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Credit Rationing and Financial Disorder

JACK GUTTENTAG and RICHARD HERRING*

ABSTRACT

We develop a model of lender behavior in the presence of default risk and moral hazard that determines default premiums and identifies the conditions under which borrowers are rationed. A hypothesis regarding a cognitive bias in the formation of expectations provides a dynamic component to our analysis and allows us to explain how an economy becomes vulnerable to a financial crisis and why vulnerability may increase over time.

UNTIL RECENTLY, THE POSTWAR literature on financial disorder has consisted almost exclusively of the work of Hyman Minsky.[1] Minsky's complex and richly detailed explanation of financial instability places special emphasis on the impact of an unsustainable economic expansion on the financial structure. He argues that rising interest rates and expectational factors that prevail during an investment boom will cause a shift toward "speculative" finance in which debt-service payments rise relative to income receipts, cash and near-cash assets decline as a proportion of total assets, and asset prices reflect euphoric expectations. The shift toward speculative finance makes the system more vulnerable to crisis by reducing the capacity of the financial system to withstand a shock.

Although we are in broad agreement with Minsky's description of the manifestations of financial vulnerability, we develop a much simpler explanation for why the system becomes more vulnerable over time. We emphasize creditor behavior in formulating, and acting on, shock probabilities rather than the business cycle as the mechanism through which the vulnerability of the system may increase. And we argue that an abrupt increase in the extent of credit rationing is the central feature of a financial crisis.

Our analytic framework is constructed from ideas drawn from two disparate areas of research. From the literature on credit rationing, we develop a model of the microeconomics of lending decisions in the presence of default risk and moral hazard. This model enables us to relate default premiums to subjective expectations of default and the borrower's capital and to establish the conditions under which borrowers will be rationed. From the empirical literature on decision-making under uncertainty, we draw our hypotheses regarding the way in which lenders formulate expectations of default. Once the model is assembled, we

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[1] See, for example, Minsky [18]. More recently several authors have examined bank runs in a general equilibrium context. See, for example, Bryant [5], Flood and Garber [7], and Waldo [26].

consider what determines vulnerability to a financial crisis, and why vulnerability may increase over time.

Our paper is divided into six major sections. The first section defines the notion of a "credit shock," distinguishes project-specific credit shocks from disastrous credit shocks that affect all projects, and identifies cognitive biases that affect expectations of disastrous shocks. The second section examines the capacity to withstand shocks and why it may diminish over time. The third section presents an analysis of lending decisions in a setting that includes credit shocks and moral hazard. The determination of default premiums is analyzed, and lender-imposed capital requirements are explained as a response to moral hazard. In the fourth section, the model of lender behavior is used to classify borrowers in terms of their capital positions. The fifth section uses the classification of borrowers by capital position to develop a taxonomy of macroeconomic financial conditions in terms of extent of vulnerability to crisis. The sixth section explains why economies become increasingly vulnerable to a financial crisis during an expansion, emphasizing the divergence between perceived and actual financial conditions.

I. Shocks and Shock Probabilities

In our model creditors make loans, L,[2] at some contract rate of interest, i, with the promised return $L(1 + i)$ that we denote as Z.[3] Borrowers undertake real investment projects that have a stochastic total return, R. (For the moment, we assume that the borrower cannot change the riskiness of the project once the lender has made a commitment to lend.) If the borrower's investment returns are not sufficient to repay the loan, that is, if $R < Z$, the creditor may claim the entire proceeds of the investment project plus as much of the borrower's capital, K, as necessary to fill the gap between the loan repayment due and the investment returns.[4] If the borrower's total capital is less than the shortfall of investment returns, the creditor suffers a loss on the loan. Thus, a loss arises if $R - Z + K < 0$. Such an event is termed a "shock."

We assume that Nature draws investment returns from a cumulative distribution, $F(R, w)$, where w is an index of project-specific risk, and the cumulative distribution is defined over a range extending from zero to some maximum return, R_M. The probability of a shock is:

$$\Pr(R < Z - K) = F(Z - K, w). \tag{1}$$

The schedules in Figure 1 show the probability of a shock corresponding to any given value of R on the assumption that the amount promised, Z, exceeds

[2] All loans are assumed to be a fixed amount, L, perhaps determined by a technologically fixed project size.

[3] For easy reference, the Appendix contains a glossary of symbols used in the text.

[4] For convenience, we have assumed that the borrower's capital is pledged as collateral for the loan. In effect, the creditor lends the borrower the full amount of the investment and holds the borrower's capital as collateral rather than permitting the borrower to invest his capital in the project and making a corresponding reduction in the loan size. This assumption enables us to highlight the dual role of capital in countering moral hazard and in providing a buffer between the lender and unfavorable investment outcomes (see Section III E).

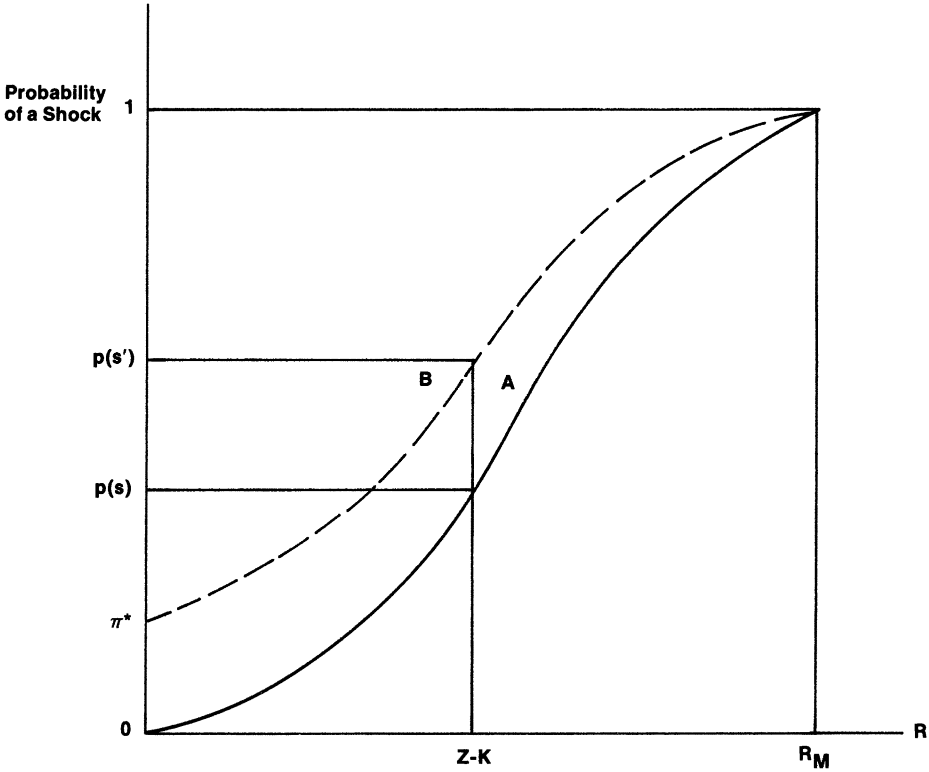

Figure 1. Shock Probabilities

that value of R plus the borrower's capital, K. For example, assuming R equal to $Z - K$ and distribution A, the probability of a shock is $p(s)$.

The probability of a shock can rise for three reasons:

(1) The contractual amount due, Z, rises;
(2) The borrower's capital, K, falls;
(3) The distribution governing investment returns shifts upward.

We shall pay particular attention to a special case of an unfavorable shift in the distribution of investment returns. Under some conditions, Nature may draw from a disastrous distribution. For simplicity, we assume that this distribution is degenerate with all returns zero. This assumption is made for analytic convenience, not because we wish to model doomsday. Rather, our concern is with infrequent shocks that have less-than-catastrophic direct consequences on real economic activity, but which, if not anticipated by lenders, have devastating financial consequences that substantially exacerbate the impact of the shock on real economic activity. Examples would include a tenfold increase in the price of oil, a 10% decline in U.S. GNP, or a 10% drop in the volume of world trade.

The subjective probability that Nature will draw from the disastrous distribution is π, where $0 \leq \pi \leq 1$. Thus, where $\pi > 0$, the subjective probability of a shock is:

$$\Pr(R < Z - K) = (1 - \pi)F(Z - K, w) + \pi. \tag{2}$$

For R equal to $Z - K$ and distribution B in Figure 1, the subjective probability is $p(s')$.

The subjective probability of a shock is a weighted average of two components: (i) the objective probability that Nature will draw an unfavorable outcome from the project-specific distribution, $F(Z - K, w)$, and (ii) the subjective probability that Nature will draw from the disastrous distribution, π. These components reflect two qualitatively different states of knowledge (or ignorance) about the future.

With regard to the probability of an unfavorable outcome from the project-specific distribution, we assume that the subjective probabilities of market participants are identical to the objective probabilities either because market participants have prior knowledge of the process generating investment returns or because the objective probabilities may be inferred from the frequency distributions of investment outcomes under a variety of circumstances.[5] There is a presumption that the subjective probabilities of market participants will converge to the objective probabilities because unfavorable outcomes are sufficiently frequent, so that participants who stubbornly cling to subjective probability distributions which differ from the objective distribution will suffer losses and be forced to withdraw from the market. In the terminology of Keynes and Knight, this state of knowledge may be described as pure "risk." This seems to characterize credit decisions in which the number of loan outcomes is very large relative to the number of borrower and transaction characteristics that govern loan outcomes. Consumer lending and installment credit may be good examples of situations in which risk predominates.

In contrast, the state of knowledge with regard to the probability that Nature will draw from the disastrous distribution is much less complete. Market participants know only that there is a small but finite probability that disasters can happen. Market participants do not have *a priori* knowledge of the parameters of the distribution that governs whether Nature draws from the disastrous distribution nor do they have sufficient evidence to infer the parameters of the distribution from the historical record. This degree of ignorance approaches what Keynes and Knight termed "uncertainty." Under such circumstances there can be no presumption that the subjective probabilities of market participants will converge to the objective probabilities. The argument that market discipline will ensure that decision-makers form expectations correctly has little force since the hazard may occur so infrequently that it may be disregarded with impunity for decades.[6] Indeed, under such circumstances, competition may drive prudent creditors from the market because a creditor who attempts to charge an appropriate default premium for a low probability hazard is likely to lose business to creditors who are willing to disregard the hazard.

[5] Since the distribution of project-specific returns may vary from project to project, there is some scope for diversification across projects.

[6] Arrow [1, p. 7] offers two additional reasons that rational behavior may not be the effective norm. Arbitrage possibilities may be inadequate and other market participants may prevent market prices from accurately reflecting future market values.

How are expectations formulated in circumstances characterized by uncertainty? Economic theory offers little guidance. As Lucas [17, p. 7] has noted, the rational expectations hypothesis and efficient market axioms simply do not apply in situations of uncertainty. Instead our hypothesis regarding the subjective probability of a disaster is drawn from work by cognitive psychologists and decision scientists on the behavioral approach to decision-making under uncertainty. We believe that two of the heuristics that have been found to characterize human behavior with regard to low-probability, high-loss hazards—the availability heuristic and the threshold heuristic—provide insights into the behavior of creditors confronted with uncertainty.

The availability heuristic is a psychological mechanism by which people evaluate the likelihood of an event. In the terminology of Tversky and Kahneman [25, p. 164], the "availability heuristic" is employed whenever a person "estimates frequency or probability by the ease with which instances or associations can be brought to mind." Frequent events are usually easier to recall than infrequent events. But ease of recall is also affected by such factors as the emotional intensity of an experience or the time elapsed since the last occurrence. These factors can give rise to an availability bias. A commonplace example of this phenomenon is the behavior of a driver who has just witnessed an automobile accident. The driver's immediate response is to drive much more cautiously, as if the probability of an accident had suddenly increased. But gradually, as time passes and the image of the accident recedes from memory, caution declines. The availability heuristic has been verified in both controlled laboratory experiments and in field work. Kahneman and Tversky report results of ten controlled experiments performed with 1500 subjects which demonstrated that even when probabilities could be objectively determined, people tended to employ the availability heuristic. They argue that their results are equally applicable to very infrequent events where probability judgments could not be based on a tally of relative frequencies. Kunreuther et al. [16] in a field survey of 2,000 homeowners in flood-prone areas and 1,000 homeowners in earthquake-prone areas conclude that insurance decisions with regard to low-probability, high-loss hazards are subject to the availability bias.

At some point after the occurrence of a disaster, the subjective probability of the recurrence of a disaster may become so low that it is treated as if it were zero. This is an example of the threshold heuristic—an implicit rule through which decision-makers allocate one of their scarcest resources—managerial attention.[7] This pattern is illustrated in Figure 2 where, with the passage of time, the subjective probability of a disaster falls (e.g., from π_t to π_{t+n}) until it reaches the threshold π^* where it drops to zero.

This cognitive bias may be reinforced by institutional factors. The performance of loan officers is usually evaluated over short periods on the basis of current income without adjustment for the uncertainty of future revenues or the front-loading of revenue streams. Concern for the future consequences of current

[7] The threshold heuristic is based on the work of Herbert Simon concerning procedural rationality (see Simon [20a] for a recent overview). Slovic et al. [21] introduced the term in an explanation of why people may refuse to buy insurance against low-probability hazards. Kunreuther et al. [16] find evidence supporting the threshold heuristic in their field survey of the insurance decisions of 3000 households.

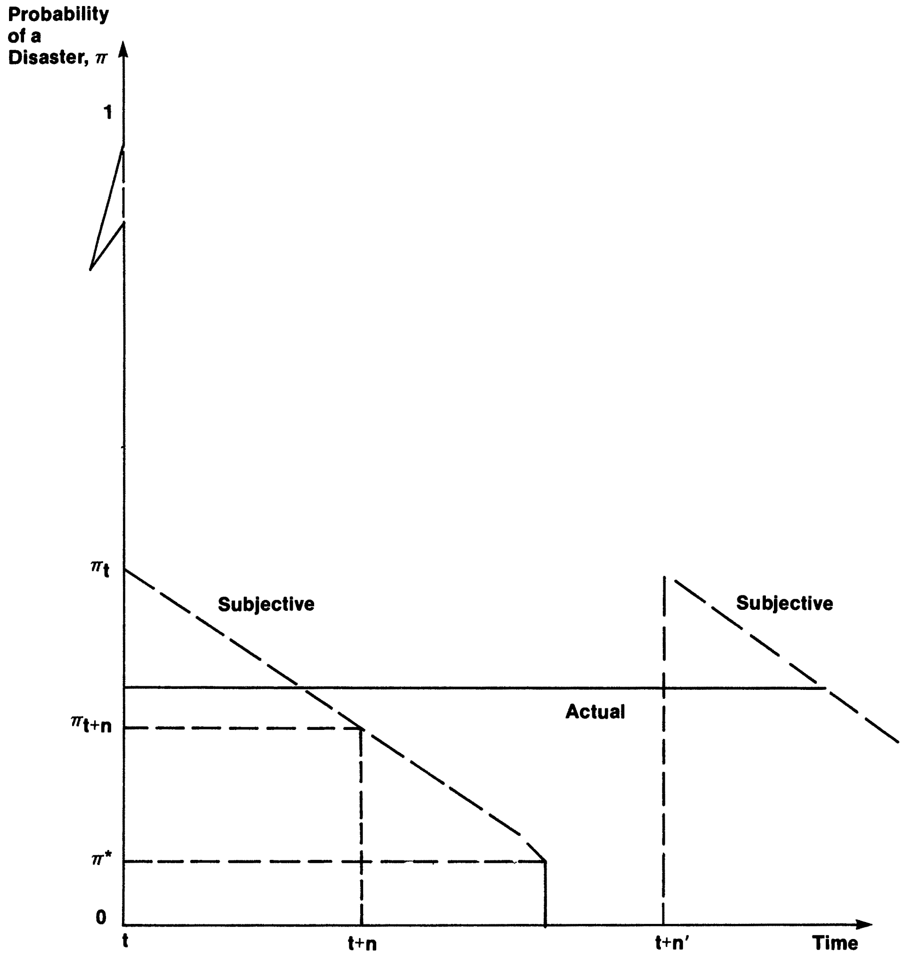

Figure 2. The Disaster Myopia Hypothesis

lending decisions may be further undercut by high job mobility among lending officers. Low frequency events are especially likely to be disregarded if the lending officer will not be personally identified with the outcome. In Appendix B, we show that this decline in the subjective probability of a disaster is also consistent with the Bayesian approach to decision-making when the time elapsed since the last occurrence of a disaster becomes very long.

II. The Capacity to Withstand Shocks

The creditor's capacity to withstand a shock is determined by his capital, K_c. The larger his capital, the larger the shock he can sustain. The probability that a creditor will become insolvent is:

$$\Pr(R < Z - K - K_c). \tag{3}$$

Figure 3 shows the probability of lender insolvency, given the shock probabilities shown in Figure 1, curve *B*. Note that if $K + K_c > Z$, the probability of the creditor becoming insolvent is zero. A rightward movement along the horizontal axis, reflecting either a rise in the amount promised, Z, a decline in the borrower's capital, K, or a decline in the lender's capital, K_c, is associated with an increase in the probability of lender insolvency. The probability of insolvency may also rise because of an adverse shift in the distribution of project-specific investment returns or an increase in π. Given $R = Z - K - K_c$ in Figure 3, the shift from $\pi^*F(R_M, w)$ to $\pi'F(R'_M, w')$ increases the probability of insolvency.

The tendency for subjective probabilities to fall below actual probabilities during periods in which no major shocks occur, we term the "disaster myopia" hypothesis. It explains why capital positions tend to decline and creditors become more vulnerable to shocks that imperil their solvency. Creditors can lend to borrowers with lower capital positions, permit loans outstanding to rise, or allow their own capital to fall, without increasing the subjective probability of their own insolvency. In Figure 4 the lender's subjective insolvency risk is the same at point *B* as at point *A*, even though capital positions are weaker or the volume of loans is larger, because the subjective probability of a disaster has fallen from π_t to π_{t+n}.

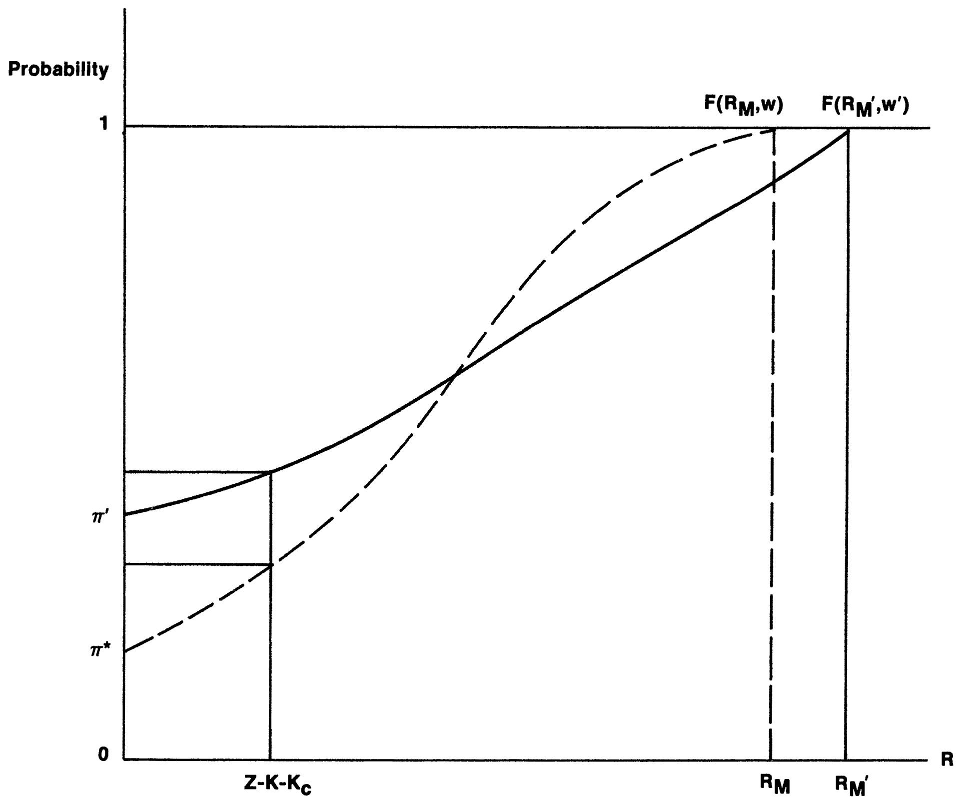

Figure 3. Probability of Lender Insolvency

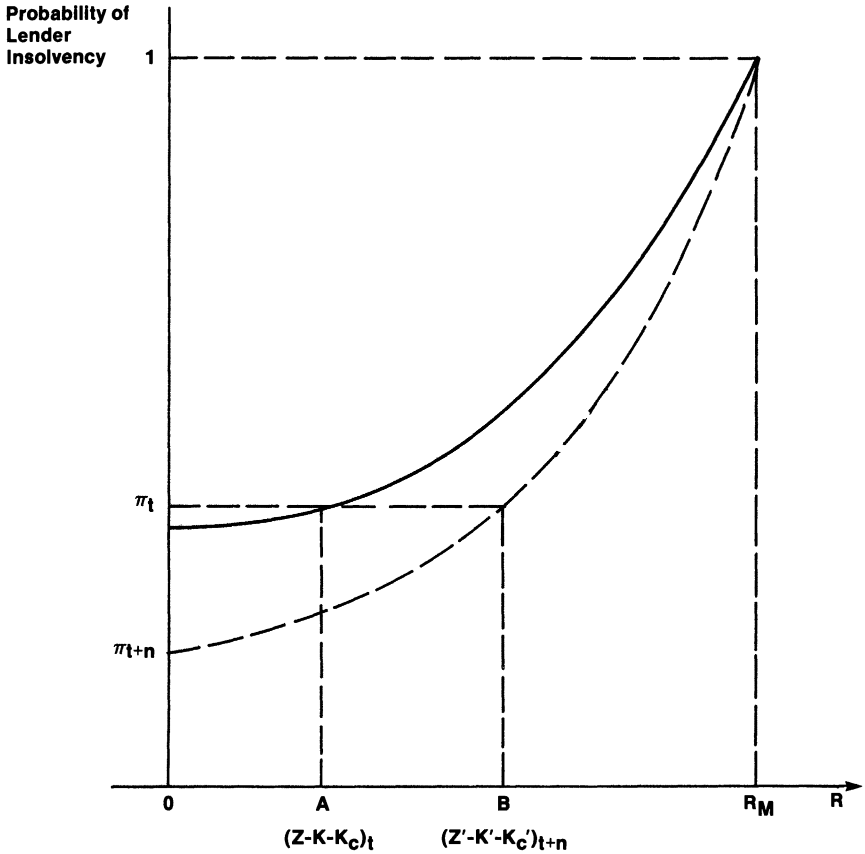

Figure 4. Increasing Vulnerability

In an expanding economy, growing confidence that is associated with the absence of major shocks strengthens the tendency for subjective shock probabilities to decline merely through the passage of time. If the real probability of a major shock has not fallen, this decline in capital positions makes the system more vulnerable.

We view the process by which declining subjective shock probabilities lead to reduced capital positions as involving largely implicit decisions associated with an expanding economy. We need not assume that firms make explicit decisions to reduce capital positions in response to declining subjective shock probabilities. It is only necessary to assume that they will accept without resistance declines that occur from forces associated with expansion that are outside of their immediate control. In an expanding economy, asset growth tends to exceed growth in retained earnings, which for financial institutions especially is always the major source of capital growth.

III. Lending Decisions in Response to Default Risk and Moral Hazard

This section highlights the factors that determine the lender's expected return from a loan and the borrower's expected return from the project financed by the loan. This comparison reveals that, under some circumstances, the borrower may be in a position to make himself or herself better off at the expense of the lender. In order to forestall this, the lender is likely to ration credit and/or impose minimum capital constraints on the borrower. The borrower's capital position thus plays a crucial role in our model.

A. The Creditor's Expected Return

The expected return to the creditor on a loan with contract rate r to a borrower with capital position, K is:

$$r_c = \frac{\pi K}{L} + \frac{(1-\pi)}{L}\int_0^{Z-K} (K+R)f(R,w)\,dR + (1-\pi)\frac{Z}{L}\int_{Z-K}^{R_M} f(R,w)\,dR. \quad (4)$$

The first term is the expected return if Nature draws from the disastrous distribution. Since the investment return is zero, the creditor receives only the borrower's capital.[8] The second and third terms describe the creditor's expected rate of return if Nature draws from the project-specific distribution. The second term is the expected rate of return in the event of a default in which the borrower's capital fails to cover the gap between the investment returns and the contractual repayment due. The third term is the expected rate of return if the borrower does not default. After integrating the second and third terms in Equation (4), this expression can be simplified to yield:

$$r_c = \frac{\pi K}{L} + (1-\pi)r - \frac{(1-\pi)}{L}\int_0^{Z-K} F(R,w)\,dR. \quad (5)$$

The minimum rate of return to the creditor is determined by the borrower's capital position, while the maximum (which is the promised return) is determined by the loan contract as graphed in Figure 5. The lowest return (when the investment return is zero) is K/L, while the promised return is obtained when the investment return is $\frac{Z-K}{L}$, the default point, or higher. Any decline in investment returns below the default point will lower the creditor's return.

B. The Borrower's Expected Return

The expected return to the borrower with capital position K and contract rate

[8] For expositional convenience, we have assumed that the borrower's capital position is equivalent to pledged, risk-free assets. For an explanation of credit rationing in which random variations in the value of the borrower's collateral play a central role, see Barro [2].

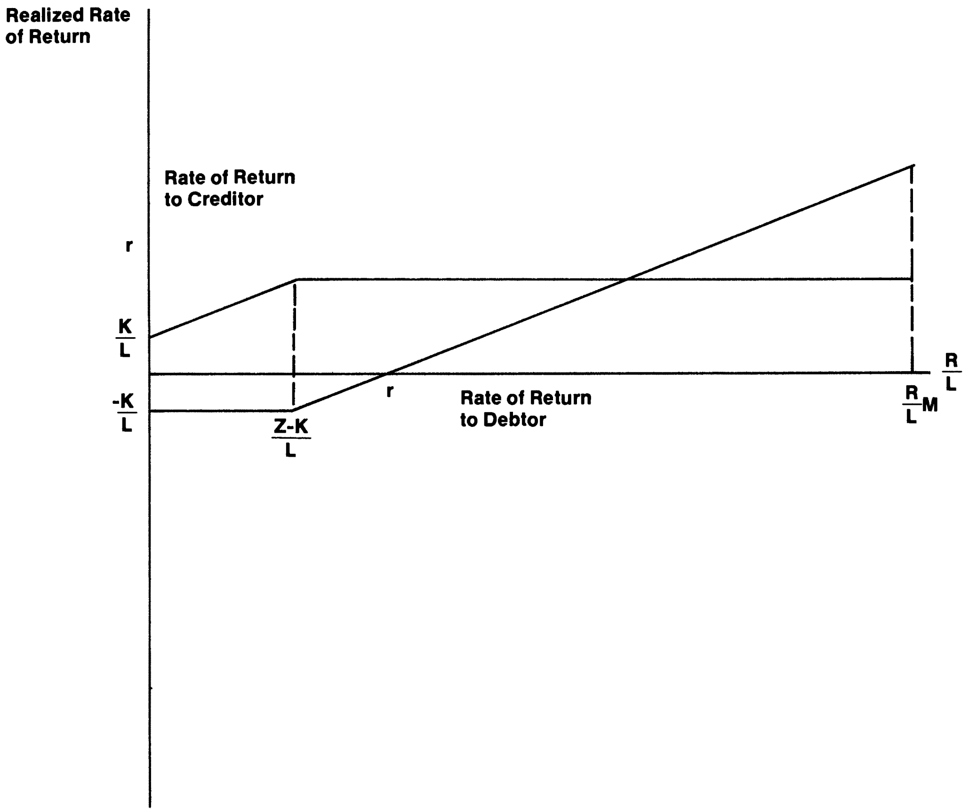

Figure 5. The Actual Rate of Return to the Creditor and Debtor

r is:

$$r_b = \frac{-\pi K}{L} - (1 - \pi) \frac{K}{L} \int_0^{Z-K} f(R, w)\, dR + \frac{(1 - \pi)}{L} \int_{Z-K}^{R_M} (R - Z) f(R, w)\, dR. \quad (6)$$

The first term indicates that the borrower will lose his or her capital if Nature draws from the disastrous distribution. The second and third terms describe the borrower's expected return if Nature draws from the project-specific distribution. The second term is the expected value of the loss if the borrower's capital position falls short of the gap between the contractual repayment due and the investment returns. The third term is the expected value of the gain when the borrower is not forced to default. By integrating the second and third terms, Equation (6) can be rewritten as:

$$r_b = \frac{-\pi K}{L} - (1 - \pi) r + \frac{(1 - \pi) R_M}{L} - \frac{(1 - \pi)}{L} \int_{Z-K}^{R_M} F(R, w)\, dR. \quad (7)$$

As shown in Figure 5, the actual return to the borrower is $-K/L$ when the investment return is below the default point and thereafter rises with the investment return.

C. Moral Hazard[9]

It is clear that the interests of the creditor and the borrower may conflict. The borrower will prefer investments that offer the opportunity to earn very high returns even if such investments also have an increased probability of yielding very low returns. Any incremental returns above the default point accrue entirely to the borrower, while his or her loss is the same no matter how far investment returns fall below that point. In contrast, returns above the default point are a matter of indifference to the creditor, but if investment returns fall below the default point, the creditor's return will depend on how far below that point they fall. Because increases in the riskiness of the investment affect the creditor and borrower differently, the creditor must be wary of moral hazard—the possibility that the borrower, after obtaining the loan, may act in such a way as to increase the probability of default in an effort to increase the probability of very high returns.[10]

The inherent conflict between creditors and borrowers may be attenuated through the use of restrictive covenants in the loan agreement.[11] But because it is costly to negotiate, administer, and enforce restrictive covenants—indeed it may not even be possible to specify all of the relevant risk characteristics in the loan agreement[12]—creditors will usually be vulnerable to some degree of moral hazard. As a consequence, the creditor must assume that the borrower will have some scope to alter the riskiness of the investment and so the creditor must be conscious of the impact of his or her actions on the borrower's incentives to increase the riskiness of the investment.

If the expected return, R, remains constant, increases in riskiness, w, represent a mean-preserving spread—a shift from the center to the tails of the density function (see Rothschild and Stiglitz [19]). In this case, the cumulative distri-

[9] More or less simultaneously, Keeton [13] and Stiglitz and Weiss [24] have developed models in which moral hazard is the crucial feature that leads to equilibrium credit rationing. This analysis draws heavily on both sources.

[10] In this paper, we emphasize the potential for moral hazard in the borrower's selection of investment projects. By assuming that the borrower's capital is the equivalent of pledged collateral, we have assumed away another aspect of moral hazard that may be important in some cases. If the creditor were lending on the basis of the borrower's expected future cash flows, not only would he or she have to make certain that the borrower does not alter the risk characteristics of the investment project after the loan has been made, but also that the borrower uses the cash flows to service the debt. Similarly, if the creditor has made a loan partly on the basis of the difference between the market (liquidation) value of the borrower's assets less other liabilities, he or she will have to make certain that the borrower will not dissipate the assets or pledge them to another creditor.

[11] For analysis of the use of contractual requirements to limit the scope for moral hazard see Black, Miller, and Posner [3], Jensen and Meckling [12], Smith and Warner [23], and Smith [22]. As we emphasize in the following discussion, collateral (or the borrower's capital position) may also be employed to limit moral hazard.

[12] Williamson [27] emphasizes that bounded rationality makes it "impossible to deal with complexity in all contractually relevant respects. . . . As a consequence, incomplete contracting is the best that can be achieved." Williamson further argues that opportunism—self-interest seeking with guile—makes open-ended promises to behave in good faith unworkable.

bution function $F(R, w)$ must satisfy two conditions:

$$\int_0^{R_M} \frac{\partial F}{\partial w}(R, w)\, dR = 0 \tag{8}$$

and

$$\int_0^{R} \frac{\partial F}{\partial w}(R, w)\, dR \geq 0 \quad \text{for all} \quad R. \tag{9}$$

If increases in w do not affect the expected return on the investment, the creditor should assume that the borrower will chose the highest possible w, without any concern for the interest charge on the loan. But if at some point increases in w reduce the expected return on the investment, the degree of risk the borrower elects may depend on the contract rate of interest. The higher the contract rate, the smaller the range of high investment outcomes that will yield a positive return to the borrower and the greater the likelihood that the borrower will choose a riskier project with a lower total expected return.[13]

To the extent that the creditor cannot control the risk of an investment project, the borrower's choice of risk characteristics must be anticipated. Differentiating the expression for the borrower's expected return, Equation (7), with respect to the risk index, w, we obtain:

$$\frac{\partial r_b}{\partial w} = \frac{-(1-\pi)}{L} \int_{Z-K}^{R_M} \frac{\partial F}{\partial w}(R, w)\, dR. \tag{10}$$

[13] Keeton [13, pp. 199–203] has developed a set of restrictions on the cumulative distribution function that imply that increases in the contract rate will necessarily lower the creditor's expected rate of return on the loan. In the context of our model, these assumptions may be restated as follows:

1) For each w, there exists an $\bar{R}$ such that $\frac{\partial F(R, w)}{\partial w} > 0$ for $0 < R < \bar{R}$ and $\frac{\partial F(R, w)}{\partial w} < 0$ for $\bar{R} < R < R_M$. This assumption implies that an increase in risk shifts probability densities from the center to the tails of the distribution and that the cumulative distribution associated with level of risk w_j, $F(R, w_j)$ can cut the cumulative distribution associated with a marginally lower level of risk w_i, $F(R, w_i)$ only once from above as in Figure A.

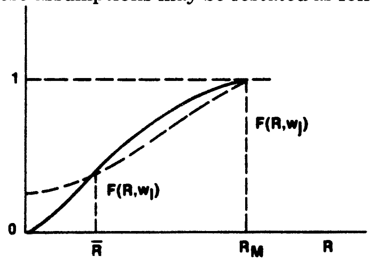

Figure A

2) For all w, the minimum possible investment outcome is less than $Z - K$. This assumption insures that default is possible and that a conflict between borrower and creditor may therefore arise.

3) $\bar{R} = 0$ at $w = w_{\min}$ and $\bar{R} = R_M$ at $w = w_{\max}$. This assumption insures that the borrower will choose neither the least risky nor the most risky investment possibility. In order to insure that the borrower will choose a riskier project when the contract rate rises, Keeton [13, p. 205] has developed two alternative, additional restrictions on the cumulative distribution function: (i) $\bar{R}$ is a continuous function of w and is nondecreasing in w for all w such that $\bar{R} < R_M$; or if $w_j > w_i$, $F(R', w_j) = F(R', w_i)$ implies $F(R, w_j) > F(R, w_i)$ for $0 < R < R'$ and $F(R, w_j) < F(R, w_i)$ for $R' < R < R_M$. These conditions insure that the optimization results hold globally, if the contract rate is initially set at a global optimum. (ii) In addition, we make the assumption that $\partial \hat{w}/\partial r$ is finitely greater than zero as $Z - K$ approaches R_M. This assumption implies that the borrower will always have an incentive to increase the riskiness of his project in response to an increase in the contract rate even when the contract rate exhausts the returns from the project.

Given the terms of the loan contract, a marginal increase in the risk of the investment will alter the borrower's expected return. Given Z and K, the optimal degree of riskiness for the borrower is the $\hat{w}$ that makes Equation (10) equal to zero.

By differentiating this condition for the optimum degree of riskiness with respect to the contract rate, we obtain:

$$\frac{d\hat{w}}{dr} = \frac{L \dfrac{\partial F(Z-K, \hat{w})}{\partial w}}{\displaystyle\int_{Z-K}^{R_M} \frac{\partial^2 F(R, \hat{w})}{\partial w^2}\, dR} > 0.^{14} \tag{11}$$

As the contract rate rises, so does the optimal riskiness of the investment project to the borrower.

In contrast, as the borrower's capital position increases, the optimal degree of riskiness decreases. Differentiating Equation (10) with respect to the borrower's capital position yields:

$$\frac{d\hat{w}}{dK} = \frac{-\dfrac{\partial F(Z-K, \hat{w})}{\partial w}}{\displaystyle\int_{Z-K}^{R_M} \frac{\partial^2 F(R, \hat{w})}{\partial w^2}\, dR} < 0. \tag{12}$$

Thus, increases in the borrower's capital position limit the scope for a conflict of interest between the creditor and the borrower. Indeed, where $K = Z$, the moral hazard problem disappears, since under these conditions the expected return to the borrower becomes:

$$r_b = \frac{-\pi K}{L} + \frac{(1-\pi)}{L} \int_0^{R_M} (R - Z) f(R, w)\, dR \tag{13}$$

and $\left.\dfrac{\partial r_b}{\partial w}\right|_{K=Z} = 0$. When the borrower's capital position equals the contractual amount due, the borrower cannot increase the expected return by shifting to riskier projects. In contrast, when the borrower's capital position is zero, the borrower will get the maximum benefit from increases in the riskiness of the investment and the lender is most vulnerable to moral hazard (see Equation (10)).

[14] That the numerator is positive follows from the condition for the optimal degree of riskiness. Since at the optimum $\displaystyle\int_{Z-K}^{R_M} \frac{\partial F(R, \hat{w})}{\partial w}\, dR = 0$, we know that $\dfrac{\partial F(R, \hat{w})}{\partial w}$ takes on both positive and negative values between $Z - K$ and R_M. By assumption, the cumulative distribution associated with a level of risk $\hat{w}$, $F(R, \hat{w})$ can cut the cumulative distribution associated with a marginally higher level of risk only once from below as in Figure A and thus $\dfrac{\partial F(Z-K, \hat{w})}{\partial w}$ must be greater than zero. The denominator is positive at the optimum level of risk, since the second-order condition for an optimum is that $\dfrac{-(1-\pi)}{L} \displaystyle\int_{Z-K}^{R_M} \frac{\partial^2 F(R, \hat{w})}{\partial w^2}\, dR < 0$. We are indebted to P. Vankudre for work on this proof.

D. Rationing as a Response to Moral Hazard

Given the distribution of investment returns, there is a contract rate that maximizes the lender's expected return. Differentiating Equation (5) with respect to the contract rate, we find that:

$$\frac{\partial r_c}{\partial r} = (1 - \pi)(1 - F(Z - K, \hat{w})) - (1 - \pi)\frac{1}{L}\int_0^{Z-K} \frac{\partial F(R, \hat{w})}{\partial w}\frac{\partial \hat{w}}{\partial r}\, dR. \tag{14}$$

The creditor maximizes expected return at the point at which the expected value of the increase in the contract rate when the borrower does not default precisely offsets the expected loss due to the induced increase in the probability of default.[15] If the creditor's expected return at this optimal contract rate $\hat{r}$ is less than the opportunity cost of funds, the borrower will be rationed, since raising the contract rate beyond $\hat{r}$ will reduce the expected return to the creditor. In effect, rationing arises from the lender's concern with the moral hazard that, at a higher contract rate, the borrower will employ the funds in a riskier venture that will reduce the expected return to the lender.

Note that if the borrower cannot increase the riskiness of the investment, raising the contract rate raises the expected return to the creditor until the rate reaches the level where it completely exhausts the expected return from the investment under the most favorable outcome plus the borrower's capital. No borrower would knowingly enter such a contract. The introduction of bankruptcy cost, which makes the borrower's capital position less valuable to the creditor than to the borrower, will result in an optimal contract rate to the lender that is lower than the contract rate that would bankrupt the borrower.[16]

E. Default Premiums in Competitive Equilibrium

If (risk-neutral) lenders are perfectly competitive, contract rates will be set so that they yield an expected return equal to the opportunity cost of funds, which we assume is the risk-free rate, r^*. Thus, in competitive equilibrium:

$$r_c = r^* = \frac{\pi K}{L} + (1 - \pi)r - \frac{(1 - \pi)}{L}\int_0^{Z-K} F(R, \hat{w})\, dR. \tag{15}$$

Solving for the contract rate, we obtain

$$r = \frac{r^*}{(1 - \pi)} - \frac{\pi K}{(1 - \pi)L} + \frac{1}{L}\int_0^{Z-K} F(R, \hat{w})\, dR^{17} \tag{16}$$

[15] Rationing will occur where $\frac{\partial r_c}{\partial r} < 0$. This condition must be satisfied at some point as increases in r cause $Z - K$ to approach R_M. As $Z - K$ approaches R_M, the first term on the right-hand side of (14) will approach zero and so the negative, second term will dominate, since $\frac{\partial w}{\partial r}$ is finitely greater than zero at R_M.

[16] See Barro [2] for a model that analyzes the impact of bankruptcy costs in a setting in which the borrower's collateral is treated as a stochastic variable.

[17] Note that the creditor's optimal contract rate depends on the borrower's optimal degree of risk. In general, changes in contractual terms that constrain the borrower's scope for increasing the riskiness of the project will increase the creditor's optimal contract rate.

and the default premium is:

$$r - r^* = \frac{\pi r^*}{(1 - \pi)} - \frac{\pi K}{(1 - \pi)L} + \frac{1}{L}\int_0^{Z-K} F(R, \hat{w})\, dR. \tag{17}$$

The default premium depends on the subjective probability of a disaster, the borrower's capital position, and the cumulative distribution governing project-specific returns.

As the borrower's capital position increases, the default premium declines:

$$\frac{dr}{dK/L} = \left(\int_0^{Z-K} \frac{\partial F}{\partial w}(R, w)\frac{\partial w}{\partial K}\, dR - \frac{-\pi}{(1 - \pi)} - F(Z - K)\right) D^{-1} < 0, \tag{18}$$

so long as

$$D = 1 - F(Z - K, w) - \frac{1}{L}\int_0^{Z-K} \frac{\partial F(R, w)}{\partial w}\frac{\partial w}{\partial r}\, dR > 0.$$[18]

The borrower's capital position affects the default premium through two channels. First, larger capital may lead the borrower to reduce the riskiness of the investment project. Second, larger capital is a buffer against loss to the creditor. In contrast to the first effect, the strength of the second effect depends on how the borrower's capital is used. If the borrower's capital is pledged as collateral, the creditor gets the full benefit of the buffer effect and Equation (17) describes the risk premium exactly. But if the borrower is permitted to invest his capital in the project and if $\pi > 0$, some of the buffer effect may be lost, and the default premium will be correspondingly higher.

IV. Classification of Borrowers by Capital Positions

We find it useful to distinguish two critical capital positions: K_s, the safe capital position, and K_m, the minimum acceptable capital position. If the borrower has a capital position equal to or greater than K_s, a default premium will not be charged. We term such borrowers "prime" borrowers. We can derive an explicit expression for the safe capital position (where $\pi > 0$) by setting the default premium in Equation (17) to zero and solving for K_s:

$$\frac{K_s}{L} = r^* + \frac{(1 - \pi)}{\pi L}\int_0^{Z^*-K_s} F(R, \hat{w})\, dR. \tag{19}$$

If $\pi = 1$, $K_s = Z^*$, that is, K_s must be sufficient to repay the loan and yield a return equal to the risk-free rate. If $\pi = 0$, then K_s is that value of K for which

$$0 = \frac{1}{L}\int_0^{Z^*-K_s} F(R, \hat{w})\, dR. \tag{20}$$

[18] This condition is satisfied over the relevant range because $D > 0$, so long as r is less than the contract rate that maximizes the expected return to the creditor. Thus, over the range of contract rates in which the default premium is priced, increasing the borrower's capital position will reduce the default premium. See Equation (14) for the point at which rationing occurs. We are indebted to David Germany for pointing out an error in an earlier formulation of this result.

This condition is satisfied if $K_s = Z^*$, but it may also be satisfied by a much lower K if there is a very low probability of the investment returns falling below the default point. The prime status of borrowers is determined by the risk characteristics of their investment projects as well as by their capital positions.

It is axiomatic that the more capital one has, the more one can borrow. But given a borrower's loan requirement, there may also be a minimum capital requirement (K_m). Borrowers with capital positions less than K_m are termed "rationed" borrowers.

What is troublesome in the concept of a minimum capital requirement is that it denies the possibility of trading off capital (or loan size) against interest rate. If there were no constraints on interest rates, there should be no minimum capital requirement. However, as we have shown, there are constraints on interest rates.

If project returns could not be altered by borrowers, it would always be in the lender's interest to charge as high a loan rate as can be negotiated (up to the maximum possible rate where the lender would take everything, as noted above). If there is a probability greater than zero that the borrower can earn enough to cover the higher rate, the lender's expected return will be higher, even though the probability of a shortfall from the promised return will also be higher. But if the borrower can change the project returns in a way that increases risk to the lender, higher rates may not be in the interest of the lender because they provide the borrower with an incentive to make this type of adjustment. Hence, moral hazard may lead to an optimal rate of interest for a given prospective borrower. At contract rates above the optimum, the loss to the lender from higher default rates exceeds the gains from higher promised contractual returns, and at rates below the optimum, the opposite is the case. The optimal contract rate, $\hat{r}$, given L, π, and the distribution of investment returns, defines a minimum acceptable capital position, K_m:[19]

$$\pi \frac{K_m}{L} = \pi r^* - (1 - \pi)(\hat{r} - r^*) + (1 - \pi)\frac{1}{L}\int_0^{Z-K_m} F(R, \hat{w})\, dR. \tag{21}$$

At the optimal rate, the borrower cannot trade off a lower capital position against a higher contract rate.

It is evident from Equation (21) that K_m depends on π (as well as on the distribution of investment returns). If $\pi = 1$, then $K_m = Z^*$, as does K_s, and the minimum acceptable capital position will equal the capital position that will qualify the borrower for the risk-free rate. In this case, the contract return makes no difference, since creditors are certain the investment will yield no returns. As the value of π drops below one, K_m falls relative to K_s. K_m must be large enough so that the difference between the optimal contract rate and the expected rate of loss in the event of a default equals the risk-free rate.

If the borrower's capital position is less than K_m, rationing will occur. Note that the borrower cannot adequately compensate the creditor by offering a higher

[19] K_m will be zero if the subjective probability of a disaster is zero, if the investment project is perfectly safe, and if it can be effectively monitored so that it remains perfectly safe after the loan is extended.

contract rate, because K_m is defined for the contract rate that maximizes the expected return to the creditor.

Borrowers with capital positions greater than or equal to K_m and less than K_s are termed "risky" borrowers. These borrowers pay a default premium proportional to their capital positions as shown in Equation (17). As a borrower's capital position rises toward K_s, the default premium declines—both because larger capital reduces default risk and because the borrower may reduce the riskiness of the investment.

V. Classifying Financial Conditions

A financial disorder or crisis is a pathological condition that has occasionally characterized financial markets. The central feature is that borrowers who in other states were able to borrow without difficulty become unable to borrow at any terms. In this section, we present a taxonomy of financial conditions that will assist our understanding of exactly what a crisis is and how it differs from other conditions. (How these conditions come into being is another question that is discussed later.) The conditions described are perceived conditions based on prevailing expectations, whether or not these expectations are justified.

As noted in the preceding section, economic units are prime borrowers when their capital positions, K, are $> K_s$, they are rationed borrowers when $K < K_m$, and they are risky borrowers when $K < K_s$ and $\geq K_m$. Three financial states of the world can be characterized largely in terms of different mixes in the proportions of these three categories of borrowers (see Table I). In "benign" financial conditions, capital positions are high and subjective shock probabilities are low ($\pi = 0$), so that a large proportion of units have capital positions above K_s. Rationed borrowers are limited to the irreducible "fringe of unsatisfied borrowers."

In "vulnerable" financial conditions, shock probabilities are higher, π is significantly greater than zero, and capital positions are lower than in benign conditions. Hence, the capital positions of a substantial proportion of units fall below K_s—they pay default premiums. In addition, a larger proportion of units have capital positions marginally less than K_m and are rationed. Greater vulnerability implies a wider range of risk premiums for risky borrowers having capital ratios within the K_m–K_s range, as discussed below.

In "crisis" conditions, a significant proportion of economic units have capital positions well below K_m. (This reflects either a sharp increase in the subjective

Table I

A Taxonomy of Financial Conditions

Financial Conditions	Borrowers: Prime $K \geq K_s$	Risky $K_s > K \geq K_m$	Rationed $K < K_m$
Benign	Most	Several	Few
Vulnerable	Few	Most	Several
Crisis	Few	Several	Most

probability of a disaster, π, or the occurrence of a shock that has reduced capital positions.) Since outstanding loans to such borrowers are above the level lenders find acceptable, no new loans are made, and creditors take all possible steps to reduce their outstanding loans. When many lenders do this who had previously adopted a strategy of dealing with low probability hazards by making short commitments, crisis states involve "runs," that is, attempts by creditors to convert their claims quickly before others do so and before the resources of the debtor are exhausted. Units subject to runs encounter major liquidity problems that may spill over to other units that may be viewed as suspect.

Some observers find it difficult to understand why it is not always possible to dampen a run by offering to pay higher interest rates. The answer is, of course, implicit in our case for K_m. If because of moral hazard the rate is already at the point where it maximizes the lender's return or if the insolvency probability is already at the maximum level the lender will tolerate, an offer to pay a higher rate will not find a taker. Indeed, the offer to pay higher rates is likely to reinforce rather than dampen any tendency for lenders to run. The reason is that when borrowers come under suspicion and other sources of information are unreliable, interest rates are viewed as a risk indicator.[20]

The taxonomy of financial conditions applies to perceived conditions, but subjective and actual probabilities of a disaster need not correspond. During a long period of declining subjective shock probabilities that lead to reduced capital positions and increased real vulnerability, perceived vulnerability will not increase until something happens to jar perceptions—a nontrivial shock of less than crisis proportions. When this occurs, the perceived π may jump very quickly (as in $t + n'$ in Figure 2), increasing K_m and K_s. (In the wake of a shock the availability heuristic leads to an overestimate of π.) Suddenly some borrowers are rationed out of the market, and others must pay risk premiums for the first time.

We can derive an explicit expression for the increase in the default premiums by taking the total derivative of Equation (16) with respect to an increase in the

[20] Our one-period model assumes that the lender knows the investment opportunities faced by the borrower and that the borrower will choose the opportunity that is most advantageous, which might be one with high risk especially if the borrower's capital position is weak. In a multiperiod model, however, the borrower may find it advantageous to forego risky projects that are most attractive in the short run if their selection would violate their understanding with the lender and prejudice their long-run relationship. When the lender extends credit on the basis of this type of understanding, he is said to base his loan decision on the borrower's character. In long-standing relationships the lender usually knows the rate a borrower can afford to pay when loan funds are used in accordance with their understanding. If the borrower suddenly expresses a willingness to pay a rate well above this level, it is likely to be interpreted by the lender as a signal that the borrower intends to violate their agreement and go for a high risk opportunity.

The interest rate may serve a similar signaling role when borrowers who look to the open market for funds come under suspicion. The cost of funds to such borrowers rises, but not because they pay higher rates. Rather, it is because they must expend greater effort to convince their customary sources that they remain sound and, failing that, to find new sources. But the judgment of bankers who have been in this situation is that an offer to pay a higher rate would be interpreted by the market as an acknowledgment by the bank of its weakness, and it would therefore be self-defeating.

probability of a major shock:

$$\left.\frac{dr}{d\pi}\right|_{dK=0} = \left(\frac{1}{1-\pi}\right)^2 (r^* - K/L)\cdot D^{-1} > 0$$

where D^{-1} is defined as in Equation (18) and

$$\left.\frac{dK}{d\pi}\right|_{dr=0} = \left(\frac{1}{1-\pi}\right)^2 (r^* - K/L)\cdot C^{-1} > 0$$

where

$$C = \frac{1}{L}\left(\frac{\pi}{1-\pi} + F(Z-K, w) - \int_0^{Z-K} \frac{\partial F(R, w)}{\partial w}\frac{\partial w}{\partial K}\, dR\right) > 0. \tag{22}$$

This relationship is graphed in Figure 6,[21] where an increase in π leads to an increase in the minimum acceptable capital position from K_m' to K_m'' and an increase in the risk premium from $r' - r^*$ to $r'' - r^*$. Note that the change in the default premium depends on the initial level of π. The higher the initial subjective probability of disaster, the larger the change in the risk premium associated with a given change in that probability. Thus, a shock has a more serious impact when financial conditions are vulnerable than when they are benign. Note also that an increase in π will lead to a larger increase in the default premium, the lower the borrower's capital position. Thus, since a rise in π has a greater effect on default premiums paid by weakly capitalized borrowers than on the premiums paid by strongly capitalized borrowers, the range of default premiums paid by risky borrowers widens. This phenomenon is termed "tiering." In recent times, it was observed in the Eurocurrency interbank market and in the U.S. certificate of deposit (CD) market in the aftermath of the failure of the Herstatt Bank and the collapse of the Franklin National Bank in 1974, and during the Mexican debt crisis in 1982. In both instances, the tiering was in response to a sharp upward revision in expectations of a major banking crisis.

Policy-makers may attempt to avert a financial crisis by announcing policies that will reduce the likelihood of a disaster or mitigate its impact in an effort to lower perceptions of π; or policy-makers may guarantee the liabilities of particular borrowers thereby increasing their effective capital positions and limiting the extent to which they are rationed. But policy shifts to compensate for vulnerable financial conditions may encounter credibility problems and involve costly departures from preferred policies. And guarantees of the liabilities of borrowers in distress raise a host of troublesome questions about the propriety and usefulness of government bailouts. Thus, there are compelling reasons for policy-makers to seek to prevent the development of financial conditions that are vulnerable to crises rather than relying on the management of crises when they occur. But policy options for preventing crises are much less obvious. The fundamental problem is that policy-makers are likely to share the disaster myopia of creditors.

[21] We are indebted to David Germany for pointing out an error in an earlier formulation of this relationship and for suggesting Figure 6.

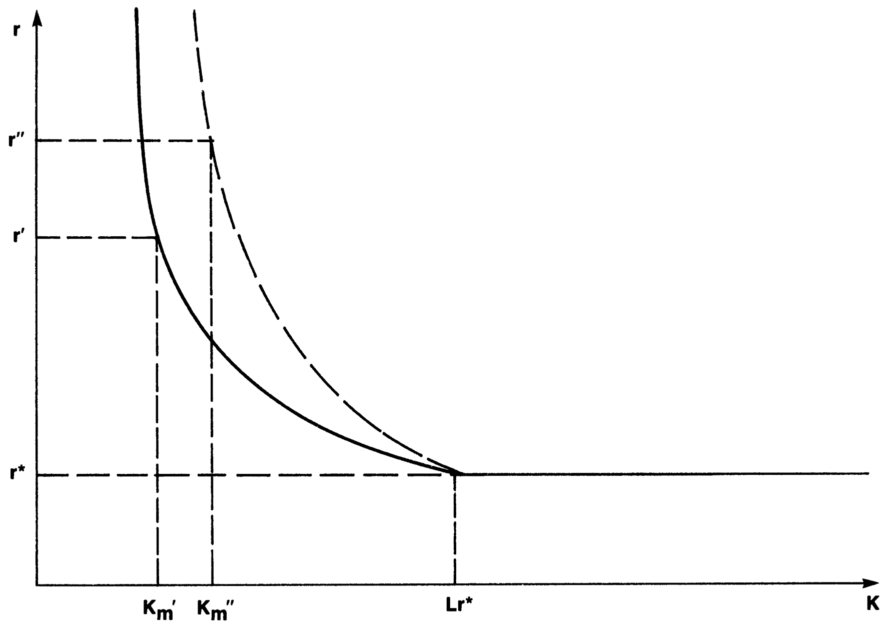

Figure 6. The Response of the Default Premium to an Increase in the Subjective Probability of a Disaster

Indeed a relaxation of prudential regulation and supervision in response to the declining subjective probability of a disaster may contribute to the increasing vulnerability of the financial system. The challenge is to develop procedures for both creditors and supervisors to counteract disaster myopia, identify exposures to major hazards, and formulate standards for evaluating the appropriateness of particular levels of exposure.

VI. Conclusions and Summary

Our analysis began with a consideration of the microeconomics of lending behavior. We showed how risk premiums were set in competitive markets in response to subjective probabilities of credit shocks, and we demonstrated how moral hazard could lead to credit rationing and the imposition of minimum capital requirements. These results enabled us to classify borrowers according to their capital positions and the default premiums they are charged. Prevailing financial conditions were then categorized as benign, vulnerable, or crisis according to whether the preponderance of borrowers were classified as prime, risky, or rationed.

The dynamics of our analysis stems from a cognitive bias that has been emphasized in the analysis of economic behavior with regard to natural disasters and observed and verified in the empirical literature on decision-making under uncertainty. The subjective probability of a major shock is a negative function of the length of time that has elapsed since the last such shock. To the extent that subjective probabilities decline even though actual probabilities remain constant or increase, the system becomes more vulnerable to financial disorder. As subjective probabilities decline, default premiums diminish, and the capital ratios of both borrowers and lenders are allowed to run down. If subjective shock probabilities then rise in response to some shock (or a series of shocks) that is larger than expected, but smaller than most creditors and borrowers can withstand, financial conditions shift from benign to vulnerable. A major shock under vulnerable financial conditions will jolt the system into a crisis state. An unfavorable event that causes a sharp increase in subjective probabilities and/or reduces capital positions will cause a sudden, substantial increase in the number of borrowers who are rationed.

The depth and duration of a crisis, and the total economic loss, depend not only on the magnitude of the shock relative to the system's vulnerability, but also on a number of structural and institutional conditions that affect creditor behavior. From a micro perspective, each lender who feels overexposed to a specific borrower not only will be unwilling to make any new loans, but also will be unwilling to roll over existing loans. When loans mature, the creditor's impulse will be to convert them quickly, before other creditors and before the assets of the debtor are exhausted. From a macro perspective, however, such behavior is counterproductive and there are at least two conditions under which it may not happen. First, if the lender is the sole creditor of a given borrower, a "work out" in the interests of both parties may be arranged. One of the social externalities of credit insurance where many creditors are insured by one insurance company (as with deposit insurance in the U.S.) is that, by converting many claims into one, runs can be avoided. We have dealt with the issue of determining the best disposition of the borrower in these cases in another paper (Guttentag and Herring [9]).

A second case is where the claims against a given borrower are so large that they constitute a major portion of the capital of its creditors. In this case, pressures for collective action, including pressures from government, are likely to be very strong. This type of situation, which has arisen recently, is also analyzed in another paper (Guttentag and Herring [10]).

Appendix A: Glossary of Symbols

- f the density function governing the returns on investment
- F the cumulative distribution of returns on investment
- K the capital position of the borrower
- K_c the capital position of the creditor
- K_m the minimum capital position that the creditor considers acceptable
- K_s the capital position that is large enough to enable the debtor to borrow at the risk-free rate
- L the loan size
- π the subjective probability that Nature will draw from the disastrous distribution where all investment returns are zero

π^* threshold probability of π, below which it is treated as if it were zero
r one plus the contractual interest rate
r^* one plus the risk-free rate of return
$\hat{r}$ one plus the contractual interest rate that maximizes the expected return to the creditor
r_b one plus the expected rate of return to the borrower
r_c one plus the expected rate of return to the creditor
R the gross return on investment
R_M the maximum possible return on investment
w an index of the riskiness of the investment; higher values of w imply increasing riskiness in the Rothchild-Stiglitz sense of greater weight in the tails of the density function governing investment outcomes
$\hat{w}$ the degree of risk that maximizes the expected return to the borrower given L, r, and K
Z the total payment due from the borrower at the end of the loan contract period (Lr)
Z^* the total payment due on a risk-free loan at the end of the contract period (Lr^*)

Appendix B: A Bayesian Approach to the Formulation of the Subjective Probability of a Disaster*

In this appendix, we show that if the prior distribution of the probability of a disaster is a Beta distribution, then the posterior distribution converges to zero as the length of time since the last occurrence of a disaster increases.

$$\text{Let } \chi_t = \begin{cases} 1 & \text{if Nature draws from the disastrous distribution,} \\ 0 & \text{if Nature draws from the project-specific distribution.} \end{cases}$$

As in the text, π is the probability of a disaster and we shall assume π is constant across all periods. Consequently χ_t is a Bernoulli process.

Suppose that decision-makers formulate their expectation regarding π by assuming that π is governed by a Beta distribution with parameters $\alpha > 0$ and $\beta > 0$. Thus, the prior distribution for π is:

$$f(\pi \mid \alpha, \beta) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} \pi^{\alpha-1}(1 - \pi)^{\beta-1}$$

where $0 < \pi < 1$. The unconditional expected value of this distribution is $E(\pi) = \dfrac{\alpha}{\alpha + \beta}$. The variance is $\operatorname{var}(\pi) = \dfrac{\alpha\beta}{(\alpha + \beta)^2(\alpha + \beta + 1)}$. DeGroot [6, p. 160] has shown that under these conditions the posterior distribution of π is a Beta distribution with parameters $\alpha' = \alpha + y$ and $\beta' = \beta + n - y$:

$$g(\pi \mid \chi_t, \cdots, \chi_{t+n}) \propto \pi^{\alpha'-1}(1 - \pi)^{\beta'-1}$$

* The authors are indebted to Prashant Vankudre for work on this appendix. Germany [8] has employed the Dirichlet distribution to make a similar point regarding the probability of a bank failure.

where $y = \sum_{i=0}^{n} \chi_{t+i}$ and $n + 1$ is the number of observations in the sequence. The proportionality symbol, $\propto$, is used to indicate that the function g is proportional to the expression on the right-hand side, but that the function may contain some other factor that does not involve π.

If Nature does not draw from the disastrous distribution, then $y = 0$ and, consequently,

$$E(\pi \mid y = 0) = \frac{\alpha}{\alpha + \beta + n}$$

and

$$\text{var}(\pi/y = 0) = \frac{\alpha(\beta + n)}{(\alpha + \beta + n)^2(\alpha + \beta + n + 1)}.$$

As the number of periods in which Nature draws from the project-specific distribution rather than the disastrous distribution increases, the expected value of π diminishes:

$$\frac{dE(\pi \mid y = 0)}{dn} = \frac{-\alpha}{(\alpha + \beta + n)^2} < 0.$$

As the length of time since the occurrence of a disaster becomes very large, the expected value of π approaches zero as does the variance; as $n \rightarrow \infty$, $E(\pi \mid y = 0) \rightarrow 0$ and $\text{var}(\pi \mid y = 0) \rightarrow 0$.

Thus, the hypothesis that the subjective probability of a major shock is a negative function of the length of time that has elapsed since the last such shock and that, in the absence of a shock, the subjective probability declines to zero is consistent with the Bayesian approach to decision-making.

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