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The Regulation of Bank Capital: Do Capital Standards Promote Bank Safety?*

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We show that in an imperfect information environment the equity value of an impaired bank may increase or decrease when it is required to meet a capital standard. Regardless of the change in the bank's equity value, however, its stock price will fall in response to a forced recapitalization, consistent with recent empirical evidence. Simulations of our model suggest that this stock price decline is likely to be larger the smaller is the share of ownership held by the managers of the bank, also consistent with recent empirical evidence in the literature. Our model further predicts a rise in bank's non-interest expenses following a required recapitalization. Given the increase in the regulator's exposure that would accompany a reduction in the bank's market value of equity, the regulator may choose *not* to enforce the regulation. Hence, capital regulation may be time-inconsistent in this situation and consequently not have its intended risk-mitigating incentives.

I. INTRODUCTION

While there has long been general agreement among financial economists of the need for a replacement of capital standards that are based on accounting measures with ones that incorporate the true riskiness of bank portfolios,

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the enormity of recent bank and thrift losses recently served to mobilize political support for such reform. Within this context, the adoption of risk-dependent capital standards was thought to provide an improved degree of equity across differing financial institutions, and more importantly, to reduce incentives for excessive risk-taking.

The change toward at least some degree of risk sensitivity in bank capital standards followed a period, since the mid-1970s, of confusion and ambiguity as to what constituted ''necessary minimum capital.'' For 20 years before that time, bank regulators used a well-defined formula to determine the minimum capital a bank needed for each particular asset category, thereby hoping to achieving at least some degree of risk sensitivity in standards. Financial innovations in the 1960s and 1970s made the formula complex, at first, then obsolete. The use of a prescribed capital standard was abandoned in favor of giving regulators discretion as to what was necessary minimum capital and whether a particular bank satisfied that minimum. Subsequently, in 1981, explicit standards for minimum capital were imposed, but in terms of an accounting-based treatment of capital with little recognition of the riskiness of bank portfolios. Furthermore, the required minimum capital levels differed across regulatory agencies and sizes of banks. By 1985, bank regulators required a minimum of primary capital—consisting mostly of common stock, perpetual preferred stock, surplus, undivided profits, and capital reserves—to assets of 5.5%, and total capital—consisting of primary capital and mostly of subordinated notes and debentures, limited life preferred stock, and mandatory convertible debt that is ineligible as primary capital—to assets of 6%. The risk independence of the capital standard was maintained. However, in 1989, the Basle Agreement moved bank regulation in the United States, as well as in other industrialized countries, closer to that developed in the early 1950s in the United States. Particular asset classes were identified, based on credit risk, and minimum required capital for each class was specified. Thus, more risky activities by the bank would generally require more bank capital to be maintained. In the United States, the Federal Deposit Insurance Improvement Act of 1991 (FDICIA) further defined capital standards and emphasized prompt regulatory action in the event of capital deficiency.[1]

There is a considerable literature in finance that focuses on bank capital and capital standards. Earlier studies, such as Taggart and Greenbaum (1978), described the role of bank capital and what constituted an ''adequate'' amount of capital. Capital can be viewed as the ''deductible'' in the

[1] While the exact description of what constituted capital varied across countries, the general feature of the new requirements were that the minimum necessary capital was linked by a formula to the institution's credit risk; greater credit risk of bank assets required more bank capital. In the United States, banks were initially required to hold capital equal to 7.25% of commercial and consumer loans, and to increase this standard to 8% by the end of 1992.

government's insurance of bank deposits and it can provide risk-mitigating incentives for bank managers.[2] For the bank, capital provides loanable funds and buffers earnings declines. Better capitalized banks have generally been viewed as "safer," although Kahane (1977) and Koehn and Santomero (1980) questioned the effectiveness of accounting-based capital standards by showing that risk-independent capital requirements without accompanying portfolio constraints are generally ineffective. This result, based on a mean-variance framework, was criticized by Furlong and Keeley (1987, 1989) and Keeley and Furlong (1990) who demonstrated that capital controls do indeed enhance bank safety. However, Gennotte and Pyle (1990) showed that the assumption in these recent papers of bank lending being zero net present value was critical. By assuming that intermediaries can invest in assets that have positive net present value, and using an option pricing framework, Gennotte and Pyle support the earlier conclusion that accounting-based capital standards may be ineffective, and indeed, may even promote greater bank risk-taking.

A different strand in the literature has focused on capital requirements in an imperfect information environment. For example, Campbell *et al.* (1992) examine the normative issue of designing a monitoring scheme cum capital standards in light of monitoring agents' incentive to shirk, and Giammarino *et al.* (1993) examine deposit insurance and capital requirements when the environment includes adverse selection and moral hazard. Most recently, Thakor (forthcoming) relates capital standards to the bank's rationing decision and provides evidence that links capital standards to aggregate bank lending.

The capital standards set by the Basle Agreement as well as by FDICIA are designed to deal with the asset-substitution incentives induced in banks by extreme leverage, limited stockholder liability, and risk-insensitive deposit insurance pricing. Requiring a higher capital to assets ratio would reduce bank's deposit funding, for a given asset base, and thereby provide a disincentive for such risk-taking. In parallel to this emphasis in the new regulations, studies in the literature on the link between capital requirements and bank risk-taking have focused either explicitly or implicitly on asset-substitution moral hazard. We too examine, in an imperfect information environment, the effect of regulatory capital standards on bank behavior. However, we argue that enforcing a higher capital requirement may perversely result in *greater* risk exposure for the regulator. Our results follow from recognizing the effect of capital standards on effort-aversion moral hazard, in addition to that involving the much analyzed asset-substitution. Our results suggest that the new more stringent capital standards may

[2] See, for example, Buser *et al.* (1981) and Dietrich and James (1983) for analysis of how capital reduces bank risk-taking.

reduce the risk associated with one type of agency problem but increase that of another, with the net effect possibly being an increase in the overall riskiness of bank assets. This conclusion is similar to that of Gennotte and Pyle but while their result applies only to accounting-based capital controls, ours applies to both accounting and market-value-based standards.

Our perspective is of bank insiders that take unobservable actions that maximize their own welfare and not necessarily that of either the bank's outside investors or the public insurer. With this setup, we find that under certain conditions, increasing capital standards may *reduce* bank safety, and indeed, a regulator whose objective is to minimize the bank's default risk would prefer *not* to enforce the existing capital standard. These effects are shown to occur even though the capital standard may induce the bank to choose a less risky loan portfolio.

Our model can be viewed as an application to banking of the Jensen and Meckling (1976) agency problem involving a firm's ''insiders'' and its ''outside'' investors.[3] The aspect here that is unique to deposit-type financial institutions is the joint effects of deposit insurance and capital requirements.[4] Lending opportunities that are positive net present value and deposit insurance that enables the bank to fund itself at the risk-free interest rate ensure that bank stockholders enjoy a surplus. If there is underpricing of the deposit insurance, then it adds to the surplus from lending. This surplus, however, is realized only if the bank's loans are repaid. In our model, insiders supply effort that increases the likelihood of the successful loan repayment state. Requiring the bank to substitute equity for deposit financing, for given assets, reduces the expected surplus available to bank stockholders. The new stockholders compensate the bank insiders for the reduction in their portion of this expected surplus by paying a competitive price for the equity. But because there is a reduction in the insiders' portion of the surplus that is contingent on loan repayment—i.e., on the realization

[3] See Barnea *et al.* (1985) for a summary of agency problems in financial economics. Saunders *et al.* (1990) provide empirical evidence suggesting an agency problem between insiders and outside investors in banking. They indicate that bank loan portfolios are less risky when insiders own a sufficient fraction of the bank's equity and more risky when banks are controlled by their (outside) stockholders.

[4] Without deposit insurance (or with risk-sensitive deposit insurance pricing), banks would be indifferent *a priori* between funding loans with (market-priced) deposits or with equity as well as satisfying the regulatory capital requirement with equity or with long-term subordinated debt. This indifference between debt and equity is generally recognized for all corporations so long as tax deductibility of interest payments is not an important factor. We discuss the latter issue later in the paper. Explanations for deposit insurance relate to the need for a small-denomination riskless asset (for ''widows and orphans'') and to prevent systemic bank runs. We do not address the motivation for deposit insurance. Since our model focuses on a single representative bank, it cannot speak to contagion. However, our analysis is consistent with risk-averse depositors having a demand for insured deposits.

of the successful state—insiders provide less effort to realize this state. The reduction in insider effort reduces the bank's stock price. This price effect is consistent with what bankers view as ''common wisdom''—they cannot sell stock without suffering a price decline. However, the price decline in our model occurs because the market correctly infers that bank insiders will now be less productive since their stake in the firm has been reduced.

The regulator/insurer's risk exposure will diminish if the bank's issue of stock to satisfy the capital standard increases the market value of the bank's equity, even if its stock price declines. However, if the bank's insiders reduce their productivity sufficiently with the sale of equity, then the bank's equity value may be reduced by the equity sale. In this situation, the regulator/insurer's welfare is worsened by requiring an impaired bank to satisfy a capital standard, and hence, the standard may not be enforced. If a bank anticipates that the regulator will not enforce the capital standard, its intended risk-reducing incentives will not be realized, i.e., the regulation is not time-consistent.[5] Consequently, depending on the anticipated effect of the standards on the bank's equity value, the bank may *a priori* either concern itself excessively with managing risk or go to the other extreme and assume (socially) excessive risk.

Empirical support for our analysis is provided by Keeley (1989) and Cornett and Tehranian (1994). Both studies find that announcements of equity issues by banks that appear, by regulatory standards, to be undercapitalized result in stock price declines. In addition, Cornett and Tehranian find that insider ownership is significant in explaining the size of the price decline: the greater the insiders' holdings, the smaller the decline. Our model not only predicts the stock price decline of undercapitalized banks that are required to issue equity to meet regulatory standards, but also the latter findings that relates insider ownership to the extent of the price decline.[6] These implications of our analysis which are consistent with the data help to provide empirical plausibility to our model and distinguish it from other explanations. An additional implication of our model is that if the insider agency problem we describe is

[5] One might think that under these circumstances, the regulator would close the bank since any attempt to increase its capital would be counter-productive. To the extent regulators would behave this way, our paper's point regarding the possible time-inconsistency issue is invalid, and we should have presented an analysis of optimal closure of capital-impaired banks. However, there is considerable evidence that regulators have been reluctant to close banks that, under any analysis, should have been closed. Boot and Thakor (1993) explain why regulators may resist shutting insolvent banks.

[6] Interestingly, while our original analysis predates Cornett and Tehranian (1994), and indeed motivates it, the result relating insider ownership to the extent of the stock price decline prompted our subsequent study of this implication of our model.

significant, the enforcement of a capital standard should result in an increase in the bank's non-interest expense ratio. This implication has not to our knowledge been tested.

A natural question concerns our interpretation of effort. We model the bank's realization of the successful state as being affected by insider effort. Our narrow view might be that it is the effort of senior management in monitoring/supervising the bank's loan officers in their evaluation and screening of loan applicants. However, a more interesting way to think about effort would be to include forgone perquisite consumption or empire-building opportunities as well as the psychic costs of terminating underperforming managers and employees. This broader notion of effort captures the commitment of insiders to activities which maximize firm value and are undertaken at the expense of those that provide them with increased utility. With this interpretation, one might question whether a slack-ridden bank is compatible with one in which top managers have sufficiently large stock holdings so that their expenditure of effort is affected by the dilution that occurs because of the equity issued to satisfy the capital standard. As we will see, though, all of the results regarding the effects of the capital standard and effort will hold irrespective of the level of insider holdings, so long as it is positive. If it is zero, of course, insiders would not supply effort regardless of the capital standard.

The remainder of the paper is organized as follows. Section II describes elements of the model used to examine the effect of the regulatory capital standard on bank behavior. Section III examines equilibrium bank behavior when the capital standard is enforced and analyzes the effect of the regulation on the bank's stock price and its probability of solvency. Section IV summarizes and concludes.

II. MODEL DESCRIPTION

There are two dates, $t = 0, 1$, and four sets of agents, a bank regulator, depositors, bank insiders, and bank outsiders. Bank insiders own a fraction of the bank's equity and make a loan portfolio decision and an effort decision which jointly determine the safety and profitability of the bank. To make the analysis tractable, we assume that all parties are risk neutral, although all our results should carry over to the case of risk-averse agents.

Events unfold as follows. At $t = 0$, the bank is endowed with risky loan opportunities, L, which are funded with deposits, D, and equity capital, K, such that $L = D + K$. The amount L of loan opportunities is exogenous and for notational simplicity we normalize it to \$1. The amount K of equity is fixed by the capital standard imposed on the bank by the regulator at

$t = 0$.[7] Although this is not the only possible interpretation, one might imagine the bank at $t = 0$ as being impaired, and K therefore would be the amount of capital the bank is required to raise following an evaluation of its condition by the regulatory authority.[8] Prior to $t = 0$, the bank's equity for regulatory purposes is assumed to be 0. This assumption is not important since the analysis would be exactly the same if the bank's capital at $t = 0$ equaled a positive amount E, where $E < K$. Thus, to take advantage of its loan opportunities, while complying with the capital standard, the bank must issue K in equity with deposits D then financing the balance $1 - K$ of the bank's loan portfolio.

Deposit and equity markets are assumed to be perfectly competitive. As in Gennotte and Pyle (1990), loans are assumed to be positive net present value investments for banks. Deposits are fully insured and will thus pay the riskless interest rate i. Outside investors will pay a competitive market price for their shares of the bank's equity. Let MV denote the period $t = 0$ market value of the bank's equity. Let $\delta_0 > 0$ be the fraction of the bank's shares owned by insiders *before* they have raised the additional equity to comply with the standard, and let δ be the fraction of that equity owned by the insiders after the necessary equity has been raised. The market clearing condition at $t = 0$ is then

$$K = \left(1 - \frac{\delta}{\delta_0}\right) MV, \tag{1}$$

where $1 - \delta/\delta_0$ is the fraction of the bank's shares owned by the purchasers of the new equity issue. The market value MV will depend on loan portfolio and monitoring effort decisions made by insiders. As we will see below, the portfolio decision is independent of δ, but the monitoring effort decision depends on δ. Thus, both MV and δ are endogenous, with δ eventually being determined by the market clearing condition (1).

At $t = 1$, both deposits and loans mature. At this point, one of two states of the world is realized: either the loans are repaid or they are not. If not, the bank becomes insolvent, and depositors will be paid by the deposit

[7] Because the bank's assets are fixed at \$1, the capital requirement K represents both an adequacy ratio of required equity to loans and an absolute amount of capital that must be raised. This distinction is unimportant in this section and the next, where it is assumed that the bank is unable to sell loans to satisfy the capital regulation. The distinction is important, though, if the bank can sell loans, because it can satisfy an adequacy ratio either by raising capital or reducing the amount of loans. The bank's incentive to sell loans is discussed in Section IV.

[8] This interpretation was incorporated formally in a previous version of this paper [see Besanko and Kanatas (1991)].

insurer. The probability of loan repayment depends jointly on the bank's loan portfolio decision and an operating decision by bank insiders.

The loan portfolio decision at $t = 0$ is modeled as a choice among two mutually exclusive risky portfolios, indexed by j, $j = 1, 2$. Portfolio j has a rate of return R_j in the successful state and a success probability $a\gamma_j$, where

$$R_1 > R_2,$$

$$\gamma_1 < \gamma_2,$$

and $a \in [0, 1/\gamma_2]$ denotes effort by bank insiders. Thus, for given effort, portfolio 1 involves a higher rate of return but a lower success probability than portfolio 2. The relationship between R_1, R_2, γ_1, and γ_2 is assumed to be

$$\frac{(1 + R_1)\gamma}{(1 + i)} = \frac{(1 + R_2)\gamma_2}{(1 + i)} - \sigma(\gamma_2 - \gamma_1), \tag{2}$$

where $\sigma \in [0, 1]$ is a parameter that, in a general sense, measures the relative attractiveness of the two portfolios.[9] If $\sigma = 0$, the portfolios exhibit mean-preserving spread; a risk-neutral investor would be indifferent between them, and a risk-averse investor would strictly prefer portfolio 2. If $\sigma > 0$, portfolio 1 is not only riskier than portfolio 2 but it also has a lower expected return. A risk-neutral investor would thus strictly prefer portfolio 2 to portfolio 1, but as we shall see below, a risk-neutral bank protected by deposit insurance may choose portfolio 1, the dominated portfolio.

Effort a increases the probability of repayment no matter which loan portfolio the bank chooses. We assume that effort involves no direct monetary costs to the bank, but does involve a positive disutility $V(a)$ to bank insiders. To allow closed-form characterization of the equilibrium, we assume that $V(a)$ is quadratic,

$$V(a) = \frac{a^2}{2\beta}, \tag{3}$$

where β is a parameter reflecting the marginal cost of effort.[10]

Given a choice of loan portfolio j and effort a, the market value $MV(j, a)$ of the bank's equity is

[9] The reason for multiplying σ by $(\gamma_2 - \gamma_1)$ in Eq. (2) will become evident below.

[10] All the insights of the model will be unchanged with an increasing and convex disutility function.

$$MV(j,a) = a\gamma_j \left[\frac{(1+R_j) - (1+i)D}{(1+i)} \right]. \tag{4}$$

Noting that $D = 1 - K$ and defining

$$Q_j \equiv \left[\frac{(1+R_j)}{(1+i)} - 1 \right], \tag{5}$$

we can write the bank's market value of equity as

$$MV(j,a) = a\gamma_j(Q_j + K). \tag{6}$$

The term Q_j represents the net present value of a hypothetical asset with a guaranteed rate of return R_j. Because $R_1 > R_2$, it follows that $Q_1 > Q_2$.

The insiders' utility $U(j, a)$ is given by

$$U(j,a) = \delta MV(j,a) - \frac{a^2}{2\beta}. \tag{7}$$

The insiders make the portfolio decision j and the effort choice a in period 0 after the outside equity has been raised to satisfy the capital standard. Note that there are two distinct incentive issues in the model. The first relates to asset-substitution and arises because of leverage and deposit insurance. The second relates to effort choice and arises because insiders bear non-pecuniary costs of effort. Even though both incentive problems bear on the bank's probability of success, they are influenced in different ways by capital regulation.

III. EQUILIBRIUM BANK BEHAVIOR UNDER CAPITAL REGULATION

Optimal Portfolio Choice

Insiders choose a portfolio j and monitoring effort a to maximize $U(j, a)$. Note that the insiders' problem is separable in a and j. Thus, the optimal portfolio j will be the one that maximizes $\gamma_j(Q_j + K)$, independent of the effort choice a or fractional ownership δ. Insiders will choose the riskier portfolio 1 if and only if

$$\gamma_1[Q_1 + K] > \gamma_2[Q_2 + K]. \tag{8}$$

Using (2) and letting $j^*(K)$ denote the optimal portfolio choice for a given capital standard K, condition (8) is equivalent to a simple rule:[11]

$$j^*(K) = \begin{cases} 1 & \text{if } K < 1 - \sigma, \\ 2 & \text{if } K \geq 1 - \sigma. \end{cases} \tag{9}$$

Recalling that σ is a measure of the relative unattractiveness of portfolio 1 as compared to portfolio 2, condition (9) implies some intuitive relationships between asset choice and capital standards. With no capital requirement ($K = 0$), the bank will choose the riskier portfolio. By contrast, with a 100% capital requirement ($K = 1$), the bank will choose the safer portfolio. For $\sigma > 0$, the bank will choose the safer portfolio if the capital standard is sufficiently high. If the portfolios exhibit mean preserving spread ($\sigma = 0$), so that portfolio 1 is not strictly dominated by portfolio 2, the bank will choose the riskier portfolio for any capital standard less than 100%. The intuition for these results is straightforward: the larger the capital standard, the greater the reduction in the deposit insurance subsidy (i.e., the extra surplus the bank gets due to the underpricing of deposit insurance). The lower the deposit insurance subsidy, the smaller the gain from substituting riskier assets for safer ones. Note that if asset-substitution moral hazard were the only consideration, an increase in the capital standard would unambiguously improve bank safety in that it reduces the range in which the bank selects the riskier portfolio.

Optimal Effort

Having chosen the optimal portfolio $j^*(K)$, insiders' effort choice solves

$$\max \delta a \gamma_{j^*(K)} [Q_{j^*(K)} + K] - \frac{a^2}{2\beta} \; a \; \varepsilon \; [0, 1/\gamma_{j^*(K)}].$$

Let $a^*(\delta, K)$ solve this problem. Incorporating the optimal portfolio choice in (9), this solution is given by

$$a^*(\delta, K) = \begin{cases} \max[\delta\beta\gamma_1[Q_1 + K], 1/\gamma_1] & \text{if } K < 1 - \sigma; \\ \max[\delta\beta\gamma_2[Q_2 + K], 1/\gamma_2] & \text{if } K \geq 1 - \sigma. \end{cases} \tag{10}$$

Because $\gamma_2[Q_2 + K] = \gamma_1[Q_1 + K]$ at $K = 1 - \sigma$, $a^*(\delta, K)$ is piecewise

[11] We adopt the convention that when the bank is indifferent between portfolios, it chooses the safer one.

continuous and everywhere increasing in K. The reason effort is increasing in K, *for fixed insider ownership,* is that substituting equity for deposits increases the bank's market value of equity, although it does reduce any deposit insurance surplus. Holding insiders' fractional ownership unchanged means that insiders' expected payoff in the successful state increases with the increase in equity value, thereby inducing greater effort.

Taking into account the optimal effort and portfolio choices, the probability $\phi(\delta, K)$ of bank solvency for a given δ and K is

$$\phi(\delta, K) = \begin{cases} \gamma_1 a^*(\delta, K), & \text{if } K < 1 - \sigma; \\ \gamma_2 a^*(\delta, K), & \text{if } K \geq 1 - \sigma. \end{cases} \tag{11}$$

We focus on the case in which there is a non-zero probability of bank failure. Thus $\phi(\delta, K) < 1$ for all (δ, K).[12] Because $\gamma_1 < \gamma_2$, $\phi(\delta, K)$ is also increasing in K. Thus, *holding the insiders' fractional ownership fixed,* stricter capital standards enhance the bank's safety. This is the principal benefit of capital regulation in the model.

The Full Equilibrium

We assume that at $t = 0$ the outside market has rational expectations regarding the portfolio and effort choices by bank insiders. Thus, the market impounds these choices into the stock price when capital is obtained to satisfy the regulatory standard. Let the equilibrium market value of the bank for a given ownership share δ and capital standard K be denoted by $MV^*(\delta, K) = MV(j^*(K), a^*(\delta, K))$. Substituting the conditions for the optimal portfolio and effort choices into (4), the equilibrium market value is given by

$$MV^*(\delta, K) = \begin{cases} \delta\beta\gamma_1^2[Q_1 + K]^2, & \text{if } K < 1 - \sigma; \\ \delta\beta\gamma_2^2[Q_2 + K]^2, & \text{if } K \geq 1 - \sigma. \end{cases} \tag{12}$$

For a given K, then, the equilibrium ownership fraction $\delta^*(K)$ solves Eq. (1), or

[12] In effect, we are restricting our attention to capital standards that do not completely eliminate a bank's default risk. The parameter restriction implied by this assumption is $\delta\beta\gamma_j^2(Q_j + K) < 1$.

$$K = \left(1 - \frac{\delta^*(K)}{\delta_0}\right) MV^*(\delta^*(K), K). \tag{13}$$

Equation (13) is a quadratic in δ with a solution given by[13]

$$\delta^*(K) = \begin{cases} \dfrac{\delta_0}{2} + \dfrac{1}{2}\left[\delta_0^2 - \dfrac{4\delta_0 K}{\beta\gamma_1^2(Q_1 + K)^2}\right]^{1/2} & K < 1 - \sigma, \\ \dfrac{\delta_0}{2} + \dfrac{1}{2}\left[\delta_0^2 - \dfrac{4\delta_0 K}{\beta\gamma_2^2(Q_2 + K)^2}\right]^{1/2} & K \geq 1 - \sigma. \end{cases} \tag{14}$$

The full equilibrium ($\delta^*(K)$, $a^*(K)$, $j^*(K)$) can now be summarized. The equilibrium portfolio choice $j^*(K)$ is given in (9). The optimal effort $a^*(K) = a^*(\delta^*(K), K)$, where $a^*(\delta, K)$ is defined in (10). The equilibrium ownership fraction $\delta^*(K)$ is given in (14).

The effect of the capital requirement on equilibrium monitoring effort and insiders' ownership is summarized in our first proposition.

PROPOSITION 1. *Insiders' ownership $\delta^*(K)$ and effort $a^*(K)$ decrease as the capital requirement K increases.*

Proof. See Appendix.

In traditional discussions of capital requirements, two effects are usually emphasized. The first is a *buffer effect*. This is the oldest rationale for capital standards. By requiring the bank to substitute equity for deposits, for a given asset portfolio, the set of states in which the bank defaults is reduced. With our simple two-state modeling structure, however, the buffer effect does not operate, but our model could easily be extended to more than two states so that it does. The second effect frequently discussed is an *asset-substitution effect.* Capital standards limit the bank's incentive to increase risky assets. This effect has been emphasized in recent years. As discussed earlier, increasing the stringency of the capital requirement in our model does limit the bank's incentive to take on risk. It does so in two ways. First, it induces the bank to substitute safer loans for riskier ones. Second, for a fixed insider ownership share δ, it increases effort, i.e., $\partial a^*(\delta, K)/\partial K > 0$. Proposition 1 highlights a third effect of capital standards, a *dilution effect*,

[13] A necessary condition for a solution to (13) to exist is $\delta_0\beta\gamma_j^2(Q_j + K)^2 \geq 4K$ for $j = 1, 2$. We assume that this condition holds. If it did not hold, the effort-aversion moral hazard problem would be so severe that the bank would be unable to raise the equity funds necessary to satisfy the capital standard. Equation (14) is the upper root of the quadratic, chosen so that $\delta^*(0) = \delta_0$.

TABLE I
CAPITAL STANDARDS AND THE BANK'S PROBABILITY OF SOLVENCY

K	$j^*(K)$	$a^*(K)$	$\delta^*(K)$	$\phi^*(K)$
0%	1	1.15	20.0%	91.9%
1%	1	1.14	19.2%	91.5%
2%	1	1.14	18.4%	91.2%
3%	1	1.13	17.7%	90.7%
4%	1	1.13	17.0%	90.3%
5%	1	1.12	16.3%	89.8%
6%	1	1.12	15.7%	89.2%
7%	1	1.11	15.1%	88.6%
8%	1	1.10	14.5%	87.8%
9%	2	1.10	14.0%	98.7%
10%	2	1.10	13.6%	98.6%

Note. $i = 7\%$, $\gamma_1 = 0.80$, $\gamma_2 = 0.90$, $R_1 = 33.9\%$, $R_2 = 30\%$, $\sigma = 0.92$, $\delta_0 = 20\%$, $\beta = 28.5$. K is the capital standard and $\phi^*(K)$ is the probability of solvency.

which has not been analyzed in the literature. Increasing the capital standard dilutes the insiders' ownership share, which reduces their marginal benefit of effort. In our model, the dilution effect is so strong that it dominates the beneficial effect that the capital standard has on effort, and equilibrium effort actually decreases as the capital standard is raised.[14] Moreover, this effect holds no matter how small the insider's initial ownership fraction δ_0, so long as it remains positive.

Proposition 1 suggests that the probability of bank solvency would not increase monotonically in the magnitude of the capital standard. The probability of solvency may thus be maximized for a capital standard that is less than 100%. Table I shows an example of this. The probability of solvency is maximized at $K = 9\%$, which is the point at which the standard is large enough to induce the bank to substitute the safer portfolio for the riskier one. For a capital ratio greater than 9%, despite the continuing choice of the safer portfolio, the dilution effect dominates, reducing the insider's equilibrium effort and the equilibrium probability of solvency.

The main insight from Proposition 1 is that satisfying a capital requirement may be costly, not only for bank insiders but also for the regulator/insurer whose risk exposure may increase as a consequence. One way in

[14] Whether this result extends to cases in which the disutility of effort function is nonquadratic is an open question. Even with a general functional form, however, the insight still holds that an increase in the capital standard weakens the incentive for insiders to supply effort.

which the costs of capital regulation may manifest themselves is through the effect on the bank's stock price. The equilibrium stock price $s^*(K)$ is given by

$$s^*(K) = \frac{MV^*(\delta^*(K), K)}{n_0 + n^*(K)}, \tag{15}$$

where n_0 is the number of original shares, and $n^*(K)$ is the number of additional shares issued to satisfy the capital standard.

Because $\delta^*(K)$ is the ownership share of insiders after the capital standard is satisfied, we have

$$\delta^*(K) = \frac{\delta_0 n_0}{n_0 + n^*(K)}. \tag{16}$$

Solving (16) for $n^*(K)$ and substituting it, along with the expression for equilibrium market value, $MV^*(\delta, K)$, into (15) yields

$$s^*(K) = \frac{\beta\delta^*(K)\gamma_{j^*(K)}(Q_{j^*(K)} + K)^2}{\delta_0 n_0} = \frac{a^*(K)^2}{\beta\delta_0 n_0}.$$

This expression for $s^*(K)$, together with Proposition 1, implies our next proposition.

PROPOSITION 2. *Issuing equity to satisfy an increased capital standard decreases the price $s^*(K)$ of the bank's stock; the decrease in price is larger for greater capital requirements. Insiders and initial shareholders unambiguously prefer the capital standard to be as low as possible.*

The result that the equity issued to comply with a capital standard reduces the price of the bank's stock is reminiscent of the Myers and Majluf (1984) result that external financing for firms is costly. However, there is an important distinction for the banking system. The costliness of external finance in Myers and Majluf applies solely to *voluntary* issues of securities, not to involuntary issues by a bank to satisfy a capital standard. In Myers and Majluf, voluntary stock issues are interpreted by the market as being overvalued at the prevailing market price, resulting in a stock price decline. However, stock issued to satisfy the capital standard would not be voluntary, and consequently would not be expected to depress the stock price for the reason Myers and Majluf emphasize. By contrast, we emphasize the agency problem of Jensen and Meckling (1976) in which insiders do not maximize on behalf of shareholders because they bear non-pecuniary costs of efficiency-enhancing activities or receive non-pecuniary benefits from perqui-

site consumption. In our model, issuing additional equity to satisfy the capital requirement worsens the effort-aversion moral hazard problem, resulting in a reduction in effort, which in turn works to reduce the bank's stock price.

Empirical evidence in Keeley (1989) and Cornett and Tehranian (1994) is consistent with the prediction of Proposition 2. Both studies found a bank stock price decline upon announcements of equity issues by relatively undercapitalized (by regulatory standards) banks. Both studies also documented a price decline at announcements of equity issues by banks that seemed to be well capitalized, a topic that we do not address in our analysis. While Keeley found that the price drop was greater for the undercapitalized banks, Cornett and Tehranian find that the price decline was greater for better capitalized banks. Both studies interpret the equity issues by the better capitalized banks a being ''voluntary,'' and they consider the observed price decline to be supportive of the Myers and Majluf (1984) model.[15] However, the price decline observed for what these studies view as capital-constrained banks is more puzzling. Both Cornett and Tehranian and Keeley consider these equity issues to be involuntary. If correct, the Myers and Majluf theory would not explain the observed stock price decline. A possible explanation is that the increased capitalization by the capital-deficient banks reduces the subsidy to their equityholders from underpriced deposit insurance, thereby resulting in an immediate stock price decline. Propositions 1 and 2 provide an alternative explanation: the substitution of equity for deposits reduces insiders' expected surplus, thereby reducing their effort and the bank's stock price. As explained earlier, this surplus in our model may originate from underpriced deposit insurance (the surplus not being passed on to borrowers), or from positive net present value lending, or both. One implication of our model, distinguishable from the explanation based on the reduction of the deposit insurance subsidy, is that an increase in the bank's non-interest expenses should be observed following the required recapitalization, if the insider agency problem that we describe is significant. No such increase would be expected based on the deposit insurance subsidy explanation. This is an implication that, to our knowledge, has not yet been tested.

While our analysis does not deal with equity issues by well capitalized banks—those interpreted as ''voluntary'' by Cornett and Tehranian and Keeley—it does offer a new explanation for the observed price decline when capital deficient banks issue equity. However, to further distinguish

[15] Our analysis could be extended, at least conceptually, to include voluntary equity issues as in extant signalling models, with a negative stock price response to equity announcements. The relative price decline between voluntary and involuntary issues, however, would depend on model parameters and the assumed size of the capital deficiency; the price declines associated with either type of issue could be greater.

TABLE II
INSIDER OWNERSHIP AND THE STOCK PRICE EFFECT OF SATISFYING A 3% CAPITAL STANDARD

δ_0	j^*	ϕ^*	Stock price decline
20%	1	77.9%	3.4%
19%	1	73.2%	4.4%
18%	1	68.6%	5.5%
17%	1	63.9%	6.7%
16%	1	59.2%	8.2%
15%	1	54.4%	10.0%
10%	1	27.9%	30.3%

Note. $K = 3\%$, $i = 7\%$, $\gamma_1 = 0.80$, $\gamma_2 = 0.90$, $R_1 = 33.9\%$, $R_2 = 30\%$, $\sigma = 0.92$, $\beta = 25$. The initial insider ownership is δ_0.

our explanation from that based on the deposit insurance subsidy, we relate the price effect in our model to inside ownership, a relation that is not evident in the alternative explanation.

The magnitude of the stock price reaction in our model depends on the insiders' fractional ownership δ_0. Although we have not been able to derive unambiguous comparative statics implications for the effect of δ_0 on the marginal impact $\partial s^*/\partial K$ of the capital standard on the stock price, numerical examples for plausible parameter values suggest that the smaller the share of insider ownership, the larger is the drop in stock price from satisfying a given capital standard. For example, Table II and III below show the drop in stock price for a bank that must issue enough equity to satisfy a 3% capital standard. The two tables differ only in the values of the effort-aversion parameter β; all other parameters are unchanged from Table I. Note that larger values of β reduce the marginal cost of effort. From Table II, when the insider's fraction δ_0 is 20%, satisfying the 3% capital standard results in a 3.4% drop in the bank's stock price. When the insider's fractional ownership is only 10%, the drop in stock price is slightly greater than 30%. However, when effort is less costly, as in Table III, the stock price decrease associated with meeting a 3% capital standard does not become significant until the initial insider ownership is down to about 10% where the price drop is 3.4%.

The intuition for why the price drop is greater for smaller insider holdings follows from the convexity of the insiders' effort-aversion function, $V(a)$, or cost of effort. Effort depends linearly on ownership fraction. Consider the two cases of high and low initial ownership, with their associated effort levels. If an amount K of securities is now issued, there is a decrease in insider ownership in both cases. Because effort depends linearly on owner-

TABLE III
INSIDER OWNERSHIP AND THE STOCK PRICE EFFECT OF SATISFYING A 3% CAPITAL STANDARD

δ_0	j^*	ϕ^*	Stock price decline
20%	1	100%	0
19%	1	100%	0
18%	1	100%	0
17%	1	100%	0
16%	1	100%	0
15%	1	100%	0
10%	1	77.9%	3.4%

Note. $K = 3\%$, $i = 7\%$, $\gamma_1 = 0.80$, $\gamma_2 = 0.90$, $R_1 = 33.9\%$, $R_2 = 30\%$, $\sigma = 0.92$, $\beta = 50$. The initial insider ownership is δ_0. Table III differs from Table II only in the disutility of effort parameter, β.

ship fraction, the percentage decrease in insider ownership is the same if effort decreases equally, but if effort is reduced by the same amount in the two cases, the *disutility* of effort would be reduced by more in the case of the higher initial ownership with its greater initial effort (because of the convexity of the function). Thus, effort would be less costly at the margin for the higher initial insider holdings case, and consequently, it would not be reduced as much. Therefore, the stock price will drop less when insiders have greater initial holdings. This intuition is straightforward as long as the same portfolio is chosen by insiders before and after the equity issue. The intuition and the analytics become less clear if the equity issue not only affects insider effort, but also their choice of portfolio. While we believe the general result is robust to changes in parameter values, we have not been able to demonstrate it analytically.

The results in Tables II and III are qualitatively consistent with the evidence in Cornett and Tehranian. They found that for stock issues by the undercapitalized banks, those that had a small fraction of managerial ownership (less than 5%) experienced a stock price decline that was significantly different from zero, while those with an intermediate level of managerial ownership (between 5 and 20%) also experienced a drop in stock price, but the drop was not statistically significant. Undercapitalized banks with a large fraction of managerial ownership (greater than 20%) experienced virtually no stock price reaction. Our numerical results depict the same inverse relation between insider ownership and extent of the stock price decline, although the specific magnitudes can differ somewhat depending on the parameters chosen. As we indicated above, this implication of our model, supported by the findings of Cornett and Tehranian, suggest that

the price effect associated with the capital-constrained banks may be better explained by our analysis than by that which emphasizes the reduction in the deposit insurance subsidy.

The next proposition shows that although the capital standard reduces the bank's share price, the equilibrium market value of equity $MV^*(\delta^*(K), K)$ may or may not decrease as the capital standard is increased.

PROPOSITION 3. *An increase in the capital standard may increase or decrease the market value* $\mathrm{MV}(\delta^*(K), K)$ *of the bank's equity. At* $K = 0$, *a marginal increase in K increases* (*decreases*) MV^* *as* $Q_1 > (<)\ 1/2\beta\gamma_1^2$.

Proof. See Appendix.

Proposition 3 indicates the market value of the bank's equity may increase or decrease depending on the bank's existing balance sheet and the extent to which effort declines as more stock is issued. At $K = 0$, a marginal increase in K will raise the intermediary's equity value the smaller the insider's marginal disutility of effort (larger β) and the larger the success probability γ_1 of the riskier portfolio.

The possible decline in the bank's equity value when it is required to issue stock shows that an impaired but solvent bank may be unable to satisfy a market-based capital requirement. An attempt to raise its regulatory capital could lead to the perverse result of an even lower market value for its equity. If the capital requirement is based on book values rather than market values, then the regulatory constraint could be satisfied, but if the market value of the bank's equity declines, the regulator's risk exposure increases. If the regulator's objective is to minimize its exposure, he/she would prefer that the standard not be enforced. If the regulator's objective is not to minimize risk exposure, but instead to maximize bank safety as measured by the probability $\phi^*(K) = \gamma_{j^*(K)}a^*(K)$ that the bank remains solvent, then it still may prefer not to enforce the capital standard. As shown in Table IV, even though increasing the standard may cause the firm to substitute safer loans for riskier ones, the effort aversion moral hazard may be sufficiently severe that the probability of solvency is maximized at $K = 0$.

These arguments raise the normative issue of how the regulator should treat a capital-impaired bank when requiring it to raise additional capital might reduce its equity value or its probability of solvency. Under these circumstances, can the regulator "control" insider behavior and consequently prevent reductions in equity value or in bank safety that would accompany the raising of capital? Interestingly, because of the perverse effect of capital standards in our model, it suggests an unexpected relationship between the stringency of capital requirements and the optimal monitoring by the regulator. It is generally thought that capital standards and

TABLE IV
CAPITAL STANDARDS AND THE BANK'S PROBABILITY OF SOLVENCY

K	$j^*(K)$	$a^*(K)$	$\delta^*(K)$	$\phi^*(K)$
0%	1	1.01	20.0%	80.6%
1%	1	1.00	19.0%	79.8%
2%	1	0.99	18.1%	78.9%
3%	1	0.97	17.3%	77.9%
4%	1	0.96	16.4%	76.7%
5%	1	0.94	15.6%	75.3%
6%	1	0.92	14.8%	73.7%
7%	1	0.90	13.9%	71.8%
8%	1	0.86	13.0%	69.2%
9%	2	0.83	12.1%	74.7%
10%	2	0.76	10.7%	68.0%

Note. $i = 7\%$, $\gamma_1 = 0.80$, $\gamma_2 = 0.90$, $R_1 = 33.9\%$, $R_2 = 30\%$, $\sigma = 0.92$, $\delta_0 = 20\%$, $\beta = 25$. K is the capital standard and $\phi^*(K)$ is the probability of solvency. Table IV differs from Table I only in the disutility of effort parameter, β.

regulatory monitoring are "substitutes"—i.e., raising capital requirements would promote desirable incentives toward risk-taking and bank safety, thereby reducing the need for monitoring.[16] However, our analysis suggests that if the regulator can control insider behavior through monitoring, any shift toward more stringent capital standards—e.g., greater risk sensitivity—would necessitate greater regulatory monitoring. Without such monitoring, the regulator's incentive might be to ignore the bank's impaired condition, and consequently, the *a priori* risk-mitigating effect of the regulation would be compromised. Alternatively, the regulator might attempt to shut down such banks, rather than enforcing the capital standard and facing increased exposure. However, the solvency of such a bank might require a long and costly legal battle to close it, thereby again providing an incentive for regulators to ignore the standard.

IV. CONCLUSIONS AND IMPLICATIONS

This paper shows that when the agency problem between insiders and outside investors, as described by Jensen and Meckling (1976), has economic significance, regulatory capital standards may not have their expected effect

[16] See Campbell *et al.* (1992), for example. This is also the rationale underlying the linking of capital levels to the extent of regulatory monitoring—banks with less capital are to be monitored more—that has been mandated by the 1991 FDICIA.

in promoting bank safety. This possibility arises because issuing equity may dilute the ownership of bank insiders sufficiently to reduce their incentives to expend effort on behalf of the bank's stockholders. This dilution effect can overcome the chief benefit of capital standards, to counteract the asset-substitution moral hazard problem.

Enforcing an accounting-based capital requirement on some capital-impaired but solvent banks may consequently have the perverse effect of reducing the market value of their equity. Likewise, such banks may be unable to satisfy a market-based capital standard. If the regulator is unable to commit to the *ex post* enforcement of such standards, then they may be ineffective in their intended purpose. If the regulator *can* commit, then they may have the *a priori* effect of motivating caution on the part of bank insiders, but their *ex post* enforcement may be socially undesirable.

While the model employs specific functional forms, the insight that there is a tension between the effect of capital standards on asset-substitution and effort-aversion moral hazards is a general one. The key point is that the effect of capital regulation on a bank's safety is not monotonic. Which of these two effects dominates depends on the level of capital and the bank's particular circumstances. To the extent that the efficacy of capital standards can be linked to observable characteristics such as bank size, this insight raises the possibility of different capital standards for different banks.

We have assumed that the bank satisfies the capital requirement by the sale of stock to outside investors. Because we show that equity sold to outsiders can be costly, one might wonder whether other approaches to meeting the capital standard would dominate the use of outside equity. Two alternatives are for the bank's insiders to provide the needed equity or for the bank to sell assets to comply with the higher capital standard. The provision of more equity by bank insiders could possibly be the choice of bank regulators. However, incomplete diversification by risk-averse insiders would generally make this option unpopular; unless the equity is undervalued, it seems unlikely that insiders would voluntarily provide additional equity in order to comply with the capital standard. However, even if the bank's insiders were *willing* to provide the necessary equity funds, wealth constraints may be an important factor in limiting this source of equity. Selling loans is another alternative. Since the minimum capital required is based on the size of the bank, the regulatory standard could be met by shrinking the bank's loan portfolio. However, this strategy may also be costly for the bank. If effort in our model is viewed, directly or indirectly, as ongoing monitoring of the bank's borrowers, and each particular bank has some advantage in monitoring their particular loans, then selling loans would result in a reduction in their value. If the bank that

sells loans is paid to continue monitoring them for the new owners, then there is an additional moral hazard problem created. If the new owner monitors, it will not likely be as efficient as the original bank, either because that bank knows the borrower better or because it has already set up a specific monitoring technology. Either way, *the loan's market value must reflect the reduced level or higher cost of monitoring*.[17] Of course, there is no reason *a priori* to expect that either the sale of loans or the issuance of equity would be inferior to the other; the observation that banks do indeed sometimes issue equity and other times sell loans to meet capital requirements suggests that both are feasible solutions, depending on circumstances.[18]

There are three empirical implications of our model that distinguish it from other theories of the impact of capital standards on banks. First, our model predicts that banks that are required to issue stock to satisfy a capital standard will experience a decline in their stock price. Second, the model suggests that the decline in stock price is greater the smaller the initial equity ownership of insiders, for a given capital deficiency. Cornett and Tehranian (1994) test both of these predictions and find strong empirical support for them. A third implication of our analysis, one that has not been tested, is that the undercapitalized bank's non-interest expense ratio (proxying for insiders' expense preference and perquisite consumption) should increase as the bank sells equity to outside investors to eliminate the capital deficiency.[19] All three of these empirical implications distinguish our analysis from that based solely on the reduction of the deposit insurance subsidy due to the increase in bank capital. In addition, one might think of testing Proposition 3 which implies that under certain conditions, enforcing a capital standard might actually lower the bank's market value. Unfortunately, finding such reductions in market value would be consistent with it, but not observing them would not reject it. If enforcing the capital requirement would indeed lower the bank's value, then it is plausible that the regulator would not enforce it, as explained above. In that case, the sample of recapitalized banks would systematically exclude those that would suffer value declines were they to recapitalize.

[17] Other reasons for not preferring loan sales might relate to adverse selection. Going outside our model, one can think of a "lemons" discount on all loans offered for sale if their quality along some dimension is not observable.

[18] This issue relates to the bank's decision on securitization of loans; see Greenbaum and Thakor (1987) for one analysis of the question. It would be useful to know the relative use of loan sales and securities issues to meet minimum capital standards. Cornett and Tehranian (1994) classify 235 issues of securities by banks during the period 1983–1989 as "mandatory," i.e., intended to meet minimum capital standards, and 238 issues as "voluntary." However, there is no reported evidence, to our knowledge, of the extent of loan sales during this period as intended to help satisfy capital requirements.

[19] The seminal price on expense-preference behavior in banking is Edwards (1977).

APPENDIX

Proof of Proposition 1.

Proof that $\delta^*(K)$ decreases in K. Because $\gamma_1[Q_1 + K] = \gamma_2[Q_2 + K]$ at $K = 1 - \sigma$, $\delta^*(K)$ is continuous in K. Thus, to prove the result that $\delta^*(K)$ decreases in K, it suffices to show that $d\delta^*(K)/dK < 0$ for $K < 1 - \sigma$ and for $K \geq 1 - \sigma$.

Differentiating either piece of (14) yields

$$\frac{d\delta^*}{dK} = -\delta_0\beta^{-1}\gamma_j^{-2}[Q_j + K]^{-3}\left[\delta_0^2 - \frac{4\delta_0 K}{\beta\gamma_j^2(Q_j + K)^2}\right]^{-1/2}[Q_j - K]. \quad \text{(A.1)}$$

Expression (A.1) will be negative if and only if $Q_j - K > 0$. We now show that this inequality is implied by earlier assumptions.

Because a solution to (13) exist, it follows that

$$\delta_0\beta\gamma_j^2(Q_j + K)^2 > 4K. \quad \text{(A.2)}$$

Moreover, the assumption that the bank's default risk is positive for all (δ, K) implies $\gamma_j a^*(\delta_0, K) = \delta_0\beta\gamma_j^2(Q_j + K) < 1$. Thus, the following chain of inequalities must hold.

$$Q_j + K > \delta_0\beta\gamma_j^2(Q_j + K)^2 \geq 4K > 2K, \quad \text{(A.3)}$$

which implies

$$Q_j > K.$$

Q.E.D.

Proof that $a^*(K)$ decreases in K. $a^*(K)$ is also continuous in K, so again to prove the result, it suffices to show $da^*(K)/dK < 0$ for $K < 1 - \sigma$ and $K \geq 1 - \sigma$.

The equilibrium conditions for $\delta^*(K)$ and $a^*(K)$ can be written as a system

$$a^* = \delta^*\beta\gamma_j(Q_j + K), \qquad j = 1, 2. \quad \text{(A.5)}$$

$$K = (\delta_0 - \delta^*)a^*\gamma_j(Q_j + K), \qquad j = 1, 2. \quad \text{(A.6)}$$

Totally differentiating (A.5) and (A.6) with respect to K yields

$$\begin{bmatrix} 1 & -\beta\gamma_j(Q_j+K) \\ -(\delta_0-\delta^*)\gamma_j(Q_j+K) & a^*\gamma_j[Q_j+K] \end{bmatrix} \begin{bmatrix} \dfrac{da^*}{dK} \\ \dfrac{d\delta^*}{dK} \end{bmatrix} = \begin{bmatrix} \delta^*\beta\gamma_j \\ (\delta_0-\delta^*)a^*\gamma_j - 1 \end{bmatrix}.$$

Straightforward algebra establishes

$$\frac{da^*(K)}{dK} = \frac{\delta_0\gamma_j a^*(K) - 1}{(2\delta^* - \gamma_0)\gamma_j(Q_j+K)} < 0, \tag{A.7}$$

where the inequality follows because (i) by (14), $\delta^* > \delta_0/2$; (ii) $a^* < 1/\gamma_j$; and (iii) $\delta_0 \leq 1$. Q.E.D.

Proof of Proposition 3. Let $MV^*(K) \equiv MV^*(\delta^*(K), K)$, and note that

$$MV^*(K) = \beta\delta^*(K)\gamma_{j^*(K)}^2(Q_{j^*(K)} + K)^2.$$

Thus,

$$\frac{dMV^*(K)}{dK} = \beta\frac{d\delta^*(K)}{dK}\gamma_j^2(Q_j+K)^2 + 2\beta\delta^*(K)\gamma_j(Q_j+K).$$

Now, evaluating (A.1) at $K = 0$ yields

$$\frac{d\delta^*(0)}{dK} = -\frac{\delta_0}{\beta\gamma_1^2 Q_1^2}.$$

Thus,

$$\frac{dMV^*(0)}{dK} = \delta_0\beta\gamma_1^2 Q_1\left[2 - \frac{1}{\beta\gamma_1^2 Q_1}\right].$$

The inequality in the proposition then follows immediately. Q.E.D.

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