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Skill, Luck and Financial Crises

by

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Abstract

This paper explains why crises follow periods of sustained banking profitability in an environment in which there is uncertainty about whether outcomes depend on the risk-management skills of banks or are just based on luck, in the spirit of Piketty's (1995) model of "left-wing" and "right-wing" dynasties. Periods of sustained banking profitability cause *all* agents to elevate their estimates of bankers' skills, despite the uncertainty about what is driving outcomes. Everybody consequently becomes sanguine about bank risk, and banks choose increasingly risky assets. The consequent increased liquidity attracts additional institutions to invest. Since banks fund themselves by borrowing from institutional investors who choose not to incur the cost to learn whether outcomes are skill-based or luck-based, the elevated perceptions of banking skills permit investment risk to continue to climb, and there are no financial crises. However, the emergence of a credit default swap (CDS) market on the bank's debt leads to price discovery through the actions of traders who can profitably become informed about the macro state pertaining to whether outcomes are due to skill or luck. This may induce the bank's creditors to infer a high probability that outcomes are based only on luck. This leads them to refuse to roll over short-term debt, and there is a positive probability of this occurring to enough banks to precipitate a crisis. In the absence of a CDS market, crises can still occur if agents can costlessly observe the occurrence of the macro state. Regulatory implications of the analysis are extracted.

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Skill, Luck and Financial Crises

I. INTRODUCTION

Financial crises have occurred throughout history (see Kindleberger (1978)). And because they have significant real consequences (see Boyd, Kwak and Smith (2005), and Reinhart and Rogoff (2008)), they are a compelling phenomenon to study. But no crisis since the Great Depression has stirred the cauldron of ideas as vigorously as the recent sub-prime crisis. Perhaps because of the unfamiliar nature of the transmission mechanisms by which it spread and the surprising suddenness with which it deepened, this crisis has caused many to question the very foundations of economic models (e.g. Cabellero (2010)).

As was the case with previous crises like the S&L crisis, the prevailing wisdom appears to be that this crisis was caused by misaligned incentives at many levels.[1] Financial institutions took excessive risks, especially socially-inefficient tail risks, because *de jure* safety-net protection via deposit insurance and *de facto* safety-net protection due to regulatory reluctance to allow large and interconnected financial institutions to fail (e.g. Bebchuk and Fried (2010), Litan and Bailey (2009), and Farhi and Tirole (2012)). Such risk-taking was permitted due to tax oversight by regulators (e.g. Barth, Caprio and Levine (2012)), whose incentives were not aligned with those of the taxpayers,[2] and facilitated by misguided politicians whose ever-zealous embrace of unregulated markets blocked regulation (e.g. Stiglitz (2010)). Indeed, this is also the principal theme in the report of the U.S. government's *Financial Crisis Inquiry Commission* (FCIC), which reviewed millions of pages of documents, interviewed more than 700 witnesses and held 19 days of public hearings.[3]

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[1] The reliance on moral hazard to explain financial crises is a recurring theme. For example, the savings and loan (S&L) crisis in the 1980s was preceded by explosive growth in S&L balance sheets and what has been characterized as excessive term-structure and credit risk that then led to the implosion of the industry. Much blame was placed in that crisis too on "greedy bankers" who supposedly exploited the government safety net and regulators who let them (e.g. Kane (1990)).

[2] This is similar to the incentive conflicts between regulators and taxpayers discussed informally by Kane (1990), and analyzed formally in a career-concerns setting by Boot and Thakor (1993).

[3] The report claims that industry players and government regulators saw warning signs of the impending crisis, but chose to ignore them. It blames the Federal Reserve for being too supportive of industry growth objectives (e.g., Federal Reserve governor Edward Gramlich, in 2004, "We want to encourage growth in the subprime lending market"). The report also criticizes credit rating agencies as well as "More than 30 years of deregulation and reliance on self-regulation by financial institutions, …"

While misaligned incentives may have played an important role in previous crises as well as the subprime crisis, they do *not* tell the whole story ─ much of the soul-searching generated by the recent crisis is due to the many perplexing stylized facts that are difficult to square with existing theories, including those based on incentive misalignment.[4] First, the frequency of crises has been increasing over time (e.g. Reinhart and Rogoff (2008)) despite the emergence of markets in derivatives (e.g. credit default swaps) that are designed to help investors and institutions manage risks better. Second, the system was flush with liquidity prior to the onset of the subprime crisis, but then liquidity seemed to dry up quickly. Third, as pointed out by Lo (2012), neither abnormally high leverage ratios in financial institutions nor incentive distortions attributable to executive compensation in banks provide a good explanation for the subprime crisis. Fourth, the recent crisis followed a longer period of high profitability and growth for the financial sector, and during those good times there was little warning of the onset and severity of the crisis from any of the so-called "watch dogs" of the financial system ─ rating agencies, regulators and creditors of financial institutions ─ who exhibited no public objection to the portfolio choices of financial institutions. While one can perhaps rationalize the behavior of rating agencies and regulators based on incentive conflicts, it is more difficult to explain why investors seemed unconcerned about the increase in banking risk and the yields on bank debt did not reflect heightened risk concerns.[5] Moreover, despite all the post-crisis outcries about the underpricing of risk and incentive conflicts, *before* the crisis there was little discussion that pointed to the ubiquity of elevated risk-taking and the complicity of regulators, and the manner in which these would lead to a crisis of this magnitude. In fact, it is easy to find evidence to the contrary. During 2004-07, the period leading right up to the crisis, the IMF reported that individual financial institutions were sound. The *Independent Evaluation Office (IEO) of the IMF* (2011) recently criticized the IMF for this, saying: "It finds that the IMF provided few clear warnings about the risks and vulnerabilities associated with the impending crisis before its outbreak." The report further states: "The banner message was one of the continued optimism after more than a decade of benign economic conditions and low macroeconomic volatility…The belief that financial markets were sound and that large financial institutions could weather any likely problem lessened the sense of urgency to address risks or to worry about the possible severe adverse outcomes."

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[4] The idea of misaligned incentives is also not easy to square with theories of financial intermediation (e.g. Coval and Thakor (2005) and Ramakrishnan and Thakor (1984)) in which intermediaries exist because they overcome contracting and incentive frictions, unless one is willing to put all of the blame for incentive problems on *de jure* government safety nets, something that would be rather tenuous to rely on for the shadow banking system, where the recent crisis originated.

[5] However, as Lo (2012) points out, yields in the markets for derivatives on bank debt reflected substantially higher risk than those in the primary bank debt market did.

These puzzling stylized facts lead to important questions that this paper seeks to address: Why do financial crises occur, why do they typically follow economic booms, why has the frequency of crises risen over time, and why does risk-taking tend to be "underpriced" by all concerned – banks, regulators and investors – prior to the beginning of crises?

As an alternative to the misaligned-incentives hypothesis, I address these questions by developing a theory in which crises are caused by rational learning; the contrast between this theory and misaligned incentives is presented later. The basic version of the model has there key building blocks. The first is that banks can choose between a relatively safe loan and a potentially more profitable risky loan. The probability of success (repayment) on the loan depends on the realization of a macroeconomic state: there is a high probability of a "skill" macroeconomic state in which outcomes are influenced by the *a priori* unknown skills of banks and a small probability of a "luck" macroeconomic state in which these outcomes are purely exogenous.[6] No one knows at the outset which state governs the economy, but there are common prior beliefs about the probabilities of the luck and skill states. If outcomes are driven only by luck, then banks prefer to invest in (and can raise financing for) only safe loans. If outcomes are skill-driven, banks will prefer to and be able to fund more profitable risky loans if these banks are viewed as being skilled enough. This building block generates a setting in which banks initially invest in safe loans, and after experiencing successful repayment on these loans they switch to more risky loans, conditional on agents believing that outcomes depend on bankers' skills. That is, initial success leads to an upward revision in the skills of bankers via rational learning and these higher skill assessments enable them to switch to riskier loans.

By itself, this building block does *not* lead to a financial crisis. Two more features are needed. The second building block is that there are multiple time periods and the realization of the macro uncertainty can change from one period to the next. That is, conditional on initial success with loan repayment and agents believing that the success was skill-driven, banks are able to invest in riskier loans. However, if beliefs about whether outcomes are skill-driven or luck-driven remain intertemporally static, then investors will always continue to fund successful banks and risk-taking will keep rising with no financial crisis. It is only when beliefs can switch from a skill regime to a luck regime that previously-sanctioned risk taking can fall out of favor with investors.

[6] An alternative interpretation is that there are two systematic risk regimes: high risk and low risk. In the high risk regime, default risk is deemed to be so high that investors will fund only low-risk loans even if banks are viewed as being highly skilled, whereas in the low-risk regime, riskier loans are funded if the bank is viewed as being skilled enough.

While adding this second building block is necessary, it is not enough to generate a crisis. The reason is that if agents shift their beliefs about whether outcomes are skill-driven or luck-driven, then banks will also switch at that point to loans that investors will support given the new beliefs. By making their loan portfolio choices move lock-step with the beliefs of their financiers, banks can avoid a crisis. This is why we need the third building block – interim refinancing risk. For each time period, it is endogenously shown that the bank will fund itself with debt that is of shorter maturity than its loans. Withdrawal risk – which can generate a financial crisis – arises from the regime shift pertaining to the macro uncertainty occurring before the loans for that period mature.

The analysis of this basic model also reveals that an essential aspect of a financial crisis is that prior beliefs must be such that the ex ante probability that the macro state is luck must be *sufficiently low*. In other words, the ex ante probability of a financial crisis must be sufficiently low for a crisis to occur ex post. A crisis can never occur if it is viewed as being highly probable. This happens despite rational beliefs, because of how it affects banks' portfolio choices. In the basic model, there are only two time periods and two types of loans. When the model is extended to have multiple periods and multiple levels of loan risk, in order to accommodate more realism, we get the result that initially banks invest in safe loans and if these are successfully repaid, they switch to loans of moderate risk. The presence of banks in the market for risky products creates liquidity that invites other institutions to enter, which further enhances liquidity. If repayments are experienced on these loans for long enough, banks switch to the riskiest loans available. A financial crisis is a possibility only after this occurs. Thus, we get the result that if there is a sufficiently long sequence of good outcomes, risk taking rises in steps, and then a crisis occurs when risk-taking is at its peak.

In both the two-period and multiperiod models, the realization of the macro uncertainty is assumed to be costlessly observed by all. This assumption is then dropped and it is assumed that only costly information acquisition is possible. It is shown that if banks finance themselves with debt provided by institutional investors, these investors have no incentive to acquire costly information.

As long as there is no market for derivatives traded on the bank's debt, initially-successful banks switch to high-risk investments and these investments continue unabated as long as banks do not experience defaults and banking profitability sustains. However, if a credit default swaps (CDS) market on the bank's debt opens up, there will be incentives for some traders to become informed about whether it is luck or skill that determines outcomes, and this information will be reflected in the CDS price.[7] The

[7] As is explained later, some traders will choose to become informed because they can trade *anonymously* and earn a profit on their information. A bank's institutional lender is identifiable, other competing lenders can observe its credit decision and free-ride on it, thereby driving down the lender's profit below its information-acquisition cost.

bank's creditors will be able to learn from this price and may form a sufficiently high posterior belief that outcomes are driven by luck. This price discovery in the CDS market causes investors to withdraw funding, liquidity dries up suddenly and a crisis commences with little warning.

This modeling approach, wherein there is a regime in which people believe outcomes are skill-dependent and another in which they believe they are just luck, is reminiscent of Piketty's (1995) model of social mobility and redistributive politics. In his model, there are two groups of agents ─ those in "left-wing dynasties" who believe outcomes are exogenous (luck) and those in "right-wing dynasties" who believe they depend on individual effort. The left-wing dynasties support higher redistributive taxation and supply less effort, while right-wing dynasties support lower redistribution and work harder. Instead of two groups of agents, in the model in this paper there are two states/regimes, which could be thought of as regimes distinguished by different types of agents representing the predominant majority.[8]

This explanation for financial crises is consonant with the earlier-mentioned stylized facts related to the subprime crisis. In particular, crises are predicted to follow economic booms ─ especially for banks ─ and risk-taking will tend to be "underpriced" by all concerned prior to the beginning of crises. The model also explains why the frequency of crises has gone up. Specifically, it suggests that the emergence of derivatives markets ─ like the CDS market ─ has led to "destabilizing learning" and financial crises. These markets have grown explosively in recent years.

The model helps explain that crisis cycles occur even if bankers are not seeking excessive risks to exploit government safety nets. Moreover, regulatory initiatives like attempts to control bank risk-taking through limits on executive pay or direct monitoring are unlikely to be effective in preventing crises because, like bank executives, "watch dogs" like regulators and rating agencies also revise upward their beliefs about bank risk-management skills subsequent to long periods of good performance. In fact, the theory suggests that the majority of regulations – including explicit risk-sensitive pricing of government safety nets, restrictions on regulatory forbearance, and regulatory monitoring of systemic risk – as well as attempts to more closely align the interest of regulators and taxpayers may not significantly reduce the likelihood of future crises. I argue that countercyclical capital requirements may be one way to diminish the likelihood of crises.

This paper is related to the large and growing literature on financial crises that has provided numerous valuable insights into the causes of crises (e.g. Acharya and Yorulmazer (2008), DeJonghe

[8] For example, the Pew Research Center surveys citizens in different countries about whether success is due to hard work or luck. *The Economist* (March 9-15, 2013) reports significant differences across countries in terms of the percentage of respondents opining that outcomes are due to luck. Thus, there may be both cross-sectional and intemporal variations in agents' beliefs about what determines economic outcomes.

(2010), Wagner (2010), and the overviews of Allen and Gale (2007) and Rochet (2008)), their consequences (e.g. Boyd, Dwak and Smith (2005)), as well as regulatory reform needed to reduce the incidence of crises (e.g. Acharya, Cooley, Richardson and Walter (2011)).

One strand of the literature focuses on the *contagion* nature of financial crises (e.g. Acharya and Thakor (2013), and Allen and Gale (2000)). The goal is to understand how the failures of a few banks can spread through the system and engulf enough banks to cause a crisis.

Another strand deals with incentive conflicts as the root cause of correlated failures among banks that then lead to a crisis (e.g. Bebchuk and Fried (2010), Farhi and Tirole (2012), Litan and Bailey (2009), and Kane (1990)).

A third strand has recently focused on the role of complexity and innovation. Allen, Babus and Carletti (2012) develop a model in which networks arise because banks swap projects to diversify individual risks and thereby become interconnected. This can then generate systemic risk. Caballero and Simsek (2010) show that growth in financial networks causes endogenous complexity to increase. The increased complexity faced by banks may cause liquidity to vanish and a crisis may come about. Other papers have focused on the role of financial innovation. Gennaioli, Shleifer and Vishny (2012) have proposed that "neglected risk" in innovative financial products, when joined with limited supply of traditional safe products, results in excess demand for innovative products. When the neglected risks are realized, investors dump these innovative products, causing banks to be stuck with them. Shleifer and Vishny (2010) focus on securitization and argue that it leads to excessive leverage and lending. Thakor (2012) shows that potential disagreement about the profitability of an innovation acts as an endogenous barrier to entry and entices banks to pursue the innovation. However, this disagreement may also cause investors to withdraw funding, leading to a crisis.

In contrast to these papers, the focus in this paper is not on incentive conflicts, complexity or innovation. The assets available to financial institutions are known at the outset and there is no disagreement over their profitability. Moreover, unlike the existing literature, the focus here is on explaining why financial crises should be expected to follow economic booms and periods of sustained banking profitability and why risk is seemingly "underpriced" just prior to the onset of crises. The central idea in this paper, and one that has not been previously examined as a *causal* factor in financial crises, is that experience-based learning, whereby outcomes are attributed primarily to skill but have a non-zero probability of being viewed in the future as being just luck, can create an environment for banks to take successively higher levels of risk that eventually leads to a crisis.

The rest is organized as follows. The two-period (five dates) model is developed in Section II, and analyzed in Section III. An analysis of the bank's loan portfolio and funding choices with more than two periods and more than two types of loan appears in Section IV, and it shows that a sufficiently prolonged sequence of good outcomes occurs before a crisis hits. The analysis is with the CDS market appears in Section V. Section VI is devoted to extensions and a discussion of the interpretations and regulatory policy implications of the analysis. Section VII concludes. All proofs are in the Appendix.

II. THE MODEL

This section describes the base model with five dates and two time periods. I begin with a description of agents and preferences. I then discuss the sequence of events, followed by the investment opportunity set. This is followed by a statement of the observability assumptions and description of how beliefs are revised. I conclude with a summary of the timeline. In this base model, there is no CDS market. This will be introduced in Section V.

A. Preferences of Key Players

Everybody is risk neutral and the riskless rate is zero. The key players in the base model are financial intermediaries and institutional investors who can provide financing for these intermediaries. The liabilities of the intermediaries are uninsured[9], so even though I will refer to these intermediaries as "banks" henceforth, it should be understood that they encompass a broad array of financial intermediaries that raise their funding via non-traded and other claims in the capital market, including investment banks and commercial banks. For commercial banks, this would be deposit funding (including uninsured deposits), and for investment banks it could be traded debt, repos, as well as longer-term borrowing from other institutions. Thus, the financial market here includes the shadow banking system.

B. Sequence of Events: Agents, Information Signals and Types of Loans

There are five payoff-relevant dates: t=0, 1, 2, 3 and 4 that cover two time periods over which banks operate. At t=0, there are N_0 banks in the market. Each bank can choose to invest \$1 at t=0 in either a prudent loan (P) or a risky loan (R). Both loans mature at t=2. For simplicity, the entire \$1 is raised at t=0 in the form of (uninsured) debt financing through non-traded debt supplied by institutional investors; the bank's choice between such debt and direct capital market financing will be considered later. The debt is competitively priced to yield investors a zero expected return. Debt maturity will be endogenized.

C. Bank Manager and Loan Monitoring

The bank's manager needs to monitor the loan in order to produce a positive payoff. If the loan is not monitored at t=0, it produces a payoff of 0 at t=2, regardless of whether it is a P or an R loan. The same is true for the second-period loan. If not monitored at t=2, it produces a zero payoff at t=4. The bank manager's utility for each period can be written as

[9] The model goes through with partially insured liabilities.

$$U(i, j) = W + \alpha\left[\text{value of bank equity with loan } i \text{ and monitoring decision } j\right] - Cj + BI_{\{survive\}} \quad (1)$$

where *W* is the manager's fixed up-front wage each period, α is a positive constant, $j \in \{1, 0\}$ where $j = 1$ if the bank monitors and $j = 0$ if the bank does not monitor, $C > 0$ is the manager's personal cost of monitoring, *B* is the personal benefit to the manager from the bank surviving until the end of the period, and $I_{\{survive\}}$ is the indicator function which is 1 if the bank survives until the end of the period and zero otherwise. It will be assumed that:

$$B > C \quad (2)$$

so that the manager's personal benefit from survival exceeds his personal monitoring cost.

The debt investors who finance the bank receive a signal at the interim date $(t = 1)$ for the first-period loan and *t*=3 for the second-period loan that informs them whether the bank monitored its loan or not. If the loan was not monitored, then its value is $L_n \in (0,1)$ if it is liquidated at the interim date (*t*=1 or *t*=3), where L_n is an arbitrarily small positive quantity. Since the value of an unmonitored loan is zero at the end of the period, debt investors will wish to liquidate the loan at the interim date if they discover it was not monitored.

D. Investment Opportunities: P and R Loans

The bank chooses at *t* =0 and then again at *t* =2 between loans *P* and *R*, a mutually-exclusive set of loans.

P Loans: Loan *P* is either good (*G*) or bad (*B*) but no one can determine for sure *a priori* whether the loan is *G* or *B*. Conditional on being monitored, a loan of type *G* pays off $X_p > 1$ with probability (w.p.) 1, and a *B* loan pays off X_p w.p. $b \in (0,1)$ and 0 w.p. $1-b$.

It is commonly believed at *t* =0 that there is a state of nature, *m*, in any given period, which could be interpreted as a macroeconomic state. The realization of this state at date *t*, denoted, m_t, has two possible values: "skill" and "luck". In the "luck" state (probability $\lambda \in (0,1)$), outcomes are pure luck, so the probability that the loan is type *G* is fixed at $r \in (0,1)$ for all banks. In the "skill" state (probability $1-\lambda$), outcomes are skill-dependent, so the probability that the loan is type *G* depends on the skill/talent of the bank in monitoring the loan after it is made, and more talented banks are viewed as having higher probabilities of making good loans. Specifically, there are two possible types of banks: talented (τ) and untalented (*u*). A type-τ bank monitors the *P* loan with perfect efficiency and is thus able to ensure that the loan is *G* w.p. 1. A type-*u* bank, however, has no monitoring ability and thus ends up with a *B* loan w.p. 1.[10] The common prior belief at t=0 is that the probability that any given bank is type-τ is r, and the probability that it is type u is $1-r$.

In any given period, the realization of the skill or luck state applies to P loans made by *all* banks, but across the two periods, these state variables are identically and independently distributed (*i.i.d.*) random variables. That is, the realization of m_t does not provide any new information about the likelihood of a particular realization of m_{t+1}.[11]

The macro state – skill or luck – is independently and identically distributed (*i.i.d.*) across time periods, and all share the common prior belief that the probability of the luck state in any period is λ. In the base model, it is assumed that, at the interim date (t=1 for the first period and t=3 for the second period), which state has been realized for the period can be costlessly discovered by all, including the bank's creditors. Later, this information will be permitted to be discovered only at a cost.

While one may interpret the skill and luck states as representing two different objective physical regimes, they may also represent nothing more than subjective assessments of agents about whether economic outcomes are driven by skill / effort or just luck. That is, the skill and luck macro states can be interpreted as states of "aggregate investor sentiment", in the spirit of Piketty's (1995) model, with the luck state being one in which market sentiment is dominated by agents in Picketty's "left-wing dynasties", and the skill state being one in which market sentiment is dominated by agents in Picketty's "right-wing dynasties". A shift from one state to the other may be triggered by events in the real economy or changes in political initiatives / rhetoric. For example, higher-than-expected defaults on subprime mortgages may cause investors to shift from beliefs that loan repayment outcomes are determined by the screening skills of bankers to the belief that they are driven largely by the bad luck experienced by subprime borrowers.

At t =0 then, the prior belief about the probability of success of the P loan at t=2 is

$$r_o^P \equiv r + [1-r]b \tag{3}$$

It is assumed that

$$r_o^P X_p > 1 \tag{4}$$

so P can be financed with debt given these prior beliefs.

[10] This assumption is merely to reduce notational clutter, and one could assume instead that a type-u bank ends up with a B loan w.p. less than 1.

[11] If the macro uncertainty, exhibited positive serial correlation, the results will get even stronger, although the algebra will become more messy. A macro uncertainty realization of skill in one period will indicate a higher (than prior) probability of the same state in the second period, making elevated risk-taking even more attractive.

However,

$$bX_p < 1 \tag{5}$$

so a bank known to be type-*u* almost surely (in the state in which the probability of having a type-*G* loan is skill-dependent) would never be able to raise financing for a *P* loan.

R Loans: The *R* loan can be either good $(\hat{G})$ or bad $(\hat{B})$. No one can determine *a priori* whether a given loan is $\hat{G}$ or $\hat{B}$. A loan of type $\hat{G}$ pays off X_R w.p. $q \in (0,1)$ and *0* w.p. $(1-q)$, whereas a $\hat{B}$ loan pays off *0* w.p. 1. It is assumed that the $\hat{G}$-type *R* loan has a higher expected value to financiers than the *G*-type *P* loan, i.e.,

$$\frac{C+\alpha}{\alpha} > q\left[X_R + Z\right] > X_P + Z \tag{6}$$

The first inequality, $\frac{C+\alpha}{\alpha} > q\left[X_R + Z\right]$, means that the manager's equity ownership is never sufficient to induce him to monitor the loan, in the absence of a liquidation threat by creditors. The second inequality, $q\left[X_R + Z\right] > X_P + Z$, means that the *R* loan has a higher expected value to financiers than the *P* loan.

As in the case of the *P* loan, there are two possible macroeconomic states of relevance with the *R* loan in any given period. In the "luck" state (which has probability λ), the loan is type $\hat{G}$ with an exogenously fixed probability *r*. In the "skill" state (w.p. $1-\lambda$), the probability that the loan is type $\hat{G}$ is dependent on the bank's monitoring skill. In this case, the common belief is that a type-τ bank will be able to ensure w.p. 1 that it is a $\hat{G}$ loan, whereas a type-*u* bank will ensure w.p. 1 that it is a $\hat{B}$ loan.

It will also be assumed, for later use, that the difference in loan repayment (success) probabilities across the good and bad loans is greater for the *R* loan than for the *P* loan, i.e.,

$$q > 1 - b \tag{7}$$

This is motivated by the observation that *R* is a more complex loan for which the importance of the bank's skill/talent is greater than for *P*.

At *t*=0 then, the prior probability of success of the type *R* loan at *t*=2 is:

$$r_o^R \equiv rq \tag{8}$$

and it is assumed that

$$r_o^R[X_R + Z] < 1 \tag{9}$$

so the *R* loan cannot be financed with debt or equity given the prior beliefs.

A summary of these loans and payoffs is provided in the table below.

Table 1: Loan Payoffs

<table>
<tr><th colspan="3">Exogenous Loan Payoff Distribution in the Luck Macro State (Probability λ)</th></tr>
<tr><th></th><th>Loan Type</th><th>Date 2 payoff:</th></tr>
<tr><td>P</td><td>G w.p. r</td><td>$X_p > 1$ w.p. 1</td></tr>
<tr><td></td><td>B w.p. $1-r$</td><td>X_p w.p. b
0 w.p. $1-b$</td></tr>
<tr><td>R</td><td>$\hat{G}$ w.p. r</td><td>$X_R > 1$ w.p. q
0 w.p. $1-q$</td></tr>
</table>

<table>
<tr><th colspan="5">Endogenous Loan (Bank-Type-Dependent) Payoff Distribution in the Skill Macro State (Probability $1-\lambda$)</th></tr>
<tr><th></th><th>Bank Type</th><th>Probability of Bank Type</th><th>Loan Type, conditional on bank type</th><th>Date 2 Payoff:</th></tr>
<tr><td rowspan="2">P</td><td>τ</td><td>r</td><td>G w.p. 1</td><td>$X_p > 1$ w.p. 1</td></tr>
<tr><td>u</td><td>$1-r$</td><td>B w.p. 1</td><td>X_p w.p. b
0 w.p. $1-b$</td></tr>
<tr><td rowspan="2">R</td><td>τ</td><td>r</td><td>$\hat{G}$ w.p. 1</td><td>$X_R > 1$ w.p. q
0 w.p. $1-q$</td></tr>
<tr><td>u</td><td>$1-r$</td><td>$\hat{B}$</td><td>0 w.p. 1</td></tr>
</table>

E. Observability and Knowledge Assumptions

Each bank's loan choice at any given date is commonly observable. So, investors know the bank's choice (P or R) before providing financing. Also publicly observable is whether the bank's loan repaid or defaulted at the end of the period (t=2 for the first period and t=4 for the second period). For now, m_t (skill or luck) is observable to all once it is realized.

F. Non-pledgeable Payoffs

Associated with each loan is a non-pledgeable payoff $Z > 0$, which is only available to the bank's shareholders if the loan stays on the books until it matures, is repaid and is not prematurely liquidated. The payoff Z is non-pledgeable in the sense that it cannot be pledged by the bank as repayment to creditors. Each loan also has an additional social value, $J \geq 0$, that is available only if the loan is successfully repaid. This social value is another non-pledgeable payoff. It can be interpreted as a benefit to society from the success of the borrower's project due to its positive employment, consumer welfare and tax-revenue-enhancing wealth generation consequences.

G. Financing From Institutional Investors

Institutional investors provide financing in a competitive private debt market, so that bank debt is priced to yield investors an expected return of zero. If investors liquidate a loan at t=1 or t=3, they collect $L \in (rqX_R, rq[X_R + Z])$, where $rq[X_R + Z] > 1$. The assumption that $L < rq[X_R + Z]$ means that a bank liquidation is inefficient ex post.

H. Definition of a Financial Crisis

A financial crisis occurs if all banks in the system are prematurely liquidated at either t=1 or t=3.

I. Summary of Timeline

At t=0, there are N_0 banks. Each bank chooses to invest \$1 in either a prudent (P) loan or a risky (R) loan. Each loan is entirely funded by uninsured debt and each matures at either t=1 or t=2.[12] The debt will be called "short maturity" if it matures at t=1 and "long maturity" if it matures at t=2.[13] At t=1, based on their discovery of the realized value of m_1, investors who funded the bank at t=0 may wish to collect their repayment at t=1 or renew funding until t=2. In the event that funding is not renewed, the bank must either repay investors in full or liquidate. If the bank survives until t=2 without liquidation, then it collects its loan payment (if available) and pays off investors. Any positive profit at t=2 on the first-period loan is paid out as a dividend to the bank's shareholders.[14] The lending cycle then restarts at t=2 and the bank makes a new choice of loan and funds it entirely with new debt. This debt is "short maturity" if it matures at t=3 and "long maturity" if it matures at t=4. The "skill" or "luck" macro state realization for the second period, m_3, occurs at t=3, and this is observed at that time by all in the second period. The terminal payoff is realized at t=4.

A summary of the sequence of events is provided in *Figure 1*. In *Figure 2*, there is a pictorial summary of the probability distributions of the projects.

Figure 1 goes here

[12] It makes little difference to the analysis if the bank was partly financed with equity, as long as it is not predominantly financed with equity. Non-trivial amounts of debt financing are essential for fragility.
[13] It will be shown in the analysis that the short maturity of the bank's debt emerges endogenously.
[14] This is for simplicity. If the bank could use its first-period profit to fund part of its second-period loan, it would reduce the reliance on outside debt. However, the analysis is qualitatively unchanged if the bank has to fund the loan even partly from outside debt.

Figure 2 goes here

III. ANALYSIS OF THE BASE MODEL WHEN THERE IS NO MARKET FOR DERIVATIVES ON BANK DEBT

The main goal of this section is to analyze the model developed in the previous section to examine how banks fund themselves, their debt maturity and their loan portfolio choices in the absence of a CDS market.

A. Bank Debt Maturity

In this subsection, the question of the bank's debt maturity is examined. The following parametric restrictions will be imposed on the model.

$$W > C > \alpha\{qX_R - 1\} \tag{10}$$

the first part of the restriction merely says that the manager's up-front wage is enough to cover his loan monitoring cost, which is sufficient for his participation constraint to be satisfied. The second part of the restriction says that, even if the bank was identified unambiguously as type τ and it invested in loan *R*, the net expected payoff to the manager (a fraction α of the payoff to the bank's shareholders) is exceeded by his personal cost of monitoring. This creates a moral hazard that the bank's creditors must account for. The following result is now immediate.

Proposition 1: *In each period the bank will finance its loan with short-maturity debt. That is, in the first period, it will issue debt at t=0 that matures at t=1 and has to be replaced with short-maturity debt that matures at t=2. In the second period, it will issue short-maturity debt at t=2 that matures at t=3 and is replaced with short-maturity debt that matures at t=4.*

The intuition is straightforward. In the absence of any refinancing risk ─ which would be the case with long-term debt ─ the bank manager would not monitor. This would make it impossible for the bank to raise financing. Thus, short-term debt is the bank's only viable financing alternative.

B. Bank Loan Market: Analysis of Outcomes at t=2

In the usual backward induction manner, I start by analyzing the second period, beginning at *t*=2, first and then the first period beginning at *t*=0. For now, it will be assumed that the bank raises financing from institutional creditors who do not produce information about the macro state. Later it will be shown that the institutional creditors will indeed prefer not to produce information.

Default/Repayment on First-Period Loan: Suppose the bank made a *P* loan at *t*=0. There are now two possible states for the bank at *t*=2; (i) its loan defaults at *t*=2, or (ii) its loan pays off.

State (i): Repayment Failure (P loan defaults at t=2): In this case, the common posterior belief about the bank's type at *t=2* is:

$$\begin{aligned}\tau_2^f(\text{skill}) &= \Pr(\tau \mid \text{default on first-period loan, } m_1 = \text{skill}) \\ &= 0\end{aligned} \tag{11}$$

if it was observed that m_1 = "skill". And it is

$$\begin{aligned}\tau_2^f(\text{luck}) &= \Pr(\tau \mid \text{default on first period loan, } m_1 = \text{luck}) \\ &= r\end{aligned} \tag{12}$$

if it was observed that $m_1 =$ "luck". We can thus compute the expected success probabilities on the second-period projects, conditional on having observed first-period failure. Using notation P_j^i and R_j^I, $j \in \{S, D\}, i \in \{1, 2\}$ to designate the event j of either successful repayment (*S*) or default (*D*) in period *i* (which is 1 or 2, corresponding to repayment outcomes observed at *t*=2 for period 1 and *t*=4 for period 2) on loans *P* and *R* respectively, one can write the posterior probabilities at t=2 as:

$$\begin{aligned}\Pr(P_S^2 \mid P_D^1, m_1 = \text{luck}) = {} & \Pr(P_S^2 \mid P_D^1, m_1 = \text{luck}, m_3 = \text{luck})\Pr(m_3 = \text{luck}) \\ & + \Pr(P_S^2 \mid P_D^1, m_1 = \text{luck}, m_3 = \text{skill})\Pr(m_3 = \text{skill})\end{aligned}$$

conditional on $m_1 = \text{luck}$ having been observed. Using (12) yields:

$$\begin{aligned}\Pr(P_S^2 \mid P_D^1, m_1 = \text{luck}) &= \lambda \mathrm{r}_0^P + [1-\lambda] r_0^P \\ &= r_0^P = r + [1-r]b\end{aligned} \tag{13}$$

Similarly, using (11):

$$\Pr(P_S^2 \mid P_D^1, m_1 = \text{skill}) = \lambda \mathrm{r}_0^P + [1-\lambda] b \tag{14}$$

Note that $\partial \Pr(P_S^2 \mid P_D^1, m_1 = \text{skill}) / \partial \lambda > 0$. Thus, for λ small enough, it will be true that

$$\Pr(P_S^2 \mid P_D^1, m_1 = \text{skill})[\mathrm{X}_P + Z] < 1 \tag{15}$$

which means that, subsequent to first-period default and the knowledge that $m_1 = \text{skill}$, no financing will be available for the *P* loan in the second period. It will be assumed throughout that (15) holds.

Similarly, using (11) and (12):

$$\begin{aligned}\Pr(R_2^S \mid P_D^1, m_1 = \text{luck}) &= \lambda \mathrm{r}_0^R + [1-\lambda] r_0^R \\ &= r_0^R = rq\end{aligned} \tag{16}$$

$$\begin{aligned}\Pr(R_S^2 \mid P_D^1, m_1 = \text{skill}) &= \lambda \mathrm{r}_0^R + [1-\lambda][\lambda r_0^R + [1-\lambda][0] \\ &= \lambda r_0^R + [1-\lambda]\lambda r_0^R \\ &< r_0^R = rq\end{aligned} \tag{17}$$

Since an *R* loan cannot be funded using prior beliefs (see 9), it cannot be funded following first-period default. This gives us Lemma 1.

Lemma 1: *A bank that makes a P loan in the first period and experiences default will exit the market if* $m_1 = \text{skill}$ *and will make a P loan in the second period if* $m_1 = \text{luck}$.

State (ii): Repayment Success (P loan repaid at t=2): In this case, the common posterior belief about the bank's type at *t*=2 is:

$$\begin{aligned}\tau_2^S(\text{skill}) &= \Pr(\tau \,|\, P_S^1,\ m_1 = \text{skill}) \\ &= \frac{r}{r + b[1-r]} > r.\end{aligned} \tag{18}$$

if it is observed that the "skill" state occurred in the first period. And it is

$$\tau_2^S(\text{luck}) = \Pr(\tau \,|\, P_S^1, m_1 = \text{luck}) = r \tag{19}$$

if it is observed that the "luck" state occurred in the first period. Now, one can write

$$\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{luck}) = \mathrm{r}_0^P \tag{20}$$

$$\Pr(P_S^2 \,|\, P_S^2, m_1 = \text{skill}) = \lambda \mathrm{r}_0^P + [1-\lambda][r_2^S(\text{skill}) + [1\text{-}\tau_2^S(\text{skill})]b] \tag{21}$$

where $\tau_2^S(\text{skill})$ is given by (18). Similarly,

$$\Pr(R_S^2 \,|\, P_S^1, m_1 = \text{luck}) = \mathrm{r}_0^R \tag{22}$$

$$\begin{aligned}\Pr(R_S^2 \,|\, P_S^1, m_1 = \text{skill}) &= \lambda \mathrm{r}_0^R + [1-\lambda]q\tau_2^S(\text{skill}) \\ &= \lambda rq + [1\text{-}\lambda]q\tau_2^S(\text{skill})\end{aligned} \tag{23}$$

Now, conditional on repayment of the *P* loan in the first period and $m_1 = \text{skill}$, the total value of a *P* loan in the second period is:

$$\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill})[\mathrm{X}_P + Z + J] \tag{24}$$

which includes its social value. Similarly, the total value of an *R* loan is

$$\lambda L + [1-\lambda]q\tau_2^S[X_R + Z + J] \tag{25}$$

if it is assumed that, conditional on $m_3 = \text{luck}$, if the bank's creditors will liquidate it at t=3 if it invested in an *R* loan in the second period.

Second-Period Lending Choice: Now consider the second-period lending choice for a bank whose first-period *P* loan was repaid, and for which $m_1 = \text{skill}$. If it makes a *P* loan at *t*=2, its expected profit is:

$$\bar{\pi}_2^P = \Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill})\{X_P - \bar{D}_P(\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill}) + Z\} \tag{26}$$

where $\bar{D}_P$ is the promised repayment on the debt financing raised by the bank at *t*=2 to finance its loan.

The bank's repayment obligation to debt investors should be such that the amount raised from these investors at *t*=0 ($1) equals the expected payoff to them at *t*=2, i.e.

$$\bar{D}_P(\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill}) = 1/\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill}) \tag{27}$$

I now turn to the *R* loan. If we assume that the bank will be liquidated in the second-period if it invests in the *R* loan at *t*=2 and $m_3 = \text{luck}$ at t=3, then the bank's expected profit from an *R* loan is:

$$\bar{\pi}_2^R = [1-\lambda]q\tau_2^S\{X_R - \bar{D}_R(\Pr(R_S^2 \,|\, P_S^1, m_1 = \text{skill})) + Z\} \tag{28}$$

where the bank's repayment obligation is:

$$\bar{D}_R(\Pr(R_S^2 \,|\, P_S^1), m_1 = \text{skill})) = [1-\lambda \text{L}]\{[1-\lambda]q\tau_2^S\}^{-1} \tag{29}$$

The following result can now be stated.

Lemma 2: *For* $\lambda \in (0,1)$ *and* $b \in (0,1)$ *sufficiently small and* $q \in (0,1)$ *sufficiently large,*

$$\begin{aligned} &[1-\lambda]q\tau_2^S(\text{skill})\text{X}_R + \lambda L \\ &> \Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill})\text{X}_P + [\Pr[P_S^2 \,|\, P_S^1, m_1 = \text{skill}) - [1-\lambda]q\tau_2^S(skill)]Z \end{aligned} \tag{30}$$

The implication of (30) is that a bank that experienced repayment success on the first-period *P* loan and observed $m_1 = \text{skill}$ will have such a high posterior probability of success on the *R* loan in the second period that the bank's shareholders' expected payoff will be higher with an *R* loan than with a *P* loan. It will be assumed throughout that the conditions stated in Lemma 2 will be satisfied, so (30) holds. The following result is now easy to derive.

Proposition 2 (Bank's Second-Period Lending): *If its first-period P loan repaid at t=2 and* $m_1 =$ skill, *the bank prefers to invest in the R loan in the second period at t=2. It raises $1 in financing at t=2 to invest in the second-period loan at t=2 and promises creditors a repayment of L if investors collect on their credit at t=3, and* $D_R(\Pr(R_S^2 \,|\, P_S^1, m_1 = \text{skill}))$ *if they provide renewed funding at t=3 that requires repayment at t=4. If the bank's creditors verify at t=3 that the bank monitored its loan, then they will renew funding at t=3 if* $m_3 =$ skill *and liquidate the bank if* $m_3 =$ luck.

The intuition is as follows. Based on the previous analysis, if the bank's first-period loan successfully repays, then the posterior belief about the bank's probability of making a second-period loan that will repay is so high that it becomes profitable for the bank to make an *R* loan and financiers will fund it. If there is no renewal of the loan at t=3, the bank has to liquidate, so it collects *L* to pay creditors. Conditional on the bank having monitored its loan, the creditors will wish to do this only if $m_3 = \text{luck}$, because in this case beliefs about repayment probabilities revert to prior beliefs. If $m_3 = \text{skill},$ then creditors get a higher expected payoff if they allow the bank to continue than if they liquidate it.

Since all banks are identical in this model, all those who experience success on their first-period *P* loan will invest in *R* loans in the second period. This is essentially the whole banking industry since banks that experienced first-period default have exited at t=2. Observation of $m_3 = \text{luck}$ at t=3 leads to liquidations of all banks and a financial crisis.

C. Analysis of Outcomes at t=0

The following result is now immediate, given our earlier analysis.

Lemma 3: (Banks First-Period Lending): *At t=0, all banks invest in P loans. Investors are promised a repayment of L at t=1 and* $D_P(r_0^P)$ *at t=2, where*

$$D_P(r_0^P) = [r_0^P]^{-1} \tag{31}$$

and the bank's shareholders' expected profit is:

$$\pi_1^P = r_0^P[X_P - D_P(r_0^P) + Z] \tag{32}$$

Investors do not liquidate the bank and agree to renew financing at t=2 regardless of the realized value of m_1. *There is no financial crisis in the first period.*

The reason there is no financial crisis in the first period is that the realized value of m_1 does not cause investors to change their beliefs from their prior beliefs about the bank's ability since no repayment/default on any loan has been observed. The reason why the bank invest in *P* is that *R* cannot be financed with investors' prior beliefs about the bank's ability.

We see then that banks start out investing in *P* loans, and then those that experience successful repayment go on to make *R* loans in the second period, as long as the probability of $m_3 = \text{luck}$ is small enough (see Lemma 2). But if $m_3 = \text{luck}$ is indeed observed at t=3, a financial crisis occurs. The crisis leads to liquidations of banks, which are ex post inefficient both because of the non-pledgeable rents, *Z*, that these banks' shareholders lose, but also due to the loss of additional social rents, *J*. The following result is now useful to note.

Lemma 4 (Social Welfare): *If the non-pledgeable social rent, J, is large enough, then the bank may invest in R in the second period even though it is socially inefficient compared to investing in P.*

The intuition is that *P* always has a higher repayment probability than *R*, and hence there is a lower probability that the social rent *J* will be lost with *P* than with *R*. This means the bank's shareholders may wish to invest in *R* and financiers will be willing to provide financing even though these loans are socially inefficient compared to the *P* loans. This can justify regulatory portfolio restrictions or capital requirements that reduce the attractiveness of *R* loans for the bank.

IV. A T-PERIOD MODEL: THE EFFECT OF MORE TIME PERIODS

Imagine now that the previous analysis represented the first two periods of an arbitrarily long time horizon, i.e., $t = T > 4$ is an arbitrarily large number. Also, instead of a single *R* loan, there is a large set of *R* loans, say $\{R_1, R_2, ..., R_N\}$, with *N* arbitrarily large. The probability distribution for loan R_i is that a type-τ bank will be able to ensure w.p.1 that it is a $\hat{G}_i$ loan, where $\hat{G}_i$ loan pays off X_R^i w.p. q, and 0 w.p. $1-q$, and $X_R^i > X_R^j$ if $i > j$, whereas a type-*u* bank will ensure w.p. 1 that it is a $\hat{B}_i$ loan, where a $\hat{B}_i$ loan generates a payoff of X_R^i w.p. b_R and a payoff of $-[i-1]k$ w.p. $1-b_R$, where *k>0* is a positive constant and $0 < \mathrm{b}_R < \min\{0.5, q\} < 1$. Specifically, it is assumed that $X_R^i = X_R^{i-1} + [i-1]k \; \forall \, i \in \{2, ..., N\}$. As in the previous analysis, $rqX_R^i < 1$. That is, it is assumed that $X_R^i = X_R$, where X_R was defined in the previous section. For simplicity, let us continue with the assumption that the bank's creditors can costlessly *observe* the realization of *m* at each odd date: *t*=1, 3,….

A parametric restriction will be imposed on *r*, which says that *r* is small enough that

$$r[1-r]^{-1} < [1-2b_R][q]^{-1} \tag{33}$$

This restriction ensures that, evaluated at the prior belief that the bank is type τ, riskier loans are less attractive to the bank.

Let the liquidation value of any loan be $L \in (L_1, L_2)$, where

$$L_1 \equiv \left[X_R^1 + [N-1]k\right]\left[rq + (1-r)b_R\right] - [1-r][1-b_R][N-1]k; L_2 \equiv \min\left\{L_1 + Z, X_R^1\left[rq + (1-r)b_R\right]\right\} \tag{34}$$

which means that all liquidations are inefficient. Note that, given (33), we know that $L_1 < L_2$.

A couple of points are worth noting. First, unlike the two-period model, the bad loan, $\hat{B}$, has a positive probability of success. This is needed in a multi-period setting to prevent the posterior belief that the bank is type τ, conditional on a successful outcome of a risky loan in the up-macroeconomic state, from becoming 1. Second, the bank's payoff on the risky loan in the default state is $-[i-1]k$, which can be viewed as the bank's loss given default, a measure of risk that goes up with *i*. That is, viewed in this sense, loan R_i is riskier than loan R_j, if $i > j$.[15]

Now the probability of success with a *P* loan at *t*=0, r_0^p, given by *r*, and we will assume (4) and (5) hold. The probability of success with a R_1 loan at *t*=0 is:

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[15] One may ask what it means to have a negative payoff for the bank in the loan default state. The idea here is that the bank makes numerous investments of tangible and intangible capital that can only be recovered if the loan repays. Default causes the bank to lose these investments.

$$r_0^{R_1} = rq + [1-r]b_R \tag{35}$$

The analog of (6) is

$$q[X_R^1 + Z] > X_p + Z \tag{36}$$

The analog of (7) is

$$q - b_R > 1 - b \tag{37}$$

and the analog of (9) is

$$r_0^{R_1}[X_R^1 + Z] < 1. \tag{38}$$

Now, the value of risky loan R_i, to financiers, evaluated at the prior beliefs is:

$$EV_i = rq\left[X_R^1 + Z + [i-1]k\right] + [1-r]\left\{b_R\left[X_R^1 + Z + [i-1]k\right] - [1-b_R][i-1]k\right\} \tag{39}$$

The following result is useful.

Lemma 5: $(i)\partial EV_i / \partial r > 0,$ (ii) $\partial EV_i(r)/\partial i < 0,$ and $(iii)\partial^2 EV_i / \partial i \partial r > 0$

The implications of this lemma are as follows. From (i), we see that as the (posterior) belief that the bank is type τ increases, so does the value of any risky loan, R_i. However, (ii) implies that evaluated at the prior belief *r*, riskier loans are less valuable. And, (iii) says that the marginal impact of an increase in the posterior belief that the bank's type is τ is greater for larger values of *i*, i.e., for riskier loans.

We now need additional notation. We know that if the bank invests in a *P* loan at *t*=0, then the posterior probability at *t*=2 that the bank is of type τ, conditional on success at *t*=2 and $m_1 = \text{skill}$, is given by (18) as:

$$\tau_2^S(\text{skill}) = \Pr\left(\tau \middle| P_S^1, m_1 = \text{skill}\right) = \frac{r}{r + b_R[1-r]}$$

The posterior belief at *t*=2 about the probability of success in the second period for R_1 (at *t*=4) is:

$$\Pr(R_1^2 | P_S^1) = \lambda r_0^{R_1} + [1-\lambda]\left\{q\tau_2^S(\text{skill}) + \left[1 - \tau_2^S(\text{skill})\right]b_R\right\} \tag{40}$$

and, it shall be assumed that:

$$\Pr(R_1^2 | P_S^1)[X_R^1 + Z] > \Pr(P_S^2 | P_S^1)[X_p + Z] \tag{41}$$

Moreover, let $\tau_2^S(\text{skill})$ be small enough that we have the following analog of (33):

$$\Pr(R_1^2 | P_S^1)\left[1 - \Pr(R_1^2 | P_S^1)\right]^{-1} < [1 - 2b_R][q]^{-1} \tag{42}$$

Essentially, the restrictions imposed by (41) and (42) guarantee that the bank will switch from the P to the R_1 loan at *t*=2 if its first-period P loan succeeded; note that (40) is sufficient for R_1 to be preferred to any other R_1, *i* >1.

Now, for an odd date *t*, define $\tau_t^S\left(\text{skill}_t^{odd}, S_t^{even}\right)$ as the posterior probability at date *t* that the bank is type τ, where the vector $\text{skill}_t^{odd} = (\text{skill}_1, \text{skill}_3, \text{skill}_5, \_\_\_\,\text{skill}_t)$ indicates that the macroeconomic state was revealed to be *m*=skill at all odd dates up to (and including) date *t*, and the vector $S_t^{even} = \left(S_2, S_4, S_6, \ldots S_{t-1}\right)$ indicates that the loans made by the bank successfully repaid at all even dates up to (and including) date $t-1$. Then, we see that $\tau_t^s\left(\text{skill}_t^{odd}, S_t^{even}\right)$ is defined recursively by:

$$\tau_t^S\left(\text{skill}_t^{odd}, S_t^{even}\right) = \frac{q\tau_{t-2}^S}{\left\{q\tau_{t-2}^S + b_R\left[1-\tau_{t-2}^S\right]\right\}} \tag{43}$$

The following result can now be proved:

Lemma 6: *There exists a large enough (odd) number,* t^**, such that* $\partial EV_i\left(\tau_t^S\right)/\partial i < 0 \forall t < t^*$ *and* $\partial EV_i\left(\tau_t^S\right)/\partial i > 0 \forall t \geq t^*$*, where* τ_t^S *is short-hand for* $\tau_t^S\left(skill_t, S_t^{even}\right)$.

This lemma says that if there is a sufficiently long sequence of successful loan outcomes along with a correspondingly long sequence of consecutive $m_t = \text{skill}$ states, the posterior belief about the bank being of type τ will be high enough to ensure that riskier loans will have higher expected values. This suggests that, after a long enough string of successful loan outcomes during a “bull market” economy, the bank will switch to the riskiest loan available. This leads us to the main result of this section.

Proposition 3: *In a credit market equilibrium with T (arbitrarily large) periods and costless discovery of the macro state m, the bank will invest in the P loan in the first period. Conditional on the first-period loan being successfully repaid* $m_1 = skill$*, the bank invests in the* R_1 *loan in the second period. Conditional on each* R_1 *loan successfully paying off in each period and* $m_t = skill$ *being realized at dates t=3, 5, …, the bank will continue to invest in* R_1 *each period until date* $t < t^*$ *(defined in Lemma 6). At any date* $t < t^*$*, if investors observe that* $m_t = luck$ *has occurred, they will not liquidate any banks and there will be no financial crisis. However, if the number of periods that the* R_1 *loan is successfully repaid in conjunction with* $m_t = skill$ *being realized is greater than or equal to* t^**, then the bank will switch to investing in* R_N *in the next period and will continue to do so in the periods that follow, conditional on each loan being successfully repaid and* $m_t = skill$ *being realized. If* $m_t = luck$ *is realized at any* $t > t^*$*, investors will liquidate all banks with* R_N *loans and a financial crisis will ensue.*

This proposition, depicted graphically in *Figure* 3, makes a number of points. First, there is a "three-asset separation" here. The bank begins by investing in the P loan, then switches to R_1, conditional on some events, and then continues with R_1 until it switches to R_N. There is no financial crisis even if $m_t = \text{luck}$ at any time *t* prior to t^*, when banks switch to R_N. For $t > t^*$, an $m_t = \text{luck}$ realization triggers a crisis. Thus, there has to be a sufficiently long "bull market run" — with the macroeconomic state being $m_t = \text{skill}$ and banks experiencing good loan outcomes — before a crisis occurs. And the occurrence of the crisis coincides with a relatively high level of risk-taking by banks.

Figure 3 goes here

The intuition for this result is that riskier loans have values that are more sensitive to the bank's skill, and thus increase more rapidly as perceptions of the bank's skill goes up. Thus, when skill perceptions are relatively low, either P or R_1 is the preferred loan. Since these loans have values, evaluated at prior beliefs about bank skill, that exceed the loan liquidation values, investors do not liquidate these loans even if $m_t = \text{luck}$ occurs. So, there is no crisis. However, when skill perceptions are sufficiently high, the R_N loan has the highest expected value, so banks switch to it. But, if $m_t = \text{luck}$ occurs in any period, skill perceptions drop down to the prior belief, and a crisis occurs because the expected value of R_N, evaluated at the prior belief, is lower than the liquidation value. This intuition is illustrated in *Figure 4.*

Figure 4 goes here

V. ANALYSIS WHEN INFORMATION ACQUISITION IS COSTLY AND A DERIVATIVES (CDS) MARKET EXISTS ON THE BANK'S DEBT

So far it has been assumed that the realization of m_t can be costlessly observed by all. This is a strong assumption. A more realistic assumption is that m_t can only be observed at a cost by those who choose to incur it. An analysis with that assumption is presented below.

A. The Extended Model With Costly Information Production

In introducing costly information production, a distinction is drawn between institutional lenders who may purchase the bank's (non-traded) debt and investors in the capital market who may acquire the information and trade anonymously.

Institutional Lenders: An institutional lender can choose to become informed about m_t at a cost *M*. However, any such investment by an institutional lender is observable to other lenders as well as the borrowing bank. So while the lender who learns about m_t can keep the information it acquires private, it becomes known that it invested in acquiring it.

Traded Derivatives on Bank Debt: Once a bank issues debt to raise financing for its loan portfolio, derivatives on this debt may be created and traded on exchanges. To fix ideas, I consider a specific contract: one unit of a credit default swap (CDS) pays investors $x > 0$ at the end of the period if the bank defaults on its debt and *0* otherwise. In the first period, if the CDS market opens, then the contract is sold at *t*=1 and settled at *t*=2. In the second period, the contract is sold at *t*=3 and settled at *t*=4. Investors who buy the CDS contract will be either noise traders whose aggregate demand in dollars, ℓ, is purely exogenous and determined based on the probability density function, $f(\ell)$, with support $(0,\infty)$, or they can be discretionary traders.[16] Assume $f'(\cdot) < 0 \, \forall \, \ell \in (0,\infty)$. The noise traders as well as discretionary traders are *a priori* unaware of whether *m*=luck or *m*=skill has been realized. However, a discretionary trader can choose to become informed at a cost $M \in (0,\infty)$, which is the same for any trader. Unlike the identifiable institutional lenders in the primary debt market, a discretionary trader who becomes informed and trades on that information can do so *anonymously*. If this investment is made, the trader discovers whether the skill or luck state has occurred before purchasing the CDS. Absent this investment, the trader remains uninformed. We thus end up with three groups of investors in the CDS contract: noise traders, discretionary uninformed traders (*dut*) and discretionary informed traders (*dit*). All trade anonymously, i.e., no one knows whether the trader is a noise trader, *dut* or *dit*.

The securities market is competitive in the sense that any trader's expected net gain from becoming informed is zero in equilibrium. There is a market maker (MM) who crosses orders and absorbs the net trade in the CDS, denoted by ξ. The market-clearing price is one that produces zero expected profit for the MM. Short sales are prohibited.

Let ξ be the MM's demand (in terms of number of units) for the security and Ω the aggregate demand (in dollar terms) from the noise traders and the *dit*. Let *P* be the price of the CDS, so we have

$$\xi = 1 - \left[\Omega_C / P_C\right] \tag{44}$$

since the supply of the CDS is fixed at 1 unit. If r_{MM}^R is the probability of repayment on the *R* loan, as assessed by the *MM* in the CDS contract, then the market-clearing price of the contract is:

$$P^e(\xi) = [1 - r_{MM}^R(\xi)] \tag{45}$$

[16] The model structure is similar to that in Boot and Thakor (1993).

That is, the *MM* observes the aggregate order flow, Ω, being unable to distinguish between traders of different types, and computes a posterior probability, $r_{MM}^{R}(\xi)$, as a function of ξ, to determine the CDS price. There is a continuum of traders of each type so that the demand-relevant measure of each individual trader is zero. Demand is positive only when integrated over a set of traders with positive measure.

Each discretionary trader has an endowment of *M+1* units, of which *M* can be invested in information acquisition and *1* can be invested in the CDS. The alternative to investment at *t*=1 is consumption, which has the same value as consumption at *t*=2. Upon investing *M*, the trader receives a signal ϕ which reveals whether the macro state is skill or luck. As in the "photocopy" information model of Grossman and Stiglitz (1980), each trader receives the same (perfectly revealing) signal. Since a *dit* knows the true value of the state, an individual *dit*'s demand can be written as:

$$\omega_I = \omega_I(\phi) = \begin{cases} 1 \text{ if } \phi = \text{ luck} \\ 0 \text{ if } \phi = \text{skill} \end{cases} \tag{46}$$

where the demand is stated in dollar terms.

Let θ be the (Lebesgue) measure of the number of discretionary traders who become *dit*. Thus, the aggregate demand from the *dit* is:

$$\Omega_I = \Omega_I(\theta,\phi) = \theta\omega_I(\phi) \tag{47}$$

Let *V* represent a *dit*'s expected net gain from becoming informed, P^e the equilibrium price of the CDS and $P(\phi)$ the value of the CDS privately known to the *dit* who receives the signal ϕ. Clearly, $P^e = P^e(\Omega(\phi,\ell))$. Since a *dit* submits a buy order only when his signal is $\phi = \text{ luck}$, we can write:

$$V = -M + \lambda\int_O^\infty [\{x[1-rq] - P^e(\theta+\ell)\} \big/ P^e(\theta+\ell)] f(\ell) d\ell \tag{48}$$

where $P(\phi) = P^e(\theta+\ell)$ and $\Omega_C(\phi,\ell) = \theta_C + \ell$ for $\phi = \text{luck}$. Here $1/\ P^e(\theta+\ell)$ is the number of units the *dit* can buy with \$1, and $x[1-rq] - P^e(\theta+\ell)$ is the expected profit per unit of the CDS as assessed by an informed trader. Assume that there is some uncertainty about whether the CDS market will open in any period: the probability that it will open at *t*=1 is $\delta \in (0,1)$ and the probability that it will open at *t*=3 *is* also δ. These two events are i.i.d. If the market opens at *t*=1, then it will remain open at *t*=3.[17]

B. Analysis of Institutional Lenders In the Absense of the CDS Market

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[17] Little changes if the uncertainty about market opening is i.i.d. across the two time periods.

Suppose there is no CDS market and banks borrow from institutional lenders in the shadow banking system. It will be shown that these lenders will choose not to become informed about m_t at any *t*, even though they can do so at a cost *M*. The key difference between this analysis and that presented in Section III is that now the lenders are *a priori* uninformed about m_t.

As before, assume that the bank makes a *P* loan in the first period. If it experiences default, then $\tau_2^f(\text{skill})$ and $\tau_2^f(\text{luck})$ are as indicated in (11) and (12). Thus,

$$\begin{aligned}\Pr(P_S^2 \left| P_D^1\right.) &= \Pr(P_D^2 | P_D^1, m_1 = \text{skill}, m_3 = \text{skill})\Pr(m_1 = \text{skill})\Pr(m_3 = \text{skill}) \\ &+\Pr(P_D^2 \left| P_D^1\right., m_1 = \text{luck and/or } m_3 = \text{luck})[1 - \Pr(m_1 = \text{skill})\Pr(m_3 = \text{skill})]\end{aligned}$$

and since (11) implies that

$$\Pr(P_S^2 \left| P_S^1\right., m_1 = \text{skill}, m_3 = \text{skill}) = r_2^f(\text{skill}) = 0$$

and $\Pr(P_S^2 \left| P_D^1\right., m_1 = \text{luck and/or } m_3 = \text{luck}) = r_2^f(\text{luck}) = r$,

we can write:

$$\Pr(P_S^2 \left| P_D^1\right.) = b[1-\lambda]^2 + r_0^P[1-(1-\lambda)^2] \tag{49}$$

where $r_0^P = r + [1-r]b$. Since $\partial \Pr(P_S^2 \left| P_D^1\right.)/\partial\lambda > 0$, it follows that, for λ small enough,

$$\Pr(P_S^2 \left| P_D^1\right.) X_P < 1 \tag{50}$$

It will be assumed throughout that (50) holds. This means that, conditional on first-period default on *P*, the bank cannot raise financing to make a second-period *P* loan.

Moreover,

$$\begin{aligned}\Pr(R_2^S \left| P_D^1\right.) &= \lambda[rq] + [1-\lambda][\lambda rq] \\ &< rq = r_O^R\end{aligned} \tag{51}$$

Since an *R* loan cannot be funded at the prior beliefs (see (9)), it cannot be funded in the second period following first-period loan default on *P*. A bank experiencing first-period default exits the market.

Now if the bank experiences successful repayment on its first-period loan, then $\tau_2^S(\text{luck})$ are as given in (18) and (19) respectively, we can write:

$$\begin{aligned}\Pr(P_S^2 \left| P_S^1\right.) &= \{\tau_S^2(\text{skill}) + [1-\tau_2^S(\text{skill})]b\}[1\text{-}\lambda]^2 + r_0^P\{1-[1-\lambda]^2\} \\ &> r_0^P\end{aligned} \tag{52}$$

Similarly,

$$\begin{aligned}\Pr(R_S^2 \left| P_S^1\right.) &= \tau_2^S(\text{skill}) q[1-\lambda]^2 + [1-(1-\lambda)^2] r_0^R \\ &> r_0^R = rq.\end{aligned} \tag{53}$$

If we assume that the bank's institutional creditors will not produce information about m_t, then there will be no liquidation at t=3 if *R* is funded at t=2. The analog of Lemma 2 then is:

Lemma 7: *For* $(\lambda, b) \in (0,1)\times(0,1)$ *sufficiently small and* $q \in (0,1)$ *sufficiently large,*

$$\Pr(R_S^2 \left| P_S^1 \right.) X_R > \Pr(P_S^2 \left| P_S^1 \right.) X_P + [\Pr(P_S^2 \left| P_S^1 \right.) - \Pr(R_S^2 \left| R_S^1 \right.)] Z \tag{54}$$

Given (54), the bank will prefer an *R* loan to a *P* loan in the second period following first-period repayment success with *P*. Thus, an analog of Proposition 2 can be written down ─ the bank invests in *P* in the first period, exits the market at t=2 if the loan defaults, and makes an *R* loan in the second period if the first-period loan repays. One difference is that if creditors wish not to renew the loan at t=1, they will be paid $1 (rather than *L*) since the bank can refinance its debt and need not liquidate. The same is true at t=3. The bank's first-period and second-period lending choices are summarized in the result below:

Proposition 4: (Bank's First-Period and Second-Period Lending Choices When the Bank Raises Financing From Institutional Lenders Who Do Not Produce Information About m: *At t=0, all banks make P loans. Investors are promised a repayment of $1 at t=1 and* $D_P(r_0^P)$ *at t=2, where*

$$D_P(r_o^P) = 1 / r_o^P \tag{55}$$

and the bank's shareholders' expected profit is

$$\pi_1^P = r_o^P [X_P - D_P(r_o^P) + Z]. \tag{56}$$

If the first-period P loan repays at t=2, the bank invests in the R loan in the second period. It raises $1 in financing at t=2 for the second-period loan and promises the second-period lender a repayment of $1 if investors collect on their credit at t=3 and $\bar{D}_R(\Pr(R_S^2 \left| P_S^1 \right.))$ *if they provide renewed funding at t=3 that requires repayment at t=4. If the first-period loan defaults, the bank ceases to exist.*

Thus, as long as the bank's creditors do not invest in learning about the macro state, the world is a pretty safe place for the bank. It invests in a *P* loan in the first period, and conditional on successful repayment on that loan, it invests in an *R* loan in the second period. There are no financial crises. The analysis that follows establishes conditions under which the bank's institutional creditors will prefer not to invest in leaning about the macro state.

The analysis proceeds in two steps. First, it will be shown that no lender will wish to invest in learning about the macro state in the first period, as indicated in the lemma below.

Lemma 3: *No lender will invest in learning about* m_1 *at t=1.*

The intuition is straightforward. Since the bank has invested in the *P* loan in the first period, the assessed success probability at *t*=2 is $r + [1-r]b$, regardless of whether the macro state m_2 is discovered to be luck or skill. This is because the probability that the bank is talented is still the prior probability *r* when evaluated at *t*=1. Thus, the investment *M* in learning about m_1 is a waste.

Next, it will be shown that no lender will wish to invest in learning about m_3 in the second period. For this, consider first a lender who offers terms at *t*=2 to a bank, with a precommitment to not screen. This lender can offer the following terms to the bank in the second period:

- Repayment of \$1 if bank settles on its debt at *t*=3.
- Repayment of $\bar{D}_R^4 = 1/\Pr(R_S^2 \mid P_S^1)$ at *t=4* for credit extended to a bank investing in the *R* loan portfolio at *t*=2 after having successfully collected repayment on its *P* loan at *t*=2.

What one needs to show is that no other competing lender can do better with a different contract. It is clear that no competing lender can do better with a contract that does not involve costly learning about m_3, since the contract above makes the lender zero profit. So we need to examine only lenders who may invest *M* to learn about m_3. There are two possibilities: (i) a lender who competes at *t*=2 by offering to learn about m_3 at *t*=3; and (ii) a lender who enters the market at *t*=3, becomes informed about m_3 and seeks to pick off a bank from a lender who does not know the realization of m_3.

Consider (i). A lender who precommits to learning about m_3 at *t*=3 will recognize that, conditional on discovering that m_3 =luck, the bank will be liquidated and the lender will collect *L*. If it is discovered that m_3 =skill, then the lender can collect \$1 at *t*=3, and the bank can raise the \$1 it needs to pay off the lender and continue by promising a repayment of $\bar{D}_R^4 = [\Pr(R_2^S \mid P_S^1, m_3 = \text{skill}]^{-1}$ at *t*=4, where $\Pr(R_S^2 \mid P_S^1, m_3 = \text{skill}) = \lambda rq + [1-\lambda]q\tau_2^S(\text{skill})$, in recognition of the fact that the lender does not know whether m_1 was luck or skill. Note that a bank that is known to invest in learning about m_3 will also signal (inadvertently) that m_3 =skill when it agrees to renew second-period funding. This allows competing lenders to free ride and offer the borrower $\bar{D}_R^4$, leaving the incumbent lender with no profit in this state. That is, such a lender can hope to only break even on the loan it makes at *t*=3. Consequently, it must ensure that it breaks even on the loan it makes at *t*=2 as well. This implies that it should set the repayment at *t*=3, $\bar{D}_R^3$, to satisfy:

$$\lambda L + [1-\lambda]\bar{D}_R^3 - M = 1, \tag{57}$$

implying that:

$$\bar{D}_R^3 = \frac{1-\lambda L + M}{1-\lambda} \tag{58}$$

Thus, a bank that is not liquidated will need to raise $\bar{D}_R^3$ at t=3 in order to continue. Its repayment obligation at t=4 will be

$$\bar{D}_R^4 = \bar{D}_R^3[\Pr(R_2^S \mid P_S^1, m_3 = \text{skill})]^{-1} \tag{59}$$

Such a bank will compute the expected payoff to its shareholders as:

$$[1-\lambda]\Pr(R_S^2 \mid P_S^1, m_3 = \text{skill})\{\mathrm{X}_R - \bar{D}_R^3[\Pr(R_S^2 \mid P_S^1, m_3 = \text{skill})]^{-1} + Z\}. \tag{60}$$

Now consider (ii). A lender who did not lend at t=2, but has invested in learning about m at t=3 can attempt to take the bank away from the lender who extended credit to the bank at t=2. Note that the *de novo* lender will not bid for the bank's debt if it learns that m_3 =luck. If it learns that m_3 =skill, it will wish to lend to the bank at t=3. The uninformed incumbent lender is offering the bank funding renewal at a promised repayment of $[\Pr(R_S^2 \mid P_S^1)]^{-1}$, whereas an informed *de novo* lender can make a profit lending at those terms, since its breakeven repayment obligation is $[\Pr(R_S^2 \mid P_S^1, m_3 = \text{skill})]^{-1} < [\Pr(R_S^R \mid P_S^1))]^{-1}$. However, competition in the credit market, based on inferences by other competing lenders, may affect what terms a poaching (informed) lender may be able to lend at. Suppose $y > 0$ is the repayment terms it can lend at. Then, such a lender would view its expected profit as:

$$[[1-\lambda]\Pr(R_S^2 \mid P_S^1, m_3 = \text{skill})y - 1] - M. \tag{61}$$

The following result can now be proved.

Proposition 5: *Consider a bank that successfully collected repayment on its first-period P loan at t=2 and has made an R loan in the second period. In the absence of a CDS market on the bank's debt, no second-period lender to the bank will choose to invest in becoming informed about the macro state* m_3 *at t=3.*

The intuition is that competitors free-ride on any lender that invests in producing information in learning about m_3. This eliminates the ability of the information producer to recoup its investment in information. Thus, as long as a CDS market does not arise, the bank borrows from institutional lenders who prefer not to learn about m, and there is no financial crisis.

C. Analysis of the CDS Market

When there is a CDS market, the bank's creditors can observe the price of the CDS on the bank's debt and infer something about m. This inference will then affect both the pricing and availability of credit to the bank, and generate the possibility of a financial crisis. In what follows, it is assumed for simplicity that each group of investors trades in only one CDS contract, i.e. there is one CDS contract trading on each bank's debt and investors who trade in the CDS contract of bank *i* do not trade in the CDS contract of bank *j*.

Before analyzing the behavior of banks, it is useful to examine what happens in the CDS market. The equilibrium measure of *dit*, θ^*, is determined by:

$$V(\theta^* \left| x, M, f(\ell)\right) = 0. \tag{62}$$

The next result is useful.

Lemma 9: *In the first period, regardless of the loan made by the bank, the equilibrium measure of discretionary informed trader in the CDS contract,* θ^**, is zero. Thus, the CDS market provides no information in the first period about whether* $m_1 = \text{luck}$ *or* $m_1 = \text{skill}$.

The intuition is as follows. In the first period, the belief about the bank's skill, conditional on outcomes being skill-dependent, is at the prior belief, so the expected repayment probability for either loan *P* or *R* is the same whether outcomes are pure luck or skill dependent. Thus, discovering whether $m_1 = \text{luck}$ or skill is of no value to a trader, and no one chooses to become informed.

Lemma 10: *After the bank's first-period loan performance is observed, the market for CDS on the bank's second-period debt will involve* $\theta^* > 0$ *as long as:*

$$M < \lambda\{[1 - rq][1 - \Pr(R_S^2 \left| P_S^1\right.)]^{-1})] - 1\} \tag{63}$$

The first-period loan outcome permits an updating of beliefs about the bank being of type τ, which is relevant if $m_1 = \text{skill}$. Once beliefs are updated, a gap opens up between the probabilities of success for either the *P* or the *R* loan across the luck and skill macro states. This makes it profitable for discretionary traders to become informed.

Lemma 11: *The MM's posterior belief,* $r_{MM}^R(\xi)$*, can be unambiguously inferred from the equilibrium CDS price,* $P^e(\xi)$.

This result means that the bank's creditors can look at the price of the bank's CDS contract and be as informed as the *MM* about whether the luck or skill state has occurred.

D. Equilibrium in the Primary Bank Lending Market with a CDS Market

As the preceding analysis indicates, in the first period the CDS market reveals no information, so the bank invests in a *P* loan as before. To examine what happens in the second period, when the bank invests in an *R* loan, let us work backward from events at *t*=3.

Creditors' Liquidation / Continuation Decision at t=3:

Assume for now that the bank invests in the *R* loan in the second period, conditional on successful repayment on the *P* loan in the first period. It will be verified later that it will indeed choose to do so. Now suppose the lender who extends credit to the bank at *t*=2 stipulates a repayment obligation of

$\bar{D}_R^3$ if the bank's debt is settled then. Let $\Pr(R_S^3 \mid P_S^1, \Omega)$ be the probability of successful repayment on the *R* loan, as assessed at *t*=3, conditional on successful repayment of the first-period *P* loan and an order flow of Ω in the CDS contract inferred from the price of the CDS on the bank's debt. Then:

$$\Pr(R_S^3 \mid P_S^1, \Omega) = \hat{\lambda}(\Omega) rq + [1-\hat{\lambda}(\Omega)]\{\lambda rq + [1-\lambda] q \tau_S^2(skill)\} \tag{64}$$

where $\hat{\lambda}(\Omega)$ is the value of λ inferred from the observed order flow of Ω in the CDS market.

How the bank's creditors deal with the bank at *t*=3 depends on their calculation of the expected value of bank debt: $\Pr(R_S^3 \mid P_S^1, \Omega) X_R$. Now there are three regions: (i) $\Pr(R_S^3 \mid P_S^1, \Omega) X_R < L$; (ii) $\Pr(R_S^3 \mid P_S^1, \Omega) \in [L, \bar{D}_R^3)$; and (iii) $\Pr(R_S^3 \mid P_S^1, \Omega) > \bar{D}_R^3$.

In region (i), the second-period creditors liquidate the bank at *t*=3 and collect *L*. In region (ii), the bank defaults on its debt obligation and creditors take over the bank, allow it to continue and reset the repayment to X_R to be made at *t*=4. In region (iii), the bank is able to pay off D_R to the creditors and roll over its debt until *t*=4.

In a competitive credit market, $\bar{D}_R^3$ is given by the following pricing condition:

$$L[\Pr(R_S^3 \mid P_S^1, \Omega) X_R < L] + X_R[\Pr(R_S^2 \mid P_S^1, \Omega) X_R \in (L, \bar{D}_R^3)] + D_R^1[\Pr(R_S^3 \mid P_S^1, \Omega) X_R > \bar{D}_R^3] = 1 \tag{65}$$

Let Ω^* be the critical order flow that satisfies

$$\Pr(R_S^3 \mid P_S^1, \Omega^*) X_R = L. \tag{66}$$

Using (64) and (66) allows us to write

$$\hat{\lambda}(\Omega^*) = \frac{L[X_R]^{-1} - [\lambda rq + [1-\lambda] q \tau_2^S(skill)]}{[1-\lambda][q\tau_2^S(skill) - rq]} \tag{67}$$

Thus, we will be in region (i) ─ the liquidation region ─ whenever the order flow $\Omega > \Omega^*$, so that $\hat{\lambda}(\Omega) > \hat{\lambda}(\Omega^*)$.

Now

$$\Pr(\phi = \text{luck} \mid \Omega) = \begin{cases} \dfrac{f(\Omega-\theta^*)\lambda}{f(\Omega-\theta^*)\lambda + [1-\lambda] f(\Omega)} & \text{when } m_3 = \text{luck} \\ \dfrac{[1-\lambda] f(\Omega)}{f(\Omega-\theta^*)\lambda + (1-\lambda) f(\Omega)} & \text{when } m_3 = \text{skill} \end{cases}$$

Thus,

$$\Pr(\hat{\lambda}(\Omega) > \hat{\lambda}(\Omega)^*)) = \lambda \int_{\Omega^*-\theta^*}^{\infty} f(\ell) d\ell + [1-\lambda] \int_{\Omega^*}^{\infty} f(\ell) d\ell \tag{68}$$

is the probability that the bank will be liquidated at *t*=3.

Similar to (66), define $\bar{\Omega}$ as the critical order flow that satisfies:

$$\Pr(R_R^3 \mid P_S^1, \bar{\Omega}) X_R = \bar{D}_R^3 \tag{69}$$

which allows us to write

$$\hat{\lambda}(\bar{\Omega}) = \frac{\bar{D}_R^3 [X_R]^{-1} - \left[\lambda rq + [1-\lambda] q\tau_S^2(\text{skill})\right]}{[1-\lambda]\left[q\tau_2^S(\text{skill}) - rq\right]} \tag{70}$$

Thus, we will be in region (ii) whenever the order flow $\Omega \in \left[\bar{\Omega}, \Omega^*\right]$ so that $\hat{\lambda}(\Omega) \in \left[\hat{\lambda}(\bar{\Omega}), \hat{\lambda}(\Omega^*)\right]$.

Thus,

$$\Pr(\hat{\lambda}(\Omega) \in \left[\hat{\lambda}(\bar{\Omega}), \hat{\lambda}(\Omega^*)\right]) = \lambda \int_{\bar{\Omega}-\theta^*}^{\Omega^*-\theta^*} f(\ell) d\ell + [1-\lambda] \int_{\bar{\Omega}}^{\Omega^*} f(\ell) d\ell \tag{71}$$

And the probability of being in region (iii) is given by:

$$\Pr(\hat{\lambda}(\Omega) < \hat{\lambda}(\bar{\Omega})) = \lambda \int_0^{\bar{\Omega}-\theta^*} f(\ell) d\ell + [1-\lambda] \int_0^{\bar{\Omega}} f(\ell) d\ell \tag{72}$$

Note that in region (iii), the bank's repayment obligation at t=4 will be

$$\bar{D}_R^3 / \Pr(R_S^3 \mid P_S^1, \Omega). \tag{73}$$

Bank's Choice Between P and R Loans at t=2:

Now, the bank's expected profit at t=2 from investing in an R loan in the second period can be written as:

$$\begin{aligned} \bar{\bar{\pi}}_2^R = \lambda \Bigg[& \int_0^{\Omega^*-\theta^*} \Pr(R_S^3 \mid P_S^1, \theta^* + \ell) Z f(\ell) d\ell + \int_0^{\bar{\Omega}-\theta^*} \left\{ \Pr(R_S^3 \mid P_S^1, \theta^* + \ell) \left[X_R - \bar{D}_R^3 \right] \right\} \Bigg] \\ & + [1-\lambda] [\int_0^{\Omega^*} \Pr(\bar{R}_S^3 \mid P_S^1, \ell) Z f(\ell) d\ell + \int_0^{\bar{\Omega}} \{ \Pr(R_S^3 \mid P_S^1, \theta^* + \ell) [X_R] - \bar{D}_R^3 \} f(\ell) d\ell] \end{aligned} \tag{74}$$

On a P loan, there is no chance of liquidation at t=3, as discussed earlier. Thus, the lender who extends credit to the bank at t=2 and settles at t=3 can specify a repayment obligation of \$1, and the bank settle it with probability 1 by raising new debt in the amount of \$1 at t=3. The bank will have to promise on this debt a repayment of $\bar{D}_P^4$, where

$$\Pr(P_S^3 \mid P_S^1, \Omega) \bar{D}_P^4 = 1 \tag{75}$$

where the posterior probability, assessed at t=3, that the P loan will be repaid is:

$$\Pr(P_S^3 \mid P_S^1, \Omega) = \hat{\lambda}(\Omega)\{r + [1-r]b\} - [1-\hat{\lambda}(\Omega)]\{\lambda\{r + [1-r]b\} + [1-\lambda]\{\tau_2^S(skill) + [1-\tau_2^S(skill]b\} \tag{76}$$

and $\hat{\lambda}(\Omega)$ is the inferred value of λ after inferring the order flow Ω from the CDS price.

Proceeding as before, the bank's expected profit from a P loan, evaluated at t=2, can be written as:

$$\bar{\bar{\pi}}_2^P = \lambda\left[\int_0^\infty \{\Pr(P_S^3 \left| P_S^1, \theta_P^* + \ell)[X_P + Z] - 1\} f(\ell)d\ell\right] + [1-\lambda]\left[\int_0^\infty \{\Pr(P_S^3 \left| P_S^1, \theta^*)[X_P + Z] - 1\} f(\ell)d\ell\right] \tag{77}$$

Some additional notation is needed. Define

$$\lambda_{\min} = \inf\{\lambda \in [0,1] \,|\, \lambda \text{ satisfies (15), (30), } (50) \text{ and } (54)\}. \tag{78}$$

E. Financial Crises

The following result can now be proved:

Proposition 6: (Financial Crisis): *With a CDS market, banks invest in a P loan in the first period at t=0, and there is no financial crisis in the first period. All banks that experience default on their first-period loans exit the market. There exists* $\lambda \in (0, \lambda_{\min}]$ *such that banks that experience successful repayments on their first-period loans extend R loans in the second period at t=2. In both periods, banks prefer to borrow from institutional lenders who do not invest in learning about the macro state m. There is a positive probability that all the banks that make R loans in the second period will be liquidated at t=3 and a financial crisis will ensue. The probability of a financial crisis occurring is positive regardless of whether* $m_3 = luck$ *or* $m_3 = skill$ *at t=3, but it is higher if* $m_3 = luck$ *is realized.*

The sequence of events is that banks initially make prudent loans, so that, regardless of what is revealed at *t*=1 in the CDS market (if it exists), there is no crisis. For banks that experience success in repayment on their first-period loans, the posterior probability of the bank being talented is sufficiently high that an *R* loan will be financed by the bank's creditors, and the bank will prefer it to a *P* loan, as long as the probability of $m_3 = \text{luck}$ at *t*=3 (as assessed at *t*=2) is low enough. The reason why it is important for λ to be low is that it is only if $m_3 = \text{skill}$ that assessments of the bank's skill are important, and it is only then that an *R* loan can possibly dominate a *P* loan.

So an implication of the proposition is that the conditions conducive to the occurrence of a crisis — such as investment in *R* loans by banks — are precisely those that involve a sufficiently low probability of occurrence of the *m*=luck macro state in the future, i.e., a low probability of a future crisis. Another condition needed for banks to invest in *R* loans — and hence for crises to occur — is that sufficiently many banks experience *good* performance. Thus, crises occur following periods during which banks experience low defaults and high profits and it is commonly believed that the likelihood of a future crisis is relatively low.

The crisis, if it occurs, is triggered by price discovery in the CDS market. Banks attempt to shield themselves from the crisis-precipitating effect of obtaining financing from "informed" lenders by obtaining it from institutional investors who prefer not to learn about the macro state *m*. But this cannot prevent the bank's financiers from making inferences from CDS prices and using these to sometimes withdraw their funding from banks, thereby generating a crisis. Thus, the CDS market, while being a source of price discovery, also sometimes destabilizes the primary bank debt market.

Proposition 7: *The set of exogenous parameters satisfying the restriction on the model ((2), (4), (5), (6), (7), (9), (10), (15), (30), (50) and (54) is non-empty.*

VI. WELFARE IMPLICATIONS, LOAN RESALE MARKET, RELATED ISSUES AND POLICY IMPLICATIONS

This section discusses a number of issues. First, I discuss the welfare implication of the model. This is followed by a discussion of what would happen if there was secondary market for bank loans, so that banks could sell in that market to avoid liquidation. Then I discuss what the model says about why the U.S. has witnessed so few banking crises in the last few decades, and how the model can be extended to generate a theory of “crisis cycles”. This is followed by a discussion of how the differences between the theory developed here and the usual moral hazard story lead to a different set of policy prescriptions for how to reduce the likelihood of crises.

A. Efficiency

A crisis is always *ex post* inefficient in this model because the value of the bank, including the value of its non-pledgeable assets, is greater than the liquidation value. Nonetheless, creditors force liquidation because they do not have access to the non-pledgeable assets. Moreover, due to the loss of the social benefit of continuing bank, *J*, a crisis is also *ex ante* inefficient.

B. The Effect of a Loan Resale Market

Since a crisis is triggered by creditor-initiated liquidations, a natural question is: what if there was a loan resale market? In this case, we need to consider two kinds of shocks. One is the macroeconomic shock in the model analyzed thus far, and the other is an idiosyncratic liquidity shock that is suffered by investors and is uncorrelated with the macroeconomic shock. In this case, the bank’s creditors will wish to liquidate the bank if they experience an idiosyncratic liquidity shock. But the bank will have the option to sell its loan to another bank to pay off creditors with the proceeds and avoid liquidation. This strategy will work if two conditions are satisfied. One is that the value of the loan exceeds the liquidation value, excluding the value of non-pledgeable assets that cannot be transferred in the sale. This will be the case if either it is an R_1 loan or an R_N loan with $m_t = \text{skill}$. Assume that m_t is costlessly observable.

The other condition is that there is actually another bank to purchase the loan, which will depend on the liquidity of the loan resale market. This raises some interesting issues, if we think of endogenizing the liquidity of this market. Suppose there are $\hat{N}$ banks in the economy and bank *i* faces a cost C_{ij} of entry into the market for risky asset R_j, with $C_{ij} > C_{ij-1} \forall i,$ the idea being that riskier assets are more complex and thus costlier to manage. Moreover, for any risky asset R_j, C_{ij} varies in the cross-section of banks. Note now that the larger the number of banks that are in the market for a risky loan R_j, the higher is the probability that any given bank faced with an idiosyncratic liquidity shock will be able to sell its loan. And the higher this probability, the higher the *ex ante* expected value of the loan to any bank since the loan resale value exceeds its liquidation value. In other words, the larger the number of banks in any given risky asset market, the higher the *ex ante* value of the asset to all banks.

Given this, consider a situation in which a relatively small number of banks, say $N_1 < \hat{N},$ are in the market for the R_N loan. The other banks are in the markets for the R_1 loan and the *P* loan. Now suppose we have a number of periods during which the banks in the markets for R_N and R_1 loans experience success and $m_t = \text{skill}$ occurs. This will induce some banks with R_1 loans to cross the threshold beyond which the R_N loan becomes more attractive than the R_1 loan. So now suppose the number of banks in the market for the R_N loan increases to $N_2 \in \left(N_1, \hat{N}\right)$. What is interesting is that just this increase from N_1 to N_2 makes the R_N loan more attractive to even those banks in the R_1 loan market that have not experienced enough successes to make the transition to the R_N loan market. Thus, *a loan resale market can actually make risk-taking more attractive for banks.*

C. Why There Have Been So Few Banking Crises in the U.S. and What Has Changed to Increase the Frequency of Crises

The model suggests that three factors may have been at work in explaining why the U.S. has experienced so few banking crises since the Great Depression. One is that λ, the probability of $m_t = \text{luck}$, may have been low. Indeed, a financial crises has a positive probability of occurrence in this model only when λ is sufficiently low. The second, more interesting, possibility is that financial innovation in U.S. banks was historically low, partly due to the Glass-Steagall separation between commercial and investment banking (see Boot and Thakor (1997)). This means that opportunities for banks to invest in riskier *R* loans were limited. However, that has now changed. Along with changing perceptions of the skills of bankers, there is also a greater availability of increasingly risky and innovative financial instruments to invest in. Finally, the analysis predicts that the emergence of derivates markets (including CDS market) also increases the likelihood of a crisis. This market was virtually non-existent prior to 2000, but grew explosively after that in the period preceding the recent subprime crisis. Thus, the analysis in this paper implies an increasing learning-based incidence of banking crises in the future.

D. A Theory of Crisis Cycles

Consider the dynamics of credit markets in the context of the T-period model analyzed in Section IV. Banks will initially make prudent loans. Some banks will fail and exit the market, similar to what happens at *t*=2 in the model presented here. With probability $1-\lambda$ (approaching 1 for λ approaching 0), the successful banks will have estimates of their ability revised upward. The larger the number of successful banks, the larger will be the number of banks making subsequent risky loans and the greater will be the liquidity of bank loans in the resale market; see Section VIB. Regulators, rating agencies, and others may then permit banks to make risky loans, and investors will be willing to finance them. In the next period, many banks may fail and exit. But the surviving banks will have even higher posterior beliefs about their abilities. Even riskier bets will be made, at least by the surviving banks, and possibly by new entrants who hire away some of the high-reputation managers from surviving banks. As long as sufficiently many banks continue to succeed and all agents continue to believe that loan repayment probabilities depend on bank skill, risk taking will keep increasing. Moreover, because the managers in the banks will be viewed as highly talented, they will command high salaries in the periods leading up to the crisis. Then, if $m_t = \text{luck}$ occurs and is observed directly or through price discovery in the CDS market, a crisis will ensue. Liquidity of bank loans will dry up quite suddenly.

During the crisis, the majority of bank managers will experience downward revisions in perceptions of their ability, and be replaced by new managers. Investors will be unwilling to fund risky loans. Lending will be confined to prudent loans, and bank balance sheets will shrink as risky loans are shed. Politicians will fret about banks not lending enough.

Over time, as banks keep making an increasing number of prudent loans, these loans will pay off and the perceptions of the abilities of the new managers will rise. While the old risky loans are largely discredited in the eyes of the investors, new types of risky loans will be introduced into the market. When perceptions of bankers' abilities are high enough, banks will begin to invest in these new risky loans and the cycle will start all over again. We will thus observe lending booms followed by crises, followed by economic and lending contractions and more conservative lending by banks, followed by lending booms and crises.

To the extent that only limited discovery about m_t is possible costlessly and further discovery is costly, we would expect that the CDS and other derivatives markets would *facilitate* this discovery process. Thus, crises will be more likely when there is a CDS market, and the growth of this market will increase the frequency of financial crises.

Numerous financial crises have been part of such boom-and-bust cycles. Prior to the Great Depression, there was a credit boom. Similarly, the S&L crisis was preceded by a lending boom, especially in real estate. And the latest crisis is another striking example. Not only was the crisis preceded by a lending boom, but also by an intertemporal escalation in risk-taking, financial innovation that brought new (and riskier) securities into the market,[18] and the growth of the CDS market.

E. Contrasting the Theory with a Standard Moral-Hazard Story: Policy Implications, and Empirical Evidence

This subsection teases out three implications of the model that enable one to sharply distinguish the theory developed here from the usual moral-hazard story. The common thread that runs through these implications is that the theory developed here explains precisely why banks, regulators, investors and credit-rating agencies would all be simultaneously sanguine about the consequences of high risk-taking by banks prior to the onset of a financial crisis, even in the absence of any incentive conflicts. This sharply differentiates the theory from the moral-hazard explanation which relies on an assumed *across-the-board* spike in incentive misalignment prior to a crisis. Moreover, it alters one's view about the regulatory interventions needed to reduce the likelihood of a financial crisis.

Financial crises arise in this model due to (rational) learning. A string of good outcomes elevates perceptions of banking skill and this skill inference entices banks to take increasing (tail) risks that promise higher and higher payoffs conditional on success. Moreover, because perceived banking skills in managing risks are high during such periods both within and outside banks, bank managers will be highly compensated, especially in institutions that are growing their book of business in these risky activities. But regulatory initiatives to limit executive pay in banking, such as those witnessed in the U.S. and elsewhere after the subprime crisis, will fail to provide an amelioration, because they will not change skill perceptions. And given elevated skill assessments, risk managers within banks — who may advocate putting the brakes on risk taking — will tend to be marginalized.

Note that it is not just the banks that elevate their skill perceptions; it is also the investors who fund banks. This means that investors will be willing to lend money to banks at relatively low risk premia even if banks choose to operate with very low capital levels. After all, who needs capital when assessed risk is low? Thus, if there is even a tiny perceived advantage associated with debt over equity—say due to taxes or a preference for reporting high ROE—banks will operate with relatively low capital levels.[19] Thus, one clear implication of this theory is:

Implication 1: *Crises are cyclical phenomena and are (almost unavoidably) highly likely to occur following a long period of relatively high banking profits, regardless of executive compensation*

[18] This has caused many to be critical of financial innovation. Stiglitz (2010), for example, states: "Paul Volcker puts the matter clearly when he said 'I wish that somebody would give me some shred of neutral evidence about the relationship between financial innovation recently and the growth of the economy'".
[19] As we pointed out in the Introduction, these developments are ubiquitous during pre-crisis periods.

and the distorting effects of government safety nets. Misaligned incentives due to compensation or safety nets will strengthen risk-taking incentives and make crises more likely, but this incentive misalignment is not necessary for generating financial crises.

However, the assumption that crises are primarily generated by misaligned incentives would imply that banks *knew* that *R* did not maximize the value of the bank, but still invested in it at t=2 because of government safety nets and bank managerial compensation that rewarded excessive tail risks at the expense of the taxpayers. In other words, the actions of banks and investors that are truly being driven by experience-based learning would be misinterpreted as moral hazard s*ubsequent* to the observation of a crisis (that would reveal *ex post* that the risk-taking was inefficient).

While numerous authors have focused on incentive problems as a cause of the crisis (e.g., Barth, Caprio and Levine (forthcoming)), the incentive-conflict viewpoint is perhaps best exemplified in the following quote:

> "But this is not a crisis caused by the failure of complex financial instruments. This is a crisis caused by the failure of leaders on Wall Street.
>
> The Heads of firms like Bear Stearns, Lehman Brothers, AIG, Countrywide Financial and Washington Mutual all too often sacrificed their firms' futures in order to maximize short-term gains. This meant under-pricing of risk in exchange for immediate fees and taking on inordinate levels of debt to invest in complex, highly uncertain instruments."
>
> *Bill George in "Wall Street's Crisis of Leadership,"*
> *Bloomberg BusinessWeek, October 3, 2008*

The contrast between the crisis explanation provided in this paper and the one above could not be more stark. While the explanation in this paper suggests that tinkering with fee structures, executive compensation packages and even the regulatory safety net will not stop future crises from occurring, the moral-hazard explanation suggests that reforming executive compensation and fixing the safety net problems will provide the necessary amelioration. In turn, the moral-hazard explanation prescribes more stringent and intrusive regulation of the form embodied in the recently-passed Dodd-Frank Act. Much of this regulation calls for increased oversight of bank investments and more sophisticated regulatory mechanisms to deal with institutions viewed as "systemically important."

However, the theory presented here suggests that these regulatory interventions may prove ineffective. Because these moral-hazard-based intervention proposals rely on regulators being aware of imprudent risk-taking *when* it is occurring (and before financial crises occur), there is an implicit assertion that regulators are *not* governed by the same (experience-based) beliefs that govern all the other agents in the economy. Thus, if regulators do not intervene and stop banks from taking excessive risks, then the conclusion is that it must be because incentive conflicts keep regulators from faithfully serving taxpayer interest. If this were true, then very heavy-handed regulation, combined with contractual approaches to aligning the interests of regulators with those of taxpayers, might be efficient. But, if regulators are making the same (rational) inferences as everybody else, then such an approach is unlikely to prevent future crises.[20] This leads to the next two implications of the learning-based theory:

Implication 2: *Even if regulators exhibit no agency problems vis-à-vis taxpayers, they will be less vigilant when banks are doing well, and unlikely to prevent investments in highly-risky assets, simply because they will believe, like everyone else, that banks are skilled enough to manage the risks.*

Implication 3: *Regulators should attempt, on an ex ante basis, to put in place mechanisms that make risk-taking more expensive for the bank's shareholders when the bank is doing well. One simple mechanism for doing this is higher (equity) capital requirements that are countercyclical.*

Since in my model the probability of success of the risky loan, R_i, is always less than the probability of success of the prudent loan, *P*, higher capital requirements make R_i less attractive than *P* for the bank's shareholders. By raising the capital requirement when banks are doing well ─ and the longer the industry has done well, the higher the requirement should be ─ risk-taking is made more expensive precisely when it is more attractive for banks.[21]

Implication 4: *Regulators should be wary of basing prudential regulation ─ such as capital requirements ─ on CDS prices, since this could potentially increase the likelihood of a financial crisis.*

There have been calls for basing prudential regulation on markets for derivatives. Presumably, regulators are advised to ask for higher bank capital when CDS prices indicate a higher default probability on bank debt. However, the analysis here indicates that this could add even further to banking instability as the bank is unlikely to be able to raise additional financing when adverse price signals from the CDS market are creating incentives for the bank's creditors to cut off funding.

In a nutshell, the analysis here provides a straightforward way to understand numerous stylized facts related to crises, such as the cyclical occurrence of crises and booms, as well as low capital levels in banks, the apparent "marginalization" of risk managers in banks, high compensation for bank CEOs, and high pre-crisis liquidity in asset markets as well as seemingly lax regulatory (and credit-rating-agencies) monitoring of banks prior to crises. Moreover, in sharp contrast to the misaligned-incentives explanation

[20] One might argue that regulators are above distortions caused by self interest that affect banks and rating agencies, and can thus prevent crises through more effective monitoring. This, however, is debatable. See Boot and Thakor (1993), and Kane (1990). The empirical evidence in Berger and Bouwman (2013) indicates that capital does increase a bank's probability of surviving a crisis. Thus, countercyclical capital requirements may not only reduce the ex ante probability of a crisis, but may also reduce the incidence of bank failures during a crisis.

[21] This argument does not rely on equity capital being more costly than debt financing. It is simply based on the idea that a bank knows that a riskier investment increases the odds of losing its capital in the event of default, as in monitoring model of Holmstrom and Tirole (1997) and the sorting model of Chan, Greenbaum and Thakor (1992).

for financial crises, the theory developed here explains why banks, regulators and rating agencies all seem to simultaneously "underestimate" risk and why market participants do not adjust contracts to correct the apparent misalignment or increase yield spreads immediately prior to the crisis in anticipation of the impending consequences of such behavior. This theory suggests that many of the regulatory initiatives that emerged in response to the recent financial crisis may not succeed in preventing future crises. These initiatives include restrictions on executive compensation in banking, pricing safety nets like deposit insurance more accurately and making the pricing risk-sensitive, putting restrictions on regulatory forbearance (e.g. of the sort put in place after the FDICIA in 1991), aligning the incentives of regulators more closely with those of taxpayers, engaging in more active monitoring of systemically important financial institutions (SIFIs), etc.[22]

VI. CONCLUSION

This paper has proposed a theory of financial crises based on learning that leads to revisions in inferences of banking skills in an environment in which skills may or may not matter, depending on a macro state that could be shaped by investor sentiment or developments in the real sector. In such a setting, a sufficiently long sequence of favorable outcomes for banks leads *all agents*—banks themselves, their investors, rating agencies, and regulators—to assign relatively high probabilities to the abilities of banks to manage their own risks. This provides banks with access to low-cost funding. Consequently, if either if agents can directly observe that outcomes are just due to luck or price revelation in the CDS market leads to such an inference, a crisis occurs as debt investors withdraw their funding from banks.[23]

This theory of financial crises can explain a substantial pre-crisis build-up of liquidity, and then a sudden collapse of the system, with a rapid drying up of liquidity. The theory developed here also predicts that such financial crises will be cyclical. That is, the framework developed here explains "crisis

[22] What does the empirical evidence suggest about whether it is moral hazard or learning-based beliefs that drove bank behavior? Recent evidence that appears to argue in favor of the explanation provided here appears in Fahlenbrach and Stulz (2011). They uncover two key stylized facts in their empirical analysis. One is that executive compensation was only a small portion of the wealth of bank CEOs prior to and during this crisis. The major portion was related to their holding of their own banks' stock. The other is that before the crisis began, these CEOs did *not* reduce their holdings in their own banks, something that they would have done if the misaligned-incentives (with deliberate pursuit of tail risk) argument held sway. It appears then that bankers were just as surprised by the crisis as others were, consistent with the analysis in this paper (with the assumption of a very small λ).

[23] The issue of what could trigger such a change in beliefs is beyond the scope of this paper, but a variety of factors could act as triggers. For example, the arrival of information that even banks with high levels of reputation for being skilled are experiencing defaults ─ which may have been a near zero-probability event in the prior credit market equilibrium ─ can be a trigger. Another trigger may be the adoption of new government policies.

cycles." Moreover, the analysis suggests that regulations enacted in response to crises that are intended to cope with moral hazards of various sorts may be ineffective in diminishing the likelihood of future crises.

An implication of the analysis is that as banks experience increasing success, they will keep lower amounts of liquid (cash asset) reserves, as they perceive lower probabilities of future crises. This then becomes another factor that adds to the severity of the crisis when it occurs.[24]

The theory also provides a possible explanation for why financial crises have increased in frequency. The explanation relies on the emergence of the market for traded derivatives, like CDS written on either bank debt or the loans taken by the bank's borrowers. While such markets aid price discovery, they can also be destabilizing.

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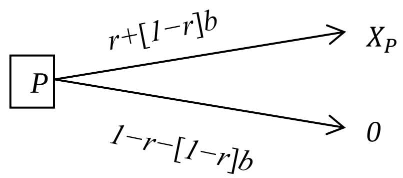
[24] The analysis in Carletti and Leonello (2011) indicates that interbank competition will also affect bank reserves, with banks in more competitive markets keeping more liquid reserves.

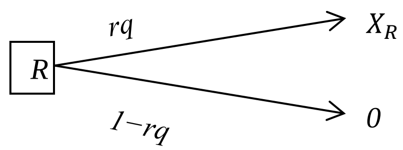
FIGURE 1. SEQUENCE OF EVENTS

0	1	2	3	4
• Banks choose between prudent (*P*) and risky (*R*) loans and invest \$1 in the chosen loan.	• Information about m_1 is costlessly available to investors.	• Loans made at *t*=0 pay off and investors are paid off if bank not liquidated at *t*=1.	• Investors learn m_3 and whether the bank monitored its second-period borrower.	• Loans made at *t*=2 pay off and new investors paid off if bank not liquidated at *t*=3.
• The loan is entirely debt financed, and financing is raised from institutional investors or through traded debt.	• Investors observe m_1 as well as whether bank has monitored first-period borrower and decide whether to liquidate the bank or renew funding.	• Investors revise their beliefs about the bank's type based on whether the loans pay off or not.	• Investors then decide whether to liquidate the bank or renew funding.	
• The common prior belief is that there is a probability $1-\lambda$ (the loan repayment probability is skill-dependent), and in this case the probability is $r \in (0,1)$ that the bank is talented (type τ) and 1-*r* that it is untalented (type-*u*). There is a probability λ of the macro state $m_1 = \text{luck}$ (the loan repayment probability is purely exogenous).	• If the bank can pay off investors their promised amount by raising new debt, it survives until *t=2*. Otherwise, it may cease to exist.	• Banks make new loans financed with new debt.		

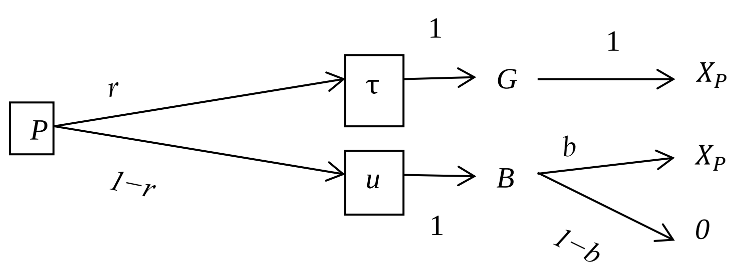
***FIGURE 2:* Pictorial Depiction of Project Success Probabilities**

***Exogenous Project Success Probabilities* (** m = luck **)**





***Skill-Dependent Project Success Probabilities* (** m = skill **)**



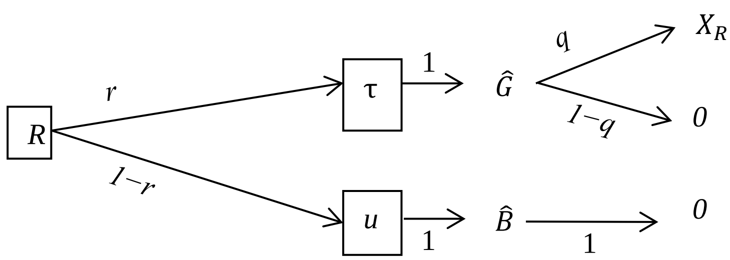


FIGURE 3: **Risk-Taking and Crisis with Many Time Periods: Three Asset Separation**

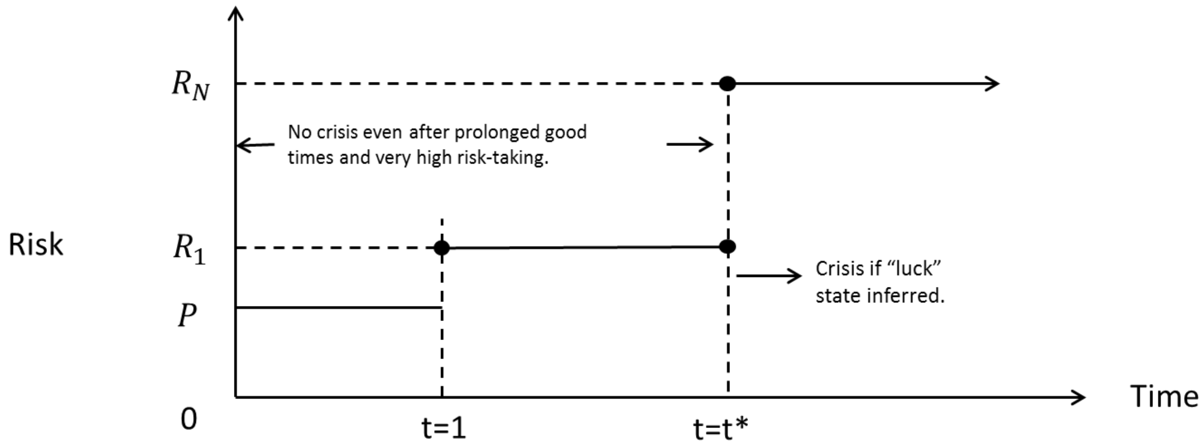


FIGURE 4: **Intuition for Three-Asset Separation**

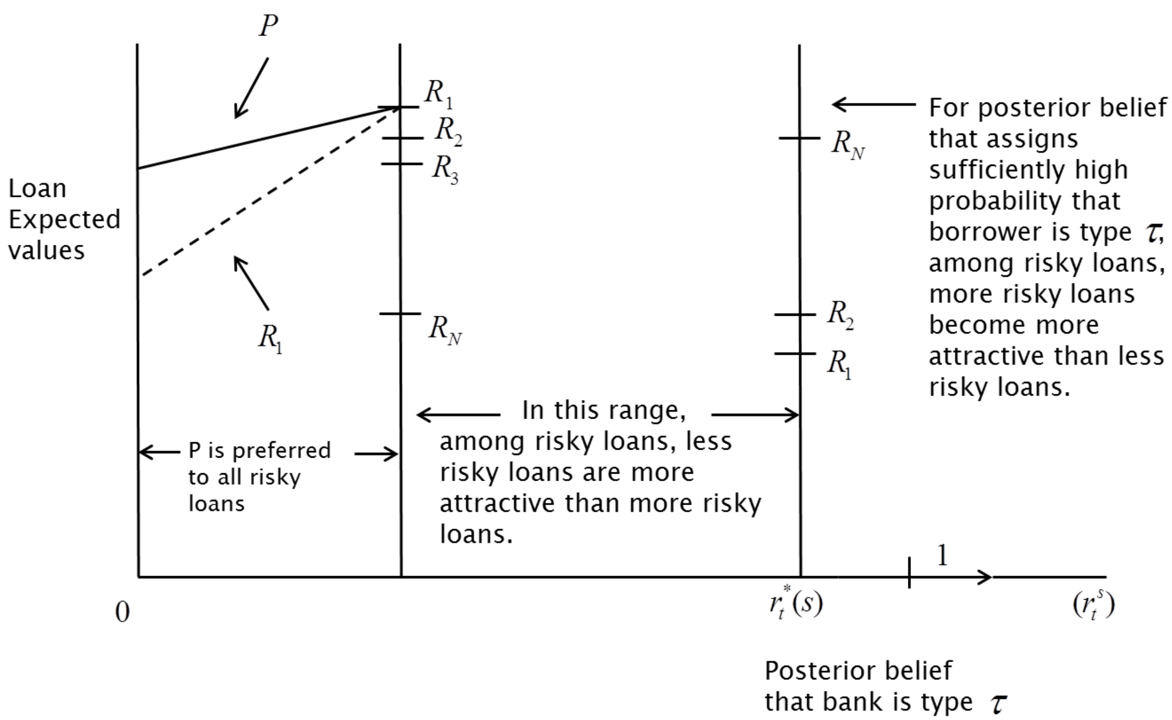


FIGURE 5. SEQUENCE OF EVENTS

0

- Banks choose between prudent (P) and risky (R) loans and invest $1 in the chosen loan.
- The loan is entirely debt financed, and financing is raised from institutional investors or through traded debt.
- The common prior belief is that there is a probability $1-\lambda$ (the loan repayment probability is skill-dependent), and in this case the probability is $r \in (0,1)$ that the bank is talented (type τ) and 1-r that it is untalented (type-u). There is a probability λ of the macro state $m_1 = \text{luck}$ (the loan repayment probability is purely exogenous).

1

- A CDS market may open up in which informed investors learn whether the macro state $m_1 = \text{skill}$ or $m_1 = \text{luck}$.
- The bank's creditors observe the price in the CDS market and decide whether to demand immediate repayment from the bank.
- If the bank can pay off investors their promised amount by raising new debt, it survives until t=2. Otherwise, it may cease to exist.

2

- Loans made at t=0 pay off and investors are paid off if bank not liquidated at t=1.
- Investors revise their beliefs about the bank's type based on whether the loans pay off or not.
- Banks make new loans financed with new debt.

3

- If it did not open at t=1, a CDS market may open up in which informed investors learn whether the macro state $m_3 = \text{skill}$ or $m_3 = \text{luck}$.
- Investors observe the price in the CDS market and decide whether to demand immediate repayment from the bank.
- If the bank can pay off investors their promised amount, it survives until t=4. Otherwise, it may cease to exist.

4

- Loans made at t=2 pay off and new investors paid off if bank not liquidated at t=3.

APPENDIX

Proof of Proposition 1:

Suppose investors provide the bank with a long-maturity debt at t=0 that matures at t=2. Then, given (15), the bank manager will prefer not to monitor the loan, since the probability that he will lose his personal benefit, *B*, by not monitoring is zero. Hence the creditors' expected payoff at t=2 will be zero, which means they will be unwilling to extend credit. With short-term debt, if creditors discover at t=1 that no loan monitoring was done, then they will liquidate the bank and the bank manager will lose *B*. Given (2), it follows that he will prefer to monitor the loan in this case. This means short-term debt is the only viable financing instrument for the bank. Q.E.D.

Proof of Lemma 1: If $m_1 = \text{skill}$ and the bank experiences default on its first-period *P* loan, then from (15) and (17), we know that neither the *P* nor the *R* loan can be funded in the second period, so the bank must exit. If $m_1 = \text{luck}$, then beliefs about the success probabilities of the *P* and *R* loans revert to those that existed at t=0.

Proof of Lemma 2: The total value of a bank to its financiers, conditional on $m_1 = \text{skill}$, successful repayment of the first-period *P* loan and investment in the *R* loan in the second period is:

$$\lambda L + [1-\lambda] q \tau_2^S(\text{skill})[X_R + Z] \tag{A-1}$$

If we assume that the loan will be liquidated at t=3 conditional on $m_3 = \text{luck}$. If the bank chooses to invest in a *P* loan in the second period, then its value to its financiers is:

$$\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill})[X_P + Z] \tag{A-2}$$

Label the expression in (A-1) as (A-1) and the expression in (A-2) as (A-2). It can be seen that (A-1) > (A-2), as long as (30) holds. Moreover, $\partial(A\text{-}1)/\partial\lambda < 0$ and $\partial(A\text{-}1)/\partial q > 0$. Further, we also see that $\partial(A\text{-}2)/\partial b > 0$. Thus, by continuity, (30) holds for λ and *b* sufficiently small and *q* sufficiently large, given that (30) holds trivially when $q = 1, \lambda = b = 0.$ Q.E.D.

Proof of Proposition 2:

Suppose the bank experiences successful repayment of its first-period loan at t=2 and $m_1 = \text{skill.}$. Then, for the second-period loan choice, compare $\overline{\pi}_2^R$, the expected profit from an R loan with $\overline{\pi}_2^P$, the expected profit from a *P* loan, where:

$$\overline{\pi}_2^P = \Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill})\{X_P - \overline{D}_P(\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill})) + Z\} \tag{A-3}$$

where $\overline{D}_P(\Pr(P_S^2 \,|\, P_S^1, m_1 = \text{skill}))$ is by (27).

Thus, substituting (27) in (A-3) yields:

$$\begin{aligned}\bar{\pi}_2^P &= \Pr\left(P_S^2 \mid P_S^1, m_1 = \text{skill}\right) X_P - 1 + \Pr\left(P_S^2 \mid P_S^1, m_1 = \text{skill}\right) Z \\ &< \Pr\left(R_S^2 \mid P_S^1, m_1 = \text{skill}\right)\left[X_R + Z\right] - 1 \text{ given Lemma 2.} \\ &= \Pr\left(R_S^2 \mid P_S^1, m_1 = \text{skill}\right)\left[X_R - \bar{D}_R\left(\Pr\left(R_S^2 \mid P_S^1, m_1 = \text{skill}\right)\right) + Z\right] \\ &= \bar{\pi}_2^R.\end{aligned}$$

Thus, the bank prefers an *R* loan to a *P* loan in the second period, conditional on first-period success. Since refinancing at t=3 is possible with probability 1, investors who provided short-term financing at t=2 that matures at t=3 will view their claim as riskless.

If creditors discover at t=3 that $m_3 = \text{skill}$, then they assess their expected payoff from refinancing the bank and getting repaid at t=4 as $q\tau_2^S(\text{skill})\bar{D}_R(\Pr(R_S^2 \left| P_S^1, m_1 = \text{skill}\right.)$, the payoff with liquidation at t=3. If $m_3 = \text{luck}$, then investors prefer to not renew funding and force liquidation since $L > rqX_R$. Q.E.D.

Proof of Lemma 3:

The proof is obvious given earlier arguments. Q.E.D.

Proof of Lemma 4:

We know that the bank will invest in *R* in the second period, conditional upon successful repayment of *P* in the first period and $m_1 = \text{skill}$. In this case its total value (including social value) is:

$$\lambda L + [1-\lambda]q\tau_2^S(\text{skill})[X_R + Z + J] \tag{A-4}$$

If it invests in *P*, the total value is:

$$\Pr(P_S^2 \left| P_S^1, m_1 = \text{skill}\right.)[X_P + Z + J] \tag{A-5}$$

For (A-5) to exceed (A-4), we need

$$\begin{aligned}&J[\Pr(P_S^2 \left| P_S^1, m_1 = \text{skill}\right.) - [1-\lambda]q\tau_2^S(\text{skill})] \\ &> \lambda L + [1-\lambda]q\tau_2^S(\text{skill})[X_R + Z] - \Pr(P_S^2 \left| P_S^1, m_1 = \text{skill}\right.)[\mathrm{X}_P + Z]\end{aligned} \tag{A-6}$$

We know that

$$\begin{aligned}\Pr(P_S^2 P_S^1, m_1 = \text{skill}) &= \lambda \mathrm{r}_0^P + [1-\lambda][\tau_2^S(\text{skill}) + [1-\tau_2^S(\text{skill})b] \\ &> [1-\lambda]\tau_2^S(\text{skill}) \\ &> [1-\lambda]q\tau_2^S(\text{skill})\end{aligned}$$

And that the right-hand side (RHS) of (A-6) is positive (but finite) by Lemma 2. Thus, for *J* large enough, (A-6) will hold. Q.E.D.

Proof of Lemma 5:

Using (39) we see:

$$\partial EV_i / \partial r = \left[q - b_R\right]\left[X_R^1 + \left[i-1\right]k\right] + \left[1-b_R\right]\left[i-1\right]k > 0 \text{ since } q > b_R \tag{A-7}$$

Next, using (39), we have:

$$\partial EV_i / \partial i = rqk + [1-r]\{b_R k - [1-b_R]k\}$$
$$= k\{rq + [1-r]b_R - [1-r][1-b_R]\}$$
$$< 0 \text{ given (33).}$$

Finally, using (A-7),

$$\partial^2 EV_1 / \partial i \partial r = [q - b_R]k + [1-b_R]k$$
$$> 0.$$

Q.E.D.

Proof of Lemma 6:

Since $\partial EV_i(r)/\partial i < 0,$ we know that by continuity, $\exists\, \overline{r}_t^S > r$ such that $\partial EV_i(\overline{r}_t^S)/\partial i < 0.$ Since from (42) we know that $\partial \tau_t^S / \partial i < 0,$ we can assert $\partial EV_i(\overline{r}_t^S)/\partial i < 0$ for $t < t^*,$ for some $t^*.$ Now, it follows that $\lim_{t\to\infty} \tau_t^S = 1.$ Moreover, writing (33) as $r < [1-2b_R][1-r][q]^{-1},$ it can be seen that, the left-hand side converges to 1 as $r \to 1,$ whereas $\lim_{r\to 1}[1-r][1-2b_R][q]^{-1} = 0.$ Thus, for t^* large enough, the inequality in (33) is reversed and $\partial EV_i(\tau_t^S)/\partial i > 0 \forall t \ge t^*.$

Q.E.D.

Proof of Proposition 3:

The proof that the bank will invest in the *P* loan in the first period follows from previous arguments. Moreover, since investors in the bank and the bank agree on values and the investors always price debt so as to break even, the previous analysis indicates that we can simply make the loan choice determination based on its total expected value. The fact that the back switches at *t*=2 from the *P* loan to the R_1 loan follows from the restrictions (41) and (42) since R_1 is preferred to $R_j \forall j \ge 2$ when the probability is $\tau_2^S(skill)$ that the bank is type $\tau.$

Using Lemma 6, we know that (33) holds with $\tau_t^S = r,$ and in that case, the economic value of R_1 exceeds the value of any $R_j,$ $j > 2.$ When $t \ge t^*,$ (33) is reversed and $EV_i / \partial i > 0,$ so R_N has the highest value, so the bank switches to $R_N.$ Q.E.D.

Proof of Lemma 7:

The proof is similar to that of Lemma 2 and is omitted here for space reasons. Q.E.D.

Proof of Proposition 4:

The proof for the bank's preference for an *R* loan over a *P* loan, conditional on successful repayment of a *P* loan in the first period and $m_1 = \text{skill}$ is similar to that in Proposition 2. The only difference is that if investors withdraw at t=3, the bank can pay them \$1 (instead of *L*) because liquidation is unnecessary given that m_3 is not revealed to investors and the bank is able to raise \$1 in new debt at t=3 in exchange for a repayment promise of $\overline{D}_R(\Pr(R_S^2 | P_S^1))$ at t=4. Q.E.D.

Proof of Lemma 8:

Suppose m_1=luck . Then, given the choice of the *P* loan in the first period, the bank's creditors will assess the probability of successful repayment on the loan as $r+(1-r)b.$ Suppose m_1 = skill . Then, once again the bank's creditors will assess the probability of success as $r+(1-r)b.$ Thus, the investment of the creditors in learning about *m* is a waste. Q.E.D.

Proof of Proposition 5:

Consider first an institutional lender who states that it will not invest in learning about *m*. Such a lender can offer the following terms:

(i) Repayment of \$1 if the debt is repaid at *t*=3.

(ii) Repayment of $\bar{D}_R^4 = 1/\Pr\left(R_S^2 \mid P_S^1\right)$ at t=4 if debt is rolled over at *t*=3.

Here, $\Pr\left(R_S^2 \mid P_S^1\right)$ is given by (51). Clearly, no other lender who commits to not learn about *m* can do better, as this contract earns the lender zero expected profit on each of its short-term debt and also guarantees that the probability of the bank being liquidated is zero. So the question is: can a competing lender do better if:

(a) it pre-commits to investing *M* in learning about *m* at *t=3*; or

(b) it enters the market at *t*=3 and seeks to pick off a bank from a lender who does not know *m*?

Consider (a) first. Such a lender will offer the following terms:

i. Repayment obligation of $\bar{D}_R^3 = [1-\lambda L+M]/[1-\lambda]$ if debt is collected at *t*=3.

ii. A repayment obligation of $\bar{D}_R^4 = \bar{D}_3^R / qt_2^S(skill)$ if there is new financing raised at *t*=3 to pay off the $\bar{D}_R^3$, and this has to be settled at *t*=4. The financiers both short-term debt issues will just break even on each issue. The bank's shareholders' expected profit is given by (60). The bank's expected profit in borrowing from a lender who pre-commits not to screen is:

$$\Pr\left(R_S^2 \mid P_S^1\right)\left\{X_R - \left[\Pr\left(R_S^2 \mid P_S^1\right)\right]^{-1} + Z\right\}$$
$$= \Pr\left(R_S^2 \mid P_S^1\right)\left[X_R + Z\right] - 1 \quad \text{(A-8)}$$

whereas, using (58) and (59), (60) can be written as:

$$[1-\lambda]\{\Pr\left(R_S^2 \mid P_S^1, m_3\text{=skill}\right)\left[X_R + Z\right]\} - 1 + \lambda L - M \quad \text{(A-9)}$$

Now,

$$
\begin{aligned}
&[1-\lambda]\Pr\left(R_S^2 \mid P_S^1,\ m_3\text{=skill}\right)[X_R+Z]-1+\lambda L-M \\
&\qquad < [1-\lambda]\Pr\left(R_S^2 \mid P_S^1,\ m_3\text{=skill}\right)[X_R+Z]-1+\lambda-M \\
&\qquad < [1-\lambda]\left\{\Pr\left(R_S^2 \mid P_S^1,\ m_3\text{=skill}\right)[X_R+Z]-1\right\}-M \\
&\qquad < [1-\lambda]\left\{\Pr\left(R_S^2 \mid P_S^1,\ m_3\text{=skill}\right)[X_R+Z]-1\right\}
\end{aligned} \tag{A-10}
$$

The quantity in (A-10) will be less than that in (A-8) if:

$$
[X_R+Z]\left\{\Pr\left(R_S^2 \mid P_S^1\right)-\Pr\left(R_S^2 \mid P_S^1, m_3\text{=skill}\right)\right\} > 1-[1-\lambda] \tag{A-11}
$$

Substituting above for $\Pr\left(R_S^2 \mid P_S^1\right)$ and $\Pr\left(R_S^2 \mid P_S^1,\ m_3\text{=skill at t=3}\right)$ from (53) and (23) respectively, (A-11) can be written as:

$$
[X_R+Z][\lambda rq] > \lambda, \text{ or } rq[X_R+Z] > 1
$$

which is true by the assumption that bank liquidation is inefficient.

Now consider possibility (b). Since it is common knowledge that such a lender enters the market only if it discovers $m_3 = \text{skill}$, all competitors will rationally infer that $m_3 = \text{skill}$ if a *de novo* lender bids for the bank's business. Thus, $y = [\Pr\left(R_S^2 \mid P_S^1,\ m_3\text{=skill}\right)]^{-1}$. So, the *de novo* lender's expected profit, using (61), can be written as: $-M < 0$. Hence, no *de novo* lender will attempt to poach at t=3, having invested in learning about m_3. Q.E.D.

Proof of Lemma 9:

The proof is obvious, given earlier arguments. No discretionary trader wishes to invest M in becoming informed for the reasons provided in the proof of Lemma 3. Q.E.D.

Proof of Lemma 10:

Consider a bank that made a P loan in the first period that successfully repaid at t=2, and the bank has now made an R loan in the second period. From (48), we can write the expected profit of a *dit* as

$$
V = -M + \lambda \int_0^\infty \left\{ \frac{x[1-rq]-P^e(\theta+\ell)}{P^e(\theta+\ell)} \right\} f(\ell)\,d\ell \tag{A-12}
$$

Now suppose θ = 0. Then, the MM will infer no information from the order flow, implying that

$$
\begin{aligned}
P^e(\ell) &= x\left[1-\Pr\left(R_S^2 \mid P_S^1\right)\right] \\
&< x[1-rq]
\end{aligned} \tag{A-13}
$$

Since

$$
\begin{aligned}
\Pr\left(R_S^2 \mid P_S^1\right) &= \lambda rq + [1-\lambda]\left\{\lambda rq + [1-\lambda]qt_S^2(\text{skill})\right\} \\
&> rq.
\end{aligned} \tag{A-14}
$$

Now, writing $V(0)$ as the value of V when θ = 0, one can write:

$$V(0)=\lambda\left\{[1-rq]\left[1-\Pr\left(R_S^2 \mid P_S^1\right)\right]^{-1}-1\right\}-M \tag{A-15}$$

where we know from (A-14) that $[1-rq]\left[1-\Pr\left(R_S^2 \mid P_S^1\right)\right]^{-1}>1$. Further, it follows from (63) that $V(0)>0$.

Thus, $\theta = 0$ cannot be an equilibrium, and $\theta^{*>}>0$. Q.E.D.

Proof of Lemma 11:

The proof follows directly from (45), which implies:

$$r_{mm}^R(\xi)=1-P^e(\xi)x^{-1} \tag{A-16}$$

It is clear that $r_{mm}^R(\xi)$ is continuously and monotonically decreasing in $P^e(\xi)$, which means $r_{mm}^R(\xi)$ is an invertible function of $P^e(\xi)$. Q.E.D.

Proof of Proposition 6:

It has already been argued that banks cannot invest in *R* loans at *t*=0, so a *P* loan is the only option. It has also been shown that a bank that experiences default on its first-period *P* loan exits the market. Moreover, from Proposition 5, we know that banks will only borrow from institutional lenders who do not learn about *m*. So, what needs to be shown next is that a bank that successfully collects repayment on its first-period *P* loan will make an *R* loan in the second period. This requires a comparison of (74) and (77).

Simplifying (74) by recognizing that all debt pricing is designed to yield creditors zero expected profits, one can write:

$$\overline{\overline{\pi}}_2^R=\Pr\left(R_S^2 \mid P_S^1\right)X_R-1+Z\Pr\left(R_S^2 \mid P_S^1\right)\left\{\lambda\int_0^{\Omega^*-\theta^*}f(\ell)\,d\ell+[1-\lambda]\int_0^{\Omega^*}f(\ell)\,d\ell\right\} \tag{A-17}$$

Similarly, (77) can be simplified and written as:

$$\overline{\overline{\pi}}_2^P=\Pr\left(R_S^2 \mid P_S^1\right)[X_P+Z]-1 \tag{A-18}$$

Thus, $\overline{\overline{\pi}}_2^P>\overline{\overline{\pi}}_2^P$ if:

$$\Pr\left(R_S^2 \mid P_S^1\right)X_R-\Pr\left(R_S^2 \mid P_S^1\right)X_P>Z\left\{\Pr\left(R_S^2 \mid P_S^1\right)-\Pr\left(R_S^2 \mid P_S^1\right)\left[\lambda\int_0^{\Omega^*-\theta^*}f(\ell)\,d\ell+[1-\lambda]\int_0^{\Omega^*}f(\ell)\,d\ell\right]\right\} \tag{A-19}$$

Given (30), we can write

$$\begin{aligned}&\Pr\left(R_S^2 \mid P_S^1\right)X_R-\Pr\left(R_S^2 \mid P_S^1\right)X_P\\ &\quad>Z\\ &\quad>Z\left\{\Pr\left(R_S^2 \mid P_S^1\right)-\Pr\left(R_S^2 \mid P_S^1\right)\left[\lambda\int_0^{\Omega^*-\theta^*}f(\ell)\,d\ell+[1-\lambda]\int_0^{\Omega^*}f(\ell)\,d\ell\right]\right\}.\end{aligned}$$

Thus, the bank prefers to invest in the *R* project in the second period.

The probability of an individual bank being liquidated is:

$$\int_{\Omega^*-\theta^*}^{\infty}f(\ell)\,d\ell+[1-\lambda]\int_{\Omega^*}^{\infty}f(\ell)\,d\ell \tag{A-20}$$

Thus, if there are N banks in the economy that have invested in R in the second period, the probability that all banks will be liquidated is:

$$\lambda\left[\int_{\Omega^*-\theta^*}^{\infty} f(\ell)\,d\ell\right]^N + [1-\lambda]\left[\int_{\Omega^*}^{\infty} f(\ell)\,d\ell\right]^N$$
$$> 0$$

for any finite N.

Moreover, conditional on $m_3 = \text{luck}$, the probability of a crisis is

$$\left[\int_{\Omega^*-\theta^*}^{\infty} f(\ell)\,d\ell\right]^N \tag{A-21}$$

which is strictly greater than the probability of a crisis conditional on $m_3 = \text{skill}$:

$$\left[\int_{\Omega^*}^{\infty} f(\ell)\,d\ell\right]^N$$ Q.E.D.

Proof of Proposition 7:

The following exogenous parameter values satisfy all of the restrictions:

$B = 1.5, C = 1, Z = 0.02, M = 0.008, r = 0.6, b = 0.6, W = 2, \alpha = 0.3, \lambda = 0.05, X_P = 1.2, q = 0.77, X_R = 2.$ Q.E.D.

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