Why Emergency Lending Facilities Go Unused *

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This draft: July 21, 2004

Abstract

In recent years, many emergency lending mechanisms have failed to serve their purpose of providing lending of last resort to borrowers in need for liquidity. The reason is that potential borrowers have been reluctant to seek financing, fearing that a request for funds could be seen as a signal of financial weakness. This was the case in the U.S. with the discount window since the mid-1980s, the Y2K Special Lending Facility, and the post-2003 Primary Lending program, and internationally, with the IMF's Contingent Credit Line and a number of bank rescue packages in Japan, Mexico, and elsewhere. We present an asymmetric information model of emergency lending that explains why lender of last resort facilities may go unused in equilibrium and why such equilibria may persist for a long time. The key feature of the model is the dependence of the choice of equilibrium in each period on the information on borrowers' private characteristics inherited from the previous period.

JEL classification: D82, E58, G21

Keywords: lender of last resort, discount window, private information

*We thank Eddie Dekel for several useful conversations, and Svenja Gudell for excellent research assistance. The views expressed here are those of the authors and need not reflect those of the Federal Reserve System.

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1 Introduction

Mechanisms for emergency liquidity provision sometimes fail dramatically simply because the institutions they are meant to serve don't want to use them. After the failure of Continental Illinois in 1984 and the subsequent U.S. banking crisis, borrowing at the Federal Reserve's discount window dried up. Even after U.S. banks regained health in the 1990s, they remained reluctant to borrow, eventually forcing the Fed to shut down discount lending in 2003. The IMF's Contingent Credit Line (CCL) suffered a similar fate last year. Modeled after domestic emergency lending mechanisms, the CCL offered short-term credit to 'pre-qualified' countries in need of liquidity assistance. However, during its life of almost five years, not a single country applied for a CCL credit line. Other emergency lending programs implemented in recent years in the United States and in other countries have met a similar fate.

Why do lender-of-last-resort facilities fail so dramatically so often? Why, in contrast, is there apparent success in other cases, such as the Bundesbank's former Lombard and discount facilities, or the Eurosystem's marginal lending facility, where banks are not reluctant to seek liquidity assistance under very similar institutional arrangements?

The explanation that (potential) borrowers offer for their reluctance to turn to lenders of last resort is simple: this action is perceived as revealing a weak financial condition. Obtaining liquidity assistance, or even applying for a credit line from a facility like the CCL, carries a stigma with both regulators and in the marketplace. Only if these facilities were more widely used, would their use not carry reputational costs and become acceptable.

This view is suggestive of a simple strategic complementarity. In a world with asymmetric information on borrowers' financial conditions, the effects of decisions to borrow from a lender of last resort depend on the actions of other borrowers: since turning to an emergency lending facility may reveal an emergency need for funds, the cost of such revelation would be lessened if other borrowers (including borrowers of perceived high quality) used the facility at the same time. This complementarity opens the door to multiple equilibria in which it is optimal to borrow from a facility if others also borrow, but optimal not to borrow if others do not borrow.

While intuitive, this argument presents a basic problem in accounting for the prolonged failure of an emergency lending facility, a problem common to many models with multiple equilibria. How is it possible for a particular equilibrium to survive for so long, if the only reason for its survival is that market participants happen to coordinate on the same equilibrium period after period? Indeed, a key conceptual attraction of models with multiple equilibria is their "prediction" of sudden, unforecastable jumps between equilibria. For this reason, the *absence* of jumps between equilibria over long enough periods makes explanations based on all agents choosing the same action unconvincing. Five years without CCL borrowing, or 20 years without discount borrowing, point to equilibria that are just too persistent to be consistent with models of multiple period-by-period equilibria.

In this paper we offer an explanation for why equilibria in a world with voluntary recourse to lenders of last resorts may display either persistent failure of emergency loans to reach their intended recipients, or persistent success under otherwise similar circumstances. The model retains the strategic complementarity inherent in the popular explanation of failure of emergency lending, but narrows potentially multiple equilibria in each period to a unique, history-dependent equilibrium, selected using information available from previous periods on borrowers' behavior.

The key mechanism at work in our model hinges on an important aspect of borrowing decisions in a world with incomplete information and decentralized decisions to seek emergency support: borrowers care less about conforming with large groups of agents — as is the case in many models with strategic complementarities — than they care about conforming with groups, however small, that are perceived to be of sufficiently high quality. This preference may imply that a decision *not* to borrow will fail to signal a borrower's sound financial condition. If this is the case, incomplete information on borrowers' characteristics is preserved, period after period, leading to a persistent equilibrium in which borrowers remain reluctant to seek support, although they would have sought support if they had followed their full information policy in the previous period. Thus, in our model, history selects one of two possible equilibria through the information revealed in the previous period's equilibrium.

An important feature of this equilibrium is that history-dependence arises only when the share of "fragile" borrowers falls below a critical value. In this case, conformity is beneficial: it pays to behave like the herd, when this is perceived to be of sufficiently high quality. Conversely, when the share of fragile borrowers is high, borrowers have no incentive to conform with others, and always follow their full-information policy.

To obtain this equilibrium, our model focuses on two key features of many actual mechanisms for emergency lending: i) asymmetric information on borrowers' quality, and its evolution in response to their observable behavior, and: ii) decentralized decision-making on whether to seek emergency support or not. The latter feature is crucial to turn a decision to borrow into a signal of a weak financial condition, thus setting our work apart from that of Goodhart and Huang (1999), Freixas, Parigi, and Rochet (2001), Jeanne and Wyplosz (2001), and Cordella and Levy-Yeyati (2003), in which the decision to provide liquidity support rests with the lender of last resort. At the opposite end, Rochet and Vives (2002) present a model with decentralized decision-making. However, their static approach prevents information on borrowers' quality to evolve over time in response to borrowers' actions, which is a key feature of our model. Finally, while earlier studies of emergency lending such as Goodfriend (1983) and Waller (1990) offer realistic representations of the U.S. discount window, they abstract from (for us) crucial uncertainty on borrowers' quality. The same is true for recent model of lenders of last resort such as Freeman (1999) and Antinolfi *et al.* (2000).

The paper is organized as follows. In Section 2 we review the failure of a number of emergency lending facilities that motivates our work. Section 3 sets out a simple model of emergency lending, which we solve in Section 4 for the benchmark case of full information and in Section 5 for the case of asymmetric information. Properties of the solution are discussed in Section 6 and their implications for analysis of emergency lending are discussed in section7. Section 8 concludes.

2 Failures of emergency lending: Recent experience

We begin by reviewing the experience with a number of emergency lending mechanisms that, in recent years, have failed in their role of providing assistance to borrowers in need of liquidity support. In assessing reasons for such failures, market observers and managers of the lending facilities have pointed, invariably, to borrowers' fear that turning to the facilities for funding might be viewed as a signal of financial difficulties.

2.1 The U.S. Discount Window

U.S. banks have become very reluctant to borrow from the Fed's discount window since the mid-1980s, for fear that seeking Fed support might raise concern with their financial condition in the marketplace and among regulators.[1] This reluctance has caused a breakdown of the historical link between discount borrowing and the spread of the federal funds rate over the discount rate — the "borrowing function" that played a key role in the execution of monetary policy in previous decades. The demise of the window is documented in Figure 1, showing the collapse of discount (technically, "adjustment") borrowing after the failure of Continental Illinois in 1984 and of hundreds of other institutions in subsequent years. Even after U.S. banks regained health in the 1990s, they

[1] See Clouse (1994), Peristiani (1998), and Hakkio and Sellon (2000). See also Board of Governors (1996), for direct survey evidence on bank managers' attitude towards discount borrowing.

remained reluctant to borrow from the window. Eventually, after many failed attempts to dispel the negative perception associated with discount borrowing (see Federal Reserve Board [1998]), traditional discount lending was discontinued in January 2003, and replaced by a "primary/secondary lending" program of unrestricted loans at penalty rates. (As noted below, the new program has faced similar problems as the old one.)

To assess the validity of the widely-held view on the role of reputation in the breakdown of the discount window, we checked if bank-level data on discount borrowing from the past two decades accorded with a few testable implications of that view. If visits to the window are to act as adverse signals of financial health, one would expect large banks to have become much more reluctant than small banks to visit the window since the mid-1980s, since their behavior at the window is both easier and more profitable for observers to monitor, hence it is more likely to affect reputation.[2] Also, since it is much more difficult (if not impossible) for observers to estimate how much a bank borrowed than simply infer a visit to the window, banks should treat the reputational cost of visiting the window essentially as a fixed *per visit* cost, independent of the amount borrowed. This should lead them to cluster needed discount borrowing over fewer visits, leading to fewer visits *per bank* and more borrowing *per visit*.

To verify these conjectures, we obtained bank-level data on discount lending from the Board of Governors' *Report of Transaction Accounts, Other Deposits and Vault Cash*, from January 1, 1981 (the inception of the archive) to August 18, 1997 (the latest date made available to us from this archive). From the more than 7000 banks registered for discount borrowing we drew daily data for 55 "large" banks (those with largest deposits in 1998:Q1) and 55 "small" banks (drawn randomly from the remaining institutions). We compared the behavior of large and small banks over an "early" subsample running from 1981 to end-1985, and a "late" subsample running from 1986 to 1997.

This comparison is summarized in Table 1, which documents a clear difference in the behavior of large and small banks in the two samples. Average yearly visits to the window dropped from 6.48 in the early sample to 0.98 in the late sample for large banks, and from 3.96 in the early sample to 1.94 in the late sample for small banks.[3] (Both drops, as well as their difference between bank groups, are

[2] While banks' visits to the window are in principle confidential, there is a long tradition of markets inferring presumed-confidential supervisory information. (Flannery and Houston [1999], for instance, show bank stock prices to respond to Fed examinations.) In the specific case of discount borrowing, and aside from leaks, banks' visits to the discount window are reportedly inferred from published district-level borrowing and from the observation of banks' aggressive bidding for funds in the market in advance of visits to the window.

[3] To identify "visits" to the window (i.e., new loans) from data on outstanding loans, we defined each positive entry

significant at less than 1 percent according to standard tests.) Clearly, large banks were the main contributors to the breakdown of the window in the 1980s. Furthermore, the decline in borrowing reflects a collapse in the number of visits, not in the amount borrowed *per visit*. The latter increased from \$170 million in the early sample to \$365 million in the late sample for large banks, and from \$1.1 million in the early sample to \$1.9 million in the late sample for small banks. Altogether, this evidence accords well with the view that the window's demise since the 1980s reflects banks' concern with the reputational impact of obtaining liquidity support from the central bank.

2.2 The IMF's Contingent Credit Line

In the aftermath of the Tequila crisis of 1994-95 and of the Asian crisis of 1997-98, in April 1999 the IMF set up an emergency lending facility, the Contingent Credit Line (CCL). The CCL was designed like traditional domestic lender-of-last-resort mechanisms, and offered short-term credit at a penalty rate to pre-qualified countries to overcome temporary liquidity problems.

With its emphasis on crisis prevention, the CCL marked a clear departure from traditional IMF financing, which focused on crisis resolution by offering loans to countries already in trouble. Pre-qualification was seen as key to enable the facility to respond quickly and stave off full-blown financial crises. The CCL's preventative approach, however, placed the burden of pre-qualification on the countries themselves, a feature that proved to be the root of the facility's demise: countries considering applying for a credit line soon realized that simply by signing up for a CCL, they risked sending a signal to markets that they, in fact, feared a crisis. In their reluctance to sign up for a CCL, countries "expressed caution about being the first to join, fear about being labeled closely with other CCL countries which would join, and concern about how the private sector would view such association" (Boorman [1991, p.3]).

The experience with the CCL is easy to assess: during its life of almost-five years, no single country registered for a credit line, despite reforms implemented in 2000 to make the terms of CCL loans more attractive. Concluding that the main reason for the CCL's failure was "fear that a request for a CCL could be viewed as a sign of weakness rather than strength" (IMF [2003]), in November 2003 the IMF closed the program.

in the series as a visit, since loans are overwhelmingly granted on an overnight basis and loan roll-overs require new application and approval. The polar definition, that only increases in outstanding loans represent a visit, yielded very similar results.

2.3 Other emergency lending mechanisms

In recent years, other well known failures of emergency lending mechanisms have been widely ascribed to borrowers' fear of relaying adverse signals about their financial conditions.

In January 2003, the Federal Reserve replaced its historical discount program with a program of "primary" and "secondary" lending that, in strict adherence to classic lender-of-last-resort principles, offers loans at penalty rates with no other requirement than adequate collateral. Thus far, U.S. banks remain reluctant to seek Fed loans, and the new program has not generated greater willingness to borrow than the program it supplanted. (Data on primary lending, comparable to previous adjustment credit data, is plotted as the observation for 2003 in Figure 1.) Early data show that U.S. banks have continued to prefer borrowing in the interbank market at higher rates than available from the Fed, and that borrowing from the new program has fallen far short of what should have been expected, after controlling for market conditions and seasonal and other factors (Furfine [2003]).

The reformed window's lack of success is not surprising: a similar fate was met by a prototype program, the Special Lending Facility (SLF), offering emergency liquidity during the Y2K period (October 1, 1999 - April 7, 2000). Like the primary/secondary lending program, the SLF was designed in accord with standard Lombard terms, offering unrestricted loans at penalty rates. And, as in the case of the primary/secondary lending program, Fedwire data show that banks borrowed far less money from the SLF than expected (e.g., a fraction of the amount they borrowed from each other at interest rates higher; Furfine [2001]).

Finally, in recent years, a number of bank rescue packages implemented in several countries has floundered, with eligible borrowers expressing fear that accepting a rescue would be perceived as a sign of weakness. Among others, this was the case for the post-1994-crisis bank rescue plan in Mexico (Mackey [1999]; McQuerry [1999]) and the 1998 package in Japan (Corbett and Mitchell [2000]; Nakaso [2001]). The latter example is especially telling, for the Japanese government is reported to have exerted significant pressure on banks concerned with the reputational damage of accepting government funds. Eventually, the rescue was accepted only when all the major banks applied together and received a simultaneous injection of capital on March 30, 1998. Similar problems have been reported for voluntary-participation rescue packages in Thailand and other countries.

Altogether, our reading of the experience reviewed in this section is that problems with emergency lending mechanisms based on voluntary participation by borrowers are widespread — beginning with mechanisms operated by the world's two main lenders of last resort: the U.S. Federal Reserve in a domestic context, and the IMF in a sovereign context. Failure of these mechanisms is rooted in borrowers' fear that the very act of turning to a lender of last resort may be viewed as revealing weakness. In the next section, we present a model that explains what conditions lead to such failures, and why equilibria displaying reluctance *or* willingness to borrow from a lender of last resort may be so persistent.

3 Model set-up

We now present a simple model that illustrates the key mechanism at work in a general class of lender of last resort arrangements — those offering emergency lending to borrowers of uncertain financial condition, on a voluntary and repeated basis. (In Appendix A we consider the case where banks are rationed in the sense they are not allowed to borrow in any two consecutive periods.)

Central to our argument is asymmetric information about borrowers' financial condition. Some of the ways in which this may differ across borrowers are obviously observable. Our interest is in the residual unobserved heterogeneity in a group of borrowers that are identical in terms of observable characteristics. Observable differences would be easy to model, for instance by applying our analysis iteratively to different groups of borrowers, each of which is homogeneous in terms of observable characteristics.

For concreteness, we refer to borrowers as "banks." We consider a world populated by a unit mass of atomistic, competitive banks. At time 0, each bank is privately informed of its "type," $T \in \{R, F\}$ (for "Robust" and "Fragile"), which measures the amount of liquidity internally available for banks to operate, where $R > F$, and the fractions of banks of type R and F are ρ and $(1-\rho)$, respectively. While individual types are not publicly observable, ρ is publicly known. We refer to banks whose type is not yet known by the public as "anonymous." Thus, the fraction of banks of type R in the anonymous pool at time 0 is ρ. In each subsequent period, the fraction of banks still in the anonymous pool is common knowledge, being pre-determined from the equilibrium in period $t-1$.[4]

The timeline of events in each subsequent period, $t = 1, 2, ...$, is as follows.

- Banks experience a common liquidity shock, S_t, describing the aggregate state of the economy. $S_t \in \{H, L\}$, with constant probabilities γ and $1-\gamma$, respectively, and $H > L$.

- Each bank decides whether and how much to borrow at the rate $\overline{r}$ from an emergency lending

[4] For simplicity, we do not write ρ as ρ_t since, as we shall see, our model exhibits only equilibria in which either ρ stays constant, or it jumps only once from a positive value to zero. These cases are easily dealt with, without making ρ explicitly time dependent.

facility. We label a decision to borrow the amount $b_t \geqslant 0$ as B, and a decision not to borrow as NB. While the action $\{B, NB\}$ is observable, the amount borrowed b_t is not.

- Each bank experiences a private, idiosyncratic liquidity shock ε_t with cumulative distribution $M(\varepsilon_t)$.[5]

- If a bank's end-period liquidity, $T+S_t+b_t+\varepsilon_t$ (which is unobservable to the public) is negative, it must pay a restructuring cost of χ per unit of liquidity shortfall, with $\chi > \overline{r}$.

Bank managers are risk neutral and choose the optimal borrowing strategy to maximize the bank's stock market value net of expected restructuring costs.

We model the reputational cost paid by banks that reveal themselves to be of type T very generally, so as to encompass the countless ways in which perception of a borrower's quality affects its value. For instance, a bank of poor quality may face higher financing costs or more stringent credit terms, may be able to employ managers or workers of lower quality, or yield lower recovery value when bankrupt. We assume that the market prices these costs efficiently: a bank's market value reflects its perceived type. Then, if we write the stock market value of a bank of type T as W^T (a known parameter), with $W^R > W^F$, the value of an anonymous bank i in a pool with ρ robust banks and $1-\rho$ fragile banks, in a risk-neutral world, is:

$$W^i = \rho W^R + (1-\rho) W^F \ . \tag{1}$$

Hence, the cost of an action that, in any period, moves bank i from a pool with ρ robust banks to a pool with ρ' robust banks is:

$$W^i - W^{i\,\prime} = [\rho W^R + (1-\rho)W^F] - [\rho' W^R + (1-\rho')W^F] = (\rho - \rho')\widehat{W} \ , \tag{2}$$

where $\widehat{W} \equiv W^R - W^F$ is the known difference in value between a robust and a fragile bank. If either $\rho = \rho'$ or $\widehat{W} = 0$, the reputational cost of a bank's action is zero.

4 Emergency borrowing under full information

Consider a bank of type T that has already decided to visit the lending facility in period t when the state of nature is S_t. After the realization of ε_t, the bank's end-period liquidity will be $T+S_t+b_t+\varepsilon_t$.

[5] For instance, a negative value of ε_t can be interpreted as residual cash needs over what banks can borrow in the open market, e.g., liquidity needs over unsecured credit lines or over the collateral that a bank can credibly pledge, or as liquidity needs occurring too late to be offset by market borrowing.

Conditional on borrowing, b_t solves the static problem:

$$\max_{b_t \geq 0} \ \chi \int_{-\infty}^{-T-S_t-b_t} [T + S_t + b_t + \varepsilon]\mathrm{d}M(\varepsilon) - \overline{r} b_t \ . \tag{3}$$

The first-order condition for this problem is:

$$M(-T - S_t - b_t^*) = \frac{\overline{r}}{\chi} \ , \tag{4}$$

from which one derives

$$b_t^* = \max \ \{ \ -T - S_t - M^{-1}(\frac{\overline{r}}{\chi}) \ , 0 \ \} \tag{5}$$

defines the optimal amount borrowed, $b^*(T + S_t)$, as a decreasing function of $T + S_t$, shifting up and down, respectively, with χ and $\overline{r}$. Notably, $b_t^* = 0$ when $\overline{r} \geq \chi \cdot M(-T - S_t)$: for lending rates higher than $\chi \cdot M(-T - S_t)$, type T does not borrow in state S_t.

Given (5), the period t payoff to borrowing b_t^* in state S_t is:

$$\begin{aligned}
\pi_{T,S_t}^{B} &= \chi \int_{-\infty}^{-T-S_t-b_t^*} [T + S_t + b_t^* + \varepsilon]\mathrm{d}M(\varepsilon) - \overline{r} b_t^* \\
&= \chi \cdot b_t^* \cdot M(-T - S_t - b_t^*) + \chi \int_{-\infty}^{-T-S_t-b_t^*} [T + S_t + \varepsilon]\mathrm{d}M(\varepsilon) - \overline{r} b_t^* \\
&= \chi \int_{-\infty}^{-T-S_t-b_t^*} [T + S_t + \varepsilon]\mathrm{d}M(\varepsilon) \ ,
\end{aligned} \tag{6}$$

where the last equality uses (4). Similarly, the period t payoff to *not* borrowing is:

$$\pi_{T,S_t}^{NB} = \chi \int_{-\infty}^{-T-S_t} [T + S_t + \varepsilon]\mathrm{d}M(\varepsilon) \ . \tag{7}$$

Therefore:

$$\pi_{T,S_t}^{B} - \pi_{T,S_t}^{NB} = -\chi \int_{-T-S_t-b_t^*}^{-T-S_t} [T + S_t + \varepsilon]\mathrm{d}M(\varepsilon) \equiv \chi \cdot \Lambda(T + S_t) \ , \tag{8}$$

where $\Lambda(T+S_t) \equiv -\int_{-T-S_t-b_t^*}^{-T-S_t} [T+S_t+\varepsilon]\mathrm{d}M(\varepsilon) \geq 0$ can be thought of as measuring type T's single-period benefit of borrowing from the facility in state S_t when the amount of borrowing is optimally chosen. Specifically, $\Lambda(T + S_t)$ is the liquidity shortage expected by a bank *not* borrowing, over the range $\varepsilon_t \in [-T - S_t - b_t^*, -T - S_t]$. Over this range, borrowing b_t^* completely prevents a liquidity shortage, while *not* borrowing b_t^* would leave the bank illiquid. Outside this range, borrowing either adds unneeded liquidity (when $\varepsilon_t > -T - S_t$), or only reduces the shortfall (when $\varepsilon_t < -T - S_t - b_t^*$); given that b_t^* is chosen optimally, the benefits of borrowing are exactly offset by the cost of borrowing, $\overline{r} b_t^*$.

Note that $\Lambda(T + S_t)$ =0 when $b_t^* = 0$. Also,

$$\frac{\partial \Lambda(T + S_t)}{\partial (T + S_t)} = M(-T - S_t - b_t^*) - M(-T - S_t) \leq 0 \ , \tag{9}$$

with strict inequality when $b_t^* > 0$: the benefit of borrowing falls with T and S_t.

The static payoffs π^B_{T,S_t} and π^{NB}_{T,S_t} can now be incorporated into the bank's intertemporal decision problem. Under asymmetric information — examined in the next section — a bank will consider the effect of a decision to borrow on its reputation when deciding whether to borrow at t or not. Under full information, however, the bank's infinite-horizon problem is just a sequence of independent one-period problems: type T borrows in state S_t at t if and only if $\pi^B_{T,S_t} > \pi^{NB}_{T,S_t}$, that is, if $\Lambda(T+S_t) > 0$.

To further characterize who borrows, the operation of actual emergency lending arrangements rules out some cases. First, the rate charged on emergency loans, $\overline{r}$, should be sufficiently high to make borrowing unattractive to the best bank (type R) arriving at the facility in the best state (state H): $\Lambda(R+H) = 0$, that is, $b^* = 0$. $\overline{r}$ should also be sufficiently low that the worst bank (type F) arriving at the facility should want to borrow in the worst state (state L): $\Lambda(F+L) > 0$. Since $\Lambda(T+S_t)$ is decreasing in $T+S_t$, these restrictions leave four possible configurations of the full-information equilibrium, in the first three of which the two types of banks do not behave identically in both states:

(a) Type F borrows only in state L, type R never borrows: $\Lambda(F+H) = \Lambda(R+L) = 0$.

(b) Type F borrows in both states, type R never borrows: $\Lambda(F+H) > \Lambda(R+L) = 0$.

(c) Type F borrows in both states, type R only in state L: $\Lambda(F+H) > 0$, $\Lambda(R+L) > 0$.

(d) Both types borrow in state L but not in state H: $\Lambda(F+H) = 0$, $\Lambda(R+L) > 0$.

To illustrate these conditions, which completely specify our model's dynamics under full information, let $\overline{r} = 0.06$, $\chi = 0.20$, and $M(.)$ be a standard cumulative normal. Then, $b^* = 0$ when $T + S_t \geq 0.52$. Let $F = L = 0$, $H = 0.1$ and $R = 0.5$. With these values, R borrows in state L but not in state H, while type F borrows in both states. For higher R, type R abstains from borrowing also in state L; for higher F, type F borrows only in state L.

5 Equilibrium with asymmetric information

Can asymmetric information about bank types imply that a lending facility that is used under full information may go unused along persistent, history-dependent equilibrium paths? One must show that banks that would have borrowed under full information may choose not to borrow and that such behavior can be persistent. As we shall see, R banks have no incentive to deviate from their full information policy. Hence, we are interested in the behavior of F banks. Might they choose to pool with R banks in a no borrowing equilibrium if their type is unknown, though they would borrow under full information?

5.1 Reputation effects

We begin with reputation effects. To establish the existence of persistent equilibria, we must find conditions such that F banks have no incentive to deviate from a path in which the share of R banks in the anonymous pool remains constant at ρ from period to period.[6] To derive these conditions, we must first address a common problem in considering whether such deviations are optimal–how are deviations that have zero probability in equilibrium (that is, off-equilibrium actions) interpreted in forming beliefs?

Suppose that a bank considers deviating in period t from an equilibrium in which all banks are borrowing from the lending facility. What would be the effect of this action on public perception of the bank's type? Since this action has zero probability in equilibrium, its impact on beliefs cannot be calculated via Bayes' rule. However, to obtain conditions for any equilibrium to be supported, we must define the reputational cost of decisions to deviate from such equilibrium.

To overcome this difficulty, we follow Selten (1975) and restrict our search to equilibria that are robust to infinitesimal perturbations ("trembles") of equilibrium strategies and beliefs. This approach allows assigning positive (yet arbitrarily small) probabilities to off-equilibrium strategies that would otherwise have zero probability. Bayes' rule can then be used to compute the cost of deviations from the equilibrium path.

Our approach to perturbing equilibrium beliefs is to assume that the public observes banks' actions with an infinitesimal error δ: if a bank chooses the policy NB at t, the public observes this choice correctly with probability $1-\delta \approx 1$; with probability $\delta \approx 0$, instead, it sees the bank borrowing from the facility; similarly if a bank chooses the policy B. While the public observes banks' actions imperfectly, it knows the probability δ with which it observes banks' behavior correctly. In fact, with atomistic banks, δ measures the mass of banks whose behavior is observed incorrectly, while $1 - \delta$ measures the mass of banks whose behavior is observed correctly. We then let $\delta \to 0$ in the resulting equilibrium. To study the impact of such trembles on equilibrium selection, we distinguish

[6] We show in Appendix B that we only need to check conditions for which, in each period t, banks pool with all other banks or completely separate. Equilibria in which banks move from a pool with a positive fraction of R banks to a pool with a strictly different fraction of R banks are (generically) not possible in our model.

states in which types R and F behave identically under full information, from states in which their behavior under full information differs.

Equilibrium in states with identical full information policy. Consider a state (say L) in which the full-information policy at t (say B) is the same for both types. (The same argument applies, with changed notation, to different state-policy pairs.) Consider a candidate "pooling" equilibrium, under asymmetric information, where all banks follow the policy NB at t. What happens to a bank of either type that considers deviating from this choice? This bank knows that the public observes (incorrectly) the action of an infinitesimal mass of banks, including $\delta\rho$ types R and $\delta(1-\rho)$ types F, as B, rather than the equilibrium NB. This group of (perceived) "deviants" is of the same average quality as the pool of banks seen as borrowing; hence, a bank knows that joining such pool would entail no reputational cost. Since, aside from reputational considerations, banks prefer to borrow in this state, they will all want to switch from the assumed NB to B.

Symmetrically, a bank that considers deviating from a pooling equilibrium at B in state L knows that such a deviation involves no reputational gain, since the bank would join a (small) pool of banks of the same average quality as the equilibrium pool. Because such deviation involves a loss with respect to the full-information policy, however, it will not be optimal for any bank.

This argument holds true for any $\delta > 0$, no matter how small. Hence, we can think of letting $\delta \to 0$ and take this equilibrium as representing the equilibrium when banks' types are correctly observed.

Taken together, these two perturbations imply that pooling on the policy preferred under full information (B, in this example) is the only equilibrium robust to imperfect observation of banks' actions.

Equilibrium in states with different the full information policy. Consider now a pooling equilibrium (say NB) in a state (say H) preferred under full information by types R but not by types F. A type R that considers deviating from this equilibrium knows that by doing so it would join an infinitesimal mass of banks (with $\delta\rho$ types R and $\delta(1-\rho)$ types F) incorrectly seen as choosing B instead of the equilibrium NB. This pool of (perceived) deviants has the same average quality as the assumed equilibrium pool. Since a type R gains no reputation by joining this pool, but incurs a loss relative to its preferred policy, it will never deviate from the assumed equilibrium.

A type F, however, gains by joining the deviants if the gain of following its full-information policy B is larger than the reputational cost of doing so. Specifically, if the gain for types F of following the full information policy is larger than $\rho\widehat{W}$, then all types F will abandon the pool with ρ robust banks and incur the reputational cost $\rho\widehat{W}$. If the gain for types F of following the full information policy is smaller than $\rho\widehat{W}$, instead, only an infinitesimal mass of types F will join the deviant pool, lowering its share of types R from ρ to ρ', just enough to make the reputational cost of joining the group, $(\rho - \rho')\widehat{W}$, equal to the gain of following the full information policy. In this case, the assumed pooling equilibrium is supported by all but an infinitesimal mass of banks.

As before, this argument holds true for any $\delta > 0$, no matter how small. We therefore let $\delta \to 0$ and take this equilibrium as representing the equilibrium when banks' types are correctly observed.

In sum, the condition for an equilibrium in which the share of R banks in the anonymous pool remains constant at ρ, is that the gain for an F bank of following its full-information policy should be smaller than $\rho\widehat{W}$, the reputational cost of separation, in states where types disagree on the full-information policy. When such condition fails, all F banks separate from R banks, and the equilibrium reverts to one with full information.[7]

5.2 Equilibria with reluctance to borrow

We may now ask whether the reputational cost of choosing B over NB outweigh the direct benefit, so that taken together pooling dominates the full information optimum of separation. Following the previous discussion, we now study cases **(a)**-**(c)** from Section 4, in which types differ in their their optimal policy under full information. (In case **(d)**, all have the same full information policy, and have no incentive to abandon such policy when their types are unknown.

To study conditions for equilibrium, note that since b_t is unobservable by the public, only the decision of whether to visit the lending facility or not has intertemporal implications: the *amount* borrowed b_t^* has no impact on reputation, and its solution remains the same as in (5).

(a) Equilibrium at NB **when banks differ on full-information policy in state** L**.** In this case, under full information type F borrows in state L while type R does not (neither borrows in state H), so that we ask when might asymmetric information induce type F to choose not to borrow in state L and hence pool with type R. Type F's payoffs from following the policies B and NB in state L, respectively, and the policy NB in state H are:

[7] If δ were strictly greater than zero, a bank considering deviating from the equilibrium should take into account the reputational cost it might suffer if its action is, in fact, seen as adhering to the equilibrium, and *vice versa*. The reputational cost then becomes a complicated function of ρ and $\widehat{W}$, obtained as the solution of a Bayesian signal extraction problem. As $\delta \to 0$, this solution converges to $\rho\widehat{W}$.

$$P^{B}_{F,L} = \pi^{B}_{F,L} + \beta \mathrm{E}[V_F(F)] \ , \qquad P^{NB}_{F,L} = \pi^{NB}_{F,L} + \beta \mathrm{E}[V_F(R)] \ , \tag{10}$$

where $\mathrm{E}[V_F(F)]$ and $\mathrm{E}[V_F(R)]$ are the discounted future streams of restructuring costs χ expected by type F when following the full-information policies of type F and type R, respectively, in this case. Choosing not to borrow to preserve reputation, that is pooling with R requires $P^{B}_{F,L} - P^{NB}_{F,L} < \rho\widehat{W}$.

Now, from (8), the current-period loss $\pi^{B}_{F,L} - \pi^{NB}_{F,L} = \chi\Lambda(F+L)$, while $\mathrm{E}[V_F(F)]-$ $\mathrm{E}[V_F(R)]$ is the stream of expected future costs incurred by type F by abstaining from borrowing in state L. These costs equal $\chi\Lambda(F+L)$ every time state L occurs, which happens with probability $1-\gamma$ in every period. Hence,

$$E[V_F(F)] - E[V_F(R)] = \chi\Lambda(F+L)[(1-\gamma) + \beta(1-\gamma) + \beta^2(1-\gamma) + ...] = \frac{\chi(1-\gamma)\Lambda(F+L)}{1-\beta}. \tag{11}$$

Therefore, the condition for pooling in this case is

$$\frac{(1-\beta\gamma)\Lambda(F+L)}{(1-\beta)} < \frac{\rho\widehat{W}}{\chi} \ . \tag{12}$$

(b) Equilibrium at NB when banks differ on full-information policy both states. When type F borrows in in both states and type R in neither under full information, we must consider type F's payoffs in each state when expected future streams of restructuring costs are calculated for the policy NB. Consider first state H. Type F's payoffs from following the policies B and NB in state L, respectively, and the policy NB in state L, are:

$$P^{B}_{F,H} = \pi^{B}_{F,H} + \beta \mathrm{E}[V_F(F)] \ , \qquad P^{NB}_{F,H} = \pi^{NB}_{F,H} + \beta \mathrm{E}[V_F(R)] \ , \tag{13}$$

with $P^{B}_{F,H} - P^{NB}_{F,H} < \rho\widehat{W}$ as the condition for pooling.

In this case, $\pi^{B}_{F,H} - \pi^{NB}_{F,H} = \chi\Lambda(F+H)$ while $\mathrm{E}[V_F(F)]-\mathrm{E}[V_F(R)]$ takes into account that, to pool with type R, type F must now abstain from borrowing in both states. This implies a cost $\chi\Lambda(F+H)$ when state H occurs and a cost $\chi\Lambda(F+L)$ when state L occurs. Hence,

$$\mathrm{E}[V_F(F)] - \mathrm{E}[V_F(R)] = \frac{\chi\gamma}{1-\beta}\Lambda(F+H) + \frac{\chi(1-\gamma)}{1-\beta}\Lambda(F+L) \ . \tag{14}$$

Therefore, the condition for pooling in both states when H is the initial state is

$$\frac{1-\beta(1-\gamma)}{1-\beta}\Lambda(F+H) + \frac{\beta(1-\gamma)}{1-\beta}\Lambda(F+L) < \frac{\rho\widehat{W}}{\chi} \ . \tag{15}$$

When the initial state is L, instead, the payoffs for type F become:

$$P^{B}_{F,L} = \pi^{B}_{F,L} + \beta \mathrm{E}[V_F(F)] \ , \qquad P^{NB}_{F,L} = \pi^{NB}_{F,L} + \beta \mathrm{E}[V_F(R)] \ . \tag{16}$$

Using $\pi^{B}_{F,L} - \pi^{NB}_{F,L} = \chi\Lambda(F+L)$ and (14) for $\mathrm{E}[V_F(F)] - \mathrm{E}[V_F(R)]$, yields:

$$\frac{\beta\gamma}{1-\beta}\Lambda(F+H) + \frac{1-\beta\gamma}{1-\beta}\Lambda(F+L) < \frac{\rho\widehat{W}}{\chi} \ , \tag{17}$$

as the condition for pooling when L is the initial state. For pooling to hold in both states, both (15) and (17) must hold. However, (17) is more stringent than (15), since $\Lambda(F+L) > \Lambda(F+H)$. Hence, (17) is the condition for an equilibrium at NB in this case.

(c) Equilibrium at NB when banks differ on full-information policy in state H. When state H is the initial state, type F's payoffs from selecting the policies B and NB in state H, respectively (and the policy NB in state L) are:

$$P^{B}_{F,H} = \pi^{B}_{F,H} + \beta\mathrm{E}[V_F(F)] \ , \qquad P^{NB}_{F,H} = \pi^{NB}_{F,H} + \beta\mathrm{E}[V_F(R)] \ , \tag{18}$$

where $\pi^{B}_{F,H} - \pi^{NB}_{F,H} = \chi\Lambda(F+H)$, and $\mathrm{E}[V_F(F)] - \mathrm{E}[V_F(R)]$, the additional cost incurred by type F by abstaining from borrowing in state H, is:

$$\mathrm{E}[V_F(F)] - \mathrm{E}[V_F(R)] = \frac{\chi\gamma}{1-\beta}\Lambda(F+H) \ . \tag{19}$$

Therefore, the condition for pooling in this case is:

$$\frac{1-\beta(1-\gamma)}{1-\beta}\Lambda(F+H) < \frac{\rho\widehat{W}}{\chi} \ , \tag{20}$$

Figure 2 summarizes the model's solution under both full and asymmetric information. In the chart, the policies chosen by types F and R for different ranges of $\overline{r}$ are plotted on the axes. Under full information, these ranges define the regions **(a)**-**(d)** characterized at the end of section 4 separated by dashed lines, with the surrounding dotted regions representing outcomes ruled out by the restrictions $\Lambda(R+H)=0$ and $\Lambda(F+L)>0$. Each possible configuration of the model's dynamic behavior is represented by a point in the interior of the chart. The equilibrium is a point on the diagonal from 0 to $\overline{r}$, since all banks face the same borrowing rate $\overline{r}$.

Type F's policies under asymmetric information are represented by the gray or white areas over the same parameter space. The impact of asymmetric information is thus represented by the overlap of the region where "F never borrows" under asymmetric information (the dark gray area) with the areas **(a)** and **(b)**, and by the overlap of the region where "F borrows only in state L" under asymmetric information (the light gray area) with region **(c)**. Lower values of ρ or $\widehat{W}$, or higher values of χ, would shift the left margins of both gray regions to the right.

6 Interpreting the results: The role of asymmetric information

6.1 Persistence of no-borrowing equilibria

Based on these results, we can address our initial question: How can imperfect information about banks' financial state explain the persistence of no-borrowing equilibria? As we argued in the Introduction, an explanation based on multiple equilibria — whereby banks are willing to turn to a lender of last resort only if, period by period, other banks are willing to do the same — fails to explain how no-borrowing equilibria can survive for as long as we see in reality.

The answer our model provides is that the type of equilibrium prevailing in period t determines the equilibrium prevailing in period $t+1$, with information on bank types acting as the only link between periods. That is, while two equilibria may be possible *a priori* in each period given the model's parameters (one equilibrium in which fragile banks use the emergency lending facility and one in which they don't), the choice between these two equilibria is resolved once the equilibrium prevailing in the previous period is known.

To illustrate the point, consider the case where an F bank borrows in both states if its type is known, but never borrows if its type is unknown *and* (17) holds (an equilibrium represented as a point in the grey section of area **(b)** in Figure 2.) In this case, if pooling at NB is the equilibrium policy in period t for F banks, no information is revealed on types, so that period $t+1$ inherits from period t the same information inherited by period t from period $t-1$. The same equilibrium then prevails at $t+1$, and so on. If, instead, types are known at the beginning of period t, then F types borrow in both states while R types do not, as all banks follow their full information policy. Types separate, full information on types is transmitted to the following periods, and the equilibrium where all banks borrow in accord with their full information policy persists. A similar result holds in cases **(a)** and **(c)**.

6.2 Average bank quality

Conditions (12), (17) and (20) can be solved as equalities to define values of the parameters that separate ranges for which history-dependent equilibria persist indefinitely from ranges for which they cannot be supported. While such critical values can be obtained for any parameter, the most interesting analysis is that of ρ, the inherited fraction of R banks in the anonymous pool.

To this end, let ρ^a, ρ^b and ρ^c be the values of ρ solving (12), (17), and (20) as equalities:

$$\rho^a = \frac{\chi}{\widehat{W}} \frac{(1-\beta\gamma)\Lambda(F+L)}{(1-\beta)} \ , \quad \rho^b = \frac{\chi}{\widehat{W}} [\frac{\beta\gamma\Lambda(F+H)}{1-\beta} + \frac{(1-\beta\gamma)\Lambda(F+L)}{1-\beta}] \ ,$$

$$\rho^c = \frac{\chi}{\widehat{W}} \frac{[1-\beta(1-\gamma)]\Lambda(F+H)}{(1-\beta)} \ . \tag{21}$$

Thus, for instance, if $\rho > \rho^b$ *and* types are unknown, then banks of type F follow the policy of types R, instead of their full information policy; if $\rho > \rho^b$ *and* types are publicly known, all types follow their full information policy; and if $\rho < \rho^b$, all types follow their full information policy irrespective of history. Similarly for ρ^a and ρ^c: only when anonymous banks are sufficiently likely to be of type R, it is optimal for F banks to abstain from borrowing to conceal their type, *if* they did so in the previous period.

The importance of the relation of ρ to its critical value may also be put in terms of the degree of public information on borrowers that would allow a lender of last resort to fulfill its purpose, i.e., to be used by "fragile" borrowers rather than falling into disuse? When anonymous borrowers are recognized as being of sufficiently low quality (that is, ρ falls below its critical values ρ^a, ρ^b, and ρ^c), they will always act in accord with their "fundamental" needs, and not abstain from borrowing to improve their reputation. That is, if the public is sufficiently convinced of the fragility of anonymous banks, anonymous banks that *are* fragile will not herd. Conversely, the more optimistic the common perception of anonymous banks is (*i.e.*, the higher ρ is), the greater is the scope for a lending facility to fall into disuse.

Comparison of ρ^a, ρ^b, and ρ^c highlights the model's predictions for the occurrence of history-dependent equilibria. First, $\rho^b > \rho^a$ and $\rho^b > \rho^c$: a lower fraction of robust banks in the anonymous pool is needed for history dependence in cases **(a)** and **(c)** (where type F needs to abstain from borrowing only in one state to reap the reputation benefits of pooling with R) than in case **(b)** (where type F has to abstain from borrowing in both states). Hence, the model predicts greater scope for history dependence when the full-information policies of banks of different types are relatively (but not completely) similar to each other. By contrast, the scope for history dependence is more limited when either: the difference between types is larger (case **(b)**), rasing the cost of deviating from the full information policy; the difference is so small that banks follow their full information policy anyway (case (**d**)).[8]

[8] The ranking between ρ^a and ρ^c depends on γ, the probability of state H: one can see that $\rho^c > \rho^a$ for values of γ above a threshold and *vice versa*. Intuitively, the scope for history-dependent equilibria is greater if banks behave more similarly in the more likely state, and more dissimilarly in the least likely state.

6.3 Interaction of banks' liquidity conditions

In our model, there is clearly *no* link between policies of different banks under full information. Under asymmetric information, however, changes in robust banks' liquidity (and hence optimal policy) may affect fragile banks, depending on whether or not fragile banks can afford to follow robust banks in their decision to forego emergency lending. This may be represented in our model by higher values of R and, graphically, by a downward shift of the horizontal dashed line in in Figure 2, reflecting decreased incentive of a robust bank to borrow in state L.

When the benefits to a fragile bank from borrowing from the facility are relatively small (for instance, because the penalty rate $\overline{r}$ is high, or the liquidity of fragile banks, F, is also high), then higher values of R cause emergency lending to collapse completely. That is, since type F mimics type R's policy in both states, if an increase in R shifts a robust bank to a policy of never borrowing (regions **(a)** and **(b)** expand), means that type F forgoes use of the facility as well (the dark gray area, representing F's optimal policy under asymmetric information expands as well).

Conversely, for low values of $\overline{r}$ or F, type F banks benefit too much from borrowing in state L, to be able to forego borrowing *also* in that state. Hence. if an improvement in the state of robust banks causes them to be more likely to forgo borrowing entirely, fragile banks to revert to their full-information policy of borrowing in both states. Then, if the probability of state L is sufficiently high, borrowing from the facility may actually increase when H rises.

7 Explaining Success and Failure of Lending Facilities

As noted in the Introduction, emergency lending facilities work reasonably well in some environments (e.g., in pre-EMU Germany, in the euro area, in the United States before the failure of Continental Illinois, etc.), even though they go unused in other environments featuring apparently similar operational arrangements. Our focus on the role of imperfect information about bank characteristics in explaining the failure of lender of last resort facilities then suggests the basic question: is the failure in some cases versus the success in others due primarily to "structural" differences other than the informational issues we have studied, or does history-dependent information across similar environments, as we have stressed, play an important role?

7.1 Why do lending facilities sometimes work?

There may be many differences in macroeconomic and financial structures explaining such different outcomes in the use of lending facilities. That is, even when the perceived quality of banks is the same in two environments, one environment may support only a full-information equilibrium with borrowing, while in the other, banks are trapped into a pooling equilibrium without borrowing.

To illustrate, consider two environments: one whose underlying parameters imply $\rho^{b'} < \rho$, thus supporting a history-dependent equilibrium, and the other where $\rho^{b''} > \rho$. Then, even if the perceived quality of banks in the two environments, ρ, is the same, the first environment's lender of last resort fails to achieve the full-information solution, while the latter environment's lender succeeds.

A key message of our analysis, however, is that one need not appeal to differences in parameters to explain differences in the performance of various lenders of last resorts: two environments with identical parameters may display different history-dependent equilibria, one with an active emergency lending facility, the other with a facility fallen into disuse. The only difference between such environments may be in the information provided by history, with fragile borrowers in the former environment having given up their attempt to act as more robust borrowers.

While these two explanations may appear as observationally equivalent, they are not. To see why, consider the latter explanation first — that inherited information plays a key role in determining success or failure of emergency lending mechanisms. Consider again an initial environment in which borrowers use the lending facility if types are known, but do not use it if types are unknown. In this environment, a shock that 'destroys' information about types (e.g., a macroeconomic shock affecting individual banks in a way unknown to the public), would cause a shift to an equilibrium without borrowing. In contrast, if parametric conditions are the main determinants of success or failure of lending mechanisms (e.g., parameters are such that banks would not borrow from the facility under any information set: $\rho^b \geq 1$), then the same shock would not lead to a persistent NB equilibrium: the equilibrium is robust to this type of shocks. That is, differences in underlying parameters not only affect the nature of the equilibrium, but also determine its robustness to certain types of shocks.

From this perspective, an appealing feature of our model is that it offers a possible interpretation of the demise of the U.S. discount window in the mid-1980s: the financial turmoil that ensued in 1984 caused the public to feel suddenly much less knowledgeable about the financial state of individual U.S. banks, leading to the entrenchment of reluctance to borrow among U.S. banks.

7.2 Fixing the broken window

Our model points to ingredients of the Fed's reform of the discount window in January 2003 that may have enhanced the history-dependence of the equilibrium in the U.S. market. At that time, the Fed implemented two major changes to its program for liquidity provision to individual banks: it lifted all restrictions on banks' ability to borrow (other than posting of adequate collateral), and raised the rate charged on loans, from a below-market to a penalty level.[9]

The Fed expected the new primary lending program to be more appealing to banks, by virtue of its unrestricted terms. Yet, as noted in Section 2, U.S. banks have remained reluctant to turn to the Fed for liquidity support in response to shocks. Our model suggests that the higher rate $\overline{r}$ charged by the Fed may have acted as a stronger deterrent to borrowing than it might have been expected.

To see this, note that (21) implies that the critical values ρ^a, ρ^b and ρ^c fall with $\overline{r}$: higher values of $\overline{r}$ make history-dependent equilibria more likely, by lowering the minimum fraction of R banks in the anonymous pool needed to support a pooling equilibrium. This is a sensible prediction: A rise in $\overline{r}$ lowers b^*, the optimal amount borrowed at the facility, lowering the value of a visit to the facility. This makes it easier for fragile banks to forego borrowing to earn a reputation for being robust.

The implication is that asymmetric information amplifies the effects of changes in $\overline{r}$: under full information, the only effect of a higher $\overline{r}$ is through a reduction in the amount borrowed, b^*. With asymmetric information, fragile banks also reduce the frequency of their visits to the facility. When the lending rate is sufficiently high, emergency borrowing stops completely, even in cases where banks would have borrowed positive amounts under full information. The analysis also suggests that a more effective reform of the window might have involved, first, relaxation of rationing and other restrictions, followed by a shift to penalty lending only *after* "normal" (i.e., full-information) borrowing behavior had become entrenched among U.S. banks.

[9] Historically, emergency lending has often been rationed, reflecting (implicit or explicit) subsidies often associated with such loans. Such practice was common in industrial countries until discount lending entered its demise stage in the 1990s (Borio [1997]; Prati and Schinasi [1999]). In Appendix A we analyze the case of rationed lending, assuming banks to be unable to borrow in any two consecutive periods. This rule mimics historical discount window rules, according to which "a bank shall not be empowered to draw on its basic borrowing privilege if such borrowing would cause to be indebted ... in more than 6-13 out of the last 13-26 reserve periods" (Board of Governors, [1971, p.10]). The key results from our benchmark model are qualitatively unchanged.

7.3 Is failure of lending mechanisms likely?

Is there good reason to argue that informational differences, rather than simply structural differences, are important in explaining persistent no borrowing equilibria? We think so. Unobservable information on the financial condition of borrowers (banks, countries, etc.) is crucial to both investors and the general public, and this is well known to potential borrowers. Hence, any environment in which there is reason to suspect that market participants feel uniformed about borrower quality and hence are especially sensitive to any action that might reveal information would be one in which our argument about why lending facilities fail may be quite relevant. Such an environment may be due to a shock which calls into question the state of borrowers, as in the U.S. in the mid 1980s. Moreover, as the previous discussion indicates, moving to a system with a penalty rate may only exacerbate the problem.

We would go one step further. Not only are the informational problems we highlight an important explanation of hte failure of emergency lending mechanisms, but also are likely to be common, so observing persistent no borrowing equilibria should not be surprising. There are two reasons for this. First, large shocks to a financial system that destroys information about the quality of financial intermediaries are not everyday occurrences, but are not extremely rare events either. Since financial crises both destroy information about the quality of intermediaries and make such information especially valuable, the persistent lack of borrowing that may result may often follow such shocks.

Moreover, an environment in which market participants are espcially sensitive to information about quality may reflect a situation to which the emergency lending facility is the *response*, as in the case of the IMF's Contingent Credit Line, discussed in section 2.2. This latter case is of course not uncommon, as section 2.3 documents, since a rational government response to bank distress (or IMF response to country distress) is to set up an emergency lending facility. Our analysis suggests that such a response is probably likely to fail since the conditions that lead to setting up the facility are those that imply that it will probably not be used.

8 Conclusions

Lenders of last resort have fallen on hard times. Lending facilities operated by the world's two main lenders of last resort — the Federal Reserve in a domestic context, and the IMF in a sovereign context — have been recently shut down, adding to the disappointing performance of many related arrangements for liquidity support of individual borrowers around the world.

This paper provides a model of why emergency lending mechanisms often fail to achieve their goal of supporting illiquid borrowers: potential users are reluctant to seek support when they need it, fearing that doing so might be viewed as a signal of financial weakness. They would be willing to turn to a lender of last resort if others did the same at the same time, but being alone in seeking support carries a costly stigma.

Albeit intuitive, the multiple-equilibrium view suggested by this argument does not explain how and why equilibria (with or without borrowing) can survive for as long as we see in reality. If equilibrium selection depended only on coordination of behavior among borrowers, jumps between equilibria would be the rule, rather than the exception. Persistent disuse of lending facilities undermines the applicability of models with multiple equilibria, pointing instead to the presence of a causal link between equilibria at different points in time. Our analysis suggests that information available from previous periods on borrowers' characteristics plays an important role in determining which equilibrium prevails at any point in time. When little information is available on individual borrowers, and there are enough "robust" borrowers in the economy, "fragile" borrowers have an incentive to act as if they were robust, and borrowing from a lending facility dries up. This behavior suppresses the role of the lending facility as a sorting device and — as a result — is transmitted from period to period.

Our model captures these ideas in the simplest possible way. The cost of such simplification includes some overly stylized predictions, pointing to items for future research. Among these, it would be useful to extend our analysis to allow for time-variation of "types," leading to a more realistic analysis of how information on borrowers accumulates and evaporates over time: in our model, once a state of nature is reached where separation prevails, types become publicly known and remain so forever. Were types not fully persistent, the inference problem faced by the market would be more complicated, but the problem of turning to lenders of last resort being seen as a sign of fragility would still be present.

Figure 1. Discount borrowing and the federal funds - discount rate spread

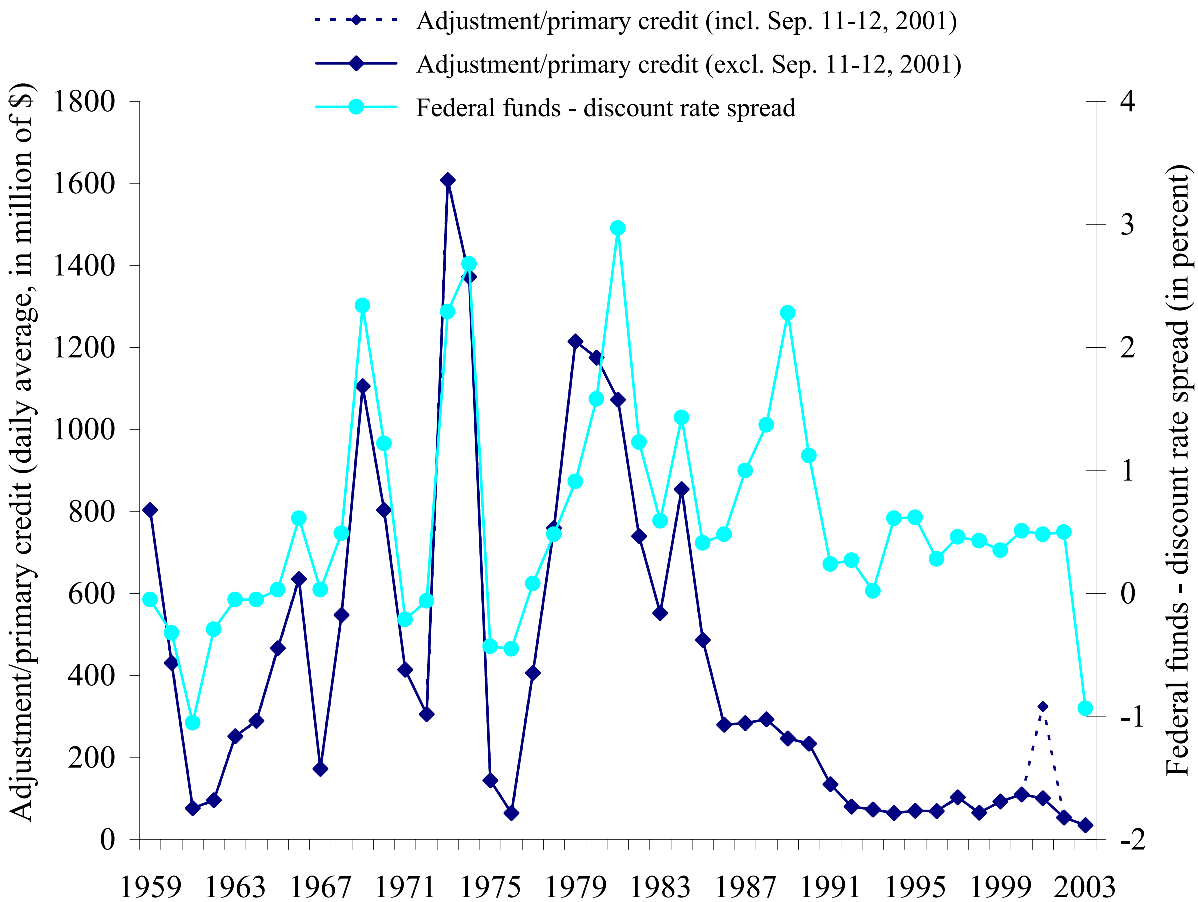

Figure 2. Equilibrium under full and asymmetric information

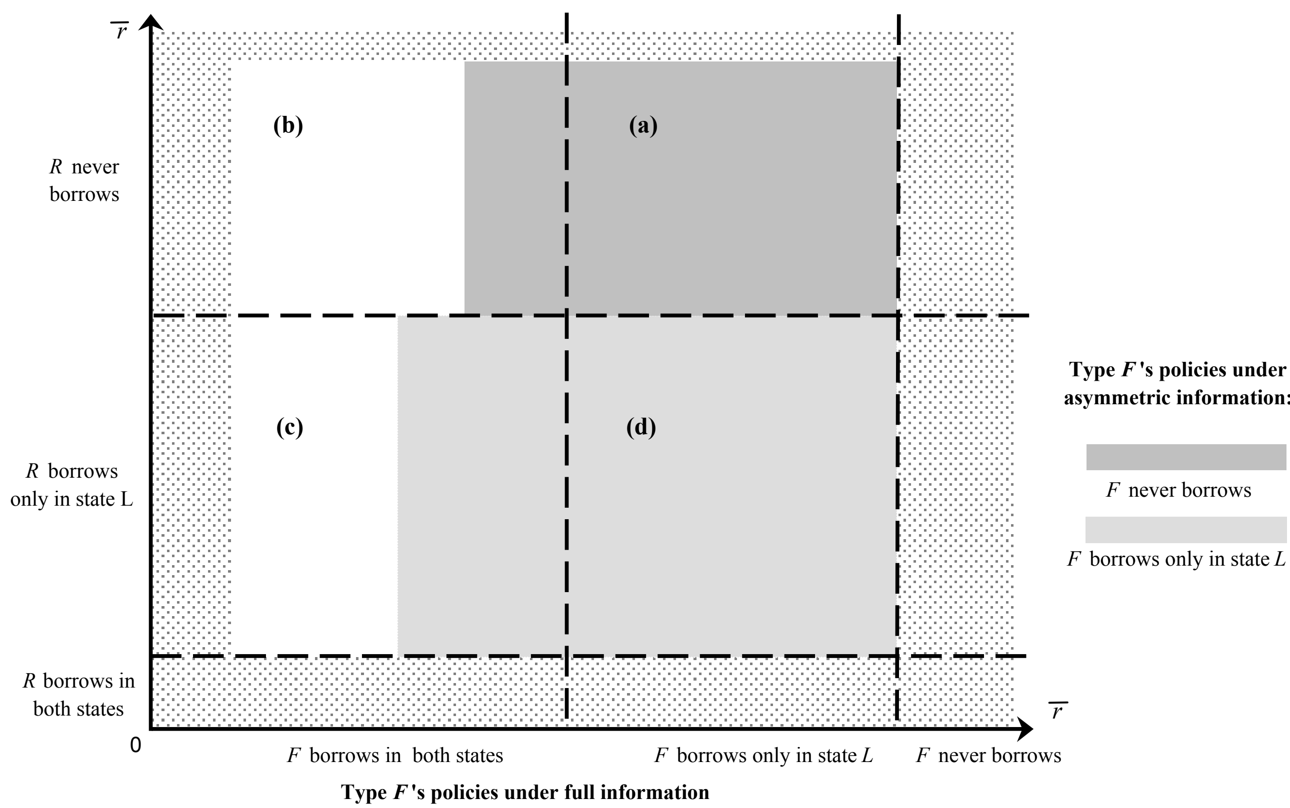

Table 1. The behavior of U.S. banks at the discount window

		Yearly # of visits	Average borrowing per visit (1,000 of US$)
All banks	Full sample	2.59	113045
	Early sample	5.22	105999
	Late sample	1.46	123883
Large banks	Full sample	2.63	220860
	Early sample	6.48	170160
	Late sample	0.98	364820
Small banks	Full sample	2.55	1489
	Early sample	3.96	1064
	Late sample	1.94	1862

Appendices

A Emergency lending with rationing

A key feature of many emergency lending facilities (including the U.S. Discount Window prior to 2003) was that borrowing is rationed. In this Appendix we consider the case of rationed borrowing, where rationing takes the form of prohibiting a bank from borrowing in any two consecutive periods. We define as "Open" (identified by a superscript O) a bank that can borrow at t because it did not borrow at $t-1$, and as "Closed" (identified by a superscript C) a bank that cannot borrow at t because it borrowed at $t-1$. The payoffs to borrowing and not borrowing in state S_t for a bank known to be of type T are:

$$P^B_{T,S_t} = \pi^B_{T,S_t} + \beta \mathrm{E}[V^C_T] \ , \quad P^{NB}_{T,S_t} = \pi^{NB}_{T,S_t} + \beta \mathrm{E}[V^O_T] \ , \tag{A}$$

where $\mathrm{E}[V^C_T]$ and $\mathrm{E}[V^O_T]$ are the expected values for type T of being closed and open, respectively, in the next period. Using (8), $P^B_{T,S_t} > P^{NB}_{T,S_t}$ when:

$$\chi \cdot \Lambda(T + S_t) > \beta(\mathrm{E}[V^O_T] - \mathrm{E}[V^C_T]) \ , \tag{22}$$

where

$$\mathrm{E}[V^C_T] = \gamma \pi^{NB}_{T,Y} + (1-\gamma)\pi^{NB}_{T,Z} + \beta \mathrm{E}[V^O_T] \ , \tag{23}$$

since a bank that is closed at $t+1$ is open at $t+2$. Also, if T borrows only in state L,

$$\mathrm{E}[V^O_T] = \gamma(\pi^{NB}_{T,H} + \beta E[V^O_T]) + (1-\gamma)(\pi^B_{T,L} + \beta \mathrm{E}[V^C_T]) \ . \tag{24}$$

Subtracting (23) from (24) and using (8) yields:

$$\mathrm{E}[V^O_T] - \mathrm{E}[V^C_T] = \frac{1-\gamma}{1+\beta(1-\gamma)} \chi \cdot \Lambda(T+L) \ , \tag{25}$$

where $\Lambda(T+L)$ is obtained as in Section 4. Combining this with (22) (evaluated at $S_t = H$), and breaking ties in favor of no borrowing, T borrows only in state L if:

$$\frac{\Lambda(T+H)}{\Lambda(T+L)} \leq \frac{\beta(1-\gamma)}{1+\beta(1-\gamma)} \ . \tag{26}$$

If, instead, T borrows in both states:

$$E[V^O_T] = \gamma(\pi^B_{T,H} + \beta \mathrm{E}[V^C_T]) + (1-\gamma)(\pi^B_{T,L} + \beta \mathrm{E}[V^C_T]) \ . \tag{27}$$

Subtracting (23) from (27):

$$\mathrm{E}[V^O_T] - \mathrm{E}[V^C_T] = \frac{1}{1+\beta}[\gamma \Lambda(T+H) + (1-\gamma)\Lambda(T+L)]\chi \ . \tag{28}$$

Combining this with (22) (evaluated at $S_t = H$), type T borrows in both states if:

$$\frac{\Lambda(T+H)}{\Lambda(T+L)} > \frac{\beta(1-\gamma)}{1+\beta(1-\gamma)} \ . \tag{29}$$

The remaining conditions are those for a bank never to borrow, $\Lambda(T+L) = 0$, and for a bank to borrow only in state H, which never holds.[10] Under the same restrictions on parameter values of Section 4 ($\Lambda(R+H) = 0$ and $\Lambda(F+L) > 0$), and defining $\kappa = \frac{\beta(1-\gamma)}{1+\beta(1-\gamma)}$, $1 > \kappa > 0$, the conditions describing the model's dynamics under full information *and* rationing are:

(a') Type F borrows only in state L, type R never borrows: $\kappa \geq \frac{\Lambda(F+H)}{\Lambda(F+L)}$, $0 = \Lambda(R+L)$;

(b') Type F borrows in both states, type R never borrows: $\kappa < \frac{\Lambda(F+H)}{\Lambda(F+L)}$, $0 = \Lambda(R+L)$;

(c') Type F borrows in both states, type R borrows only in state L: $\kappa < \frac{\Lambda(F+H)}{\Lambda(F+L)}$, $0 < \Lambda(R+L)$;

(d') Both types borrow only in state L: $\kappa \geq \frac{\Lambda(F+H)}{\Lambda(F+L)}$, $0 < \Lambda(R+L)$;

Compared with **(a)-(d),** conditions **(a')-(d')** incorporate the option value of borrowing from the lending facility in state H at t, which may prevent the bank from borrowing in the more urgent state L at $t+1$. Thus, a bank borrows in state H (if open) only if $\Lambda(T+H) > \kappa\Lambda(T+L)$: the benefit of borrowing in state H must be sufficiently close to that of borrowing in state L for the bank to exercise its option to borrow in H.

To analyze how asymmetric information alters these conditions, we first use tools from the analysis of Markov chains to calculate the expected discounted payoffs for type F of following its three possible policies under rationing. We represent the state space in terms of *four* states: H^O, H^C, L^O, and L^C, with superscripts O and C describing open and closed banks, respectively.

(i) Expected costs when borrowing neither in state L nor in state H. In this case, the probability of going from any state to a closed state is zero, while the probabilities of going from any state to H^O and L^O are γ and $1-\gamma$, respectively. Ordering states as $\{H^O, H^C, L^O, L^C\}$, the resulting transition matrix and single-period payoffs are:

$$A^i = \begin{bmatrix} \gamma & 0 & 1-\gamma & 0 \\ \gamma & 0 & 1-\gamma & 0 \\ \gamma & 0 & 1-\gamma & 0 \\ \gamma & 0 & 1-\gamma & 0 \end{bmatrix}, \quad \Pi^i = \begin{bmatrix} \pi^{NB}_{F,H} \\ \pi^{NB}_{F,H} \\ \pi^{NB}_{F,L} \\ \pi^{NB}_{F,L} \end{bmatrix},$$

[10] To see this, switch H and L and, correspondingly, γ and $1-\gamma$, in (26), so that type F borrows in H but not in L if $\frac{\Delta(T+H)}{\Delta(T+L)} > \frac{1+\beta\gamma}{\beta\gamma}$. However, this condition can never hold, since $\Delta(T+H) < \Delta(T+L)$.

where the rows and columns of A^i identify initial and final states, respectively, and the elements of Π^i are defined by (6) and (7). This transition matrix yields the probabilities of being in each state at $t+\tau$ as $(A^i)^\tau$. The present discounted payoff associated with this chain is, then, $I \cdot \Pi^i + A^i \beta \Pi^i + (A^i)^2 \beta^2 \Pi^i + ... = (I - \beta A^i)^{-1} \Pi^i$. Therefore,

$$\begin{bmatrix} \pi^{NB}_{F,H} + \beta \mathrm{E}[V^O_F(R)] \\ \pi^{NB}_{F,H} + \beta \mathrm{E}[V^O_F(R)] \\ \pi^{NB}_{F,L} + \beta \mathrm{E}[V^O_F(R)] \\ \pi^{NB}_{F,L} + \beta \mathrm{E}[V^O_F(R)] \end{bmatrix} = (I - \beta A^i)^{-1} \Pi^i = \begin{bmatrix} \frac{1-\beta(1-\gamma)}{1-\beta} & 0 & \frac{\beta(1-\gamma)}{1-\beta} & 0 \\ \frac{\beta\gamma}{1-\beta} & 1 & \frac{\beta(1-\gamma)}{1-\beta} & 0 \\ \frac{\beta\gamma}{1-\beta} & 0 & \frac{1-\beta\gamma}{1-\beta} & 0 \\ \frac{\beta\gamma}{1-\beta} & 0 & \frac{\beta(1-\gamma)}{1-\beta} & 1 \end{bmatrix} \Pi^i \ .$$

(ii) Expected costs when borrowing only in state L. Now the transition matrix and single-period payoffs are:

$$A^{ii} = \begin{bmatrix} \gamma & 0 & 1-\gamma & 0 \\ \gamma & 0 & 1-\gamma & 0 \\ 0 & \gamma & 0 & 1-\gamma \\ \gamma & 0 & 1-\gamma & 0 \end{bmatrix}, \quad \Pi^{ii} = \begin{bmatrix} \pi^{NB}_{F,H} \\ \pi^{NB}_{F,H} \\ \pi^{B}_{F,L} \\ \pi^{NB}_{F,L} \end{bmatrix},$$

so that:

$$\begin{bmatrix} \pi^{NB}_{F,H} + \beta \mathrm{E}[V^O_F(R)] \\ \pi^{NB}_{F,H} + \beta \mathrm{E}[V^O_F(R)] \\ \pi^{B}_{F,L} + \beta \mathrm{E}[V^C_F(R)] \\ \pi^{NB}_{F,L} + \beta \mathrm{E}[V^O_F(R)] \end{bmatrix} = (I - \beta A^{ii})^{-1} \Pi^{ii} =$$

$$\begin{bmatrix} \frac{1-\beta^2(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta^2\gamma(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta^2(1-\gamma)^2}{(1-\beta)(1+\beta(1-\gamma))} \\ \frac{\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))} & \frac{1-\beta^2(1-\gamma)^2-\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta^2(1-2\gamma+\gamma^2)}{(1-\beta)(1+\beta(1-\gamma))} \\ \frac{\beta^2\gamma}{(1-\beta)(1+\beta(1-\gamma))} & \frac{(1-\beta\gamma)\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))} & \frac{1-\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))} & \frac{(1-\beta\gamma)\beta(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} \\ \frac{\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta^2\gamma(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} & \frac{\beta(1-\gamma)}{(1-\beta)(1+\beta(1-\gamma))} & \frac{1-\beta^2\gamma+\beta^2\gamma^2-\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))} \end{bmatrix} \Pi^{ii} \ .$$

(iii) Expected costs when borrowing in both states. The transition matrix and single-period payoffs are:

$$A^{iii} = \begin{bmatrix} 0 & \gamma & 0 & 1-\gamma \\ \gamma & 0 & 1-\gamma & 0 \\ 0 & \gamma & 0 & 1-\gamma \\ \gamma & 0 & 1-\gamma & 0 \end{bmatrix}, \quad \Pi^{iii} = \begin{bmatrix} \pi^{B}_{F,H} \\ \pi^{NB}_{F,H} \\ \pi^{B}_{F,L} \\ \pi^{NB}_{F,L} \end{bmatrix},$$

from which:

$$\begin{bmatrix} \pi^{B}_{F,H} + \beta \mathrm{E}[V^C_F(R)] \\ \pi^{NB}_{F,H} + \beta \mathrm{E}[V^O_F(R)] \\ \pi^{B}_{F,L} + \beta \mathrm{E}[V^C_F(R)] \\ \pi^{NB}_{F,L} + \beta \mathrm{E}[V^O_F(R)] \end{bmatrix} = (I - \beta A^{iii})^{-1} \Pi^{iii} = \begin{bmatrix} \frac{1-\beta^2(1-\gamma)}{1-\beta^2} & \frac{\beta\gamma}{1-\beta^2} & \frac{\beta^2(1-\gamma)}{1-\beta^2} & \frac{\beta(1-\gamma)}{1-\beta^2} \\ \frac{\beta\gamma}{1-\beta^2} & \frac{1-\beta^2(1-\gamma)}{1-\beta^2} & \frac{\beta(1-\gamma)}{1-\beta^2} & \frac{\beta^2(1-\gamma)}{1-\beta^2} \\ \frac{\beta^2\gamma}{1-\beta^2} & \frac{\beta\gamma}{1-\beta^2} & \frac{1-\beta^2\gamma}{1-\beta^2} & \frac{\beta(1-\gamma)}{1-\beta^2} \\ \frac{\beta\gamma}{1-\beta^2} & \frac{\beta^2\gamma}{1-\beta^2} & \frac{\beta(1-\gamma)}{1-\beta^2} & \frac{1-\beta^2\gamma}{1-\beta^2} \end{bmatrix} \Pi^{iii}.$$

(a') Equilibrium at *NB* when banks differ on full-information policy in state L. The payoff differential to borrowing and not borrowing in state L for type F is

$$P^B_{F,L} - P^{NB}_{F,L} = \pi^B_{F,L} - \pi^{NB}_{F,L} + \beta(\mathrm{E}[V^C_F(F)] - \mathrm{E}[V^O_F(R)]) \ . \tag{30}$$

To obtain $\pi^B_{F,L} - \pi^{NB}_{F,L} + \beta(\mathrm{E}[V^O_F(F)] + \beta\mathrm{E}[V^C_F(R)])$, subtract the third row of $(I - \beta A^i)^{-1}\Pi^i$, the payoff for type F from borrowing in no state, from the third row of $(I - \beta A^{ii})^{-1}\Pi^{ii}$, the payoff fortype F from borrowing in state L, in both cases using L as the initial state:

$$\pi^B_{F,L} - \pi^{NB}_{F,L} + \beta(\mathrm{E}[V^C_F(F)] - \mathrm{E}[V^O_F(R)]) = \frac{1-\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))}\chi \cdot \Lambda(F+L) \ , \tag{31}$$

Therefore, the condition for pooling over this parametric region is

$$\frac{1-\beta\gamma}{(1-\beta)(1+\beta(1-\gamma))}\Lambda(F+L) < \frac{\rho\widehat{W}}{\chi} \ . \tag{32}$$

(b') Equilibrium at *NB* when banks differ on full-information policy in both states. As in Section 5, the tightest condition for pooling in this case holds in state L, where

$$P^B_{F,L} - P^{NB}_{F,L} = \pi^B_{F,L} - \pi^{NB}_{F,L} + \beta(\mathrm{E}[V^C_F(F)] - \mathrm{E}[V^O_F(R)]) \ . \tag{33}$$

Subtracting the third row of $(I - \beta A^i)^{-1}\Pi^i$ from the third row of $(I - \beta A^{iii})^{-1}\Pi^{iii}$,

$$\pi^B_{F,L} - \pi^{NB}_{F,L} + \beta(\mathrm{E}[V^C_F(F)] - \mathrm{E}[V^O_F(R)]) = \frac{\beta^2\gamma}{1-\beta^2}\chi \cdot \Lambda(F+H) + \frac{1-\beta^2\gamma}{1-\beta^2}\chi \cdot \Lambda(F+L) \ . \tag{34}$$

Therefore, the condition for pooling in this case is

$$\frac{\beta^2\gamma}{1-\beta^2}\Lambda(F+H) + \frac{1-\beta^2\gamma}{1-\beta^2}\Lambda(F+L) < \frac{\rho\widehat{W}}{\chi} \ . \tag{35}$$

(c') Equilibrium at *NB* when banks differ on full-information policy in state H. In this case,

$$P^B_{F,H} - P^{NB}_{F,H} = \pi^B_{F,H} - \pi^{NB}_{F,H} + \beta(\mathrm{E}[V^C_F(F)] - \mathrm{E}[V^O_F(R)]) \ . \tag{36}$$

Subtracting the third row of $(I - \beta A^{ii})^{-1}\Pi^{ii}$ from the third row of $(I - \beta A^{iii})^{-1}\Pi^{iii}$,

$$\begin{aligned}\pi^B_{F,H} - \pi^{NB}_{F,H} + \beta(\mathrm{E}[V^C_F(F)] - \mathrm{E}[V^O_F(R)]) \quad &= \quad \frac{1-\beta^2(1-\gamma)}{1-\beta^2}\chi \cdot \Lambda(F+H) \\ &\quad - \frac{\beta(1-\gamma)[1-\beta^2(1-\gamma)]}{(1-\beta)[1+\beta(1-\gamma)]}\chi \cdot \Lambda(F+L).\end{aligned} \tag{37}$$

Therefore, the condition for pooling in this case is

$$\frac{1-\beta^2(1-\gamma)}{1-\beta^2}\Lambda(F+H) - \frac{\beta(1-\gamma)[1-\beta^2(1-\gamma)]}{(1-\beta)[1+\beta(1-\gamma)]}\Lambda(F+L) < \frac{\rho\widehat{W}}{\chi} \ . \tag{38}$$

B The impossibility of partially revealing equilibria

We stated in the text that the only equilibria we need to consider are those with either complete pooling or complete separation. To verify this claim, we now show that there cannot be equilibria in which two groups of banks coexist, each containing a strictly positive mass of both F and R types, one group choosing to borrow, the other choosing not to borrow.

Suppose there is such an equilibrium: at time t, banks separate into two sub-groups, with a fraction ρ^{B} $(\rho > \rho^{B} > 0)$ of banks of type R in the group that borrows and a fraction $\rho^{NB} = \rho - \rho^{B}$ of banks of type R in the group that does *not* borrow.

Consider first a state in which the two types differ in their full-information policy: under full information, type F would borrow in this state, while type R would not. Then, if $\rho^{B}\geqslant \rho^{B}$, all types F that borrow would like to switch policy, since borrowing is preferred under full information and allows them to join a group of average higher quality. For the same reason, if $\rho^{B}< \rho^{NB}$, then all types R that borrow would like to switch policy and not borrow. Hence, no value of ρ^{B} and ρ^{NB} in the interior of $[0,\rho]$ can be supported in equilibrium.

Consider next a state in which types have the same full-information policy, say they both prefer to borrow. If $\rho^{B} \geqslant \rho^{NB}$, then any bank that does not borrow would like to switch to borrowing, since this policy is both preferred under full information and yields better reputation. If $\rho^{B} < \rho^{NB}$ instead, a bank may be in equilibrium with its current policy (either B or NB) if the higher reputation of the group that does not borrow exactly offsets banks' full-information preference for borrowing. Now, while there exist pairs $\{\rho^{B},\ \rho^{NB}\}$ for which B and NB are equivalent for *either* R *or* F, both types cannot generically be indifferent between B and NB for the same pair. In case **(a)**, indifference for both types requires:

$$\frac{(1-\beta\gamma)\Lambda(R+L)}{(1-\beta)} = \frac{(\rho^{NB}-\rho^{B})\widehat{W}}{\chi} = \frac{(1-\beta\gamma)\Lambda(F+L)}{(1-\beta)} \ ,$$

which cannot hold since $\Lambda(R+L) < \Lambda(F+L)$. In case **(c),** indifference for both types requires:

$$\frac{1-\beta(1-\gamma)}{1-\beta}\Lambda(R+H) = \frac{(\rho^{NB}-\rho^{B})\widehat{W}}{\chi} = \frac{1-\beta(1-\gamma)}{1-\beta}\Lambda(F+H) \ ,$$

which cannot hold since $\Lambda(R+H) < \Lambda(F+H)$. In case **(b)**, indifference for both types requires:

$$\frac{\beta\gamma}{1-\beta}\Lambda(R+H) + \frac{1-\beta\gamma}{1-\beta}\Lambda(R+L) = \frac{(\rho^{NB}-\rho^{B})\widehat{W}}{\chi} = \frac{\beta\gamma}{1-\beta}\Lambda(F+H) + \frac{1-\beta\gamma}{1-\beta}\Lambda(F+L) \ ,$$

which allows for at most a single pair $\{R,\ F\}$, of measure zero over the parameter space, for which two pools of different average quality can coexist. Hence, no value of ρ^{B} and ρ^{NB} in the interior of $[0,\rho]$ can be generically supported in equilibrium.

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