Cash-in-the-Market Pricing and Optimal Resolution of Bank Failures

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As the number of bank failures increases, the set of assets available for acquisition by surviving banks enlarges but the total liquidity available with surviving banks falls. This results in "cash-in-the-market" pricing for liquidation of banking assets. At a sufficiently large number of bank failures, and in turn, at a sufficiently low level of asset prices, there are too many banks to liquidate and inefficient users of assets who are liquidity-endowed may end up owning the liquidated assets. In order to avoid this allocation inefficiency, it may be ex-post optimal for the regulator to bail out some failed banks. We show, however, that there exists a policy that involves granting liquidity to surviving banks in the purchase of failed banks, which is equivalent to the bailout policy from an ex-post standpoint. Crucially, this liquidity provision policy gives banks incentives to differentiate, rather than to herd, makes aggregate banking crises less likely, and thereby dominates the bailout policy from an ex-ante standpoint. (*JEL* G21, G28, G38, E58, D62)

Empirical evidence on the resolution of bank failures suggests that regulatory actions taken in response to banking problems vary significantly. Kasa and Spiegel (1999) and Santomero and Hoffman (1999) document that these actions appear to depend on whether the problems arise from idiosyncratic reasons specific to particular institutions or from aggregate reasons with potential threats to the whole system. Hoggarth, Reidhill, and Sinclair (2004) also study resolution policies adopted in 33 banking crises over the world during

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1977–2002. They find that when faced with individual bank failures, authorities have usually sought a private-sector resolution where the losses have not been passed onto taxpayers. However, during systemic crises, liquidity support from central banks and blanket government guarantees have been granted, usually at a cost to the budget; bank liquidations have been rare and creditors have rarely made losses.

We argue in this article that such variation arises from the fact that resolution options open for an isolated bank failure are different from those available for systemic failures. When only a few banks fail, these banks can be acquired by surviving banks. However, for a large number of failures, the liquidity of surviving banks enables them to acquire all failed banks only at fire-sale prices, an effect akin to the industry-equilibrium hypothesis of Shleifer and Vishny (1992). The resulting "cash-in-the-market" pricing, as in Allen and Gale (1994, 1998), makes it more likely that investors outside the banking sector, who are liquidity-endowed but potentially not the most efficient users of these assets, end up purchasing some failed banks' assets. Thus, there are "too many (banks) to liquidate" and regulatory intervention in the form of bailing out some banks may be optimal in order to avoid allocation inefficiencies.

The ex-post optimal bailout policy may, however, be suboptimal from an ex-ante standpoint since it induces banks to herd, for example, by lending to similar industries or betting on common risks such as interest and mortgage rates, in order to increase the likelihood of being bailed out. This increases the ex-ante likelihood of experiencing systemic crises. Can other regulatory policies mitigate this time-inconsistency problem? We show that the answer is yes. We propose a novel liquidity provision policy that subsidizes surviving banks for the purchase of failed banks. This policy can be designed to be ex-post equivalent to the bailout policy, and yet gives banks incentives to differentiate ex-ante, rather than to herd.

In this article, we build a framework wherein the ex-ante and the ex-post optimal regulatory policies and the cash-in-the-market pricing are endogenously derived. We consider a two-period model with n banks, a regulator, and outside investors who can purchase banking assets were they to be liquidated. Allowing for an arbitrary number of banks enables us to explore the richness of the cash-in-the-market price function.

The regulator adopts policies to resolve bank failures with the objective of maximizing the total output of the banking sector net of any costs associated with the adopted policies. We consider the following policies: failed banks may be sold to surviving banks and outsiders at market-clearing prices; failed banks may be bailed out, in which case their owners are allowed to continue operating the banks; and finally, the regulator may also provide liquidity, essentially a grant or a subsidy, to various players—failed banks, surviving banks, and outsiders. For simplicity, we assume that deposits are fully insured (at least in the first period). The immediacy of funds required for deposit insurance and for the liquidity granted during failure resolution, net of proceeds from bank sales, entails fiscal costs for the regulator.

Three central assumptions drive our results: (i) banks have limited liquidity—in particular, we assume that surviving banks only have their first-period profits to acquire failed banks' assets; (ii) banks are more efficient users of banking assets than outsiders as long as bank owners take good projects; and (iii) there is a possibility of moral hazard in that bank owners derive private benefits from bad projects; hence, banks take good projects only if bank owners retain a large enough share of bank profits.

Banks whose return from first-period investment is low are in default. Surviving banks, if any, use their first-period profits to purchase failed banks' assets. Up to a critical number of failures, surviving banks' liquidity is enough to purchase all failed banks' assets at the "fundamental" price: surviving banks compete for these assets and their surplus is eroded to zero. Beyond this critical number of failures, additional assets cannot be absorbed by the available liquidity of surviving banks at the fundamental price. Thus, the market-clearing price declines with each additional failure. Under assumption (ii), outsiders enter the market only when the price declines sufficiently. Since outsiders are not as efficient as surviving banks in using these assets, this results in an allocation inefficiency.

The regulator decides whether to let surviving banks and outsiders purchase failed banks' assets, or to intervene. We first consider intervention in the form of bailing out failed banks. In a bailout, a failed bank is allowed to operate under its existing owners. Bailouts are thus associated with an opportunity cost: the regulator incurs a higher fiscal cost to pay off insured deposits since no proceeds are collected through bank sales. Since bailouts are costly, the regulator does not intervene as long as all failed banks are acquired by surviving banks. However, when asset prices decline sufficiently, it is optimal for the regulator to prevent sales to outsiders by bailing out banks as long as the fiscal cost of a bailout is lower than the misallocation cost.

With limited outsider funds, once the number of failures is sufficiently large, total liquidity of surviving banks and outsiders is not enough to clear the market for bank sales at the threshold value of outsiders. Thus, there is a further decline in the market-clearing price as the number of failures increases. Additional bailouts do not entail any opportunity cost as proceeds from bank sales always equal total liquidity in the market. Hence, the regulator bails out failed banks until prices are sustained at the threshold value of outsiders. Crucially, there is always a welfare loss when the number of failures is high—either fiscal cost from bailouts or misallocation cost from liquidation to outsiders.

We show that liquidity provision of a specific form to the surviving banks is ex-post equivalent in welfare terms to this bailout policy.[1] Intuitively, bailouts are ex-post optimal when the price falls sufficiently to elicit participation of outsiders in asset purchase. The lack of sufficient liquidity with efficient users—the surviving banks—is the primary cause for this price drop. Hence, assisting

[1] It is suboptimal in our model to grant liquidity to outsiders or to a bank that is bailed out.

surviving banks in purchasing failed banks by granting them sufficient liquidity can ensure that the price never falls enough to draw outsiders into the market, thereby eliminating the allocation inefficiency. We show that the minimum amount of liquidity provision required to achieve this entails the same fiscal cost as the ex-post optimal bailout policy.

Next, we compare these two policies from an ex-ante standpoint in a setting where banks choose to differentiate or herd. Each bank invests either in a common industry or in a bank-specific industry. This decision affects the correlation of bank returns and the likelihood that banks fail together. Ex ante, the regulator wishes to implement a low correlation between banks' investments to minimize the likelihood that many banks fail, and simultaneously implement resolution policies that are ex-post optimal. The regulator can achieve this by employing the bailout policy, only if it can commit to sufficiently diluting the share of bank owners when they are bailed out. By doing so, the bailout subsidy becomes small enough that banks prefer to differentiate and capture the surplus from buying assets at cash-in-the-market prices. However, assumption (iii) implies that such a dilution may not always be feasible. If moral hazard due to private benefits is sufficiently severe, then excessive dilution of a bank's equity leads bank owners to choose bad projects, generating continuation values that are worse than liquidation values. In this case, a low correlation can only be implemented by committing to liquidate a large number of failed banks. But, in general, this is ex-post inefficient and lacks commitment. We show that this time-inconsistency problem leads to inefficient herding when the likelihood of bank failure is sufficiently high.

From an ex-ante standpoint, the liquidity provision policy dominates bailouts. Subsidizing surviving banks in acquiring failed banks increases the anticipated surplus and strengthens incentives to differentiate. Thus, relative to the bailout policy, the liquidity provision policy can implement a low correlation over a wider range of the severity of the moral hazard problem due to private benefits. To summarize, the important policy implication of our analysis is that assisting surviving banks rather than the troubled ones can ameliorate the commitment problem in optimal resolution of bank failures.[2]

Our article is related to the banking literature that has focused on optimal bank closure policies. Mailath and Mester (1994) and Freixas (1999) discuss the time-inconsistency of closure policy in a single-bank model. Penati and Protopapadakis (1988) assume that the regulator provides insurance to uninsured depositors when the number of bank failures is large, and show that this leads banks to invest inefficiently in common markets so as to attract deposits at a lower cost. Mitchell (1997) extends the "signal-jamming" model of Rajan

[2] This liquidity provision policy has similarities as well as differences with the much-studied lender-of-last-resort (LOLR) policy of providing liquidity to banks that are in distress. Like the LOLR policy, the liquidity provision policy aims at resolving problems arising from illiquidity. However, unlike the LOLR policy, liquidity is provided to *surviving* banks to assist them in purchasing failed banks. Furthermore, unlike the LOLR policy, the liquidity provision policy is in the form of a grant.

(1994) to show that if the regulator bails out banks when they fail together, then banks coordinate on disclosing their losses and delay classifying bad loans by rolling them over.

Closest to our article is the work of Perotti and Suarez (2002), Cordella and Yeyati (2003), and Gorton and Huang (2004). Perotti and Suarez consider a dynamic model where selling failed banks to surviving banks, by reducing competition, increases the charter-value of surviving banks and gives banks ex-ante incentives to stay solvent. The liquidity provision policy we propose is similar in spirit to this policy since it raises anticipated surplus for banks from surviving and gives banks incentives to differentiate. Similarly, Cordella and Yeyati (2003) show that the regulator, by bailing out banks during systemic crises, can increase the charter value of banks, which induces banks to manage their risk prudently. In their model, systemic crises occur because of adverse macroeconomic shocks that are exogenous, whereas in our article, systemic crises arise endogenously as a result of banks' overinvestment in particular industries.[3] Gorton and Huang (2004) also analyze the optimal resolution of bank failures and focus on the risk-taking incentives of banks. An important difference between our analysis and theirs is that we assume a cost to the regulator in providing funds to the banking sector with immediacy. Gorton and Huang assume that since such funding can be recovered through taxes in the future, there are no costs of immediacy. As a result, our setup gives rise to the time-inconsistency of regulatory policies that does not arise in their model.

Finally, some of the ideas presented in this article are related to the analysis in Acharya (2001) and Acharya and Yorulmazer (2007). In our opinion, the strongest differentiating point of the current article is its modeling generality in allowing for an arbitrary number of banks and endogenously deriving the cash-in-the-market pricing. This lends the model an element of richness that we have exploited to provide an in-depth normative analysis of the various options available to regulators to resolve and restructure failed banks.[4]

The remainder of the article is structured as follows. Sections 1–3 present the model and its analysis. Section 4 provides empirical evidence supporting the model's assumptions and results. Section 5 concludes. Proofs not contained in the text are contained in the Appendix.

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[3] While direct exposure to the common risks analyzed in our article is one reason banks may fail together, interbank linkages may also lead to joint failures since these linkages may lead to the problems of one bank being transmitted to other banks in a contagion-type phenomenon, as analyzed by Rochet and Tirole (1996), Allen and Gale (2000), and Kahn and Santos (2005). In a different contagion model, Diamond and Rajan (2005) show that a bank failure can cause aggregate liquidity shortages. They show that liquidity and solvency problems interact in a complex manner and are difficult to distinguish ex-post. They do not analyze implications of such effects for the ex-ante investment choices of banks.

[4] Acharya and Yorulmazer (2007), for example, consider a two-bank model, which focuses on comparing the too-big-to-fail problem with the too-many-to-fail problem, and show that herding incentives are stronger for small banks than for large banks. They do not consider the liquidity provision role of the regulator in subsidizing purchases of failed banks by surviving banks—a novel policy implication of this article.

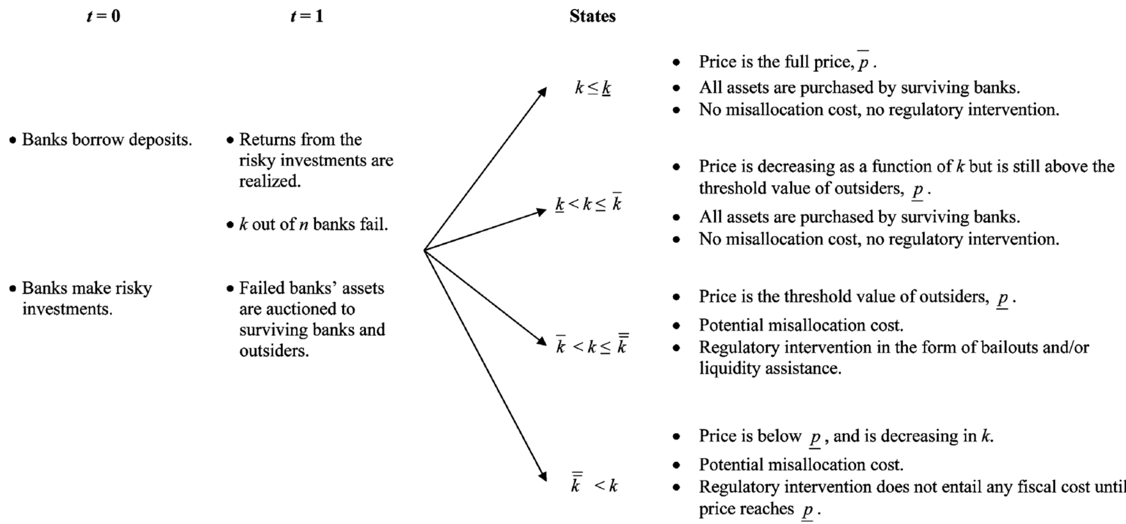

Figure 1
Timeline of the model.

1. Model

The benchmark model is outlined in Figure 1. We consider an economy with three dates, $t = 0,1,2$, n banks, bank owners, depositors, outside investors, and a regulator. Each bank borrows from a continuum of depositors of measure 1. Bank owners and depositors are risk-neutral and obtain a time-additive utility u_t, where u_t is the expected payoff at time t. Depositors receive a unit of endowment at dates 0 and 1, and have access to a reservation investment opportunity that gives them a utility of 1 per unit of investment. In each period, that is at dates 0 and 1, depositors choose to invest their good in this reservation opportunity or in their bank.

Deposits take the form of a simple debt contract with maturity of one period. In particular, the promised deposit rate is not contingent on investment decisions of the bank or on its realized returns. In order to keep the model simple and yet capture the fact that there are limits to equity financing (e.g., due to asymmetric information as in Myers and Majluf, 1984), we do not consider any bank financing other than deposits.

Banks require one unit of funds to invest in a risky technology, which is to be thought of as a portfolio of loans to firms in the corporate sector. The performance of the corporate sector determines its random output at date $t+1$. We assume that all firms a bank has lent to can either repay fully the borrowed bank loans or they default. In the case of a default, we assume for simplicity that there is no repayment. Suppose R_t is the promised return on a bank loan at time t and we denote the random repayment on this loan as $\tilde{R}_t$, $\tilde{R}_t \in \{0, R_t\}$. The probability that the return from these loans is high in period t is denoted by α_t. We assume that the returns in the two periods are independent and allow the probability, as well as the level of the high return, to be different in the two periods. This helps isolate their effect on our results.

There is potential moral hazard at the individual bank level. If bank owners choose a bad project, then when the return is high, they do not generate R_t but only $(R_t - \bar{\Delta})$ and enjoy a nonpecuniary benefit of $B < \bar{\Delta}$. Therefore, appropriate incentives have to be provided to bank owners to choose the good project. We denote the share of bank owners as θ. If r_t is the cost of borrowing deposits, then the incentive-compatibility constraint is

$$\alpha_t[\theta(R_t - r_t)] \geq \alpha_t[\theta((R_t - \bar{\Delta}) - r_t) + B]. \quad \text{(IC)} \tag{1}$$

We have assumed that the promised deposit rate r_t can be paid when the investment has a high return irrespective of whether the project is good or bad. The (IC) constraint implies that bank owners need a minimum share of $\bar{\theta} = B/\bar{\Delta}$ to choose the good project.[5] We assume that at $t = 0$, the entire share

[5] See Hart and Moore (1994) and Holmstrom and Tirole (1998) for models with similar features. Also, for detailed evidence on large inside ownership of banks around the world and their role in alleviating moral hazard problems, see Caprio, Laeven, and Levine (2005).

of the bank profits belongs to the bank owners, and therefore, moral hazard is not a concern at the beginning.

In addition, there are risk-neutral outside investors who have limited funds amounting to w to purchase banking assets were these assets to be sold. Outsiders are inefficient users of banking assets relative to bank owners, provided bank owners take good projects. This can be considered a metaphor for some form of expertise or "learning-by-doing" effect in making and administering loans. It is also a simple way of introducing barriers to entry into the banking sector. Formally, we assume that outsiders cannot generate R_t in the high state but only $(R_t - \Delta)$. Thus, when banking assets are sold to outsiders, there may be a social welfare loss due to a misallocation of the assets. We also assume that $\bar{\Delta} > \Delta$ so that outsiders can generate more than what the banks can generate from bad projects. The notion that outsiders may not be able to use banking assets as efficiently as the existing bank owners is akin to the notion of *asset-specificity*, first introduced in the corporate-finance literature by Williamson (1988) and Shleifer and Vishny (1992). This literature suggests that firms, whose assets tend to be *specific*, that is, whose assets cannot be readily redeployed by firms outside of the industry, are likely to experience lower liquidation values or "fire-sale" discounts in cash auctions for asset sales, especially when firms within an industry get simultaneously into financial distress.[6]

Finally, there is a regulator who employs policies such as sale of failed banks' assets, bailouts, and provision of liquidity with the objective of maximizing the total output of the banking sector net of any costs associated with these policy options. These policies are rationally anticipated by banks and depositors. Below we describe these policies informally. The formal description follows in the model analysis.

We assume that deposits are fully insured in the first period. The provision of immediate funds to pay off failed deposits, net of any proceeds from the sale of failed banks' assets, entails fiscal costs for the regulator (assumed to be exogenous to the model). These fiscal costs can be linked to a variety of sources: (i) distortionary effects of tax increases required to fund deposit insurance and bailouts and (ii) the likely effect of huge government deficits on the country's exchange rate, manifested in the fact that banking crises and currency crises have often occurred as "twins" in many countries (especially, in emerging market countries). Ultimately, the fiscal cost we have in mind is one of immediacy: government expenditures and inflows during the regular course of events are smooth, relative to the potentially rapid growth of liabilities, such as deposit-insurance funds, costs of bank bailouts, and liquidity provision,

[6] There is strong empirical support for this idea in the corporate-finance literature, for example, in Pulvino (1998) for the airline industry, and in Acharya, Bharath, and Srinivasan (2007) for all defaulted firms in the USA over the period 1981 to 1999 (see also Berger, Ofek, and Swary, 1996; Stromberg, 2000). In the evidence of such specificity for banks and financial institutions, James (1991) studies the losses from bank failures in the USA during the period 1985 through mid-year 1988, and documents that "there is significant going concern value that is preserved if the failed bank is sold to another bank (a "live bank" transaction) but is lost if the failed bank is liquidated by the Federal Deposit Insurance Corporation (FDIC)."

etc.[7] Note that the second period is the last period in our model and there is no further investment opportunity. As a result, our analysis is not affected by whether deposits are insured for the second period or not.

If the bank return from the first-period investment is high, then the bank operates for one more period and makes the second-period investment. For a bank to continue operating, it needs to pay its old depositors r_0, and it needs an additional one unit of funds for the second investment. A failed bank cannot generate the needed funds, $(1 + r_0)$, from its depositors at $t = 1$: Its depositors are endowed with only one unit at $t = 1$. Thus, if the return is low, then the bank is in default. We assume that surviving banks (if any) use their first-period profits (and the liquidity provided by the regulator, if any) to purchase failed banks' assets. The regulator decides whether to let surviving banks and/or outsiders purchase failed banks' assets or to intervene and bail out some or all of the failed banks, and whether to grant liquidity to the surviving banks for purchasing assets.[8] Proceeds from the sale of failed banks reduce the net costs of providing deposit insurance. Hence, bailouts are associated with an opportunity cost for the regulator. In a bailout, the regulator may dilute the equity share of bank owners. In liquidity provision policy, the regulator simply transfers liquidity to surviving banks without it being returned in the future. Therefore, provision of liquidity also increases the net costs of providing deposit insurance. These costs are a part of the regulator's objective function.

Depending on the first period returns, say k out of n banks fail. Since banks are identical at $t = 0$, we denote the possible states at $t = 1$ with k.

2. Analysis from an Ex-Post Standpoint

We analyze the model proceeding backwards from the second period to the first period. The deposit rate at t is denoted by r_t and we assume throughout that $R_t > r_t$.

The surviving banks operate for another period at $t = 1$. The probability of having the high return in the second period is equal to α_1 for all banks. As this is the last period, there is no further investment opportunity and the expected payoff to a bank from its second-period investment, $E(\pi_2)$, is equal to $[\alpha_1(R_1 - r_1)]$.

[7] See, for example, the discussion on fiscal costs associated with banking crises in Calomiris (1998). Also, see Dell'Ariccia, Detragiache, and Rajan (2007) for an analysis of the effect of banking crises on real economic activity. Hoggarth, Reis, and Saporta (2001) find that the cumulative output losses have amounted to a whopping 15–20% of annual GDP in the banking crises of the past 25 years. Caprio and Klingebiel (1996) argue that the bailout of the thrift industry cost \$180 billion (3.2% of GDP) in the USA in the late 1980s. They also document that the estimated cost of bailouts was 16.8% for Spain, 6.4% for Sweden, and 8% for Finland. Honohan and Klingebiel (2000) find that countries spent 12.8% of their GDP to clean up their banking systems, whereas Claessens, Djankov, and Klingebiel (1999) set the cost at 15–50% of GDP.

[8] Note that given the relative expertise of banks compared to outsiders, it is never optimal to provide liquidity to outsiders. Also, there is no benefit of providing liquidity to a bailed-out bank.

An important possibility is that surviving banks and outsiders may purchase failed banks. Next, we investigate the sale of failed banks' assets and the resulting liquidation values when there are no bailouts or liquidity provision.

2.1 Asset sales and liquidation values

In examining the sale of failed banks' assets, several interesting issues arise. First, surviving banks and outsiders may compete with each other if there are enough resources with them to acquire all failed banks' assets. Second, unless the game for asset sales is specified with reasonable restrictions, an abundance of equilibria arises. To keep the analysis tractable and, at the same time, reasonable, we make the following assumptions:

(i) The regulator pools all failed banks' assets and auctions them to surviving banks and outsiders. Assets of a failed bank can be acquired partially, and the purchasing bank can access the same portion ("branches") of the failed bank's depositors. This assumption of partial sales is motivated by the literature on share auctions (Wilson, 1979) and simplifies the analysis substantially.

(ii) We denote the surviving banks as $i \in \{1, 2, \ldots, (n-k)\}$ and the outsiders as $i = 0$. Each surviving bank and outsiders submit a schedule $y_i(p) \in [0, k]$ for the amount of assets they are willing to purchase at the price p at which a unit of the banking asset (inclusive of associated deposits) is being auctioned.

(iii) We assume that surviving banks cannot raise additional financing. Hence, the resources available with each surviving bank for purchasing failed banks' assets, denoted by l, equal the first-period profits, $(R_0 - r_0)$.

(iv) The regulator cannot price-discriminate in the auction.

(v) The regulator determines the auction price p to maximize the expected output of the banking sector, subject to the market-clearing condition $\sum_{i=0}^{n-k} y_i(p) \leq k$. Given the allocation inefficiency from sales to outsiders, if surviving banks and outsiders pay the same price, the regulator optimally allocates the maximum possible amount to surviving banks.

(vi) We focus on the symmetric outcome where all surviving banks submit the same schedule, that is, $y_i(p) = y(p)$ for all $i \in \{1, 2, \ldots, (n-k)\}$.

First, we derive the demand schedule for surviving banks. Let $\bar{p} \equiv [\alpha_1(R_1 - r_1)]$, which is the expected second-period profit $E(\pi_2)$ to a surviving bank from the risky asset. The expected profit to a surviving bank from the asset purchase can be calculated as $y(p)[\bar{p} - p]$. The surviving bank wishes to maximize these profits subject to the budget constraint $y(p) \cdot p \leq l$. Hence, for $p < \bar{p}$, surviving banks are willing to purchase the maximum amount of assets using their resources so that their optimal demand schedule is $y(p) = (l/p)$. And, for $p > \bar{p}$, the demand is $y(p) = 0$, and for $p = \bar{p}$, $y(p)$ is indeterminate.[9]

We can derive the demand schedule for outsiders in a similar way. Note that outsiders can generate only $(R_1 - \Delta)$ in the high state. Let

[9] A formal derivation of the surviving banks' demand schedule that takes into account the correlation structure of assets is available upon request.

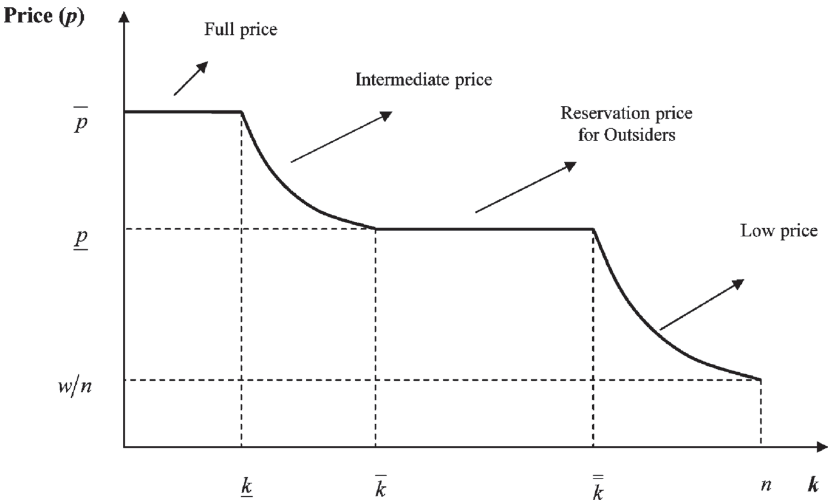

Figure 2
Price without bailouts and liquidity provision.

$\underline{p} \equiv [\alpha_1((R_1 - \Delta) - r_1)] = [\bar{p} - \alpha_1\Delta]$ be the expected second-period profit for outsiders from owning the risky asset. For $p < \underline{p}$, outsiders are willing to supply all their funds for the asset purchase and their optimal demand schedule is $y_0(p) = (w/p)$. For $p > \underline{p}$, the demand is $y_0(p) = 0$, and for $p = \underline{p}$, $y_0(p)$ is indeterminate.

Next, we analyze how the regulator optimally allocates the assets and the price function that results (see Figure 2). Note that, in the absence of financial constraints, the efficient outcome is to sell all assets to surviving banks. However, surviving banks may not be able to pay the threshold price of $\underline{p}$ for all assets. If prices fall further, these assets become profitable for outsiders and they enter the auction.

The regulator cannot set $p > \bar{p}$ since in this case we have $y(p) = y_0(p) = 0$. If $p \leq \bar{p}$, and the number of failed banks k is sufficiently small, then surviving banks have enough funds to pay the full price $\bar{p}$ for all assets. Specifically, for $k \leq \underline{k}$, where:

$$\underline{k} = \text{floor}\left(\frac{nl}{l + \bar{p}}\right), \tag{2}$$

floor(z) being the largest integer smaller than or equal to z, the regulator sets the auction price at $p^* = \bar{p}$. At this price, surviving banks are indifferent between any quantity of assets purchased. Hence, the regulator can allocate a share $y(p^*) = k/(n-k)$ to each surviving bank.

For $k > \underline{k}$, surviving banks cannot pay the full price for all assets but until a critical value $\bar{k}$, they can still pay at least the threshold value of $\underline{p}$, below which outsiders have a positive demand. Formally, for $k \in \{\underline{k}+1, \ldots, \bar{k}\}$, where

$$\bar{k} = \text{floor}\left(\frac{nl}{l+\underline{p}}\right), \tag{3}$$

the regulator sets the price at $p^* = ((n-k)l/k)$, and again, all assets are acquired by surviving banks. In this region, surviving banks use all available funds and the price falls as the number of failures increases, an effect akin to the cash-in-the-market pricing in Allen and Gale (1994, 1998) and the industry-equilibrium hypothesis of Shleifer and Vishny (1992).

For $k > \bar{k}$, surviving banks cannot pay the threshold price of $\underline{p}$ for all assets, and outsiders have a positive demand and are willing to supply their funds for asset purchase. With the injection of outsider funds, prices can be sustained at $\underline{p}$ until some critical number of failures $\bar{\bar{k}} \geq \bar{k}$. However, for $k > \bar{\bar{k}}$, even the injection of outsiders' funds is not enough to sustain the price at $\underline{p}$. Formally, for $k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}$, where

$$\bar{\bar{k}} = \text{floor}\left(\frac{nl+w}{l+\underline{p}}\right), \tag{4}$$

the regulator sets the price at $p^* = \underline{p}$. At this price, outsiders are indifferent between any quantity of assets purchased. Hence, the regulator can allocate a share of $y(\underline{p}) = (l/\underline{p})$ to each surviving bank, and the rest, $y_0(\underline{p}) = (k - (n - k)l/\underline{p})$, to outsiders.

And for $k > \bar{\bar{k}}$, the price is again strictly decreasing in k and is given by $p^*(k) = (((n-k)l + w)/k)$, with $y(p^*) = (l/p^*)$ and $y_0(p^*) = (w/p^*)$.

The resulting price function is downward-sloping in the number of failed banks, k, in two separate regions. In the first downward-sloping region, outsiders have not yet entered the market and there is cash-in-the-market pricing given the limited liquidity of surviving banks. In the second downward-sloping region, even the liquidity of outsiders is not enough to sustain the price at $\underline{p}$ and there is cash-in-the-market pricing given the limited liquidity of the *entire* set of market players bidding for assets. This price function is formally stated below.

Proposition 1. *In the absence of bailout and liquidity provision policies, the price of failed banks' assets as a function of the number of failed banks is as follows:*

$$p^*(k) = \begin{cases} \bar{p} & \text{for} \quad k \leq \underline{k}, \\ \frac{(n-k)l}{k} & \text{for} \quad k \in \{\underline{k}+1, \ldots, \bar{k}\}, \\ \underline{p} & \text{for} \quad k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}, \\ \frac{[(n-k)l]+w}{k} & \text{for} \quad k > \bar{\bar{k}}. \end{cases} \tag{5}$$

Note that by assumption (iii), surviving banks cannot raise additional financing from outsiders. In an extension in the unabridged version of the article, we relax this assumption and show that our results are robust to allowing surviving banks to issue equity to outsiders.[10]

2.2 Bailouts

To summarize the result from previous analysis, when the number of bank failures is sufficiently small, $k \leq \bar{k}$, all assets are purchased by surviving banks. Since this entails no misallocation cost, the regulator does not have an incentive to intervene ex-post. In contrast, if $k > \bar{k}$, then some of these assets are purchased by outsiders who are not the most efficient users. Hence, it may be optimal for the regulator to bail out some banks (we analyze the liquidity provision policy later). In particular, the regulator compares the misallocation cost resulting from asset sales to outsiders with the cost of bailing out failed banks. Since the misallocation cost is constant, equal to $(\bar{p} - \underline{p}) = (\alpha_1 \Delta)$ per unit of failed banks' assets, the regulator bails out failed banks as long as the marginal cost of a bailout is less than this misallocation cost.

Note that for a failed bank to continue operating at $t = 1$, it needs a total of $(r_0 + 1)$ units. Since available deposits for a bank amount to only one unit (the endowment of its depositors), the bank cannot operate unless the regulator injects r_0. Under our assumption of full deposit insurance, the regulator does inject r_0, so that a bailout is equivalent to the regulator granting permission to a failed bank's owners to operate one more period.

In order to analyze the regulator's decision to bail out or liquidate failed banks, we make the following assumptions:

(i) The regulator incurs a fiscal cost of $f(c)$ when it injects c units of funds with immediacy into the banking sector. We assume that this cost function is strictly increasing and convex (possibly linear): $f' > 0$ and $f'' \geq 0$.

(ii) If the regulator decides not to bail out a failed bank, the existing depositors are paid r_0 through deposit insurance and the failed bank's assets are sold at the market-clearing price. Thus, if the regulator bails out b of the k failed banks, the fiscal cost incurred is $f(kr_0 - (k - b) \cdot p^*(k - b))$, where proceeds from sale of the remaining $(k - b)$ banks are $[(k - b) \cdot p^*(k - b)]$. The crucial difference between bailouts and asset sales from an ex-post standpoint is that proceeds from asset sales lower the fiscal cost, whereas bailouts produce no such proceeds. Hence, bailouts entail an opportunity cost to the regulator in fiscal terms.

[10] In this case, we have two markets: one for the assets of failed banks and one for the shares of surviving banks. When the number of failures is large ($k > \bar{\bar{k}}$), the price of assets falls below the threshold value of outsiders, $\underline{p}$. Since purchasing assets at such prices becomes profitable for outsiders, in equilibrium they must be compensated for purchasing shares in surviving banks. As a result, the share price of surviving banks also falls below the fundamental value, $\bar{p}$. In other words, surviving banks can raise equity financing only at a discount. The resulting dilution limits their ability to raise such financing and purchase more assets. Thus, limited funds within the whole system and the resulting cash-in-the-market pricing affects not only the price of failed banks' assets but also the price of shares of surviving banks.

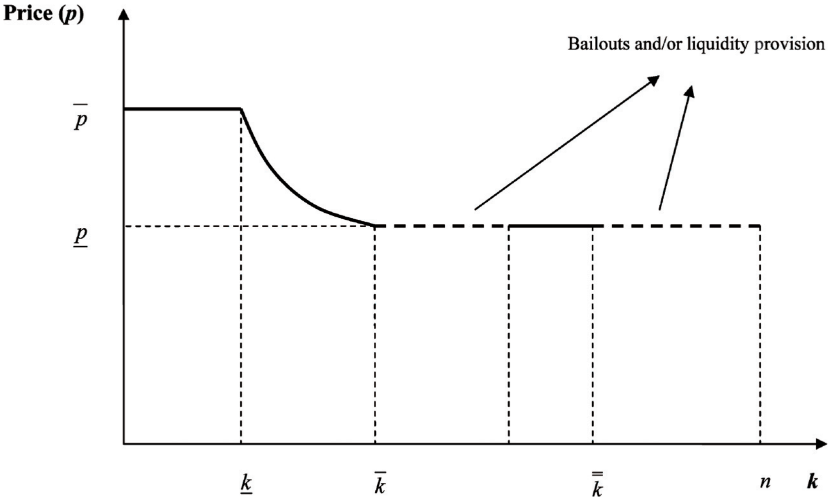

Figure 3
Price with bailouts and/or liquidity provision.

(iii) The regulator can take an equity share β in the bailed-out bank(s). ex-post, such dilution of a bailed-out bank's equity is merely a transfer from the bank owners to the regulator. However, as argued before, if the regulator takes a share β that is greater than $(1 - \bar{\theta})$, then bank owners are left with a share of less than $\bar{\theta}$ so that they choose the bad project. Since sales to outsiders generate a higher payoff compared to that from a bailed-out bank that chooses a bad project ($\bar{\Delta} > \Delta$), the regulator never takes a share greater than $(1 - \bar{\theta})$. As the value of this stake will be realized in the future, it is assumed not to affect the cost of providing deposit insurance with immediacy.

We characterize the optimal bailout policy under these assumptions. As argued before, the regulator never intervenes when $k \leq \bar{k}$. When $k \in \{\bar{k} + 1, \ldots, \bar{\bar{k}}\}$, the price for assets is $\underline{p}$ and the marginal cost of bailing out the bth bank is:

$$g(k, b) = f(kr_0 - (k - b)\underline{p}) - f(kr_0 - (k - b + 1)\underline{p}). \qquad (6)$$

Since $f(\cdot)$ is convex, this marginal cost is weakly increasing in b. Hence, there is a maximum number of banks, denoted by $\bar{b}(k)$, up to which the bailout costs are smaller than misallocation costs. Formally, $\bar{b}(k)$ satisfies the following conditions:

$$g(k, \bar{b}) \leq \alpha_1 \Delta < g(k, \bar{b} + 1). \qquad (7)$$

The maximum number of banks that can be acquired by surviving banks is $(n - k)y(\underline{p})$, where $y(\underline{p}) = l/\underline{p}$. Thus, the regulator bails out $b^*(k) = \min\{\bar{b}(k), [k - (n - k)y(\underline{p})]\}$ banks.

Finally, when $k > \bar{\bar{k}}$, all funds with surviving banks and outsiders, a total of $[(n-k)l + w]$, are collected through asset sales. Hence, if the regulator decides to bail out a bank, proceeds from sales are not affected and bailouts do not lead to any incremental fiscal cost. Thus, the regulator first bails out $\hat{b}(k)$ banks, where $\hat{b}(k)$ is the maximum number of bailouts such that the regulator can collect all available liquidity in the system, $[(n-k)l + w]$, by selling the remaining $[k - \hat{b}(k)]$ banks. With $\hat{b}(k)$ bailouts, the price for the remaining $[k - \hat{b}(k)]$ assets never falls below $\underline{p}$ (see Figure 3). Formally, $[(n-k)l + w] = (k - \hat{b}(k))\underline{p}$, which gives

$$\hat{b}(k) = \left\lfloor k - \frac{(n-k)l + w}{\underline{p}} \right\rfloor. \tag{8}$$

An additional bailout beyond $\hat{b}(k)$ decreases the proceeds from asset sales by $\underline{p}$. Hence, the regulator's decision to bail out additional banks is similar to that for the case where $k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}$. In particular, the regulator bails out a total of $[\hat{b}(k) + \bar{\bar{b}}(k)]$ banks, until the marginal bailout cost exceeds the misallocation cost. Thus, $\bar{\bar{b}}(k)$ is given by the conditions

$$h(k, \bar{\bar{b}}) \leq \alpha_1 \Delta < h(k, \bar{\bar{b}} + 1), \tag{9}$$

where

$$h(k, \bar{\bar{b}}) = f(kr_0 - ((k - \hat{b}(k)) - \bar{\bar{b}})\underline{p}) - f(kr_0 - ((k - \hat{b}(k)) - \bar{\bar{b}} + 1)\underline{p}). \tag{10}$$

Note that $[(k - \hat{b}(k)) - \bar{\bar{b}})\underline{p}]$ are the proceeds the regulator receives from asset sales.

To summarize, the regulator's optimal bailout policy $b^*(k)$ is such that[11]

$$b^*(k) = \begin{cases} \min\{\bar{b}(k), [k - (n-k)y(\underline{p})]\} & \text{for } k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}, \\ \min\{\hat{b}(k) + \bar{\bar{b}}(k), [k - (n-k)y(\underline{p})]\} & \text{for } k > \bar{\bar{k}}. \end{cases} \tag{11}$$

Banks are chosen randomly between the three options of being sold to surviving banks, bailed out, or liquidated to outsiders, and the regulator takes a share of β in all bailed-out banks.

To summarize, when $k \leq \bar{k}$, surviving banks purchase all failed banks' assets and the regulator does not intervene. When $k > \bar{k}$, the regulator bails out $b^*(k)$ failed banks, given by conditions in Equations (7), (9), and (11). This optimal bailout policy has the intuitive property that, in states with a large number of

[11] The general behavior of the bailout policy $b^*(k)$ is illustrated in Figure 4. The bailout policy $b^*(k)$ is not always monotone increasing in k since the marginal cost of bailout, $g(k, b)$, is strictly increasing in k when the fiscal cost function is strictly convex: with more bank failures, the fiscal cost is higher, and given the convexity of this cost function, the opportunity cost of bailouts becomes greater. In other words, $\bar{b}(k)$ is decreasing in k when the cost function is convex. A similar argument applies to the marginal cost, $h(k, \bar{\bar{b}})$.

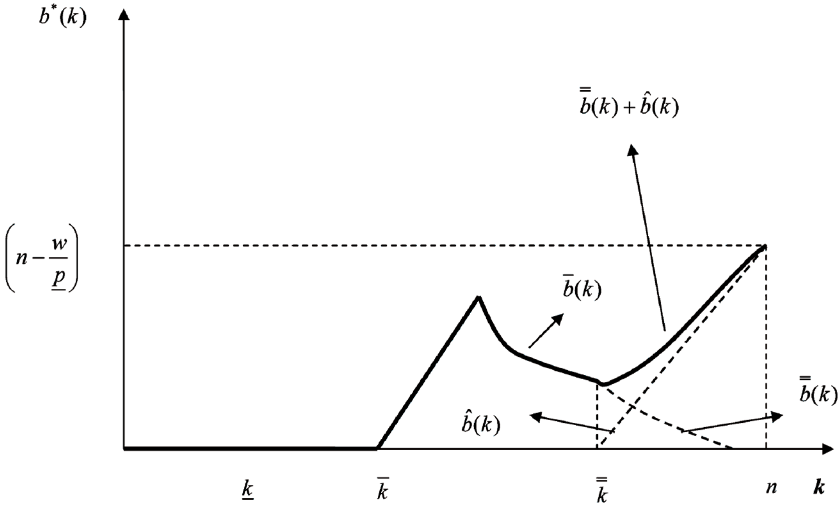

Figure 4
Number of bailouts as a function of the number of failures with convex fiscal cost.

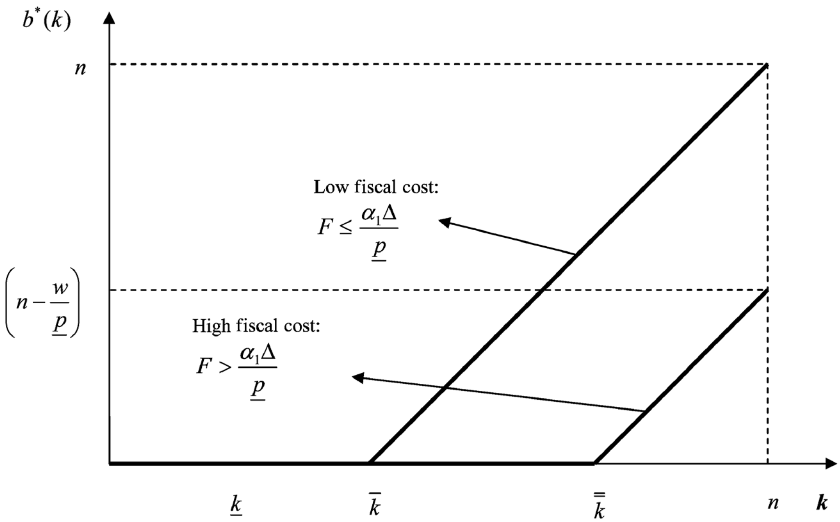

Figure 5
Number of bailouts as a function of number of failures with linear fiscal cost.

bank failures, there are "too many (banks) to liquidate" and the regulator is forced to bail out some failed banks. In particular, irrespective of the fiscal cost function, it is always optimal to bail out up to $\hat{b}(k)$ banks in the region of high bank failures, $k > \bar{\bar{k}}$. Bailouts in this region entail no opportunity costs for the regulator but help avoid misallocation costs. With bailouts, the price never falls below the reservation price of outsiders, $\underline{p}$.

In order to derive and exploit a closed-form expression for the optimal bailout policy, we consider a linear cost function: $f(c) = Fc$, $F > 0$. One analytical advantage of the linear fiscal cost function is that the bailout policy $b^*(k)$ is always monotone increasing (Figure 5). Specifically, if the cost parameter F is sufficiently small, then surviving banks acquire as many failed banks as they can and the remaining failed banks (if any) are bailed out, that is, $b^*(k) = [k - ((n-k)l/\underline{p})]$, for $k > \bar{k}$. Otherwise, $b^*(k) = \hat{b}(k)$, for only $k > \bar{\bar{k}}$. This bailout policy is formally stated below.

Proposition 2. *With a linear fiscal cost function $f(c) = Fc$, the regulator bails out $b^*(k)$ of the k failed banks when $k > \bar{k}$, where $b^*(k)$ is defined as follows:*

$$\text{(i) } \textit{When } F \leq \frac{\alpha_1 \Delta}{\underline{p}}, b^*(k) = \left\lceil k - \frac{(n-k)l}{\underline{p}} \right\rceil. \tag{12}$$

$$\text{(ii) } \textit{When } F > \frac{\alpha_1 \Delta}{\underline{p}}, b^*(k) = \begin{cases} 0 & \textit{for } k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}, \\ \hat{b}(k) & \textit{for } k > \bar{\bar{k}}, \end{cases} \tag{13}$$

with $\hat{b}(k)$ given by Equation (8).

Note that the number of bailed-out banks increases linearly in the number of failed banks k with a slope of $[1 + (l/\underline{p})]$, which is greater than one. The reason is that as more banks fail, not only do assets to be sold increase but also total available liquidity with surviving banks decreases. Hence, an additional bank failure increases the quantity of assets that cannot be acquired by surviving banks by more than one. By implication, as more banks fail, the probability of being bailed out $(b^*(k)/k)$ increases as well (at a rate of $l/\underline{p}$): as more banks fail, not only the number of bailed-out banks but also the likelihood of being bailed-out increases. We interpret this result as a stronger form of the too-many-to-fail problem.

2.3 Liquidity provision

While the regulator can use bailouts to prevent allocation inefficiency resulting from sales to outsiders, the regulator can also employ other policies. We consider one such policy of assisting surviving banks for asset purchases wherein the regulator grants liquidity to these banks without it being returned in the future. Since surviving banks are efficient users, this policy can also prevent misallocation of assets. We show below that a specific form of the liquidity provision policy and the ex-post optimal bailout policy result in the same level of ex-post social welfare.

There are two cases to consider: first, when $k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}$, and second when $k > \bar{\bar{k}}$.

Note that for $k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}$, the participation of outsiders in the auction ensures that the price stays at $\underline{p}$ (see Figure 2). Thus, bailing out a bank increases the total funds needed by the regulator to resolve bank failures by $\underline{p}$. Alternatively, the regulator can grant $\underline{p}$ units of funds to surviving banks to assist their asset purchase. Hence, both liquidity provision and bailout policies increase the funds needed by the regulator by $\underline{p}$ and both policies prevent the misallocation cost of $(\alpha_1 \Delta)$. Thus, from an ex-post welfare standpoint, bailouts and liquidity provision to surviving banks are equivalent.

Formally, when the regulator employs the ex-post optimal bailout policy for $k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}$, $b^*(k)$ banks are bailed out, where $b^*(k)$ is given by Equation (11). The proceeds from asset sales equal $[(k - b^*(k))\underline{p}]$ and outsiders acquire $[k - ((n-k)l/\underline{p}) - b^*(k)]$ units of assets. Hence, we can write the social welfare cost as:

$$C_b(k) = f(kr_0 - [(k - b^*(k))\underline{p}]) + \left[k - \frac{(n-k)l}{\underline{p}} - b^*(k)\right](\alpha_1 \Delta). \quad (14)$$

Suppose instead that the regulator grants a total of $[b^*(k)\underline{p}]$ units of liquidity to surviving banks so that they can altogether acquire $[((n-k)l/\underline{p}) + b^*(k)]$ units of assets. Then, all assets are sold at a price of $\underline{p}$, resulting in total proceeds of $k\underline{p}$. Outsiders acquire $[k - ((n-k)l//\underline{p}) - b^*(k)]$ units of assets, so that we can write the social welfare cost as

$$C_l(k) = f([kr_0 + b^*(k)\underline{p}] - k\underline{p}) + \left[k - \frac{(n-k)l}{\underline{p}} - b^*(k)\right](\alpha_1 \Delta), \quad (15)$$

which equals $C_b(k)$ in Equation (14), the welfare cost under the bailout policy.

For the second case, recall from the discussion of bailouts that for $k > \bar{\bar{k}}$, bailing out up to $\hat{b}(k)$ banks does not give rise to any incremental fiscal cost. Thus, the regulator first bails out $\hat{b}(k)$ failed banks, so that the price for remaining $[k - \hat{b}(k)]$ assets is $\underline{p}$. Thus, the regulator requires $[kr_0 - (k - \hat{b}(k))\underline{p}]$ units of funds for deposit insurance.

Suppose, instead, that the regulator provides $[\hat{b}(k)\underline{p}]$ units of liquidity to surviving banks. With these additional funds, surviving banks have a total liquidity of $[(n-k)l + \hat{b}(k)\underline{p}]$, and with outsider funds of w, this is just enough to keep the price at $\underline{p}$. Thus, surviving banks can acquire the $\hat{b}(k)$ failed banks that would have been bailed out and the regulator collects $(k\underline{p})$ units from asset sales. Thus, funds needed by the regulator equal $[(kr_0 + \hat{b}(k)\underline{p}) - k\underline{p}]$, which is identical to the funds needed under the bailout policy.

Once $\hat{b}(k)$ banks have been sold, the total amount of liquidity in the whole system is sufficient to sustain the price for the sale of remaining $[k - \hat{b}(k)]$ banks at $\underline{p}$, whereby an additional bailout or liquidity provision decreases the proceeds from asset sales by $\underline{p}$. Hence the regulator's decision is similar to that for the case where $k \in \{\bar{k}+1, \ldots, \bar{\bar{k}}\}$. Therefore, as argued above, we can show that the liquidity provision policy and the ex-post optimal bailout policy result in the same level of ex-post social welfare.

To summarize, consider a liquidity provision policy of granting $\hat{l}(k)$ units of liquidity to each surviving bank for assistance in asset purchase, where:

$$\hat{l}(k) = \begin{cases} 0 & \text{for } k \leq \bar{k}, \\ \frac{b^*(k)p}{(n-k)} & \text{for } k \in \{\bar{k}+1, \ldots, n-1\}, \\ 0 & \text{for } k = n, \end{cases} \tag{16}$$

and $b^*(k)$ is the ex-post optimal bailout policy characterized in Equation (11).[12] Then, we obtain the following formal proposition.

Proposition 3. *The ex-post optimal bailout policy characterized in Equation (11), and the liquidity provision policy in Equation (16) result in the same level of ex-post social welfare.*

3. Analysis from an Ex-Ante Standpoint

Having shown that the regulator is indifferent between the bailout and liquidity provision policies from an ex-post standpoint, we next analyze the ex-ante optimality of these policies. We allow banks to choose the level of correlation in their investments (so-called the interbank correlation, denoted by ρ), analyze the incentives different regulatory policies create for this choice, and compare the resulting social welfare from an ex-ante standpoint. For the remainder of the article, we use the linear fiscal cost function $f(c) = Fc$.

At $t = 0$, banks choose the composition of loans in their portfolios. There is a common industry that all banks can access and there are n other industries, one for each bank, such that only bank i can access industry i (region, set of customers, etc.). To focus on the effect of interbank correlation, we assume that the returns to all industries are independent and identically distributed. That is, the return from industry i, denoted by $\tilde{R}_{it}$, takes the values $\tilde{R}_{it} \in \{0, R_t\}$, where the probability of having the high return R_t is given by α_t and $i \in \{1, 2, \ldots, n\}$ denotes the bank-specific industries, whereas $i = c$ denotes the common industry. Banks choose whether to invest one unit in the bank-specific industry ($x_i = 0$) or in the common industry ($x_i = 1$). The vector of choices $(x_1, \ldots, x_n)$ determines the joint probability distribution of bank returns. We focus on the joint choice of banks and hence denote x_i's simply as x.

If banks lend to different industries ($x = 0$), then their returns are independent ($\rho = 0$). In this case, we obtain a binomial distribution for the number of

[12] This liquidity provision policy can be shown to be equivalent to a form of price-discrimination, where the regulator charges different prices to surviving banks and outsiders in the auction for asset sales.

bank failures:

$$\Pr(k) = C(n,k)\alpha_0^{n-k}(1-\alpha_0)^k \quad \text{for } k \in \{0, 1, \ldots, n\}, \tag{17}$$

where $C(n,k)$ is the number of combinations of k objects from a total of n. However, if banks choose the common industry ($x = 1$), then their returns are perfectly correlated ($\rho = 1$). In this case, they all survive with probability α_0, that is, $\Pr(0) = \alpha_0$, or they all fail with probability $(1-\alpha_0)$, that is, $\Pr(n) = (1-\alpha_0)$.

Next, we analyze the choice of interbank correlation under different regulatory policies.

3.1 Interbank correlation under bailout policy

We first consider the ex-post optimal bailout policy. We show that the choice of interbank correlation depends on the expected profit from the purchase of failed banks' assets when they survive and the expected subsidy from bailouts when they fail. In Proposition 4, we formally state the conditions under which banks choose to invest in the common industry.

The objective of each bank is to choose the level of interbank correlation ρ at date 0 that maximizes $[E(\pi_1(\rho)) + E(\pi_2(\rho))]$, where discounting has been ignored since it does not qualitatively affect the results. The expected payoff from the first-period investment, $E(\pi_1)$ equals $[\alpha_0(R_0 - r_0)]$, which does not depend on interbank correlation. Hence, banks only take into account the second-period profits, $E(\pi_2)$, while choosing ρ.

If banks invest in the same industry and the return is low, then all banks fail and the regulator bails out (randomly picked) $b^*(n)$ of them taking an equity stake of β in the bailed-out banks. Thus, the expected profit from the second-period investment is given as

$$E(\pi_2(1)) = \alpha_0\, E(\pi_2) + (1-\alpha_0)\left(\frac{b^*(n)}{n}\right)(1-\beta)E(\pi_2). \tag{18}$$

If banks invest in idiosyncratic industries, then using the price function in Figure 3, we can see that when only a few banks fail, $k \leq \underline{k}$, surviving banks pay full price for the acquired assets. Thus, banks profit from asset purchase only in states that exhibit cash-in-the-market pricing, that is, when $k > \underline{k}$. For $k \in \{\underline{k}+1, \ldots, \bar{k}\}$, each surviving bank captures a surplus from asset purchase that equals:

$$y(p^*) \cdot [\bar{p} - p^*] = \frac{k}{(n-k)} \cdot \left[\bar{p} - \frac{(n-k)l}{k}\right]. \tag{19}$$

Note that for $k \leq \bar{k}$, all failed banks are purchased by surviving banks and bank owners of failed banks have no continuation payoffs.

For $k > \bar{k}$, the regulator bails out some of the failed banks and the remaining banks are sold at $\underline{p}$. As a result, failed banks receive a bailout subsidy equal to

$$\phi(k) = \left(\frac{b^*(k)}{k}\right) \cdot (1 - \beta)E(\pi_2), \tag{20}$$

and the surplus per unit of asset purchased is $(\bar{p} - \underline{p}) = (\alpha_1 \Delta)$, so that each surviving bank captures a surplus equal to $[(l/\underline{p}) \cdot (\alpha_1 \Delta)]$. However, surviving banks do not receive any *additional* benefit as k increases (including for $k > \bar{\bar{k}}$), as all their funds are used to purchase assets at price $\underline{p}$.

Given this analysis, we can calculate $E(\pi_2(0))$, which has returns from investments, asset purchases, and bailouts in different states in the second period [see Equation (25) in the Appendix]. Comparing this to $E(\pi_2(1))$ in Equation (18), we obtain the following result.

Proposition 4. *Under the ex-post optimal bailout policy (characterized in Proposition 2), there exists a critical threshold* $\beta^* \in (0, 1)$ *such that*

(i) *if the continuation moral hazard is severe, that is,* $(1 - \bar{\theta}) < \beta^*$, *then the regulator takes an equity stake of* β *in the bailed-out bank*(*s*), *such that,* $\beta \leq (1 - \bar{\theta}) < \beta^*$, *and banks invest in the common industry.*

(ii) *if* $(1 - \bar{\theta}) \geq \beta^*$, *then the regulator takes an equity stake* β, *such that* $\beta^* \leq \beta \leq (1 - \bar{\theta})$, *and banks invest in different industries.*

This result is in contrast to the case with no bailouts. Without bailouts, failed banks receive no subsidy from the regulator, whereas surviving banks capture some surplus through asset purchase at discounted prices. Hence, without bailouts, banks choose the low correlation. In summary, bailouts lower the ex-post allocation inefficiency but give banks incentives to herd, since bailouts occur only when a sufficiently large number of banks have failed. The presence of moral hazard implies that the regulator cannot always dilute the equity stake of bailed-out banks up to a level that induces banks to invest in different industries.

Intuitively, as w decreases, the second cash-in-the-market region becomes larger ($\bar{\bar{k}}$ decreases). Thus, the region over which $\hat{b}(k)$ banks are always bailed out increases (see Proposition 2). This increases the bailout subsidy when many banks fail and aggravates incentives to herd. Furthermore, β^* is decreasing in w: as w decreases, the regulator must hold a larger share in bailed-out banks to induce low correlation, and, in turn, herding incentives prevail over a larger range of the continuation moral-hazard parameter $\bar{\theta}$.

This leads to the interesting conclusion that the herding incentives of banks are likely to be more pronounced in economies where banking crises are accompanied by lower aggregate wealth. Also, the too-many-to-fail (or too-many-to-liquidate) problem and the induced herding are likely to be more prevalent in economies where the governance of banks is poor: when agency problems such as fraud by bank owners are more severe, banks hold greater equity stakes (high $\bar{\theta}$) for incentive reasons (Caprio, Laeven, and Levine, 2005).

3.2 Interbank correlation with liquidity provision

Under the liquidity provision policy, the expected profit for banks when they invest in different industries can be calculated as in the case of bailout policy. We do not repeat the derivation but highlight the important differences.[13]

On the one hand, when the regulator follows the liquidity provision policy, surviving banks acquire a larger proportion of assets. In particular, for $k > \bar{k}$, they acquire $b^*(k)$ bailed-out banks so that each surviving bank acquires $[b^*(k)/(n-k)]$ additional units of assets. This gives each surviving bank an extra surplus of

$$\gamma(k) = \left(\frac{b^*(k)}{n-k}\right)\bar{p} \tag{21}$$

from asset purchase, relative to the case with bailouts.

On the other hand, under the liquidity provision policy, there are no bailouts (unless all banks fail), whereas under the bailout policy, a failed bank is bailed out with probability $(b^*(k)/k)$, giving rise to a bailout subsidy that is given by $\phi(k)$, for $k > \bar{k}$ [see Equation (20)].

Proposition 5 characterizes the choice of interbank correlation under the liquidity provision policy.

Proposition 5. *Under the liquidity provision policy characterized in Equation* (16)*, there exists a critical threshold* $\beta_l^* \in (0, 1)$*, such that*

(i) if the continuation moral hazard is severe, that is, $(1-\bar{\theta}) < \beta_l^*$*, then the regulator takes an equity stake of* β *in the bailed-out bank(s), such that* $\beta \le (1-\bar{\theta}) < \beta_l^*$*, and banks invest in the common industry.*

(ii) if $(1-\bar{\theta}) \ge \beta_l^*$*, then the regulator takes an equity stake* β*, such that* $\beta_l^* \le \beta \le (1-\bar{\theta})$*, and banks invest in different industries.*

This result is qualitatively similar to the result in Proposition 4 with the bailout policy. However, outsiders' funds w have a different effect on herding incentives when the regulator employs the liquidity provision policy. Intuitively, for efficient allocation of assets, it is desirable to have as much liquidity with surviving banks as possible relative to the liquidity with outsiders. Recall that as outsider funds w decrease, the second cash-in-the-market region becomes larger ($\bar{\bar{k}}$ decreases). Thus, the region over which the regulator provides liquidity to surviving banks widens. This increases the expected surplus surviving banks make from asset purchase and mitigates bank incentives to herd. Formally, β_l^* is decreasing in w: as w decreases, $E(\gamma)$ increases and the regulator can induce a low ex-ante correlation amongst banks by holding a smaller share in bailed-out

[13] See Equation (29) in the Appendix for the whole expression. Note that when all banks fail ($k = n$), there is no surviving bank to acquire assets and the regulator follows the ex-post optimal bailout policy. As a result, the expected profit for banks when they invest in the common industry ($x = 1$) is the same under liquidity provision and bailout policies, and is given in Equation (18).

banks. In turn, herding incentives can be mitigated over a larger range of the continuation moral-hazard parameter $\bar{\theta}$.

3.3 Welfare analysis

Having derived the choice of interbank correlation under different regulatory policies, we now analyze ex-ante welfare under this choice. We start with the bailout policy.

Let $E(\Pi_t(\rho))$ be the expected output of the banking sector at date t, net of liquidation and bailout costs. If banks invest in the same industry, then with probability α_0, all n banks have the high return, so that $E(\Pi_1(1)) = n\alpha_0 R_0$. However, if they invest in different industries, then with probability $Pr(k) = C(n,k)\,\alpha_0^{(n-k)}(1-\alpha_0)^k$, k banks have the low return and the remaining $(n-k)$ banks have the high return. Thus,

$$E(\Pi_1(0)) = R_0 \sum_{k=0}^{n} (n-k)\,\Pr(k) = R_0 \left[n - \sum_{k=0}^{n} k\,\Pr(k) \right]. \tag{22}$$

Note that $[\sum_{k=0}^{n} k \ \Pr(k)]$ is the expected number of failed banks and is equal to $[(1-\alpha_0)n]$ for the binomial distribution, so that $E(\Pi_1(0)) = E(\Pi_1(1)) = n\alpha_0 R_0$. Thus, total expected output in the first period is independent of the choice of interbank correlation.

In the second period, the number of banks that survive depends on the outcome of the first-period investments and the regulator's action. If banks invest in the same industry, then with probability α_0, they all succeed; with probability $(1-\alpha_0)$, they all fail, $b^*(n)$ of them are bailed out by the regulator at a fiscal cost of $f(nr_0 - (n - b^*(n))\underline{p})$, and the remaining $(n - b^*(n))$ failed banks are sold to outsiders resulting in a misallocation cost of $[(n - b^*(n))(\alpha_1 \Delta)]$. Thus,

$$E(\Pi_2(1)) = n(\alpha_1 R_1) - (1-\alpha_0)[f(nr_0 - (n - b^*(n))\underline{p}) + (n - b^*(n))(\alpha_1 \Delta)]. \tag{23}$$

If banks invest in different industries, then from Proposition 2, we know that for $k > \bar{k}$, $b^*(k)$ banks are bailed out, $(n-k)$ surviving banks buy $((n-k)l/\underline{p})$ assets, and the remaining $[k - ((n-k)l/\underline{p}) - b^*(k)]$ banks are sold to outsiders. This gives

$$\begin{aligned} E(\Pi_2(0)) = n\,(\alpha_1 R_1) &- \sum_{k=1}^{\bar{k}} \Pr(k)\ f(kr_0 - k \cdot p^*(k)) \\ &- \sum_{k=\bar{k}+1}^{n} \Pr(k)\ f(kr_0 - (k - b^*(k))\underline{p}) \\ &- (\alpha_1 \Delta) \cdot \sum_{k=\bar{k}+1}^{n} \Pr(k) \left[k - \left(\frac{(n-k)l}{\underline{p}} + b^*(k) \right) \right]. \end{aligned} \tag{24}$$

The last term in the RHS represents the expected misallocation cost. The second and third terms represent the fiscal cost for small and large number of bank failures, respectively.

From a welfare standpoint, the optimal level of correlation is $\rho = 0$ when $E(\Pi_2(0)) > E(\Pi_2(1))$. Hence, we compare $E(\Pi_2(1))$ in Equation (23) and $E(\Pi_2(0))$ in Equation (24) term by term. First, we compare the misallocation cost in these two cases. The number of assets purchased by outsiders (weakly) increases in the number of failures. Therefore the misallocation cost is maximum when all n banks fail. When banks choose the high correlation, the probability that they all fail is $(1 - \alpha_0)$, whereas when they choose the low correlation, there is a positive misallocation cost with probability of at most $[\sum_{k=\bar{k}+1}^{n} \Pr(k)]$. Thus, $(1 - \alpha_0) \geq [\sum_{k=\bar{k}+1}^{n} \Pr(k)]$ is a sufficient condition for the expected misallocation cost to be higher when banks' returns are perfectly correlated.

Next, we show that the expected fiscal cost of deposit insurance net of proceeds from asset sales is strictly greater if banks choose the high correlation. Recall that the expected number of bank failures is equal to $[(1 - \alpha_0)n]$ for both levels of correlation. Hence, the expected amount of funds needed for deposit insurance is $[(1 - \alpha_0)nr_0]$ in both cases. However, when banks choose the high correlation, if all banks fail, then the regulator collects only $\underline{p}$ per unit of assets from outsiders. In contrast, if banks choose the low correlation, then up to an intermediate number of failures, $\bar{k}$, surviving banks are able to pay a price that is higher than $\underline{p}$. Thus, expected proceeds from asset sales are greater when banks choose the low correlation. Thus, $(1 - \alpha_0) \geq [\sum_{k=\bar{k}+1}^{n} \Pr(k)]$ is in fact a sufficient condition for low correlation to dominate high correlation. For example, if $\bar{k} \geq n/2$ (a condition that simplifies to $l \geq \underline{p}$), then $\alpha_0 < 1/2$ is sufficient to suggest that the socially optimal level of correlation is $\rho = 0$. Hence, we obtain the following formal result.

Proposition 6. *For all α_0, such that $\alpha_0 < (\sum_{k=0}^{\bar{k}} \Pr(k))$, the expected total output of the banking sector at date* 0 *(net of any anticipated costs of liquidations and bailouts) is maximized when banks operate in different industries, that is, when $\rho = 0$.*

We showed that when the likelihood of bank failures is sufficiently high, social welfare is maximized when banks invest in different industries. Thus, the regulator may wish to implement "hard" closure policies, such as liquidating a sufficient number of banks, in order to create incentives for banks to choose the low correlation.[14] These policies may, however, lack commitment. For example, conditional upon a large number of failures, liquidation of banks may not be credible if bailout costs are smaller than liquidation costs. The regulator can

[14] We assume that the regulator cannot write contracts that "force" banks to adopt specific investment choices, that is, the regulator cannot impose regulation that is explicitly contingent on interbank correlation.

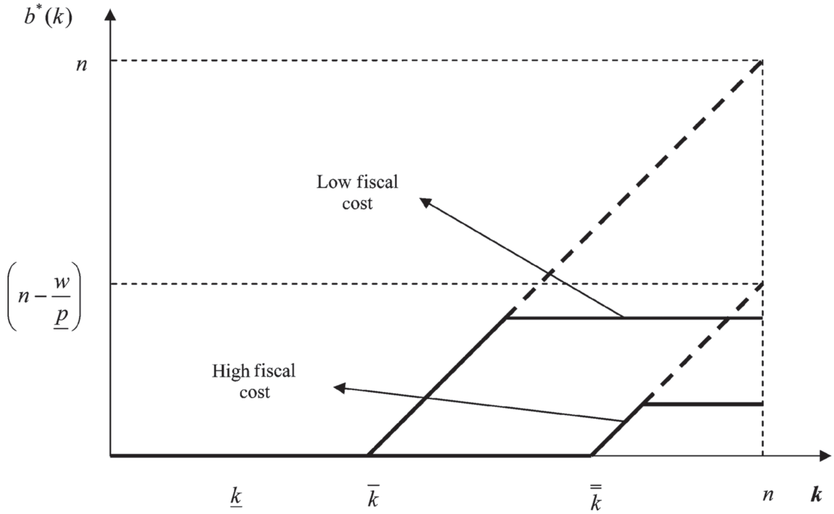

Figure 6
Bailout strategy that implements low correlation.

also induce low interbank correlation by diluting the equity share of bailed-out banks (see Proposition 4). However, this may also lack commitment ex-post: if the minimum dilution required to induce low correlation is sufficiently large, then such dilution may have adverse consequences for continuation moral hazard and banks may choose bad projects. We formalize this trade-off below. In particular, we characterize the ex-ante optimal bailout policy assuming that the regulator can commit to its implementation and examine when this policy is not subgame perfect and thus time-inconsistent.

If the regulator commits not to bail out more than a threshold number of banks, then banks may choose to invest in different industries. Thus, we focus on a bailout policy $\tilde{b}^*(k) = \min\{b^*(k), \tilde{b}\}$, where $\tilde{b}$ is the maximum number of bank bailouts that implements the low correlation (see Figure 6).[15] Since it is optimal ex post to bail out more than $\tilde{b}$ banks, it suffices to concentrate the analysis on $\tilde{b}^*(k)$ among the set of bailout strategies that implements the low correlation.[16]

It is optimal for the regulator to commit to not bailing out more than $\tilde{b}$ banks if and only if the expected output of the banking industry in this case is higher compared to the case where the regulator follows the ex-post optimal bailout policy and banks choose the high correlation. The trade-off is simple: ex-post, the regulator cares only about continuation payoffs in states where $k > \bar{k}$,

[15] A policy that never bails out banks ($\tilde{b} = 0$) implements the low correlation. Hence, $\tilde{b}$ is well defined.

[16] This analysis is interesting only when the ex-post optimal bailout policy $b^*(k)$ induces banks to choose the high correlation. In other cases, the regulator can implement a low correlation using the ex-post optimal closure policy and we would not observe time-inconsistency in the regulatory actions.

whereas ex ante, the regulator is willing to give up some of these payoffs in order to induce better incentives for banks to be less correlated. This gives us the following proposition, which shows that the time-inconsistency of ex-ante optimal policy arises when the likelihood of bank failures, $(1-\alpha_0)$, is sufficiently high.[17]

Proposition 7. *For all* α_0, *such that* $\alpha_0 \leq [1-(\lambda(\underline{p}/\tilde{p}^*(n))\sum_{k=\bar{k}+1}^{n}\Pr(k))]$, *where* $\lambda = \max\{[(\alpha_1\Delta)/(F\underline{p})], 1\}$, *if the regulator can credibly commit to a bailout strategy ex-ante, then it is optimal to commit to the strategy* $\tilde{b}^*(k) =$ *min*$\{b^*(k), \tilde{b}\}$, *where* $\tilde{b}$ *is the maximum number of bank bailouts that implements the low correlation and* $b^*(k)$ *is defined in Equation (12).*

It is possible that the regulator can mitigate this time-inconsistency problem using the liquidity provision policy characterized in Equation (16), which achieves the same level of ex-post social welfare as the ex-post optimal bailout policy. With liquidity grant, the surviving banks' surplus from asset purchase increases. Thus, to mitigate herding incentives, the regulator may not have to resort to excessive liquidation in states where banking crises are systemic. To illustrate this, we show that under the liquidity provision policy, the regulator can implement low correlation over a wider range of parameter values.

Recall that under the liquidity provision policy, surviving banks receive an additional surplus of $\gamma(k)$ given by Equation (21), but there are no bailouts. Under the ex-post optimal bailout policy, a failed bank receives an expected bailout subsidy of $\phi(k)$, as given in Equation (20). Hence, the condition $\gamma(k) > \phi(k)$ for all $k > \bar{k}$ is sufficient to show that the expected surplus for banks from asset purchases outweighs the expected loss of bailout subsidy. In particular, if this condition holds, then the regulator can implement low correlation under the liquidity provision policy by taking a smaller stake in the bailed-out banks, that is, $\beta_l^* \leq \beta^*$. Proposition 8 states a sufficient condition for this result to hold.

Proposition 8. *For* $l \geq \underline{p}$, *we have* $\beta_l^* \leq \beta^*$.

First, $l \geq \underline{p}$ is only a sufficient condition which guarantees that $\gamma(k) > \phi(k)$ for all $k > \bar{k}$. Herding incentives are in fact mitigated under the liquidity provision policy over a larger range of parameter values. Second, the condition $l \geq \underline{p}$ simplifies to $\bar{k} \geq n/2$, a condition under which it is socially optimal to have low interbank correlation for all $\alpha_0 < 1/2$. Furthermore, $\gamma(k)$ increases faster in the number of failures k than $\phi(k)$. Hence, $\gamma(\bar{k}) > \phi(\bar{k})$, is sufficient to obtain $\gamma(k) > \phi(k)$ for all $k > \bar{k}$. And the condition $l \geq \underline{p}$ simply guarantees that. To summarize, assisting surviving banks by granting them liquidity to purchase failed banks is an ex-post optimal policy that dominates the bailout policy from an ex-ante standpoint.

[17] The proof for this Proposition is available upon request.

4. Empirical Support and Robustness

In this section, we discuss how our article relates to the resolution of bank failures in practice and also provide empirical support for the assumptions and results of our model.

4.1 Resolution of bank failures

One of our main results is that in states with a small number of bank failures ($k \leq \bar{k}$), the regulator should let surviving banks acquire failed banks, whereas with a larger number of failures ($k > \bar{k}$), it may be optimal for the regulator to intervene. In particular, we allowed the regulator to employ a variety of policy options including bailouts, sales to surviving banks with and without liquidity assistance, and finally, sales to outsiders.

These policies broadly cover the spectrum of options regulators employ in practice to resolve bank failures. The report by the Basel Committee on Banking Supervision (BCBS) (2002) provides a detailed discussion. We provide a brief summary. At one end of the spectrum, regulators seek a private-sector resolution first, where the troubled bank is sold to another healthy institution without any government assistance. These arrangements are typically called "Merger and Acquisition" (M&A) agreements.

However, during systemic crises, such private-sector resolution is not always feasible and regulators employ other policies, which are broadly classified as "Purchase and Assumption" (P&A) agreements with surviving banks. Such P&A agreements are generally enhanced by government guarantees to attract buyers. For example, if the whole bank is purchased, then the acquirer may receive a government payment covering the difference between the market value of assets and liabilities. If only some deposits are purchased, the acquirer may be given the option of purchasing any of the others and get their pick of bank assets. Furthermore, P&A agreements typically include some form of a put option, whereby the government promises to buy back the assets at a stated percentage of value within a specified time frame, and often also include a contractual profit or loss-sharing agreement. And, at the other end of the spectrum, banks are kept open through an injection of capital, which corresponds to bailouts in our article. Goodhart and Schoenmaker (1995) provide a cross-country survey of 104 bank failures in 24 different countries during the 1980s and early 1990s that corroborates this summary. They show that liquidation of failed banks has not been the rule but the exception. While 31 of the 104 banks were liquidated, 22 were bailed out using a rescue package and 49 were taken over by other banks. Hawkins and Turner (1999, Table 12, p. 40) document evidence on the resolution methods used during the banking crises in the 1980s and 1990s for 23 countries. They show that in 20 of these countries, government capital injection was used as one of the resolution policies; in 20 countries, domestic bank mergers were employed; and, troubled banks were taken over by foreign banks in 9 countries.

Santomero and Hoffman (1999) discuss the US Thrift Crisis, banking crises in Norway, Sweden, and Finland, and the Credit Lyonnais experience in France. They document that liquidation of banking assets has not been a preferred strategy during systemic crises since fire-sale prices, large bid-ask spreads, and the virtual lack of bids are common elements of a mass liquidation. Furthermore, they report that during systemic crises, it has been costly for regulators to close down a significant portion of the banking system due to issues relating to investment disruption and consumer confidence. Kasa and Spiegel (1999) use bank closure data for the USA for the period 1992 through 1997 and provide similar evidence. They compare an *absolute* closure rule, which closes banks when their asset/liability ratios fall below a given threshold with a *relative* closure rule, which closes banks when this ratio falls sufficiently below the industry average. A direct implication of the relative closure rule is forbearance when the banking industry as a whole performs poorly. They find strong evidence that US bank closures were based on relative performance during this period.

Finally, Brown and Dinc (2006) analyze failures among large banks in 21 major emerging markets in the 1990s and show that the government decision to close or take over a failing bank depends on the financial health of other banks in that country. In particular, intervention is delayed if other banks are also weak. They show that this too-many-to-fail effect is robust to controlling for bank-level characteristics, macroeconomic factors, political factors such as electoral cycle and potential IMF pressure, as well as worldwide time-specific factors.

4.2 Evidence on herding

We modeled herding by banks as coordination in lending to similar firms or sectors of the economy. This coordination is a rational choice of banks given the trade-off between surplus from differentiation and herding. This form of herding is different from irrational herding, reputation-based herding, or herding resulting from informational externalities.[18]

In practice, there are countervailing effects such as competition in loan margins, which make herding less attractive (Winton, 2000; and Acharya, Hasan, and Saunders, 2006). Though our model does not allow for competition in lending, it does consider one countervailing effect on herding incentives: when banks survive, they acquire failed banks at discounted prices. This feature of our model leads to precise implications for when we should expect herding incentives to dominate. In particular, herding incentives are stronger when the likelihood of bank defaults is high (Proposition 7). Thus, the question of whether banks herd or not, and in which states, is ultimately an empirical one.

[18] See the survey by Devenow and Welch (1996) for a detailed discussion of various forms of herding.

Hence, we provide evidence supportive of our modeling approach and results, and also document that banks correlate their portfolios in several other ways that are less likely to erode profit margins.

In evidence that studies correlation of different banks' assets measured through the correlation of their equity returns, Luengnaruemitchai and Wilcox (2004) find that during the period 1976–2001, banks in the USA chose market and asset betas that clustered together more when the banking sector was troubled, in terms of banks having low capital ratios. They find a lower standard deviation of bank betas in such times. Their interpretation of this finding is one of herding by banks to seek "safety in similarity" : "[Banks] more tightly mimicked each other during troubled times." In troubled times, banks would be concerned more about regulatory bailouts, as implied by our model.

A number of studies have analyzed herding by employing evidence from the over-exposure of banks to emerging market economies before the debt crisis of 1982–1984. Guttentag and Herring (1984), for example, discuss three potential explanations. While their first two explanations are related to the bounded rationality of banks, the only rational explanation they consider is that too-many-to-fail guarantees created incentives for banks to get over-exposed to risks in these countries. They suggest that deposit insurance, existence of lender-of-last-resort facilities, as well as official support for debtor countries from the IMF gave banks the impression that they would be protected against risks. They also suggest that by herding and keeping concentrations in line with each other, banks made sure that any problem that occurred would be a system-wide problem, not just the problem of an individual institution. Banks reasoned that this in turn would make it harder for the regulatory authorities to blame or discriminate against individual institutions and would induce governments to take actions to prevent the adverse consequences of a system-wide banking crisis.

While directly investing in similar industries is one way for banks to increase the correlation of their returns, there are also other approaches. First, banks could bet on systematic risk factors such as interest-rate risk through choosing from a range of products such as mortgages and interest-rate derivatives. That is, banks could specialize within a class of risk exposures to achieve a trade off between incentives to correlate and to differentiate. Second, banks can achieve high levels of default correlation through interbank lending since this leads to the problems of one bank being transmitted to other banks in a contagion-type phenomenon, which indirectly increases the likelihood of bailout of the problem bank.

Another interesting alternative for banks to get exposed to similar risks without erosion of profit margins is to participate in syndicated loans to common set of borrowers (as in the debt crises of 1980s for less developed countries and the extension of telecom loans in late 1990s). Through syndication, banks can ensure that they are more likely to receive regulatory subsidies when loans perform poorly, affecting all syndicate members. Adams (1991, Chapter 10) argues that before the emerging market debt crisis, banks comforted themselves by herding, thinking that as long as all banks made similar loans, any crisis would be system-wide and would force governments to bail out those countries in trouble.[19] She also argues that syndicated loans acted as an important vehicle for herding and hundreds of billions of dollars in loans were syndicated between 1970 and 1982. On a similar point, Jain and Gupta (1987) also discuss the role of syndicated loans for bank herding during the emerging market debt crisis.

5. Conclusion

In this article, we developed a theoretical framework with an arbitrary number of banks wherein liquidity effects in the market for asset sales lead to welfare costs during systemic crises, which is conducive to a comprehensive normative analysis of regulatory options to resolve bank failures.

The framework is flexible and tractable to provide a foundation for examining several other aspects of financial crises and their resolution. For example, surviving banks are financially constrained in our model and use their first-period profits for asset purchase. It would be interesting to extend the model to endogenize banks' choice of available funds for asset purchase, in particular, by allowing banks to choose ex-ante a portfolio of liquid and illiquid assets. Such an extension can shed light on the relative levels of socially and privately optimal liquidity choices of banks, and how they respond to regulatory policies. Repullo (2005), for instance, argues that the traditional lender-of-last-resort policies (without penalty rates on borrowers) can lead to smaller liquidity buffers in the banking system. Interestingly, the liquidity provision policy proposed in our article does not suffer from this problem: banks receive liquidity under this policy when they survive and not when they are in trouble.

Appendix

Proof of Proposition 4. For $k \leq \bar{k}$, no bank is bailed out, all assets are purchased by surviving banks (capturing a surplus of $[(k/(n-k))E(\pi_2) - l]$), and a failed bank's expected second period profit is equal to zero. For $k > \bar{k}$, $b^*(k)$ banks are bailed out, where $b^*(k)$ is given in Proposition 2. The expected continuation payoff for a bailed-out bank is $(1-\beta)E(\pi_2)$, where β is the regulator's share, and each surviving bank captures a surplus of $[(l/\underline{p})(\alpha_1\Delta)]$.

[19] According to Pedro-Pablo Kuczynski, a former World Bank official, Peruvian cabinet minister, and later an investment banker with First Boston Corporation, "Banks preferred to lend to the public sector, not for ideological reasons but because government guarantees eliminated commercial risk."

If banks choose $x = 0$, their returns are independent and we have a binomial distribution for the number of failures, k. We can write banks' expected profit $E(\pi_2(0))$ as

$$
\begin{aligned}
&= \alpha_0 \left[E(\pi_2) + \sum_{j=\underline{k}+1}^{\bar{k}} \left[P(j) \left[\left(\frac{j}{n-j} \right) \ E(\pi_2) - l \right] \right] \right] \\
&\quad + \alpha_0 \left[\sum_{j=\bar{k}+1}^{n-1} \left[P(j) \left(\frac{l(\alpha_1 \Delta)}{\underline{p}} \right) \right] \right] \\
&\quad + (1-\alpha_0) \left[\sum_{j=\bar{k}}^{n-1} \left[P(j) \left(\frac{b^*(j+1)}{j+1} \right) (1-\beta) E(\pi_2) \right] \right], \qquad (25)
\end{aligned}
$$

where j is the number of failures among the remaining $(n-1)$ banks and $P(j)$ is the corresponding probability for this event, when we exclude the bank that we calculate the expected profit for. For the binomial distribution, we have that $P(j) = C(n-1, j)\, \alpha_0^{n-1-j}\, (1-\alpha_0)^j$.

If banks choose $x = 1$, they are perfectly correlated and their expected return is

$$
E(\pi_2(1)) = \alpha_0 E(\pi_2) + (1-\alpha_0) \left(\frac{b^*(n)}{n} \right) (1-\beta) E(\pi_2). \qquad (26)
$$

Next, we derive the critical equity share, denoted by β^*, which if taken by the regulator in each bailed-out bank, then banks would choose not to invest in the common industry.

Note that, banks choose $x = 1$ if and only if $E(\pi_2(1)) - E(\pi_2(0)) > 0$. Let $d(\beta) = [E(\pi_2(1)) - E(\pi_2(0))]$, where

$$
\begin{aligned}
d(\beta) &= (1-\alpha_0)\,(1-\beta) E(\pi_2) \left[\frac{b^*(n)}{n} - \sum_{j=\bar{k}}^{n-1} \left[P(j) \left(\frac{b^*(j+1)}{j+1} \right) \right] \right] \\
&\quad - \alpha_0 \left[\sum_{j=\underline{k}+1}^{\bar{k}} \left[P(j) \left[\left(\frac{j}{n-j} \right) \ E(\pi_2) - l \right] \right] \right. \\
&\quad \left. + \sum_{j=\bar{k}+1}^{n-1} \left[P(j) \left(\frac{l\,(\alpha_1 \Delta)}{\underline{p}} \right) \right] \right]. \qquad (27)
\end{aligned}
$$

Note that only the first term depends on β. Also, note that $(b^*(k)/k)$ is increasing in k. Hence, $(b^*(n)/n) > (b^*(k)/k)$ for all $k \in \{0, \ldots, n-1\}$ and we have $\partial d/\partial\beta < 0$. Thus, there exists a unique β^*, such that

$[E(\pi_2(1)) - E(\pi_2(0))] > 0$ if and only if $\beta < \beta^*$, where

$$\beta^* = 1 - \left[\frac{\alpha_0 \left(\sum_{j=\underline{k}+1}^{\bar{k}} \left[P(j) \left[\left(\frac{j}{n-j} \right) E(\pi_2) - l \right] \right] + \sum_{j=\bar{k}+1}^{n-1} \left[P(j) \left(\frac{l(\alpha_1 \Delta)}{\underline{p}} \right) \right] \right)}{(1-\alpha_0) E(\pi_2) \left[\frac{b^*(n)}{n} - \sum_{j=\bar{k}}^{n-1} \left[P(j) \left(\frac{b^*(j+1)}{j+1} \right) \right] \right]} \right]. \tag{28}$$

For $\beta^* \leq 0$, banks always choose $x = 0$. For $\beta^* > 0$, banks choose $x = 1$ when $\beta < \beta^*$, otherwise, they choose $x = 0$.

Note, however, that the regulator will ex-post never take a share β that exceeds $(1 - \bar{\theta})$: it is better to liquidate the bank than to have it run inefficiently by bank owners due to poor provision of incentives. Thus, if $(1 - \bar{\theta}) < \beta^*$, then the regulator's share β is smaller than β^* in the subgame perfect equilibrium, and banks choose $x = 1$. If $(1 - \bar{\theta}) \geq \beta^*$, then the regulator takes a share β between β^* and $(1 - \bar{\theta})$ and this induces banks to choose $x = 0$.

Also, note that with the linear cost function, $(b^*(k)/k)$ is increasing in k, whereby the denominator in the last term in Equation (27) is positive, and, in turn, $\beta^* < 1$ always. $\diamond$

Proof of Proposition 5. Note that, under the liquidity provision policy characterized in Equation (16), for $k > \bar{k}$, each surviving bank can acquire $[(l/\underline{p}) + (b^*(k)/(n-k))]$ units of failed banks' assets, where $b^*(k)$ is given by the ex-post optimal bailout policy. Hence, if banks choose $x = 0$, we can write each bank's expected profit $E(\pi_2^l(0))$ as

$$\begin{aligned} &= \alpha_0 \left[E(\pi_2) + \sum_{j=\underline{k}+1}^{\bar{k}} \left[P(j) \left[\left(\frac{j}{(n-j)} \right) \bar{p} - l \right] \right] \right] \\ &\quad + \alpha_0 \left[\sum_{j=\bar{k}+1}^{n-1} \left[P(j) \left[\left(\frac{l}{\underline{p}} + \frac{b^*(j)}{(n-j)} \right) \bar{p} - l \right] \right] \right] \\ &\quad + (1-\alpha_0)^n \left(\frac{b^*(n)}{n} \right) (1-\beta) E(\pi_2), \end{aligned} \tag{29}$$

where j is the number of failures among the remaining $(n-1)$ banks and $P(j)$ is the corresponding probability for this event, when we exclude the bank that we calculate the expected profit for.

If banks choose $x = 1$, they are perfectly correlated and their expected return is

$$E(\pi_2^l(1)) = \alpha_0 E(\pi_2) + (1-\alpha_0) \left(\frac{b^*(n)}{n} \right) (1-\beta) E(\pi_2). \tag{30}$$

Note that, banks choose $x = 1$ and only if $E(\pi_2(1)) > E(\pi_2(0))$. Let $d_l(\beta) = [E(\pi_2(1)) - E(\pi_2(0))]$, where:

$$d_l(\beta) = (1-\alpha_0)(1-(1-\alpha_0)^{n-1})\left(\frac{b^*(n)}{n}\right)(1-\beta)E(\pi_2) - \alpha_0\left[\sum_{j=\underline{k}+1}^{\bar{k}}\left[P(j)\left[\left(\frac{j}{(n-j)}\right)\bar{p} - l\right]\right] + \sum_{j=\bar{k}+1}^{n-1}\left[P(j)\left[\left(\frac{l}{\underline{p}} + \frac{b^*(j)}{(n-j)}\right)\bar{p} - l\right]\right]\right]. \tag{31}$$

Note that only the first term depends on β and we have $\partial d_l/\partial\beta < 0$. Thus, $E(\pi_2(1)) - E(\pi_2(0)) > 0$ if and only if $\beta < \beta_l^*$, where

$$\beta_l^* = 1 - \left[\frac{\alpha_0\left[\sum_{j=\underline{k}+1}^{\bar{k}}\left[P(j)\left[\left(\frac{j}{(n-j)}\right)E(\pi_2) - l\right]\right] + \sum_{j=\bar{k}+1}^{n-1}\left[P(j)\left[\left(\frac{l}{\underline{p}} + \frac{b^*(j)}{(n-j)}\right)\bar{p} - l\right]\right]\right]}{(1-\alpha_0)(1-(1-\alpha_0)^{n-1})\left(\frac{b^*(n)}{n}\right)E(\pi_2)}\right]. \tag{32}$$

For $\beta_l^* > 0$, banks choose $x = 1$ when $\beta < \beta_l^*$, otherwise, they choose $x = 0$.

Note, however, that the regulator will ex-post never take a share β that exceeds $(1-\bar{\theta})$: it is better to liquidate the bank than to have it be run inefficiently by bank owners due to the poor provision of incentives. Thus, if $(1-\bar{\theta}) < \beta_l^*$, then the regulator's share β is smaller than β_l^* in the subgame perfect equilibrium, and banks choose $x = 1$. If $(1-\bar{\theta}) \geq \beta_l^*$, then the regulator takes a share β between β_l^* and $(1-\bar{\theta})$ and this induces banks to choose $x = 0$.

Note that the denominator in the last term in the above expression for β_l^* is positive, and, in turn, $\beta_l^* < 1$ always. For $\beta_l^* \leq 0$, banks always choose $x = 0$.

Proof of Proposition 6. The socially optimal level of correlation is $\rho = 0$ when $E(\Pi_2(0)) > E(\Pi_2(1))$. With the linear fiscal cost function $f(c) = Fc$, we have

$$E(\Pi_2(1)) = n(\alpha_1 R_1) - \underbrace{(1-\alpha_0)[nFr_0]}_{\text{expected cost of insurance}} + F\underbrace{(1-\alpha_0)[(n-b^*(n))\underline{p}]}_{\text{expected recovery from asset sales}} + \underbrace{(1-\alpha_0)[(n-b^*(n))(\alpha_1\Delta)]}_{\text{expected misallocation cost}}, \tag{33}$$

$$E(\Pi_2(0)) = n(\alpha_1 R_1) - \underbrace{\sum_{k=1}^{n} \Pr(k)\, k\, (Fr_0)}_{\text{expected cost of insurance}}$$

$$- \underbrace{\left[\sum_{k=\bar{k}+1}^{n} \Pr(k) \left(k - \frac{(n-k)l}{\underline{p}} - b^*(k) \right) \right] [\alpha_1 \Delta]}_{\text{expected misallocation cost}}$$

$$+F \left[\underbrace{\sum_{k=1}^{\bar{k}} \Pr(k)\, (k \cdot p^*(k)) + \sum_{k=\bar{k}+1}^{n} \Pr(k)\, ((k - b^*(k))\underline{p})}_{\text{expected recovery from asset sales}} \right]. \quad (34)$$

For $E(\Pi_2(0))$, we can write the expected cost of insurance as $(1 - \alpha_0)nFr_0$. Note that this term is common in $E(\Pi_2(1))$ and $E(\Pi_2(0))$.

Note that $p^*(k) > \underline{p}$ for $k = 1, \ldots, \bar{k}$ and we can show that the expected recovery from asset sales when $\rho = 0$ is greater than

$$\underline{p} \left[\sum_{k=1}^{n} \Pr(k)\, k - \sum_{k=\bar{k}+1}^{n} \Pr(k)\, b^*(k) \right]. \quad (35)$$

If $(1 - \alpha_0) \geq [\sum_{k=\bar{k}+1}^{n} \Pr(k)]$, then the above expression is greater than the expected funds recovered from asset sales when $\rho = 1$, which is equal to $((1 - \alpha_0)(n - b^*(n))\underline{p})$.

Note that, using Equations (12) and (13), we can show that the number of failed banks' assets that are sold to outsiders (weakly) increases in k. Thus, $[k - ((n - k)l/\underline{p}) - b^*(k)] \leq (n - b^*(n))$ for all $k = \bar{k} + 1, \ldots, n - 1$, and these two expressions are equal when $k = n$. Again, if $(1 - \alpha_0) \geq [\sum_{k=\bar{k}+1}^{n} \Pr(k)]$, the expected cost of misallocation of failed banks' assets is greater when $\rho = 1$.

Thus, if $(1 - \alpha_0) \geq [\sum_{k=\bar{k}+1}^{n} \Pr(k)]$, which can also be written as $\alpha_0 < [\sum_{k=0}^{\bar{k}} \Pr(k)]$, then $E(\Pi_2(0)) > E(\Pi_2(1))$ and the socially optimal level of correlation is $\rho = 0$.

Proof of Proposition 8. Recall from the proofs of Propositions 4 and 5 that:

$$d(\beta) = [E(\pi_2(1)) - E(\pi_2(0))] \text{ and}$$
$$d_l(\beta) = \left[E\left(\pi_2^l(1)\right) - E\left(\pi_2^l(0)\right)\right].$$

Let $D(\beta) = d(\beta) - d_l(\beta)$. Note that under both the bailout and liquidity provision policies, the expected return for banks from investing in the common industry is the same, that is, $E(\pi_2^l(1)) = E(\pi_2(1))$. Hence, we have

$$D(\beta) = E(\pi_2^l(0)) - E(\pi_2(0)).$$

Recall that $\partial d/\partial\beta < 0$ and $\partial d_l/\partial\beta < 0$. Hence, $D(\beta) \geq 0$ for all β, implies that $\beta_l^* \leq \beta^*$.

Next, we find a sufficient condition under which $D(\beta) \geq 0$.

We have $D(\beta) = E(\pi_2^l(0)) - E(\pi_2(0))$ given as

$$\begin{aligned} &= \alpha_0 \left[\sum_{j=\bar{k}+1}^{n-1} \left[P(j) \left[\left(\frac{b^*(j)}{n-j} \right) \bar{p} \right] \right] \right] \\ &\quad - (1-\alpha_0) \left[\sum_{j=\bar{k}}^{n-2} \left[P(j) \left(\frac{b^*(j+1)}{j+1} \right) (1-\beta)\bar{p} \right] \right], \end{aligned} \tag{36}$$

where j is the number of failures among the remaining $(n-1)$ banks and $P(j)$ is the corresponding probability, when we exclude the bank that we calculate the expected profit for. Note that we can write this as

$$= \sum_{k=\bar{k}+1}^{n-1} \left[\Pr(k) \left[\underbrace{\left(\frac{b^*(k)}{n-k} \right) \bar{p}}_{=\gamma(k)} \right] \right] - \left[\sum_{j=\bar{k}+1}^{n-1} \left[\Pr(k) \left[\underbrace{\left(\frac{b^*(k)}{k} \right) (1-\beta)\bar{p}}_{\phi(k)} \right] \right] \right] \tag{37}$$

$$= \sum_{k=\bar{k}+1}^{n-1} \left[\Pr(k) \left[(\gamma(k) - \phi(k)) \right] \right], \tag{38}$$

where $\Pr(k)$ is the probability of having k failed banks out of the n banks. The benefit from the liquidity provision policy, which is denoted by $\gamma(k)$, arises from the extra units of failed banking assets a surviving bank can purchase. The cost of the liquidity provision policy, denoted by $\phi(k)$, is basically the forgone bailout subsidy.

Hence, a sufficient condition for $[E(\pi_2^l(0)) - E(\pi_2(0))] \geq 0$ is $[\gamma(k) - \phi(k)] \geq 0$ for all $k \in \{\bar{k}+1, \ldots, n-1\}$. We have

$$\gamma(k) - \phi(k) = \left[\left(\frac{b^*(k)}{(n-k)} \right) - \left(\frac{b^*(k)}{k} \right) (1-\beta) \right] \bar{p} \tag{39}$$

$$= b^*(k)\bar{p} \left[\left(\frac{k - (n-k)(1-\beta)}{(n-k)k} \right) \right]. \tag{40}$$

Note that $[\gamma(k) - \phi(k)]$ is increasing in k. Hence, if $[\gamma(\bar{k}+1) - \phi(\bar{k}+1)] \geq 0$, then $[\gamma(k) - \phi(k)] \geq 0$ for all $k \in \{\bar{k}+1, \ldots, n-1\}$. Thus,

$$(\bar{k}+1) - (n - (\bar{k}+1))(1-\beta) \geq 0, \tag{41}$$

is a sufficient condition for $[E(\pi_2^l(0)) - E(\pi_2(0))] \geq 0$.

Also, note that $(\bar{k}+1) \geq (nl/(l+\underline{p}))$ from the expression for $\bar{k}$ from Equation (3). And note that the expression in Equation (41) is increasing in the number of failed banks, so that the inequality in Equation (41) is satisfied for $(\bar{k}+1)$ if it is satisfied for $(nl/(l+\underline{p}))$. Hence, we can show that the condition in Equation (41) is satisfied when

$$l - (1-\beta)\underline{p} \geq 0. \tag{42}$$

Hence, for $(1-\beta) \leq (l/\underline{p})$, we have $\gamma(k) \geq \phi(k)$, for all $k > \bar{k}$. A sufficient condition for this to hold for all $\beta \in [0, 1]$ is $l \geq \underline{p}$. This guarantees that the expected profit from choosing idiosyncratic industries is higher when the regulator uses the liquidity provision policy instead of the ex-post optimal bailout policy. Hence, for $l \geq \underline{p}$, the regulator can induce banks to choose the low correlation for a wider range of parameter values when the liquidity provision policy is used, that is, $\beta_l^* \leq \beta^*$. $\diamond$

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