Regulating Bank Capital Structure to Control Risk

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The most important recent developments in bank regulation are based on capital requirements. For example, the Basle Accord of 1988 specifies that bank capital must be at least 8 percent of a bank's risk-weighted assets.[1] Also, the Federal Deposit Insurance Corporation Improvement Act of 1991 (FDICIA) requires regulators to shut down a bank whose capital has dropped below a cutoff level.

While these regulations are important, their focus is too narrow in that they concentrate solely on equity. There are other types of financial instruments available, and these can be even more effective than capital requirements at controlling risk. Proposals to require banks to issue subordinated debt recognize this, but even those proposals do not make full use of the possibilities available. This article argues that capital regulation can be improved by using financial instruments like convertible debt and warrants with high strike prices. Furthermore, some of the improvement brought about by these instruments would allow a reduction in the traditional capital requirements.

Any economic study of bank capital regulation requires a theory of capital structure. Modern theories of corporate financial structure start with the celebrated result of Modigliani and Miller (1958): that in a world without taxes or bankruptcy costs, the value of a firm does not depend on its capital structure. These theories then consider departures from the world of Modigliani and Miller—departures that cause the capital structure to matter. The particular departure studied in this article is agency theory. In the agency theory of capital structure, limited liability creates an incentive for highly leveraged firms to take excessive risk. These incentives are made worse in banking because

[1] Recent proposals by the Basle Committee on Banking Supervision are still based on capital requirements even though they change the way the requirements are calculated.

of deposit insurance. This idea was developed by Merton (1977) and Kareken and Wallace (1978) in the context of deposit insurance and is related to the agency theory of capital structure developed by Jensen and Meckling (1976).[2]

The analysis presented in this article is a simplified exposition of the analysis contained in Marshall and Prescott (2001). They examine the value of augmenting capital regulations with securities that fine-tune the payoff received by a bank. In the Marshall and Prescott model, a bank chooses the risk and mean characteristics of its loan portfolio. For reasons described later, limited liability and government insured bank debt gives banks an incentive to take risk. They find that capital requirements are much more effective at controlling risk taking if they are augmented with securities like warrants or convertible debt. As in Green (1984), these latter instruments control risk taking because they lower the net return to a bank when it performs extremely well.

The present article's focus on controlling risk taking is particularly relevant to banking. The most striking example of a failure to control risk-taking incentives is the savings and loan crisis of the 1980s. The standard story told about this event is that the inflation of the 1970s lowered the value of the savings and loans' fixed rate mortgages to the point that many had a negative net worth. Because of this negative net worth, the savings and loans had nothing to lose by taking on lots of risk. The deregulation of the early 1980s gave the savings and loans the opportunity to take on the risk, and many failures throughout the 1980s resulted.[3]

There is additional evidence of excessive risk taking. Boyd and Gertler (1994) argue that large banks, who had stronger deposit insurance protection due to the "too big to fail" doctrine, took more risk than smaller banks during the late 1980s, which was a period of widespread banking problems. Other studies have found a connection between low capital levels and bank risk. The survey in Berger, Herring, and Szego (1995) lists studies that imply that a higher capital ratio is associated with lower bank risk, though this relationship is sometimes weak. On a related point, several researchers have found that franchise value is negatively correlated with risk. Franchise value is the value of continued operations by the bank and can represent organizational capital or the present value of future lending opportunities. Failure of the bank would mean a loss of its franchise value, which implies that high-franchise-value

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[2] For a survey on non-tax-driven theories of capital structure, see Harris and Raviv (1992).

[3] Another important part of this story is why so few banks failed from World War II until the early 1980s. Keeley (1990) argues that in this period, banking was heavily regulated with numerous protections that reduced competition. These protections included restricted entry by limiting charters and branching, and limited price competition by interest rates controls. Because of these protections, banks received a flow of monopoly profits that would be lost if the bank went bankrupt. For this reason, banks behaved prudently.

banks would behave more prudently than low-franchise-value banks. Evidence that in the 1990s U.S. banks with low franchise value took more risk than those with high franchise value is contained in Demsetz, Saidenberg, and Strahan (1996). In an international sample of banks, De Nicolo (2000) finds that franchise value decreases and risk increases with bank size.

1. THE PURE DEBT AND EQUITY CASE

This section analyzes bank capital regulation when a bank is restricted to issuing only debt and equity. This simple environment is useful for reviewing corporate finance theory and for discussing bank regulation. It will also be valuable in assessing the gain from introducing instruments like warrants into bank capital regulation, as is done in Section 2.

A bank's financing problem is considered under three different sets of assumptions. The first set illustrates the Modigliani-Miller Theorem. The second set of assumptions is based on the agency cost theory of Jensen and Meckling (1976). The present article, however, restricts its focus to the agency cost of debt; agency costs of equity are ignored because the focus on debt costs is all that is needed to illustrate the risk-control properties of warrants and convertible debt.[4] The final set of assumptions adds deposit insurance to the agency cost story; this set illustrates how deposit insurance creates additional risk-taking incentives and how it shuts down the market's incentive to control the bank's risk taking. Recent subordinated debt proposals are discussed.

Consider a bank with an investment project that requires exactly one dollar of investment. The risk-neutral owner or manager of the bank also has one dollar of funds that he or she can either invest outside the bank at the risk-free rate of zero or hold as equity in the bank.[5] Any investment not funded by equity must be funded by debt that is raised from the market. For the purposes of this article, the terms *debt* and *deposits* will be used interchangeably. Because of limited liability, debtholders cannot be repaid out of the returns to the banker's market investments. Instead, if the face value of the debt cannot be repaid out of the bank's investment project, then the bank is liquidated and whatever is left is used to pay the debtholders. Finally, since the exogenous risk-free rate is zero, debtors must receive an expected gross return of 1.0 on their debt.

After raising the investment funds, the bank chooses one of two investment strategies. It can choose a high-mean, low-risk strategy or a low-mean, high-risk one. The high-mean strategy has a one-half probability of paying 0.5

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[4] Marshall and Prescott (2001) contains additional features that generate an agency cost for equity.

[5] The treatment of equity owners and managers as the same entity is common in the corporate finance literature. This assumption, however, is not without consequences. Even so, the analysis in this article should still apply to managerial pay.

and a one-half probability of paying 1.5. In expectation this strategy pays 1.0, which is the risk-free gross return. The low-mean strategy has a one-half probability of paying 0.25 and a one-half probability of paying 1.6. It pays 0.925 in expectation. The high-mean strategy is the socially desirable option.[6]

The Modigliani-Miller Theorem

For the first set of assumptions, the bank can commit to the investment strategy that it will take. Let D be the amount of debt raised and let F be the face value of the debt, or the amount the bank repays if it has the available funds. Also, let I be the amount of funds invested in the market by the banker. Of course, for each dollar of own funds invested in the market, the banker has to raise one dollar in debt; therefore, $D = I$ in this environment.

If the bank commits to the safe, high-mean investment strategy, then for debt $D \leq 0.5$ the bank always has enough funds to pay back debtholders. In this case, $F = D$ and the banker's expected payoff is

$$0.5(0.5 - D) + 0.5(1.5 - D) + I = 1. \tag{1}$$

For debt in the range $0.5 < D \leq 1.0$, the bank cannot fully pay back the depositors if it produces the low return. To compensate for this loss, the face value of debt needs to reflect a risk premium. The risk premium depends on the amount of debt issued. In particular, the face value of debt must satisfy $(0.5)(0.5) + (0.5)F = D$, which implies that $F = 2D - 0.5$. Therefore, if the bank's investment project is entirely financed with debt, that is, if $D = 1.0$, then the face value of the debt would be 1.5. If the bank fails the debtholders receive 0.5, and if it succeeds they receive 1.5, which in expectation is 1.0, the risk-free rate.

For $0.5 < D \leq 1.0$, the bank's expected payoff is

$$0.5(0.0) + 0.5(1.5 - 2D + 0.5) + I = 1, \tag{2}$$

which is the same level as if it issued debt such that it never defaulted.

Similar calculations for the risky investment strategy reveal that the bank's expected payoff of committing to that strategy is also independent of the debt and equity structure, though the bank's expected payoff is at the lower value of 0.925. The value of the firm depends only on its investment decision, and its capital structure has no effect on its investment decision. This invariance of the value of the firm to its financing decision is an example of the Modigliani-Miller theorem (Modigliani and Miller 1958).

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[6] Implicit in the analysis is the assumption that the bank must make an investment decision; that is, it cannot simply invest its funds in the market and not operate. This assumption prevents the trivial regulatory solution of shutting the bank down, and it is only necessary because the bank's return under the high-mean strategy is the same as that of the market and this is a linear partial equilibrium model. In a general equilibrium model with some diminishing returns, the expected returns would be equal in equilibrium and the banking sector would still operate.

Jensen and Meckling

For the second set of assumptions, I assume that a bank's investment decision is private information, that is, known only to the bank. Jensen and Meckling (1976) use this assumption to establish a connection between the investment and financing decisions of a bank.[7] Under private information, a bank cannot commit to its investment strategy. Instead, given its capital structure, an investment strategy must be in the best interest of the bank, that is, incentive compatible. Of course, the market anticipates the bank's inability to commit and the price of debt will reflect whichever strategy the bank is expected to choose given its debt structure.

There are three distinct ranges of debt to analyze. If $D \leq 0.25$, then the bank can always honor its obligations no matter which investment strategy it chooses. For this case, the analysis is the same as that in the Modigliani-Miller case. The face value of debt is $F = D$. The bank owner receives a payoff of 1.0 by taking the high-mean strategy and 0.925 by taking the low-mean strategy, so he or she takes the safe strategy.

For the second debt range, of $0.25 < D \leq 0.5$, there is no failure if the bank takes the safe, high-mean strategy. In this case $F = D$ and the bank's return is 1.0 as before; however, because of the private information assumption, it must now be verified that this strategy is incentive compatible. We therefore need to calculate the bank's expected payoff from issuing this debt contract and taking the low-mean, risky investment strategy. If this number is less than or equal to 1.0, then the safe strategy is incentive compatible; if it is greater than 1.0, then it is not. In this case, the market will recognize that under this debt structure the bank takes the risky strategy and it will price the debt accordingly.

When the market thinks the bank is taking the safe strategy but it is really taking the risky strategy, the bank's return is

$$0.5(0) + 0.5(1.6 - F) + I = 0.8 - 0.5F + I = 0.8 + 0.5D. \qquad (3)$$

For $D \leq 0.4$, the value of equation (3) is less than or equal to 1.0 (what the bank receives from taking the safe strategy), so the safe strategy is incentive compatible. Above 0.4, however, the value of equation (3) is greater than 1.0, so at these debt levels the safe strategy is not incentive compatible.

Figure 1 illustrates the risk-taking incentives created by limited liability. The solid line is the bank's payoff as a function of the return given that the bank has raised $D = 0.50$ and that the market assumes that the bank is taking the safe strategy, that is, $F = D$. The payoff function is piecewise linear and convex because of limited liability. This convex shape generates a taste for risk on the part of the bank. If the bank takes the safe strategy, its payoffs range

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[7] Jensen and Meckling's (1976) analysis applies to all firms, not just to banks.

Figure 1 Risk-Taking Incentives Created by High Levels of Debt
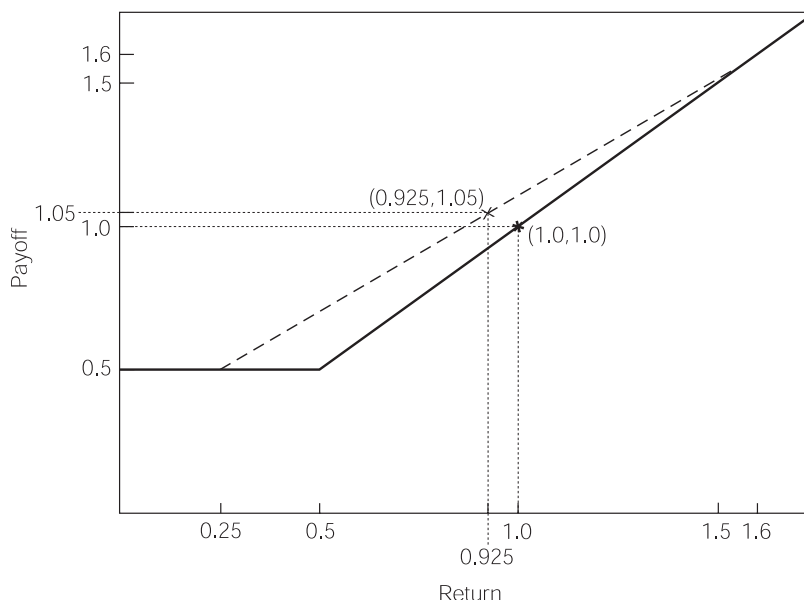
The solid line is the bank's payoff as a function of the return given that $D = 0.5$. It is horizontal over the range 0.0 to 0.5 because of limited liability. Above 0.5, the slope of the line is 1.0 because once the debt is repaid all returns above 0.5 accrue to the bank. The dashed line connects the two possible returns (0.25 and 1.6) if the risky investment is taken. The first coordinate of x (0.925) is the expected return if the risky strategy is taken. The second coordinate of x (1.05) is the bank's expected payoff. The first and second coordinates of * are the corresponding values if the bank takes the safe strategy.

over a linear portion of the returns (over 0.5 and 1.5) and the bank's expected payoff is 1.0, just like that of the investment project. In contrast, if the bank takes the risky strategy, it gains from the convexity. Consider the dashed line in Figure 1, which connects the payoff from the two returns produced by the risky strategy (0.25 and 1.6). Because of limited liability, a return of 0.25 gives the bank a payoff of 0.5 (the return on its market investment). The convex payoff function rewards a bank on the upside without punishing it on the downside, and this payoff structure is reflected in its higher expected payoff of 1.05, despite producing a socially inefficient investment return of only 0.925, as indicated by the x in Figure 1.

Of course, for $0.4 < D \le 0.5$, the market realizes that the safe strategy is not incentive compatible, and it prices the bank's debt as if it has taken the risky strategy. Thus, if the bank takes the risky strategy, the face value of the debt is $F = 2D - 0.25$ and the bank's expected payoff is 0.925.

The final range of debt levels is $D > 0.5$. For this range, there is a chance of default even if the safe strategy is taken. This changes the formula for the face value of the debt, but the high-mean strategy is still not incentive compatible for the same reasons described earlier in relation to the second range of debt levels. Consequently, the bank will choose the risky strategy so the face value of debt is $F = 2D - 0.25$ and the bank's expected payoff is 0.925.

Market Responses

Given these expected payoffs, the bank will choose a capital structure with $D \leq 0.4$ and then take the safe, high-mean strategy. The value of the firm is 1.0, the expected payoff of the safe, high-mean strategy. For higher levels of debt, the market realizes that the bank cannot commit to the safe strategy. Consequently, it prices the debt as if it were taking the risky strategy. The value of the bank for these debt levels is 0.925, the expected payoff of the risky, low-mean strategy. In the world of Jensen and Meckling (1976), the value of a firm is not invariant to its capital structure.

Debt prices are not the only area in which a market may respond to capital structure. For example, debt contracts often include covenants that restrict borrower activities or trigger call options. The market also may decide to spend resources monitoring the borrower. All of these activities can be viewed as costly methods for reducing the adverse effects of private information. In the present article, with no costs to equity these unmodeled additional features are not needed, but in more general environments they very well may be. I will return to this issue below in the discussion of bank regulation.

Deposit Insurance

The final set of assumptions I consider is the addition of deposit insurance to the agency theory of Jensen and Meckling (1976). In practice, deposits (up to a limit) are the only debt explicitly insured. But bailouts may implicitly insure other types of bank debt. To keep the analysis simple, I assume that all bank debt is insured in one way or another. Insurance in this context means that if the bank does not have enough funds to pay back debtholders, the government insurer will make them whole. More specifically, insurance means that debtholders always receive a payment of D, so the face value of the debt is $F = D$. I also assume that the government provides deposit insurance for free. This assumption is a reasonable approximation of present FDIC policies. My analysis in this section is quite similar to that done under the second set of assumptions, which had no deposit insurance, but now the government insurance also leads to transfers to the bank via underpriced debt.

For $D \leq 0.25$ the bank can always pay back debtholders, so there is no incentive problem and the analysis is the same as under the first two sets of assumptions. The bank's expected payoff is 1.0 if it takes the safe strategy and 0.925 if it takes the risky strategy. Consequently, it will choose the safe strategy.

For $0.25 < D \leq 0.5$ most of the analysis is the same as that under the previous set of assumptions. At or below 0.4, the safe investment is incentive compatible and since $F < 0.5$, there is no default; that is, $F = D$. For $D > 0.4$, the safe investment is no longer incentive compatible, so the bank takes the risky investment, just as it did without deposit insurance. What changes, however, is the face value of the debt and the bank's expected payoff. Deposit insurance always makes debtors whole, so there is no longer a need for a risk premium. Consequently, $F = D$ and the bank's expected payoff increases because it has to pay out less when it does well. For $D > 0.4$, the bank's expected payoff is

$$0.5(0.0) + 0.5(1.6 - F) + I = 0.8 + 0.5D. \tag{4}$$

Figure 2 describes the bank's expected payoff as a function of its investment strategy and debt level. The higher expected payoff level indicates which investment strategy is incentive compatible at a particular level of debt. For debt levels below 0.4, the bank chooses the safe investment, but for debt levels above 0.4, it chooses the risky investment. The bank's choice of investment strategies is identical to the previous case without deposit insurance. However, as can be seen in Figure 2, the bank's expected payoff exceeds 1.0 for debt levels exceeding 0.4 and it increases with leverage. The value of the bank increases with leverage because expected transfers from the government increase. These expected transfers are considered by the market as part of the return generated by investment in the bank's debt. These additional transfers are sometimes referred to as the value of the deposit insurance put option (Merton 1977). A put option is the right to sell something at a fixed price. In this case, the bank has the right to sell its losses at a strike price of zero to the deposit insurance fund. Because the bank is able to dump its losses on the insurance fund, the value of its investments increases and, in this example, this increase accrues entirely to the banker.

In contrast with the second set of assumptions, risk is *not* reflected in the face value of bank debt, which shuts down the market's desire to control risk. The problem is so severe in this example (i.e., with deposit insurance) that without any restriction on its capital structure, the bank would choose $D = 1$ and the risky investment strategy. In this example, the loss in output is the only social cost from deposit insurance. There are, however, additional unmodeled costs of deposit insurance. For example, deposit insurance payments could require some potentially distorting taxes, while the high returns would encourage too much entry into banking.

**Figure 2 Bank's Expected Payoff as a Function of Debt under Deposit
            Insurance**
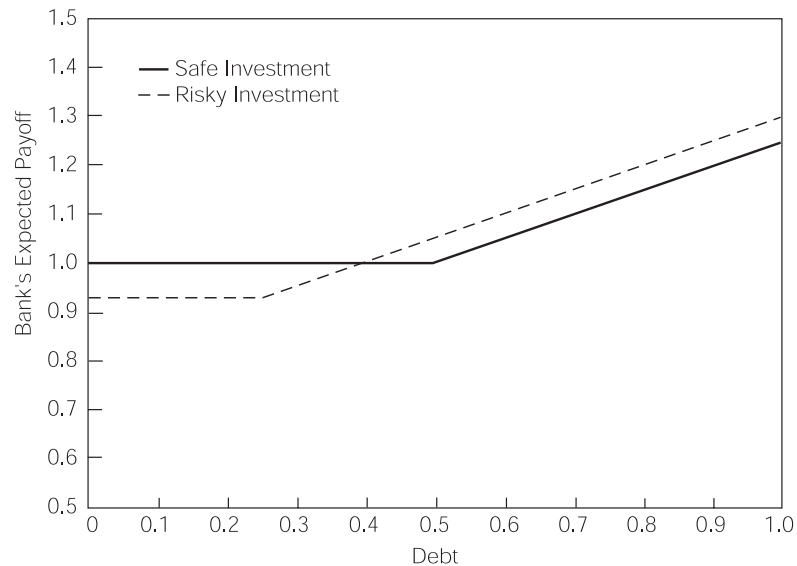
The solid line lists the bank's expected payoff as a function of the debt level and given
that it takes the safe investment strategy. The dashed line corresponds to the risky invest-
ment strategy. Both lines are horizontal over lower levels of debt. In these ranges there
is no default and the bank's expected payoff depends only on the return to its investment.
This is not true at higher levels of debt because of deposit insurance. The price of debt
does not reflect the true risk of the bank's investment. Instead, debt is priced as if it
is risk free because the deposit insurer makes debtors whole by transferring resources to
them in the case of failure. These expected transfers increase with the size of the debt.
Furthermore, from the perspective of the bank and its investors, these transfers are simply
additional returns generated by the bank's investment strategy. Consequently, the bank's
expected payoff increases in leverage.

Bank Regulation

Without deposit insurance, the market prices debt to accurately reflect risk
and monitors or imposes debt covenants to control risk. These measures align
the bank's interests with those of society. With deposit insurance, however,
the market has no reason to properly price the risk, to impose limitations on
bank capital structure, or to place restrictive covenants in debt contracts, so
the bank's interests are not aligned with society's.

   Much of safety and soundness regulation can be viewed as an attempt
by the government to replicate what the market would do in the absence
of government deposit insurance. Capital requirements are the most striking

example of this. In the numerical example, a capital requirement of 60 percent would eliminate any risk-taking incentives and generate the social optimum. It would also prevent banks from maximizing their leverage in order to exploit the deposit insurance put option. FDICIA seems to acknowledge the dangers of high leverage when it allows regulators to shut down or limit the activities of undercapitalized banks.

The parallels between market measures and governmental regulations extend to other regulations as well. For example, the activities in which banks may engage are limited. There are prohibitions on the amount of lending a bank can do to a single entity. Examiners audit and assess bank practices.

Recent proposals that require banks to issue subordinated debt can be viewed as an attempt to return some of the monitoring role to markets. Unfortunately, much of the discussion about the merits of these proposals focuses on the signal about risk revealed by prices, as in the example. But as was discussed in the section about market responses, debtholders not only price risk but may require covenants or changes such as increased transparency of investment. For an excellent discussion of the parallels between market measures and bank regulation, see Black, Miller, and Posner (1978).

## 2. MORE GENERAL CAPITAL STRUCTURES

The analysis in Section 1 limited the available financial instruments to debt and equity (the latter is really the banker's own funds). This limitation illustrated the corporate finance principles at work and demonstrated how capital requirements can work. For some purposes, restricting the analysis to debt and equity is not limiting. For example, in a Modigliani and Miller world, the invariance of firm value to capital structure still holds for more general capital structures. In the Jensen and Meckling world, however, additional financial instruments can be quite effective at controlling risk, and by extension, these same financial instruments can be effective regulatory tools.

Section 2 builds on the previous analysis by adding a richer return structure, which brings us a step closer to the full model in Marshall and Prescott (2001). The new example is first studied in the case in which the bank regulatory capital requirements can only take the form of minimum equity requirements, as under present regulations. Next, the example is studied in the case in which capital requirements can restrict the entire capital structure; that is, regulations can require issue of securities other than debt and equity. As will be shown, much more debt can be issued in the latter case.

As before, there is deposit insurance and the bank can choose a high-mean, safe investment strategy or a low-mean, risky one.[8] Now, however, a multitude

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[8] The example posits a reverse mean-variance tradeoff in investment returns. Marshall and Prescott (2001) study a more general set of possible investment strategies where the bank chooses

Figure 3 Probability Distribution of Returns
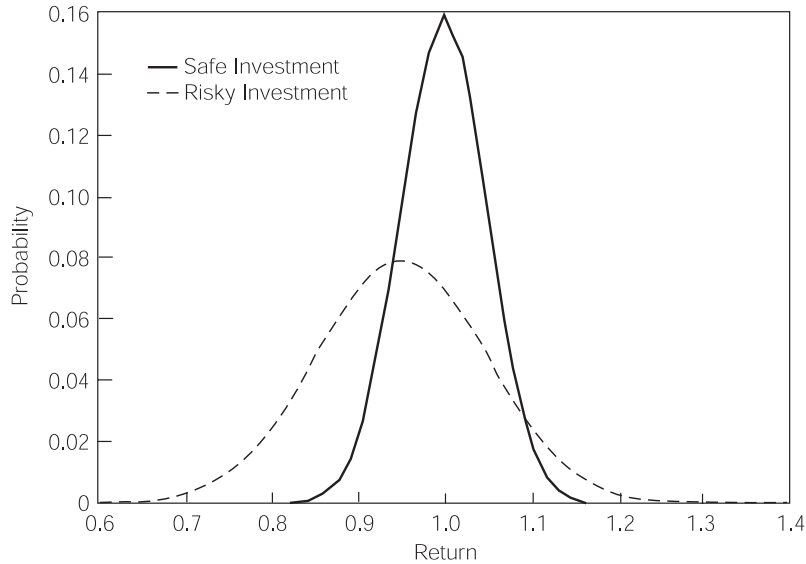
The two lines list the probability distribution of returns for each investment strategy. Both distributions are approximately normal, though truncated from above and below. The safe investment strategy has a mean of 1.0 and a low variance. The risky investment strategy has a mean of 0.95 and a higher variance. If the risky strategy is taken, the return is much more likely to be very low or high than if the safe strategy is taken.

of returns can be generated. Figure 3 shows the probability distribution of the returns for each investment strategy. The solid line is the return for the risky strategy and the dashed line is the return for the safe strategy. The mean of the risky strategy is 0.95 while the mean of the safe strategy is 1.0. Both distributions are approximately normal but with differing means and variances.[9]

The other difference from the previous section is that the bank is allowed to lower its return without cost if it so desires. This assumption is reasonable

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both the mean and variance of its investment strategy. In that setup, the incentive constraint that matters the most is the one where the agent deviates to the high-risk, low-mean strategy. The formulation adopted herein is designed to capture this feature.

[9] The distributions were generated in the following way. The set of returns was divided into an equally spaced grid of 21 points over the range 0.6 to 1.4. The risky investment strategy probability distribution was created by evaluating each return with a normal distribution of mean 0.95 and standard deviation 0.3. These numbers were then normalized to sum to one in order to generate a probability distribution. The safe investment strategy was created in the same way except that the mean is 1.0 and the standard deviation is 0.2.

because it is easy enough to raise costs in order to lower profits. It is also appealing to make the assumption because it guarantees that the net payoff to the bank is monotonically increasing in its return, otherwise, the bank would destroy returns to a point where its net return was highest.[10]

For each case, we find the regulatory policy that is best from society's perspective. Because the example leaves out any costs of equity finance, an all equity financed firm would face no incentive problem and would receive no transfers in expectation from the deposit insurer. To avoid this result, I use as society's criterion the maximum amount of debt the bank could raise while keeping the high-mean, safe investment strategy incentive compatible. This social objective function is sufficient for the purpose of illustrating the risk-control features of warrants and subordinated debt. Marshall and Prescott (2001) contains additional features such as liquidity services from bank deposits and franchise value that lead to additional factors in determining optimal capital regulation.

The most debt that can be supported in the minimal equity requirement case is $D = 0.94$ with equity equal to 0.06. The bank provides 0.06 of its own funds to satisfy the capital requirement and raises the rest in deposits. This quantity is the most highly leveraged capital structure that the bank can have while still providing an incentive for it to take the safe, high-mean investment. The expected payoff of the bank is 1.0466, which is greater than 1.0 because in expectation some transfers are made to the bank from the deposit insurance fund when the bank fails. Under the assumptions in this example, these extra funds accrue to the bank's owner as additional expected profits.

Under more general capital requirements, much more debt can be supported while keeping the high-mean strategy incentive compatible. The solution to the general capital structure problem contains much more debt. In this example, the bank can fund its investment entirely with debt, that is, $D = 1.0$. The bank's expected payoff is 1.0729, reflecting the increased transfers from the government.[11] Despite the high leverage, the safe investment is incentive compatible because of the way payoffs to the bank are structured.

Figure 4 reports the payoff to the bank as a function of the return for both the minimal equity requirement problem and the general capital regulation problem. The dashed line lists the payoff for the pure debt and equity case. It is horizontal at a level of 0.94 from 0.6 to 0.94. For this range of returns, the bank's entire payoff comes from its own funds that it invested with the market at the risk-free rate. Everything produced by the investment project goes to debtholders. Above 0.94, the investment project begins to pay off for

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[10] This assumption has no effect on the pure debt and equity case because equity is intrinsically monotonically increasing.

[11] Since there is nothing that resembles equity when $D = 1.0$, the return to the bank should be viewed as payments to the banker for supplying investment services.

Figure 4 Bank's Payoff as a Function of the Return
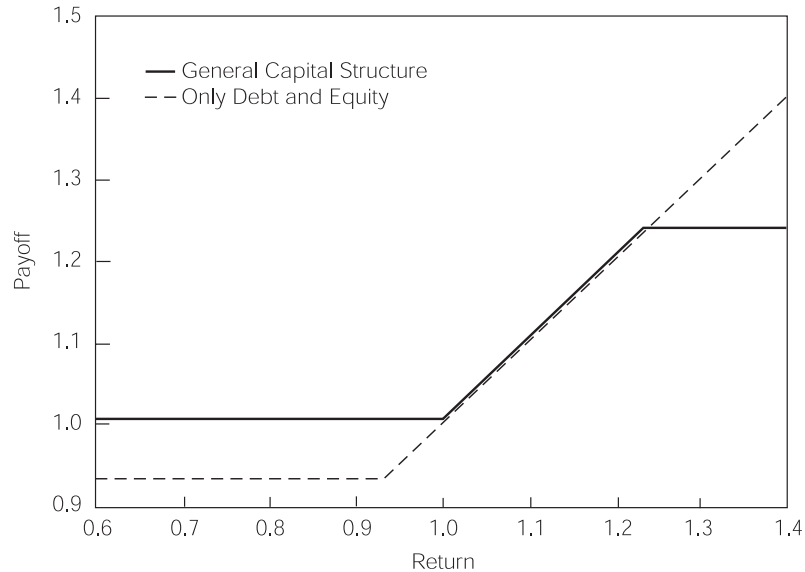
The dashed line lists the payoff to the bank if a minimal equity requirement of 0.06 is imposed on it. For returns above 0.94, the bank's payoff increases because it has paid off its debt and keeps the remainder. The solid line lists the payoffs to the bank generated by the best set of general capital requirements that can be imposed. Under these capital requirements, the bank issues 1.0 units of debt but cannot keep returns in excess of 1.26. These returns must be paid to outside investors. By limiting the payoff from high returns, this payoff structure makes the high-variance investment strategy unappealing.

the bank. All additional returns accrue to the equity holders (the banker) so their payoff is linear in the return with a slope of one. This payoff structure is convex, but the 6 percent capital requirement is enough to prevent the bank from taking the risky investment. However, if the bank issued more debt the payoff structure would shift to the right, making the payoff structure even more convex and making the safe strategy no longer incentive compatible.

The solid line lists the payoff structure to the bank that general capital regulations should try to duplicate. At this point, I only discuss the payoffs, but later I describe how specific financial instruments can be used to generate this payoff structure. Over the range of 0.6 to 1.26, the payoff for the general capital structure case has a similar shape to that of the pure debt and equity case. Above this range, however, the bank's payoff is horizontal in the return. This feature reduces the range of returns over which the bank's payoff is convex, which helps to control risk taking. Furthermore, an examination of

Figure 3 reveals that low and high returns are much more likely under the risky strategy than under the safe strategy. The ratio of the probability of a given return under the risky strategy to the probability of that return under the safe strategy is called the *likelihood ratio* for that return.[12] The goal of the capital structure is to keep payoffs to the bank low when the ratio is high, and to keep it high when the ratio is low. This payoff structure rewards the safe strategy relatively more than it rewards the risky strategy if the bank indeed followed that strategy.

The role of likelihood ratios can be seen more formally. For simplicity, assume there is a finite number of returns. Let $p_s(R)$ be the probability of return R if the safe investment strategy is chosen, and let $p_r(R)$ be the corresponding probability if the risky investment is chosen. Also, let $u(R)$ be what the bank receives, net of payments to all security holders. The incentive constraint is

$$\sum_R p_s(R)u(R) \geq \sum_R p_r(R)u(R).$$

This constraint says that the expected payoff the bank receives from the safe strategy must be at least as much as it would receive if it took the risky strategy. If $p_s(R)$ is low and $p_r(R)$ is high, then it is desirable to set a low $u(R)$. Conversely, if $p_s(R)$ is high and $p_r(R)$ is low, then it is desirable to set a high $u(R)$.

In this example, the likelihood ratio is at its highest level for low returns. The regulator would like to prevent the bank from taking the risky investment by lowering the bank's payoff for these returns as much as possible. Because of limited liability, however, these payoffs cannot be lowered below zero. (Recall that the bank still receives payments from its risk-free investment. This accounts for its positive payoff.) At high returns, this ratio is also high, but limited liability does not bind so payoffs to the bank are lowered. Interestingly, it would be desirable to lower payoffs in these returns to zero, but because of the monotonicity requirement (from the costless destruction of returns assumption) there are limits to which these returns can be lowered.[13]

A Capital Structure That Replicates the Payoffs

Figure 4 describes the optimal payoff structure. But can this structure be replicated with a combination of financial instruments that regulators can require banks to hold? The answer is yes. One way to do this is for the bank to issue warrants with a strike price of 1.26. A warrant is an option that gives the

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[12] See Hart and Holmstrom (1987) for more analysis of likelihood ratios in moral hazard models.

[13] For more details see Marshall and Prescott (2001), who compare solutions with and without the monotonicity constraint.

owner the right to buy shares at the strike price. If the bank produces a return of more than 1.26, a warrant holder collects the difference between the return and the strike price by exercising his or her warrant, and the bank receives just 1.26. This accounts for the flat payoff to the bank for returns above 1.26. But, more generally, if the exercised warrants make up only a fraction of the equity, then the bank's payoffs for returns above 1.26 will increase (though at a slope less than one).

Selling a warrant is equivalent to selling a portion of the bank's return above the strike price; the exact portion depends on the relative share of warrants and existing equity. In this example, selling the warrant is valuable because it allows the bank to be more highly leveraged than in the pure equity case, while keeping the safe, high-mean strategy incentive compatible. Furthermore, because the bank can finance its entire investment with debt, the income received from selling the warrants is reinvested at the market rate along with the banker's own 1.0 units of funds. For this reason, the bank's payoff slightly exceeds 1.0 for the range of returns between 0.6 and 1.0.

The analysis contains a clear message about capital regulation. Capital requirements that control risk by lowering the upper-tail payoff to banks can improve upon the existing capital regulations. Warrants with a high strike price are not the only financial instruments that can do this. For example, convertible debt is debt that can be converted into equity at some agreed-upon price. For a high enough strike price, convertible debt could substitute for warrants. Alternatively, equity swaps might be possible.

Some Caveats

In assessing different financial instruments, it may be important to consider additional features of financial instruments like control features or ability to trade. If the banker sold warrants at a strike price of 1.26, he or she would be turning the bank over to the warrant holders whenever the warrants were exercised. Managers rarely want to give up control. The static analysis in this article is inappropriate for an analysis of control; however, if control was indeed an issue, then other financial instruments like swaps that separate control from cash flow might be valuable.

Another point is that in this analysis, it matters who holds the warrants. In the example, there is an anonymous market that purchases them, but if the banker bought them, it would undo his or her incentives since his or her payoff structure would then look convex again. In practice it would be necessary to ensure that owners of the warrants are not the same people who own the equity of the firm.

3.   FINAL COMMENTS

This article argues that financial instruments, such as warrants or convertible debt, should be considered as part of capital regulations. They are effective at controlling risk-taking incentives because they lower the payoff to a bank that engages in risky activities without adversely affecting a bank engaged in safe activities. Furthermore, at least in the example in Section 2, imposing these requirements would allow a reduction in the traditional capital requirement of an equity minimum.

While the example necessarily leaves things out, the analysis in Marshall and Prescott (2001) includes several additional features and still finds that financial instruments like warrants and convertible debt are potentially valuable regulatory tools. They include franchise value and disutility to managers from screening the quality of its loans. These two features give equity some value in their environment. They also include a utility value of deposits, which is designed to capture the payment and liquidity services that deposits provide but other kinds of debt do not. Furthermore, they allow banks to choose from a richer set of investment strategies. Banks are allowed to choose the variance and by screening, the mean, of its investment portfolio.

They find that the most binding incentive constraint is the one on the bank taking the low-mean, high-variance investment. The regulator sets its capital requirements mainly to prevent the bank from taking this investment strategy. This reverse mean-variance tradeoff is the justification for the simple two distribution choice faced by banks in this article. For low franchise values, they find results qualitatively very similar to those in this article. Equity minimums are higher under standard capital requirements than under a capital requirement that also uses instruments like warrants with a high strike price. For higher franchise values, they find that capital requirements are not that important and that the banks will choose high levels of capital, in order to reduce the chance of bankruptcy.

One important feature that Marshall and Prescott (2001) do not study is that warrants and convertible debt may punish banks whose high returns are generated by innovation or just simply better management. The investment choices in their paper, as well as in this article, do not capture this phenomenon. Future research should be concerned with determining the efficacy of payoff structures for these kinds of situations.

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