origins of the

[6] At least between 1894 up to its foundation in 1913 there were debates in which bankers from New York, Chicago, the American Bank Association, also merchants from several Chambers of Commerce throughout the states, academicians, and politicians participated in(Wicker 2005).

Fed (White op. cit.) notes that the original proposals for monetary and banking reform in the U.S did not include at all the existence of a central bank. It was during the travels of the members of the Monetary Commission, organized by Senator Nelson Aldrich between 1908 and 1910, that the idea of establishing a central bank was adopted. Since the other leading economic countries of the time, such as England and France, had central banks, it seems that imitative behavior can also lock us into a standard not necessarily Pareto optimal.

5. Concluding Remarks

I have increased the number of banks and gradually added institutional complexity to the baseline model of Romero (2009). The agents are very simple in that they do not have sophisticated cognitive capabilities or full information, but they interact dynamically within a microeconomic environment, yielding 'emergent' aggregate results à la Epstein and Axtell.

In most of the cases introduced here, except in the interbank market case or when the monetary base was always 8 units when a central bank was present, bank runs persisted. The models as they stand here are still very stylized, yielding mostly qualitative results. An important step forward is to empirically validate their main implications.

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