Bank panics and the endogeneity of central banking

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Abstract

Central banking is intimately related to liquidity provision to banks during times of crisis, the lender-of-last-resort function. This activity arose endogenously in certain banking systems. Depositors lack full information about the value of bank assets, so that during macroeconomic downturns they monitor their banks by withdrawing in a banking panic. The likelihood of panics depends on the industrial organization of the banking system. Banking systems with well-diversified big banks are less prone to inefficient bank runs because diversification alleviates the information asymmetry. In addition, big banks can self-monitor through publicly observable branch closure. Systems of many small banks form incentive-compatible bank coalitions to emulate the big banks during times of crisis. Such coalitions improve efficiency by monitoring member banks and issuing money that is a kind of deposit insurance—a precursor of central banking.

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1. Introduction

The most important function of a central bank is to provide liquidity to the banking system in times of crisis. The classic work on central banking, Lombard Street, by Walter Bagehot, published in 1877, offered the advice that in times of panic the central bank (Bank of England) should lend freely and continue to pay out currency (Bagehot, 1877). At the time Lombard Street was published, there was no central bank in the US and yet the private arrangement of banks in the US clearinghouse system had already discovered Bagehot’s precepts and was acting on them. In this paper we argue that the lender-of-last-resort function of “central banking” arose endogenously through the formation of state contingent bank coalitions, such as clearinghouses, which provided liquidity during banking panics.

In the model we propose, central banking emerges endogenously as a response to the banking system’s problems of asymmetric information and concomitant moral hazard. In some banking systems these problems can lead to banking panics. But, these banking panics are not irrational manifestations of multiple equilibria. Rather, these episodes represent depositors monitoring their banks, which are vulnerable to moral hazard problems in certain states of the world. With the information asymmetry, such episodes involve inefficiencies because banks may be mistakenly liquidated. Banks cannot honor the demands of all depositors; there is not enough liquidity in the banking system. Efficiency can be improved in two ways. First, banks can be more accurately identified, so that only those banks in bad states are liquidated. Secondly, liquidity can be created which, as we show below, mitigates the problem of moral hazard. The industrial organization of the banking system is crucial in determining whether these improvements are operable. We show how central banking arose endogenously as a by-product of the interaction between the industrial organization of banking and the problems emanating from asymmetric information.

Specifically, we study three different organizational forms of the banking industry: a system with small independent unit banks; a system with a few highly branched and well-diversified big banks; and a system with a bank coalition. The unit banking system is the least efficient, because it suffers from severe asymmetric information problems, due in part to the fact that these banks are not diversified. Costly economy-wide liquidations following banking panics are the only way to forestall moral hazard. The big bank system is more efficient for two reasons. First, diversification alleviates the asymmetric information problem so that mistaken bank runs can be avoided. Second, big banks can self-monitor by closing branches to improve the quality of assets. The self-monitoring mechanism enables big banks to send credible signals to depositors that incentives to engage in moral hazard have been removed. Once depositors’ confidence is restored, bank runs are stopped. The bank coalition system partially replicates the big bank system in certain states of the world through state contingent coalition operations, including mutual monitoring and liability pooling. However, ownership and property rights of individual banks give rise to incentive compatibility constraints that prevent coalitions from fully replicating big banks.

The implications of the model are consistent with banking history. A comparison of the US and Canadian banking experiences from the middle of the 19th century is a particularly instructive example of the importance of industrial organization in banking and its relation to central banking. Haubrich (1990), Bordo et al. (1994, 1995), and White (1984), among others, study the drastic contrast between these two systems. During the period 1870 to
1913, Canada had a branch banking system with about 40 chartered banks, each extensively branched, while at the same time the US had thousands of banks that could not branch across state lines. The US experienced panics, while Canada did not. There were high failure rates in the US and low failure rates in Canada. Thirteen Canadian banks failed from 1868 to 1889, while during the same period hundreds of bank failed in the US (see the Comptroller of the Currency, 1920). During the Great Depression, there were few bank failures in Canada, but the Canadian banking system did shrink by about the same amount as in the US (see White, 1984). Overall, the Canadian banking system survived the Great Depression with few effects, while in the US, which had enacted the Federal Reserve Act in 1914, the banking system collapsed. Canada’s central bank came into being in 1935, well after the Great Depression.

Associated with the likelihood of bank panics is the prevalence of private arrangements among banks. In the US, for example, where panics were not infrequent, the private clearinghouse system developed over the course of the 19th century (see Cannon, 1910; Sprague, 1910; Timberlake, 1984; Gorton, 1984, 1985; Gorton and Mullineaux, 1987; and Moen and Tallman 2000, among others). During a banking panic member banks were allowed to apply to a clearinghouse committee, submitting assets as collateral in exchange for “clearing house loan certificates,” which is a form of private money issued by bank coalitions. The loan certificates were the joint liability of the clearinghouse, not the individual bank. During the Panics of 1873, 1893, and 1907 the clearinghouse loan certificates were issued directly to the banks’ depositors, in exchange for demand deposits, in denominations corresponding to currency. If the depositors would accept the certificates as money, then the banks’ illiquid loan portfolios would be directly monetized. In this way, a depositor who was fearful that his particular bank might fail was able to insure against this event by trading his claim on the individual bank for a claim on the portfolio of banks in the clearinghouse. This lender-of-last-resort function was the origin of deposit insurance.

Bank coalitions are also not unique to the US. There are many examples of bank coalitions forming on occasion in other countries as well (see Cannon, 1910 for information on the clearinghouses of England, Canada, and Japan). We mention a few examples. According to Bordo and Redish (1987), the Bank of Montreal (founded in 1817) emerged very early as the government’s bank performing many central bank functions. The pattern of the Bank of Montreal (and earlier precursors like the Suffolk Bank in the US) in which the bank coalition is centered on one large bank, is quite common. Similarly, in Germany the Bankhaus Herstatt was closed June 26, 1974. There was no statutory deposit insurance scheme in Germany, but the West German Federal Association of banks used $7.8 million in insurance to cover the losses. Germany is a developed capitalist country where deposit insurance is completely private, being provided by coalitions of private banks that developed following the Herstatt crisis of 1974 (see Beck, 2001).

The paper proceeds as follows. In Section 2 we present a simple model of a banking system that is then analyzed in subsequent sections. Our first step is to analyze two polar

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1Calomiris and Gorton (1991) identify six panics in the US prior to 1865, seven during the National Banking Era.

2The amount of private money issued during times of panic was substantial. During the Panic of 1893 about $100 million of clearinghouse hand-to-hand money was issued (2.5 percent of the money stock). During the Panic of 1907, about $500 million was issued (4.5 percent of the money stock). See Gorton (1985).
cases using the model. The first case is a banking system with small independent unit banks (Section 3) and the second is a system of large, well-diversified, branched banks (Section 4). Neither of these systems literally represents reality, though they come close to the experiences of some countries. The US historically has been a system of small independent unit banks and when private clearinghouses were in existence, not all banks were members.\(^3\) The system of large branched banks, the other polar case, does resemble many of the world’s banking systems, such as Canada. In Section 5 we consider the system with small independent unit banks that can form a coalition in the event of a banking panic. Section 6 concludes. Proofs of the propositions can be found in the appendix of the paper on SSRN or NBER Working Paper #9102.\(^4\)

2. The model

There are three dates, 0, 1, and 2 in the model economy and two types of agents: consumers/depositors and bankers. Bankers are unique in having the ability to locate risky investment opportunities. Also, only banks can store endowments (i.e., provide the service of safekeeping).

There is a continuum of bankers. Each banker has capital \(b\) and a measure one of potential depositors. Each bank has access to a riskless storage technology and to a risky investment technology. The fraction of the portfolio invested in the riskless storage technology is \(\alpha\); this investment will be referred to as reserves. The remaining fraction \(1 - \alpha + \beta\) is invested in the risky technology. Investments in the risky projects have to be made at date 0, and the returns are realized at date 2. The return to a unit (of endowment good) invested in the risky project is \(\pi + r\), that is, there is a systematic component, \(\pi\), and an idiosyncratic component, \(r\), to the return. So, the state of the macroeconomy is indicated by \(\pi\), while the bank’s individual prospects are indicated by \(\tilde{r}\). We assume that \(\tilde{\pi}\) is uniformly distributed in the interval \([\pi_L, \pi_H]\) and \(\tilde{r}\) is uniformly distributed in the interval \([0, 2M]\). For future reference, the probability density function of \(\pi\) will be referred to as \(A\), where \(A \equiv 1/(\pi_H - \pi_L)\).

At date 1, information about the date 2 return is realized, but there is asymmetric information between bankers and depositors. Depositors observe the realized state of the macroeconomy (\(\pi\)), but they do not observe the realized state of their bank’s idiosyncratic return (\(r\)). Each banker knows his own bank’s state (\(r\), and observes the realizations of other banks’ idiosyncratic shocks at date 1. Idiosyncratic shock realizations at date 1 are not verifiable among banks, but realized cash flows at date 2 are verifiable. So, to be clear, banks cannot write contracts with other banks contingent on idiosyncratic shocks at date 1. At date 0, we assume that banks’ capital \(b\) and choice of reserve level \(\alpha\) are observable and verifiable.

There is a moral hazard problem in that bankers have an opportunity to engage in fraud at date 1. Fraud is socially wasteful. If a banker engages in fraud, he gets a proportion \(f\) of the return, i.e., \(f(\pi + r)\), where \(f\) is strictly less than 1. The remaining amount,

\(^3\)Some banks were too far away to be members. Rural banks and banks in smaller cities did not have formal clearinghouse arrangements.

is wasted and depositors receive nothing. Projects can be liquidated at date 1, yielding a constant return of $Q$, regardless of the state of the project.

Depositors have a subsistence level of 1. Their utility function is:

$$u(c_1, c_2) = \begin{cases} 
  c_0 + c_1(1 + \varepsilon_1) + c_2(1 + \varepsilon_2) & \text{if } c_0 + c_1 + c_2 \geq 1, \\
  -\infty & \text{if } c_0 + c_1 + c_2 < 1,
\end{cases}$$

where $c_0$, $c_1$ and $c_2$ are consumptions at dates 0, 1 and 2, respectively. $\varepsilon_1$ and $\varepsilon_2$ represent depositors’ preference for later consumption. We assume $\varepsilon_2 > \varepsilon_1 > 0$, and they are both very small such that they can be ignored in the following analysis. The depositors’ utility function implies that they will always wait until date 2 to withdraw if they believe their deposits are safe. However, they will withdraw at date 1 if they anticipate that there is any chance that their bankers are going to engage in fraud. Depositors deposit in a single bank.

Because of their utility functions, depositors need to be assured that their claim will be worth 1 unit and banks can satisfy this need. Implicitly, individual banks can diversify to this extent. Gorton and Pennacchi (1990) show that uninformed consumers/traders with uncertain consumption demands prefer to transfer wealth intertemporally with riskless claims. A better arrangement for these consumers could be claims on a diversified bank that are always worth 1 unit (i.e., so that there is no private information that informed traders could take advantage of). We do not explicitly incorporate all this here. Rather, in the model here the structure of preferences dictates the type of claim that banks will offer depositors: the bank must offer the right to withdraw deposits at face value at date 1, i.e., a demand deposit contract.

We assume that bankers are risk neutral and they get the entire surplus from investment. In addition, we assume the following:

**Assumption 1.** $(1 + \beta)(1 - f)(\pi_L + M) < 1$. This assumption assures that there is a potential moral hazard problem. Suppose a banker invests all of his assets in the risky project, and the economy turns out to be in the worst possible state ($\pi_L$) at date 1. Consider the banker with the mean return $\pi_L + M$. If he engages in fraud, he will receive $f(1 + \beta)(\pi_L + M)$. If he does not engage in fraud, his payoff will be $(1 + \beta)(\pi_L + M) - 1$. The assumption $(1 + \beta)(1 - f)(\pi_L + M) < 1$ implies that the banker has an incentive to engage in fraud.

**Assumption 2.** $\pi_L > Q > f(\pi_H + 2M)$. In words, there is a dead weight loss if liquidation or fraud occurs. If fraud does not occur, then the value of a risky project is greater than the liquidation value, $Q$, even if the project is in the lowest possible state. If fraud occurs, then the value of a risky project is less than the liquidation value even if the project is in the highest possible state.

**Assumption 3.** $(\pi_L + \pi_H)/2 + M > 1 > Q$. This assumption says that, ex ante, a risky project is more efficient than riskless storage, if there is no liquidation or fraud. However, if liquidation or fraud happens, then a risky project is dominated by investment in riskless storage.

**Assumption 4.** $(1 + \beta)Q > 1$. That is, if depositors withdraw from their bank at date 1, then their deposit contract can always be honored.
Assumption 5. A risky project is indivisible when liquidation occurs. Although at date 0, a banker can choose how much to invest in a risky project, at date 1 all the assets in a risky project must be liquidated if liquidation occurs.

The essential ingredients of the model are the moral hazard problem and the information asymmetry. Fraud, the assumed moral hazard in this model, has historically been the most common reason for bank failure. The Comptroller of the Currency (1873), reporting on the Panic of 1873, wrote that all the bank failures during the panic were due to “the criminal mismanagement of their officers or to the neglect or violation of the national-bank act on the part of their directors” (p. xxxv). A century later, the Comptroller of the Currency (1988b) reported that:

The study found insider abuse in many of the failed and rehabilitated banks during their decline. Insider abuse—e.g., self-dealing, undue dependence on the bank for income or services by a board member or shareholder, inappropriate transactions with affiliates, or unauthorized transactions by management—was a significant factor leading to failure in 35 percent of the failed banks. About a quarter of the banks with significant insider abuse also had significant problems involving material fraud. (p. 9).

For purposes of the model, it is important that there be a moral hazard problem, but it is not essential that the problem be fraud. Any one of a number of moral hazard problems would suffice. Fraud, however, is a realistic and significant problem.

Since a banker may have an incentive to engage in moral hazard in certain states of the world, actions needs to be taken to stop them. Specifically in this model, we make the following definition.

Definition. Monitoring means to prevent a bank from engaging in fraud.

There are different ways to prevent fraud (or monitor the banks). The simplest way is to take the assets away from the bankers.

Definition. A bank run is an event in which a large number of depositors, fearing the banker engaging in fraud, withdraw their funds at date 1. A bank panic is an event in which many banks suffer from bank runs.

Because of the problem of information asymmetry, there can be “good” runs and “bad” runs. Good runs prevent the moral hazard problems; bad runs force banks that are not going to suffer from moral hazard problems to liquidate their projects. According to Assumption 2, good runs are efficient while bad runs are inefficient. If the information asymmetry problem can be alleviated, then bad runs might be avoided. This generates the demand for a lender-of-last-resort.

Definition. A lender-of-last-resort is an institution which provides liquidity to banks so that they do not have to liquidate their projects.

Note that liquidity provision has broader meanings than cash injection. For example, if an institution can provide insurance for a bank, then a run can be stopped. A more interesting example is that the lender-of-last-resort can save a bank by delivering a convincing signal that the bank is in good state. In other words, alleviating information
asymmetry is also a way to provide liquidity. This is the point we want to emphasize in this paper.

Bankers can commit to not engaging in moral hazard by holding reserves. The higher the level of reserves, the lower the probability of a bank run. However, ex post, if the state of the economy is good at date 1, then it would have been better to have invested reserves in risky projects. The bankers’ task at date 0 is to choose an optimal reserve level, \( \alpha \) (the fraction of bank assets held in the riskless storage technology). This is the only choice variable. The optimal reserve choice depends on whether bank branching is allowed and on the interaction between the bankers. We interpret branching restrictions and different interactions between the bankers as different banking systems. We consider three basic forms of organization, two polar cases and one intermediate case. The first case is a system of many small independent unit banks. The next is a system of large, well-diversified banks, and the last is a system of small unit banks that can form a coalition in certain states of the world. Below, we proceed to solve the bankers’ optimization problem under the different organizations of the banking industry, examining the reserve level, banking stability, and social welfare under each system.

3. The system of independent unit banks

The first banking system we examine is one in which there are many small, independent unit banks. That is, implicitly the banks are small so they are undiversified. This is because they have no branches and they do not interact with each other ex ante or ex post (they are independent). This system characterizes those periods of US history, for example, where banks were not allowed to branch and where they did not form explicit or implicit coalitions. We will call this banking system the “unit bank” system.

Unit banks are “small” in the following sense: a banker in charge of a unit bank can only manage one risky project. Implicitly, we imagine that banks are spatially separated so that risky projects have the idiosyncratic risk of the individual bank’s location. A banker only has the expertise in managing the project in his local region. The assumption also implies that at date 1, the project of a banker cannot be transferred to another banker, who lacks the skill to manage it. In other words, a project involves a relationship specific investment that cannot be transferred.

We solve the bankers’ optimization problem by backward induction. First, given a unit bank’s choice of reserve level, \( \alpha \), we characterize the states in which bankers will have incentives to engage in moral hazard and, hence, depositors will withdraw their deposits. Second, we will calculate the bankers’ optimal choice of reserve level, \( \alpha \), at date 0.

At date 1, depositors receive the signal about the state of the macroeconomy, \( \pi \); they do not observe the realization of their bank’s idiosyncratic shock, \( r \). Because their utility functions are kinked and they will get minus infinity if consumption is less than one, they do not care about the likelihood of their bank engaging in fraud, but only consider whether there is any chance of this occurring. They, therefore, assume that \( r = 0 \) and check whether their banker has an incentive to engage in fraud. Suppose a banker has reserves \( \alpha \) and the realized state of the macroeconomy is \( \pi \). If the banker does not engage in fraud, his payoff will be \( \pi(1 + \beta - \alpha) + \alpha - 1 \). If he engages in fraud his payoff will be \( \pi f(1 + \beta - \alpha) \), since he cannot steal anything from the reserves. The banker has incentive to engage in fraud if and only if \( \pi f(1 + \beta - \alpha) > \pi(1 + \beta - \alpha) + \alpha - 1 \), or \( \pi < (1 - \alpha)/(1 - f)(1 + \beta - \alpha) \). If such an incentive exists (i.e. \( \pi < (1 - \alpha)/(1 - f)(1 + \beta - \alpha) \)), depositors withdraw all their savings.
Since all the depositors receive the same macroeconomic information and all the banks are, form their viewpoint, homogeneous, if one bank suffers from a run, there are runs on all the other banks. Therefore, a panic occurs.

At date 0, anticipating what will happen in different states of the world at date 1, bankers choose the optimal reserve level to maximize their expected payoff. On the one hand, bankers want to maximize investment in the risky projects because this is more profitable, but on the other hand, they want to avoid being prematurely liquidated in a banking panic at date 1. If bankers hold reserves such that 

\[
\frac{1}{C_0} \left( 1 - (1 + \beta)(1 - f) \pi' \right) \Rightarrow U_{\max} \frac{1}{C_0} \left( 1 - (1 - f) \pi' \right),
\]

then they have no incentive to engage in the moral hazard even if the economy is in the lowest state. Therefore, bankers solve the following optimization problem at date 0:

\[
\text{Max}_x \int_{\pi_L}^{\pi'} [x + (1 + \beta - x)(\pi + M) - 1]dF(\pi) \\
+ \int_{\pi_H}^{\pi} [x + (1 + \beta - x)Q - 1]dF(\pi)
\]

s.t. \[\pi' = \frac{1 - x}{(1 - f)(1 + \beta - x)},\]

\[x \in [0, U_{\max}].\]

**Proposition 1.** There exists a unique optimal reserve level \(x \in [0, U_{\max}]\) that solves the bankers' optimization problem.

(The proof of Proposition 1, and all other proofs can be found in the longer version of the paper on SSRN or the NBER Working paper.)

The purpose of a panic is to monitor the bankers, to prevent them from engaging in fraud. The panic is not irrational; it is not motivated by externalities due to actions of other depositors when there is a sequential service constraint. Rather, the panic is related to the macroeconomy, which may create incentives for bankers to engage in moral hazard. The fear of not being able to satisfy subsistence should the banker engage in moral hazard, a kind of extreme risk aversion, causes the depositors' withdrawals. However, not all bankers will engage in moral hazard. The problem is that depositors do not know which bankers have high idiosyncratic shock realizations and which have low idiosyncratic shock realizations. Depositors liquidate all banks because of information asymmetry. Bankers hold high reserves to avoid being liquidated, but ex ante this is inefficient.

### 4. The big bank system

At the other extreme from a banking system composed of many independent unit banks is a system where banks are large and heavily branched, or well diversified. We call this the "big bank" system. Most banking systems in the world are closer to this system than to the system of independent unit banks, discussed above.

Because a big bank is well diversified, it has a portfolio of assets that has a realized return of \(\pi + M\) at date 1. In other words, a big bank’s return is the systematic return plus the diversified idiosyncratic mean return, \(M\). This is the essential point, namely, that the idiosyncratic risk is diversified away, implicitly by virtue of the bank’s size via branching.
Consequently, at date 1, the state of macroeconomy is sufficient information for assessing the state of a big bank. As a result, depositors know for sure whether a big bank is going to engage in moral hazard or not and they never run a big bank wrongly.

In addition to more transparent information, a second benefit is that a big bank has the flexibility to liquidate individual projects. By liquidating projects with low idiosyncratic returns, a big bank implements “self-monitoring” and improves the quality of assets. More importantly, since branch closure is public information, depositors know that a big bank’s situation has been improved. If a big bank can convince depositors that its incentive to engage in moral hazard has been eliminated by self-monitoring, depositors’ confidence can be restored and they will allow the big bank to continue the non-liquidated projects till completion.

Since the risky projects have the same liquidation value $Q$ in spite of their idiosyncratic returns, a big bank will always liquidate those projects that have the lowest realized idiosyncratic returns. Suppose the big bank is to liquidate a fraction $x$ of the risky projects. It will liquidate those projects with realized idiosyncratic returns, in the interval $[0, x2M]$. The average return on the remaining, i.e., nonliquidated, $(1 - x)$ fraction of projects is $\pi + (x2M + 2M)/2 = \pi + (1 + x)M$. In order to make a commitment not to engage in fraud, the big bank has to liquidate a fraction $x$ of the risky projects such that:

$$x + (1 + \beta - \alpha)Q + (1 + \beta - \alpha)(1 - x)(\pi + (1 + x)M) - 1 \geq (1 + \beta - \alpha)(1 - x)(\pi + (1 + x)M).$$

This is a quadratic inequality, which admits a solution in the interval $[0,1]$.\(^5\)

$$x = \frac{Q - (1 - f)\pi - \sqrt{(Q - (1 - f)\pi)^2 - (4M(1 - f)(1 - x)/1 + \beta - \alpha) + 4M(1 - f)^2(\pi + M)}}{2M(1 - f)}.$$

Anticipating what will happen in different states of the world at date 1, the banker who owns a big bank chooses the optimal reserve level to maximize the expected payoff at date 0. If the reserve level is higher than $x^R_{\text{max}} \equiv (1 - (1 + \beta)(1 - f)(\pi_L + M))/(1 - (1 - f)(\pi_L + M))$, then he has no incentive to engage in moral hazard even if the economy is in the lowest state. The date 0 optimization problem can be written as

$$\begin{align*}
\text{Max}_x & \int_{\pi_L}^{\pi} [x + (1 + \beta - \alpha)Q + (1 + \beta - \alpha)(1 - x)(\pi + (1 + x)M) - 1]dF(\hat{\pi}) \\
& + \int_{\pi}^{\pi_L} [x + (1 + \beta - \alpha)(\pi + M) - 1]dF(\hat{\pi}) \\
\text{s.t.} & \quad \pi' + M = \frac{1 - x}{(1 - f)(1 + \beta - \alpha)}, \\
& \quad \alpha \in [0, x^R_{\text{max}}], \\
& \quad x = \frac{Q - (1 - f)\pi - \sqrt{(Q - (1 - f)\pi)^2 - (4M(1 - f)(1 - x)/1 + \beta - \alpha) + 4M(1 - f)^2(\pi + M)}}{2M(1 - f)}.
\end{align*}$$

\(^5\)Since depositors can only observe how many branches, but not which branches are closed, they form beliefs consistent with the Big Bank’s action on equilibrium path. It is easy to characterize depositors’ off-equilibrium path. For example, depositors always believe that a Big Bank closes the branches with lowest idiosyncratic returns and use this belief to check the Big Bank’s incentive.
Proposition 2. The above objective function is strictly concave in \( \alpha \). There is a unique optimal reserve level, \( \alpha \in [0, \alpha_{B_{\text{max}}}^{\text{B}}] \), that solves the big bank’s optimization problem.

To emphasize, note that in the big bank system banks may experience withdrawals at date 1, but they do not fail because of their ability of “self-monitoring”. This is the major difference from the unit banking system, in which bank panics cause bank failures. In the big bank system, although some of the projects might be liquidated and branches closed, the system can survive. The unit banking system cannot survive panics.

In broad outlines, the distinction between the big bank system and the system of small independent unit banks corresponds to the difference between the Canadian and US systems. As mentioned above, the Canadian system generally displayed fewer failures and no panics. In addition, as Table 1 makes clear, Canadian banks held fewer reserves (in the form of securities) and, correspondingly, they made more loans per asset dollar.

After 1920, the comparison is also stark. By 1920 the private clearinghouse system in the US that functioned as a lender-of-last-resort was gone, having been replaced by the Federal Reserve System. In Canada, the bank merger movement, from 1900 to 1925, reduced the number of banks and resulted in a small number of banks with large branch networks. Prior to the merger movement, Canadian banks were branched, but there were many more banks. The post-merger movement banking system in Canada is clearly the big bank system. The comparison between the two systems during this period is the subject of Bordo et al. (1994), who emphasize the fact that between 1920 and 1980 there was one bank failure in Canada, in contrast to hundreds and thousands in the US, particularly during the Great Depression. There were no banking panics in Canada, though the reduction in deposits during the Great Depression was of similar magnitude, as noted above.

5. Bank coalitions

The above two polar cases, the unit banking system and the big bank system, can be thought of as representative benchmarks. In this section, we introduce the possibility of a bank coalition, i.e., a state contingent agreement between banks. The discussion of bank...
coalitions will follow the US clearinghouse experience, briefly described above, but the argument is more general, as discussed below.

The basic idea for the coalition is as follows. The failure of individual small unit banks as a result of bank runs at date 1, despite holding high levels of reserves, can be improved upon if the small banks can replicate, at least partially, the performance of a big bank. Diversification allows big banks to alleviate the information asymmetry problem. In addition, big banks can “monitor” themselves by liquidating part of their portfolio, in the face of withdrawals, to boost the depositors’ confidence. For small banks to attempt to replicate the performance of a big bank, a mechanism that achieves these two functions must be invented.

Credibility of a coalition is established by a signal of its solvency; the signal is the coalition’s act of issuing claims backed by all member banks to depositors in exchange for individual bank deposits. These claims, the loan certificates, are supported by a sharing rule that combines assets and liabilities at date 1 and provides incentives for the member banks with high idiosyncratic shock realizations to monitor member banks with low idiosyncratic shock realizations. “Monitoring” means to prevent member banks from engaging in moral hazard, by liquidating these banks or subsidizing them. The internal workings of the coalition are not observable to depositors, so they will not accept the loan certificates unless they believe that the coalition’s behavior is incentive compatible. In equilibrium depositors’ beliefs will be consistent with the behavior of the coalition. We now turn to providing the details.

5.1. The setting with bank coalitions

Suppose that there are small independent unit banks at date 0. They are prohibited from forming a big bank. (For example, banks are prohibited from branching across state lines.) Without forming a big bank, however, unit banks can get together to form a coalition by reaching an agreement about their individual capital and reserve levels at date 0. The coalition stipulates date 1 state contingent rules indicating which banks to be liquidated and how to share liabilities among the remaining non-liquidated banks. Because the idiosyncratic shocks are not verifiable, and thus not contractible, the coalition has no power to force its members to comply with the rules and the member banks are free to quit at any time they want. In other words, coalition rules have to be incentive compatible. Depositors cannot observe whether the rules have been carried out or not at date 1. They can only observe whether the coalition liquidates some of the member banks and combines the assets and liabilities of the remaining member banks.

The sequence of events at date 1 begins with depositors observing the realized state of the macroeconomy and deciding whether to withdraw their deposits or not. Then the banks decide whether to trigger the operation of the coalition. We define the coalition and the operation of the coalition as follows:

Definition. The bank coalition is an agreement between member banks at date 0 about the following issues to maximize the total payoffs to its member banks:6

(i) Bank reserve levels, \( z \), at date 0.

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6For simplicity, we do not go into the details how decisions are made inside the coalition. We assume that the internal organization of the coalition is equivalent to assuming the existence of a coalition decision maker who is independent of any of the member banks and maximizes the total payoffs to all member banks.
(ii) A date 1 state-contingent rule, \(P(\alpha, \pi)\), indicating when the coalition is to operate \((P = 1)\) or not operate \((P = 0)\). If \(P = 0\), then banks act as unit banks. (The contingency, in fact, will be a panic; this is shown below.)

(iii) If the coalition is set into operation, then the coalition applies two rules: a liquidation rule \(L(\alpha, \pi, r)\), which is a mapping from \([0, 2M]\) to \([1, 0]\), indicating whether a member bank with idiosyncratic shock \(r\) is to be liquidated \((L = 1)\) or not liquidated \((L = 0)\); and a debt transfer rule, \(D(\alpha, \pi, r)\), which is a mapping from \([0, 2M]\) to \(R^+\), indicating the liability reallocated to a non-liquidated member bank with idiosyncratic shock \(r\). Deposits in non-liquidated banks are replaced with loan certificates, which are debt claims of the coalition, backed by all the assets of all the member banks.

The operation of the coalition is intended to achieve two goals. First, by liquidating some of the member banks the coalition tries to inform depositors that “mutual monitoring” has started and the non-liquidated banks are in relatively more sound states. This partially alleviates the asymmetric information between the banks and depositors. Second, by pooling the liabilities the coalition quells depositors’ concern over banks’ idiosyncratic states and convinces depositors that the coalition as a whole is healthy and good banks will provide liquidity to bad banks.

5.2. Equilibrium with bank coalitions

Suppose at date 1 the systematic macroeconomic state, \(\pi\), is realized. Define \(r^* \equiv (1 - \alpha) / ((1 - f)(1 + \beta - \alpha) - \pi)\). We have \(f(1 + \beta - \alpha)(\pi + r) > \alpha + (1 + \beta - \alpha)(\pi + r) - 1\) for \(r < r^*\), i.e., only banks with \(r < r^*\) have incentives to engage in fraud. If these banks act as unit banks (i.e., the coalition does not operate, \(P(\alpha, \pi) = 0\)), the total payoff to all the banks is

\[
\int_0^{r^*} f(1 + \beta - \alpha)(\pi + r) dF(\tilde{r}) + \int_{r^*}^{2M} [\alpha + (1 + \beta - \alpha)(\pi + r) - 1] dF(\tilde{r}).
\]

If the coalition operates \((P(\alpha, \pi) = 1)\), the liquidation rule and the sharing rule are carried out. Under any given coalition rules, the coalition as a whole can be either solvent or insolvent at date 2. If it is solvent, the total payoff cannot exceed \(\int_0^{2M} [\alpha + (1 + \beta - \alpha)(\pi + r) - 1] dF(\tilde{r})\), which can be reached when none of the member banks engages in fraud. If it is insolvent, the total payoff cannot exceed \(\int_0^{2M} f(1 + \beta - \alpha)(\pi + r) dF(\tilde{r})\), which can be reached when all member banks engage in fraud. Therefore, the maximum total payoff a coalition can achieve is

\[
\max \left\{ \int_0^{2M} [\alpha + (1 + \beta - \alpha)(\pi + r) - 1] dF(\tilde{r}), \int_0^{2M} f(1 + \beta - \alpha)(\pi + r) dF(\tilde{r}) \right\}.
\]

\[7\text{Although } r \text{ is not verifiable, } D \text{ is verifiable at date } 2. \text{ Moreover, the coalition needs to prevent member banks revealing their } r \text{ by showing depositors their } D(\alpha, \pi, r). \text{ We can imagine that the coalition takes out a note “You owe the coalition } D(\alpha, \pi, r)^* \text{” and asks the banker for his signature. In this way, only the coalition holds the verifiable contracts, which specify all non-liquidated banks’ liabilities } D(\alpha, \pi, r).\]
it is better not to carry out the coalition rules voluntarily.

Depositors are rational and they understand that the coalition is not going to operate without a bank panic. So they run the banks to trigger the state contingent operation of the coalition.

Once the depositors run the banks, the coalition has to operate to convince the depositors that it will exert its monitoring and coinsurance functions, the following proposition presents the details.

**Proposition 3.** Suppose that at date 1 \( \pi \leq (1 - \alpha)/(1 - f)(1 + \beta - \alpha) \) and, consequently, depositors run the banks. Define

\[
x \ast (\alpha, \pi) = \max \left\{ 0, \min \left\{ 1, \frac{1 - \alpha - \pi(1 - f)(1 + \beta - \alpha)}{M(1 - f)(1 + \beta - \alpha)} - 1 \right\} \right\}.
\]

The coalition operates, i.e., \( P(\alpha, \pi) = 1 \). It applies the liquidation rule, setting \( L(\alpha, \pi, r) = 1 \) (i.e., liquidation) for banks with idiosyncratic shocks \( r \in [0, x \ast (\alpha, \pi)2M] \) and pays these bankers \( \alpha + (1 + \beta - \alpha)Q - 1 \). For non-liquidated banks, the coalition reallocates liabilities according to the members type, \( r \): \( D(\alpha, \pi, r) = \alpha + (1 - f)(1 + \beta - \alpha)(\pi + r) \); loan certificates backed by all non-liquidated banks are issued to replace deposits in these banks. All member banks comply with coalition rules.

The proposition shows how the coalition behaves as a lender-of-last-resort by monitoring and by providing insurance.\(^8\) Monitoring corresponds to liquidating bad banks, those with the worst idiosyncratic shock realizations \( r \in [0, x \ast (\alpha, \pi)2M] \). These banks would have engaged in fraud. The insurance comes from the transfers implemented among the non-liquidated banks \( r \in [x \ast (\alpha, \pi)2M, 2M] \). These banks are assigned new debt obligations according to \( D(\alpha, \pi, r) = \alpha + (1 - f)(1 + \beta - \alpha)(\pi + r) \). Their original debt, i.e., face value of the demand deposits, was one. Note that banks with \( r < (1 - \alpha)/(1 - f)(1 + \beta - \alpha) - \pi \) have their liabilities reduced, i.e., \( D(\alpha, \pi, r) < 1 \), so they no longer have incentives to engage in fraud. This is efficient because the continuation values of these projects are worth more than the liquidation value if they are immune to fraud. Member banks with \( r > (1 - \alpha)/(1 - f)(1 + \beta - \alpha) - \pi \) have their liabilities increased, i.e., \( D(\alpha, \pi, r) > 1 \), so they are taxed to pay the subsidy to the low \( r \) banks. Banks with high idiosyncratic shock realizations cannot be taxed too much, or they will engage in fraud. The transfers of the debt obligations must satisfy the budget constraint

\(^8\)Here again, for expositional purposes, we omit the characterization of the off-equilibrium path beliefs held by depositors when they observe that the number of banks liquidated by the coalition is different from what the liquidation rules stipulate. The most reasonable belief is that depositors always believe the coalition liquidates banks with lowest idiosyncratic returns. It is easy to check that such a belief does not allow the coalition to deviate from the liquidation rule and the sharing rule.
\[ \int_{x}^{2M} D(z, \pi, \alpha) \, dF(\tilde{r}) = 1. \]  
This limits how much liquidity the coalition can provide and, therefore, determines the point at which member banks are liquidated.

The banking panic creates an externality for banks that would not engage in the moral hazard problem, the “good” banks. Without a panic, they would have no incentive to monitor the banks that are going to engage in fraud, the “bad” banks. Because depositors do not know the idiosyncratic states of each bank and bad banks can always mimic good banks, good banks cannot renge on their responsibilities by quitting the coalition. Facing the prospect of being liquidated, they are forced to monitor the bad banks by liquidating the worst ones and providing liquidity to the others via liability sharing.

There is a critical difference between how the coalition and the big bank deal with panics. The difference has to do with the difference between the ownership and property rights in these two systems. The banker of a big bank (implicitly) hires branch managers to manage branches for him, and he gets the entire surplus. We do not need to consider the branch managers’ incentives because the branch manager has no property rights over his branch. A coalition member cannot be forced to operate his bank in a certain way, nor can he be involuntarily separated from his assets. Consequently, when a big bank closes a branch, it gets \( z + (1 + \beta - x)Q - 1 \) after paying off the branch depositors and uses this amount as additional reserves. These additional reserves change the incentives of the big bank. But, the coalition cannot increase reserves in this way because member banks have the property rights and hence control of their assets; they are free to quit the coalition. In addition, while the big bank “monitors” itself, the coalition works through “mutual monitoring”. Non-liquidated good banks need to bribe/subsidize non-liquidated bad banks to keep them from engaging in fraud. This restricts the coalition’s liquidation rule and the sharing rule because each banker has to be promised a payoff at least equal to what he can get from quitting the coalition or staying and engaging in fraud. Otherwise the coalition would have more freedom to set these rules and act more like a big bank.

At date 0, each bank must decide whether to join the coalition and the coalition must determine the optimal reserve level \( x \). The optimal reserve for the coalition is the solution of the following problem:

\[
\text{Max}_x \; \int_{\pi L}^{\pi^*} \left[ z + (1 + \beta - x)Q + (1 - x) \right. \\
\times \left( \pi + (1 + x)M \right) \, dF(\tilde{r}) \\
\left. + \int_{\pi^*}^{\pi H} \left[ z + (1 + \beta - x)(\pi + M) \right] \, dF(\tilde{r}) - 1 \right] \\
\text{s.t.} \; \pi^* = \frac{1 - x}{(1 - f)(1 + \beta - x)} \\
x = \max \left\{ 0, \min \left\{ 1, \frac{1 - x - \pi(1 - f)(1 + \beta - x)}{M(1 - f)(1 + \beta - x)} - 1 \right\} \right\} \text{,} \\
x \in [0, x^U].
\]

\( ^9 \)The banker of a big bank is the owner and has the cash flow rights. Even though a manager can engage in fraud, it does not mean he can reap the benefit of doing so, because the realized cash flows go to the banker first before they are redistributed to the managers. In addition, since the banker has the full control, it is easy for him acquire evidence and bring a manager to the court in case the manager engages in fraud without his agreement.
Proposition 4. The coalition’s objective function is strictly concave in $a$. There is a unique optimal reserve level, $a \in [0, a_{\text{max}}^U]$, that solves the coalition’s optimization problem. At date 0, every bank strictly prefers to join the coalition.

The coalition system is an intermediate case between the unit banking system and the big bank system. When the macroeconomy is in the good state, the coalition system is the same as the Unit Bank system. Contingent on banking panics following a negative systematic shock, the coalition system is triggered and mutual monitoring and insurance take place. The coalition partially replicates the big bank. The unique feature associated with the coalition is that when a panic occurs, it suspends convertibility and issues certificates. This feature is important because it is a commitment made to depositors that the non-liquidated member banks will not engage in fraud and it provides incentives for member banks to monitor and insure each other. The role of suspension of convertibility here is quite different from a coordination device used to eliminate Pareto-dominant equilibria in other models (e.g. Diamond and Dybvig, 1983).

5.3. Comparing the different bank systems

We have studied three different banking systems: the independent unit banking system, the big bank system, and the bank coalition. In this section, we compare these systems in terms of welfare. Keep in mind that, on the one hand, holding reserves is inefficient because the risky project earns a higher return. But, on the other hand, holding fewer reserves means a higher chance of a panic and project liquidation.

Proposition 5. The unit banking system holds more reserves than the coalition system, which, in turn, holds more reserves than the big bank system. The big bank system is more efficient than the coalition system, which is more efficient than the independent unit banking system.

In the unit banking system, if depositors monitor banks by withdrawing, then the bank panic results in all banks being liquidated. Independent unit banks cannot monitor each other, nor do they have (private) deposit insurance like the coalition system. Banks in the unit banking system can only resort to excess reserves to avoid the ex post losses from forced liquidations. The big bank has two advantages. First, diversification eliminates the information asymmetry problem. And second, it can close branches and use the proceeds as reserves to alter its incentives to engage in fraud—self-monitoring and liquidity provision. Such advantages allow the big bank to invest more in the risky projects and hold less reserves. The coalition system lies between the unit banking system and the big bank system. State contingent monitoring and co-insurance provide banks in the coalition with a way to survive panics if they are solvent. However, because property rights in the coalition do not allow it to completely replicate the big bank, mutual monitoring and insurance is not as efficient as self-monitoring and liquidity improving, and banks in the coalition have to hold more reserves than banks in the big bank system.

6. Discussion

We studied the relation between the industrial organization of banking and banking panics. Banking panics occur in systems of small unit banks. Panics result from depositors monitoring/liquidating banks in a setting where some banks are more likely to be engaging
in moral hazard, but the depositors do not know which banks are the more likely because of asymmetric information. Banking systems with large, well-diversified, banks are more efficient because diversification alleviates asymmetric information problem. In addition, branch closure as a publicly observable self-monitoring mechanism allows big banks to improve the quality of assets and restore depositors’ confidence. When branching is not allowed, the lender-of-last-resort functions, including money creation, monitoring, and deposit insurance arose from private arrangements among banks. Small banks form bank coalitions to monitor members and provide insurance to depositors. Banking panics play a crucial role in making such private bank coalitions work. They impose an externality on member banks so that they are forced to commit to pool resources and liquidate some members.

Why did government central banks replace private bank coalitions? In the above analysis, there is no obvious rationale for the government to step in and provide the lender-of-last-resort function unless the government has much more power than private agents, more resources than private agents, or there are costs to panics that have not been considered. Gorton and Huang (2003) consider the above model, but include a transactions role for bank liabilities. A panic disrupts the role of bank liabilities as a medium of exchange. They argue that in this context the government may be able to improve welfare with deposit insurance.

References

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