Agency incentives and reputational distortions: a comparison of the effectiveness of Value-at-Risk and Pre-commitment in regulating market risk

Arupratan Daripa*

and

Simone Varotto**

* Birkbeck College, Department of Economics, 7-15, Gresse Street, London, W1P 2LL. E-mail: adaripa@econ.bbk.ac.uk

** Bank of England, Threadneedle Street, London, EC2R 8AH. E-mail: s.varotto@bankofengland.co.uk

The views expressed are those of the authors and do not necessarily reflect those of the Bank of England. The content of the paper as well as the exposition have benefited enormously from regular interactions with Patricia Jackson and Ian Michael. We have also benefited from comments on an earlier version by William Perraudin and two referees for the Bank of England Working Paper series. We are grateful to all of them.

Issued by the Bank of England, Threadneedle Street, London, EC2R 8AH to which requests for individual copies should be addressed: envelopes should be marked for the attention of Publications Group. (Telephone: 0171-601 4030).

Bank of England 1997

ISSN 0142-6753

Contents

Abstract

In regulating the market risk exposure of banks, the approach taken to date is to use a 'hard-link' regime that sets a relation between exposure and capital requirement exogenously. A new 'pre-commitment' approach (PCA) proposes the use of a 'soft-link'. Such a link is not externally imposed, but arises endogenously. Such an approach is of much greater economic appeal, as it is incentive-based and so less prescriptive.

But, we argue that there is a trade-off. The use of incentives by the new approach implies that a whole host of strategic interactions in the bank are relevant in evaluating its effectiveness. This aspect of a soft-link regulation such as PCA seems to have received little attention. We attempt to clarify the precise nature of the trade-off by analysing two potential sources of distortion: agency and reputational.

In the context of a simple principal-agent model, we study the incentives generated by PCA on managerial risk-taking when the level of risk is not directly observable by the bank owner. We identify contexts in which a distortion might arise. Second, we study the effect of reputational concerns under public disclosure of a breach. We show that this might lead to a perverse pattern in the relative size of the trading activities compared with the size of bank as a whole. A hard-link approach avoids such distortions.

The results form a first step towards modifying PCA to construct optimal incentive-compatible regulatory schemes. We discuss informally how PCA might be modified to rectify the distortions identified here.

1 Introduction

1.1 The background

Traditionally, regulation of banks has focused on the risk carried by bank loans. Loans are typically non-traded assets. In recent years, another component of bank assets has become increasingly important: assets actively traded in the financial markets.(1) These assets form the 'trading book' of a bank, as distinct from the 'banking book' that includes the non-traded assets such as loans. Though for most large banks the trading book is still relatively small compared with the banking book, its rising importance makes market risk of banks an important regulatory concern. Further, there is now a move towards securitising even the traditional banking book assets, which adds to the importance of regulating the risk exposure of traded assets.

In January 1996, the European Union adopted rules to regulate the market risk exposure of banks, setting risk-based capital requirements for the trading books of banks and securities houses. The approach taken is to use a 'hard-link' regime that sets a relation between exposure and capital requirement exogenously. The adopted requirements, known as the standardised approach, laid down rules for calculating the capital requirement for each separate risk category (ie UK equities, US equities, UK interest rate risk and so on). These are added together to give the overall requirement. A weakness in this method is that it does not take into account the diversification benefits of holding different risks in the same portfolio, and so yields an excessive capital requirement. One way to correct for this is to use the value-at-risk (VaR) models that some banks have developed to measure overall portfolio risk. The Basle Supervisors' Committee has now agreed to offer an alternative regime, with capital requirements based on such internal VaR models.

Though the way of measuring risk employed by the two regimes is different, in both approaches the regulator lays down the parameters for the calculation of the capital requirement for a given exposure. So both embody a hard link.

Under VaR, the capital requirement for a particular portfolio is calculated using the internal risk management models of the banks.(2) For any portfolio, the

(1)For example, securities and foreign exchange or commodities positions that are held for short-term trading purposes.

(2)The value-at-risk of a given portfolio can be calculated via parametric or non-parametric aim is to estimate a level of potential loss over a particular time period which would only be exceeded with a given probability. The probability and the period are both laid down by the regulator. Basle has set these at 1% and 10 days. The capital requirement is based on this potential loss. Under Basle there is an additional multiplier of 3 which is applied to the results of the VaR model to convert it into a capital requirement.

But using VaR comes at a price. The regulator must ensure that the internal model used to calculate risk is accurate. Otherwise, banks might misrepresent their risk exposure. But, backtesting to check the accuracy of an internal VaR model is difficult.(3) This motivated economists Kupiec and O'Brien (1995b) of the Federal Reserve Board to put forward a new 'pre-commitment' approach that proposes the use of a 'soft-link'. Such a link is not externally imposed, but arises endogenously, and is induced by the threat of penalties whenever trading losses exceed a level pre-specified by the bank (known as the pre-commitment capital).

Specifically, under PCA, banks are asked to choose a level of capital to back their trading books for a given period of time (say, a quarter). If the cumulative losses of the trading book exceed the chosen cover at any time during the period, the banks are penalised, possibly by fines. The chosen capital is thus a 'pre-commitment' level, beyond which penalties are imposed. The task of the regulator is to choose an appropriate schedule of penalty to induce a desirable choice of cover for each level of risk. The banks would then position themselves in terms of risk and capital choices for the trading book. The idea is attractive because it does not require the regulator to estimate the level of trading book risk of any particular bank or to approve the firm's model, and promotes more 'hands off' regulation.

1.2 Hard links and soft links: a potential trade-off

PCA not only circumvents the problems of backtesting, but it gives the banks much greater freedom to choose the portfolios they wish to carry backed by a given level of capital. Since the trading desks of banks are likely to be more adept

(historical simulation) models. Parametric approaches are based on the assumption that the distribution of future returns belongs to a given parametric class. The historical simulation approach produces a time series of profits and losses that would have occurred if the portfolio had been held over a specified estimation period.

(3)See Kupiec (1995), Jackson *et al* (1996).

at estimating risks of various trades, it seems inefficient to impose hard links. Indeed, incentive-based regulation such as PCA is inherently more attractive to economists.

Though these advantages of PCA have been discussed in the literature, another aspect of this soft-link approach seems to have received little attention. The flexibility of a soft-link approach such as PCA derives from the fact that it is not directly prescriptive, but creates incentives through the use of penalties. In more general terms, PCA tries to solve what is known as a 'mechanism design' problem. It attempts to specify a mechanism (in this case a set of rules that the banks take into account in choosing portfolio risk and committed capital) that would make it incentive-compatible for the banks to choose the socially desirable risk profile. The success of such a programme depends on how well the regulator anticipates the strategic opportunities that a mechanism might create.

In other words, while soft-link approaches are flexible and not subject to measurement problems, they create a host of strategic issues. To build a successful soft-link regulatory policy, one must recognise all possible conflicts of interest that might arise subsequently, and provide incentives to align them with the objectives of the regulator.

The first step towards building an optimal soft-link policy is to analyse the incentive effects of PCA in a detailed model of the conflicts of interest within the bank. This is the objective of the present paper. We have attempted to make precise the content of the above claim that there is a trade-off in switching to PCA from a hard-link approach. We find that there may be some adverse incentive effects from the adoption of the PCA approach.

Optimal incentive-based regulation would presumably attempt to retain the essential features of a soft-link approach such as PCA and combine them with certain properties of a hard-link approach that circumvent certain incentive problems. We discuss some of these issues in the conclusion. But, detailed analysis of more general soft-link approaches is outside the scope of the present paper. This remains an area of our active research interest.

In this paper we identify two potential sources of distortion, and analyse their effects under PCA. We describe the problems below.

1.3 Separation of ownership and control in large banks: the agency problem

The Kupiec and O'Brien papers are set in a world where the regulator interacts with the bank. This leaves aside the issue of the effects of the incentive structure within the bank. But, as in most large corporations, an integral feature of large modern banks is the separation of owners from day-to-day decision-making. The ownership is diffuse - there are numerous small shareholders who have little impact on most decisions. Even relatively large shareholders would in general have hardly any impact on day-to-day risk taking. It is the incentives of, say, the traders of the bank that determine what specific strategies they might adopt on a particular day. Thus it is important to see to what extent the owners can control their actions.

As a device of control, the owners write contracts with managers, and then the managers take most of the trading decisions. Moreover, managers cannot usually be fined (ie paid negative salaries) in the event of losses.(4) So decisions about trading book risk are taken by managers with limited liability, while the owners have to suffer the losses(5) in the trading book, and pay the penalty in the case of a breach under PCA.

This implies that to study the effectiveness of the incentive structure generated by PCA, it is no longer sufficient to consider the bank as a single entity whose actions are directly influenced by the regulatory incentives. Without explicitly modelling the agency structure and the nature of optimal incentive contracts in the bank, it is difficult to gauge the effect of regulatory policies on large banks.

In other words, to evaluate a soft-link regulatory scheme, the appropriate question to ask relates to the effect of the regime on the incentive structure in the bank. An analysis of the response would tell us which regulatory objectives are filtered through, and what aspects need further modification. In this paper, we aim to provide such an analysis.

(4) Even when fired, most managers are usually able to find other jobs.

(5) Deposit insurance implies a lower limit, but if the trading book is relatively small compared with the banking book, this limit would hardly ever be reached. See section 3.2 for a discussion. In any case, limited liability only adds to the list of trouble spots.

1.4 Disclosure of breaches: reputational concerns

The concern about agency incentives is a general one. To be effective, any regulatory scheme must generate the right incentives throughout the delegated decision-making structure within a bank. But a second set of incentive issues applies specifically to a feature of PCA.

Banks, and especially the large banks, are concerned not just about current earnings, but also about future prospects. So it is important for them to have an impeccable reputation. Maintaining a position of prestige is also often an end in itself.

Under PCA, losses exceeding commitment capital are penalised. If a policy of public disclosure of breaches is adopted, it would give rise to concerns by the banks about the effect of breaches on their reputation. Note that this concern is not unrelated to the agency issue discussed above. The manager might not be too concerned about the reputational effects of breaches - but the price of bank shares might indeed have a lot to do with such effects.

So in analysing the incentives generated by PCA, reputational issues need to be included. Indeed, our analysis points out the main effects of reputational concerns, and the distortions it might produce.

2 A summary of the results

We investigate the above issues in a simple principal-agent framework. We obtain the following results.

2.1 Agency incentives under a hard link approach

First, we show that conflicts of interest within the bank have no implication for hard-link policies. The regulator sets a capital requirement for each level of risk. At any time the risk cannot exceed the level consistent with the given capital. It is easy to see that this is true irrespective of the incentive structure in the bank.

So, while a hard-link regime such as VaR is subject to measurement problems that have been highlighted in the literature, and is economically unattractive in some respects, the presence of a hard link does manage to sort out the potential strategic complications. A hard link works because it sets an exogenous legal requirement that cannot be breached.[6]

This is not to say that we therefore recommend a hard-link regime. But this property of strict compliance generated by a hard link is worth noting because one might be able to design an incentive-based system that is flexible and at the same time builds in some hard links to avoid strategic or reputation-based distortions.

2.2 Agency incentives under PCA

The structure of agency would be a concern under any soft-link regime, but the precise effects would differ across different soft-link policies. In this paper we analyse the effects of agency on the outcomes generated by PCA.

Under PCA, the capital chosen does not constrain the manager's choice of riskiness. In the absence of *a priori* restrictions on the choice of risk, the outcome depends on the manager's preferences. We show that if managers care only about monetary compensation, the principal (ie the bank owner/shareholders) could design contracts which would generate incentives for the manger to behave consistently with the principal's objectives and in turn the regulator could therefore achieve the right capital levels. But the manager might also be interested in attaining star status by generating large positive returns and so might undertake high-risk strategies (limited managerial liability implies that only the upside matters). We show that in this case tighter controls on the manager can be achieved only at the cost of the principal's own profit. This leads the principal to choose a level of control that is not too tight, resulting in a non-trivial probability of very risky investments and large losses in relation to the amount of capital committed.

2.3 Loss aversion under reputational concerns and distortions in the choice of trading book size

Reputational effects of the disclosure of a breach could be quite perverse. For large banks, trading books are small relative to banking books. For such banks,

[6] We assume implicitly that the legal system generates incentives enough to ensure compliance irrespective of individual preferences. This is, of course, a standard assumption in many economic studies.

there is an important asymmetry in the effects of trading book gains and losses above the committed capital.

With a relatively small trading book, any gains are on average small relative to the earnings of the bank as a whole. But, the damage to reputation from a breach implies large costs for the entire bank: for example, it could affect funding costs for the whole bank. So gains are in proportion to the trading book size, but losses caused by the damage to reputation are in proportion to the total size of the bank (trading book plus banking book).

This asymmetry implies that banks may become 'loss averse'. Since a loss is much more important than a gain of the same size, a reduction in the trading book size (which would reduce losses and gains symmetrically) increases expected payoffs. This implies that banks with relatively large banking books would tend to minimize the size of their trading books. Further, such banks would attempt to control the trading book risks tightly - and thus (applying the second result above) sacrifice trading book return. Finally, such banks would also tend to over-commit capital.

So the banks that are the best candidates (from the social point of view) for carrying larger trading books and undertaking higher trading book risk are precisely the banks that would carry smaller trading books and undertake very low trading book risk.

2.4 Modifying PCA: optimal regulation

Finally, we informally discuss possibilities for constructing other soft-link approaches that modify PCA, retaining its flexibility and at the same time mitigating the above problems.

Reputational distortions are a result of the piecemeal approach. To eliminate such intra-bank allocational distortions induced by reputational concerns, we need to have the same regime, whatever that is, for the whole bank. Second, we argue that a solution to the agency distortions might be achieved by manipulating the structure of incentives in a repeated game by hardening the soft link on penalty paths.

Formal construction of an incentive-compatible optimal mechanism is beyond the scope of this paper, but it is an area of our active research interest.

3 The model

In this paper we construct a framework to describe the interactions between regulators and banks. The problem is compounded by the fact that economic agents with different interests and objectives interact within the same regulated institution.

In our model there are three economic agents - the regulator, the principal (bank ownership) and the manager. The preferences of the three are as follows.

1. The regulator seeks to reduce the probability of large losses within an acceptable margin.

2. The principal is risk neutral, and maximizes expected profit.

3. The manager is risk neutral and subject to limited liability. The manager could be one of many types. Some managers care more about the monetary payoff while others care more about their careers. The latter type of managers adopt strategies that generate high positive returns for the firm. Since high-risk strategies attach a higher probability to the tails (the lower tail is irrelevant given limited liability), career concerns imply a preference for high-risk strategies.

   The manager knows his own type, but the principal cannot observe the type of the manager.

   More formally, the types are described as follows. We denote the type of the manager by a random variable q (remember that the manager's type is a random variable from the principal's point of view). The utility function of a manager of type q puts a weight q on portfolio risk and a weight $(1-q)$ on the monetary payoff. Here, q is a random variable with a uniform distribution on $[0,1]$.

The bank needs to choose both a trading portfolio and a regulatory capital. The riskiness of the trading portfolio is chosen by the manager and is not directly contractable. The capital level is observable and verifiable irrespective of who chooses it. Thus in terms of the results here it is immaterial who chooses it. We therefore assume for simplicity that the principal chooses the capital level.

The structure of the moves is as follows. The regulator moves first, and sets the policy regime. The principal moves second, setting the terms of the contract with the manager, and setting a capital level. Finally, the manager chooses a portfolio given the incentive structure implicit in the contract.

3.1 The opportunity set

The regulator aims to make the banks choose the socially desirable portfolio volatility σ associated with the capital set aside. Let $\widetilde{V}$ and V_0 denote the change in the value and the current value of the trading book respectively. We assume that the return on the trading book is proportional to the initial investment in the trading book (V_0), and has a normal distribution. Thus:

$$\widetilde{V} \sim N(\mu V_0, \sigma V_0).$$

Our model of the differing objectives of the regulator, the bank owners, and the bank manager builds on the following assumption about the opportunity set (the set of possible trading book investment portfolios from which the manager chooses).

Assumption 0a In the absence of any regulatory constraint, the preferred portfolio of the bank owner involves high risk.

Remark: Indeed, without this assumption there would hardly be any need for regulation. Also, an equilibrium choice of high risk for the whole bank can be derived formally in a model with deposit insurance (thus limiting the downside and creating a "virtual" risk-loving preference). Such issues are tangential to the present analysis, which focuses on internal incentive structures. It would not be difficult to rewrite the model to include deposit insurance, but that would neither change any result nor add to the insights of the paper. So we simply assume, as stated above, that regulation is not vacuous.

We also need the opportunity set to satisfy a regularity property which states that portfolios with risk close to zero should earn a return close to the riskless return:

Assumption 0b The opportunity set satisfies the following (right) continuity property - as the riskiness of portfolios decrease to zero from above, the associated returns decrease to the riskless rate.

Given the preferences above, assumption 0 (a and b) is all we need to derive our results. Indeed, with normally distributed returns, a sufficient condition for the assumption 0 is that portfolios with higher variance also yield a higher mean return. Such a relation could either be a basic property of the return structure - deriving from an efficient portfolio frontier, or it might be that given limited liability (through deposit insurance), the conditional mean (conditional on the lower truncation of the distribution of returns) increases with variance. To keep the algebra uncluttered, we make the simplifying assumption that mean and variance are linked by a linear relationship (this is a special case of assumption 0).

ASSUMPTION 1 $\mu = \beta\sigma$, where β is a strictly positive constant.

Remark: We emphasize once again that assumption 1 should be treated only as an "as if" device. The assumption of a precise functional form serves to facilitate derivations. All results hold whenever the more general assumption 0 is satisfied(7).

Finally, to keep all solutions finite, we assume that there is a highest possible portfolio variance of $\overline{\sigma}^2$, which is finite.

3.2 Trading losses and the extent of liability

Our analysis of agency problems arising inside the bank is most pertinent for large banks where the ownership is diffuse and the separation of ownership and control is a well established fact. For such large banks the size of regulatory capital for the banking book is usually large compared with the trading book capital. Thus a loss arising in the trading book could erode much more capital than initially set aside to back the trading activity. As far as the optimal trading policy is concerned the principal's liability can be considered to be unlimited (8).

The regulatory aim, then, is to limit the losses. This is purely a modeling choice - one could translate the large losses into an increase in default probabilities

(7)See appendix B for a discussion of this claim.

(8)This assumption might seem to be in conflict with the statement above that deposit insurance can be modeled easily without affecting the results. However, the point is that the assumption about the extent of liability has nothing to do with the agency-induced tradeoffs facing the bank. The extent of liability has no implication for the effectiveness of hard-link regimes, while under limited liability PCA is subject to the additional problem of non-payment of fines in case of losses in excess of regulatory capital. Our assumption of unlimited liability simply abstracts away from such problems with PCA to focus only on the agency-induced issues.

by adding the probability of banking book losses in excess of the total capital. That would not change the analysis here, but add to the notation.

3.3 Cost of regulatory capital

The capital level is observable and verifiable irrespective of who chooses it. Thus in terms of the results here it is immaterial who chooses it. We therefore assume for simplicity that the principal chooses the capital level.

Regulatory capital is usually costly for the bank. This is not surprising. One possible explanation is as follows. Suppose the appropriateness of the assumption that investors are risk neutral derives from the fact that in equilibrium, risk averse individuals can diversify risk. Raising additional capital in order to adopt higher risk trading strategies might create imbalances in the investors' portfolios.

As for raising capital from new investors - there is a very large literature in economics exploring capital market imperfections, credit constraints and other distortions facing firms who attempt to raise external capital. For example, adverse selection can create a wedge between the value of internal and external finance[(9)].

Indeed, in the absence of any cost for raising additional capital, optimal regulation is a trivial exercise and does not put any constraints on bank risk-taking. Under any regulatory scheme, the bank could always take arbitrary risks by raising an arbitrarily high capital. In fact, the statement that the standardized approach "overestimates" the level of capital would have no content if equity capital can be raised costlessly. The overestimation is a concern only if there is a more desirable estimate - and a correct estimate is more valuable only when there is a cost of regulatory capital.

We denote the cost of regulatory capital by $C(K)$. We assume that $C' > 0$, and $C'' > 0$. Thus the cost of capital is an increasing, strictly convex function.

[(9)]For example, suppose the investors do not know the riskiness of the firm they invest in, and therefore a firm must pay a premium to borrow funds. Under certain conditions, the premium per unit increases with the amount borrowed. See, for example, ?) for a model of and a discussion of the literature on such distortions in the context of a firm raising capital from a bank. Exactly the same analysis applies when the firm is a bank and it raises capital from outside investors.

4 Agency incentives under hard-link approaches

In what follows, we use the terms hard-link regulation and VaR interchangeably. Under a hard-link regime, the regulator chooses a function that specifies a level of regulatory capital for each level of risk of the bank portfolio. Here the risk is parameterized by the portfolio standard deviation σ. Thus the regulator chooses K as a function of σ. Let $K_{reg}(\cdot)$ denote this function. We assume that $K'_{\mathrm{reg}}(\cdot) > 0$, $K''_{\mathrm{reg}}(\cdot) \geq 0$.

4.1 The bank's problem

For any given $K_{reg}(\cdot)$, we first analyze the outcome of the internal optimization of the bank. Recall that the principal specifies the level of capital (the manager does not contribute to the capital of the bank) and writes a contract with the manager, who chooses a portfolio.

Limited liability implies that the managerial pay must be non-negative. Note that if the principal chooses any non-negative increasing payoff function (increasing with the value of the trading book, $\widetilde{V}$), for any choice of σ, the manager would choose the highest associated μ. In other words, so long as the payoff function is increasing and non-negative, the limited liability constraint is satisfied, and also the manager's portfolio choice belongs to the efficient frontier.

Now, given any regulatory function $K_{reg}(\cdot)$, any given any choice of k^* by the principal, the manager is restricted to choose $\sigma \leq \sigma^*$ such that

$$k^* = K_{reg}(\sigma^*). \tag{4.1}$$

For any increasing payoff function, the manager will in fact choose $\sigma = \sigma^*$. Thus equation (4.1) is the solution to the problem of the manager under VaR. Note that from equation (4.1), there is a one-to-one correspondence between the principal's choice of k and the manager's choice of σ. By choosing a capital equal to $K_{\mathrm{reg}}(\sigma^*)$, and any positive increasing payoff function, the principal can force the manager to choose $\sigma = \sigma^*$. Thus under VaR, the principal can fully control the manager's choice of σ by the appropriate choice of k - agency problems do not affect the outcome. The following result summarizes the above discussion.

Proposition 1 *Under VaR, the information asymmetry between the manager and the principal does not lead to any loss of control by the principal in choosing σ. The principal has a forcing contract.*

Thus in a VaR regime the principal's choice describes the problem of the bank completely. The principal's gross payoff is given by $\pi_p = \tilde{V} - C(k)$, and the principal's objective is to maximize $E\pi_p = \mu V_0 - C(k)$ subject to the constraint of managerial incentives. Given that $\mu = \beta\sigma$, and the solution to the manager's problem (given by equation (4.1)), we have:

$$E\pi_p = \beta\sigma V_0 - C(K_{reg}(\sigma)) \tag{4.2}$$

From proposition 1 above, we know that in solving the principal's problem we can simply solve for the optimal σ (as any such σ can be enforced by the right choice of k). From equation (4.2) above, the first order condition for the optimal σ for the principal is given by σ^* such that

$$V_0 = C'(K_{reg}(\sigma^*))K'_{\text{reg}}(\sigma^*),$$

where the left hand side is the marginal benefit from increasing σ, and the right hand side is the marginal cost of capital multiplied by marginal capital requirement. Thus the right hand side is the cost to the principal arising from a marginal increase in σ[(10)].

4.2 Regulatory control under a hard-link regime

The objective of the regulator is to specify the maximum probability of making a loss in excess of the capital set aside to back the trading book. If a bank has capital K and the probability that returns fall below $-K$ is set equal to p, the regulatory constraint is given by: $Prob(\text{portfolio returns} < -K) \leq p$, which can be rewritten as

$$Prob(V_0 + \tilde{V} < V_L) = p, \tag{4.1}$$

where the value-at-risk is $K_{\text{VaR}} = V_0 - V_L$.

Now, we know that the manager's optimum is given by equation (4.1). Using equation (4.1), this can be written as:

$$\sigma = \frac{K}{V_0(\Phi^{-1}(1-p) - \beta)}.$$

[(10)] It can be easily checked that given our assumption about the shapes of $K_{reg}(\cdot)$ and $C(\cdot)$, the second order condition is satisfied.

See section **A**.1 in the appendix for details of derivation. Thus the regulatory function is given by

$$K_{\text{reg}}(\sigma) = \sigma V_0(\Phi^{-1}(1-p) - \beta). \tag{4.2}$$

As we show in section **A**.1 of the appendix, under this rule, a loss of $V_0 - V_L$ would be exceeded with probability p. Thus this function implements the required regulatory objective.

5 Agency incentives under the pre-commitment approach (PCA)

Under the PCA, the regulator specifies a fine as a function of any loss over and above the committed capital. Suppose the committed capital is given by K_c. Then the fine function is denoted by $f(-K_c - \tilde{V})$. For simplicity, we will assume that the fine is a linear function of the breach:

$$f(-K_c - \tilde{V}) = \begin{cases} -d(K_c + \tilde{V}) & \text{if } \tilde{V} < -K_c \\ 0 & \text{otherwise.} \end{cases}$$

This assumption is purely simplifying, and all the results would hold for any other increasing fine function.

In this section we show that the agency problem inside the bank is no longer irrelevant to the choice of σ in situations where the manager cares not just about the monetary payoff but also about own reputation (i.e. the manager puts positive weight on the variance for the trading-book portfolio - higher variance strategies increases the chance of higher returns).

First, note that the agency problem would not arise here if the standard deviation σ is observable and contractable - in that case the principal could specify the σ to be chosen by the manager. Then the problem would be exactly the same as under a hard-link approach and thus the resulting choice of riskiness would be the same.

Now suppose σ is not observable. This introduces an agency problem.

Recall from the specification of the model that there are managers of various types. The utility function of a manager of type q puts a weight $q \in [0,1]$ on the standard-deviation of the bank portfolio and a weight $(1-q)$ on the monetary payoff. Let $g_m(\tilde{V})$ denote the payoff function of the manager. The utility function of the manager is given by

$$U_m = (1 - q)\, g_m(\widetilde{V}) + q\sigma \tag{5.1}$$

Recall that q is a random variable with a uniform distribution on $[0, 1]$. Further, limited liability implies that $g_m(\cdot) \geq 0$.

First, we consider the special case where the manager only cares about his monetary payoff.

5.1 Agency incentives under PCA: the special case of $q = 0$

If $q = 0$, the manager only cares about monetary payoff. We show below that in this case, the principal can design a contract to enforce any σ. Thus asymmetry of information (choice of σ by the manager not observable) makes no difference to the control by the principal, and thus, in turn, to regulatory control.

Consider a payoff function $\hat{g}_m(\widetilde{V})$ given by the following:

$$\hat{g}_m(\widetilde{V}) = \begin{cases} W & \text{for } \widetilde{V} \geq \dfrac{1}{2r} \\ \frac{2}{3}(1 + r\widetilde{V})W & \text{for } -\dfrac{1}{r} < \widetilde{V} < \dfrac{1}{2r} \\ 0 & \text{otherwise} \end{cases}$$

where W is the top salary level. In the above function the scale factor and the origin have been chosen for convenience. Note that in keeping with limited liability of the manager, the payoff function is always greater than or equal to zero. Figure 1 shows a picture of this. The parameter r controls the induced level of prudence of the manager when selecting the optimal investment strategy.

Section **A**.2 in the appendix shows that the expected payment of the manager is a function of r and σ only through the term $r\sigma$.

Let $\theta \equiv r\sigma$. Then,

$$E\hat{g}_m(\widetilde{V}) = t(\theta, \beta). \tag{5.2}$$

Differentiating with respect to θ and solving the first order condition for a maximum, we get θ^* such that $t_1(\theta^*, \beta) = 0$, where the subscript 1 denotes derivative with respect to the first argument. Thus θ^* is some constant T_0, and

$$\sigma^* = \frac{T_0}{r}.$$

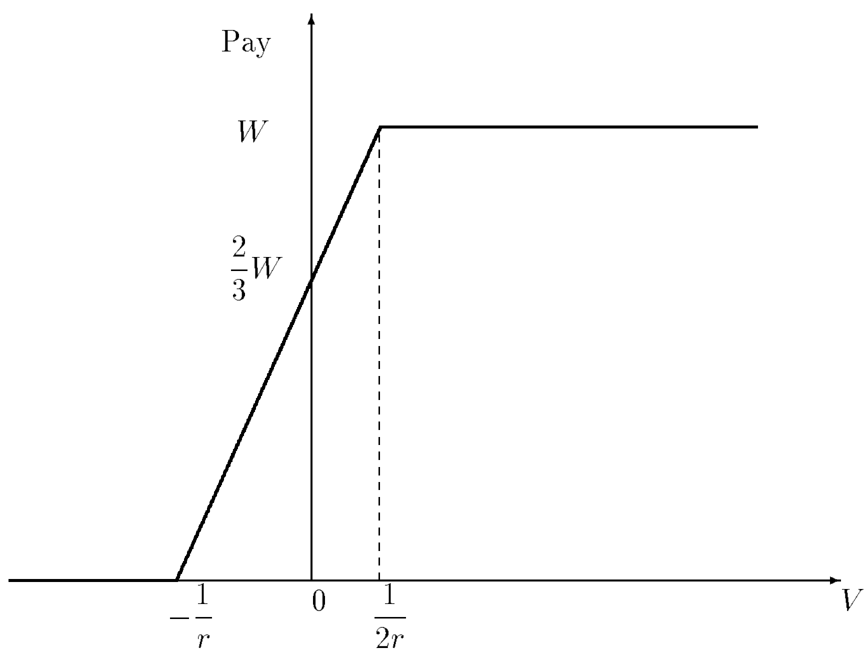

Figure 1: The manager's payoff function

Thus by varying r, any choice of σ^* can be enforced.

If the principal can control the manager fully, it is easy to see that a soft-link approach generates no further incentive problems, and the regulatory problem once again becomes (virtually) a problem of interaction between the regulator and the bank as a whole. The reason, briefly, is as follows.

The expected payoff of the principal (section **A**.3 derives a formal expression for the payoff) depends on two factors. First, the higher the committed capital, the higher the cost of capital, but lower the expected fine payment. Second, the expected fine payment depends also the managerial choice of σ (which in turn depends on r). An increase in σ implies a higher expected fine, but it also implies a higher expected return. These tradeoffs decide the optimal choice of K_c and r (which controls σ). The principal maximizes his expected payoff with respect to K_c and σ, and enforces the optimum σ by choosing r such that $T_0/r = \sigma^*$.

Since the principal is affected by the fine, and a greater fine makes the principal more conservative in terms of his choice of σ, the regulator can enforce any desired level of σ by choosing the appropriate fine function. In this case, any outcome that can be obtained under a hard-link regime can also be achieved under PCA. In fact, all the usual advantages of PCA apply - and there is no downside.

5.2 Agency incentives under PCA: the general case

When $q > 0$, the manager cares not just about monetary payoff, but also about high-risk strategies in order to generate high positive returns for the bank.

Consider any payoff function $g_m(\widetilde{V}) \geq 0$, where the inequality reflects the limited liability constraint. The manager's utility function is now given by equation (5.1). The first order condition for expected utility maximization is

$$\frac{\partial E g_m(\widetilde{V})}{\partial \sigma} = -\left(\frac{q}{1-q}\right) V_0. \tag{5.3}$$

As $q \to 1$, the right hand side approaches $-\infty$. Now, if the payoff function is such that the left hand side is bounded below, there exists a $q^* \in (0,1)$ such that for $q > q^*$, the first order condition cannot be satisfied in the interior[(11)]. - and thus the solution would be at $\overline{\sigma}$. Thus all types in $(q^*, 1]$ would adopt $\overline{\sigma}$. This

[(11)] If L_* denotes the lower bound of the left hand side, q^* is given by $L_*/(L_* - V_0)$. Note that $L_* < 0$ and $V_0 > 0$, so that $q^* \in (0,1)$.

implies that in order to keep control of the manager, the principal would like to choose a payoff function such that it could set $\frac{\partial E g_m(\tilde{V})}{\partial \sigma}$ unboundedly low at some $\sigma^* > 0$. Then all types would choose some $\sigma \in (0, \sigma^*)$.

Note that control is parametrized by q^*. Tighter control implies a higher q^*. An optimal payoff function would therefore attempt to maximize control. However, as the following result shows, in attempting to tighten control, the principal faces a tradeoff.

Proposition 2 *For any optimal payoff function $g_m(\cdot)$,*

$$\frac{\partial E g_m(\tilde{V})}{\partial \sigma} = \frac{M_0}{\sigma}$$

where $M_0 < 0$ and finite and independent of σ.

Proof: See appendix **A**.4. □

This has important implications. First, as we noted above, to tighten control (i.e. to raise q^*), we need to lower the left hand side of equation (5.3). But the proposition tells us that the way to do that is by implementing a lower σ. In particular, the term is unbounded below only as σ approaches zero. This proves the following corollary.

Corollary 1 *As we approach full control over all types (ie $q^* \to 1$), $\sigma \to 0$. This, in turn, implies $\mu \to 0$.*

Remark: This key result shows the trade-off faced by the principal. On the one hand, increasing control lowers the weight on $\overline{\sigma}$. On the other hand, as the control increases, and q^* goes to 1, σ^* goes to zero for all $q \leq q^*$. Thus to make the agency distortion very small, the principal must choose a payoff function that implies a very high control. But at such a high degree of control, the average return is very small.

6 Agency distortion under PCA

Under a hard-link regime, the regulator can enforce optimum loss probabilities irrespective of the managerial utility function. But this is not the case under

PCA. The reason is as follows. Under standard assumptions, the principal's choice problem is well defined, and has interior solutions for K_c and σ. This implies that the principal chooses to set $q^* < 1$. Thus there is a non-trivial probability (given by $(1 - q^*)$) that a very high-risk portfolio (with $\sigma = \bar{\sigma}$) is chosen by the manager. This proves the following result.

Corollary 2 *Under the pre-commitment approach, the managerial choice of σ equals $\overline{\sigma}$ with probability $\phi = (1 - q^*(r))$, where ϕ is bounded away from zero.*

Under a hard-link regime, the principal chooses a σ given the regulatory function $K(\sigma)$. We showed that the regulator can enforce any σ as the principal's optimum, and the principal in turn can control the manager fully - thus the principal's optimum is implemented as the final outcome.

Under PCA, the first step is still true. The regulator can enforce any σ as the principal's optimum through the use of punishments in the event of a breach of commitment capital. But the second step is no longer true. To implement any $\sigma > 0$, the principal must necessarily allow $q^* < 1$. Thus there remains a probability of $(1 - q^*)$ with which a very high-risk portfolio is chosen.

Thus when the choice of σ by the manager is not contractable, and the manager's utility depends not just on managerial salary but also on career concerns or preference for attaining star-status, the expected losses increase under the pre-commitment approach (compared to a hard-link approach).

7 Public disclosure of breach: reputational distortion under PCA

We now proceed to the second source of distortion arising under PCA.

When the breach (under PCA) is publicly announced, this can have a serious impact on the reputation of the bank, which leads to lowering of its future profitability[(12)]. In this section we discuss the impact of such reputational concerns on banks.

[(12)]Even if the breach is not disclosed publicly, once an institution has been fined significantly, the cost that the penalty generates has to be reported in the balance sheet. This implies that large breaches would probably be uncovered (even though with some delay).

The first point to note is that when discussing reputational concerns, we must include into our calculation the value of the entire bank - not just the trading book. Even though the reputational concerns arise from a potential breach with respect to the trading book capital, the effect of a poor reputation affects also the banking book. With any breach, whenever there is less than full deposit insurance, the cost of both debt and equity funding rises. This reduces the return of the trading portfolio, but even more importantly, makes the value of the banking book sensitive to the variance of the trading book. A higher variance induces a higher probability of a breach, and consequent loss of reputation.

The above considerations create an asymmetry between gains and losses. Suppose a bank has a large banking book relative to the trading book. While a profit on the trading book would not be very important for the overall return of the bank, a loss on the trading book in excess of the precommitted capital would have a very large reputation effect on the entire value of the bank. Thus a small trading book can jeopardize the large banking book. This makes the bank loss-averse with respect to the trading book and leads the bank to marginalize its trading book even further, and possibly also to overcommit trading book capital.

7.1 An illustration

Let us give an illustration of the kind of distortions that reputational concerns introduce in a very simplified setting.

Let the current value of the bank be denoted by V_B^0. Then

$$V_B^0 = V_{\text{bb}}^0 + V_{\text{tb}}^0,$$

where the subscript "bb" denotes banking book and the subscript "tb" denotes trading book. Suppose

$$V_{\text{bb}}^0 = \alpha V_{\text{tb}}^0, \quad \alpha > 0.$$

Now, normalize V_{tb}^0 to unity. Then $V_{\text{bb}}^0 = \alpha$, and $V_B^0 = 1 + \alpha$.

Let $\widetilde{V}_{\text{bb}}$ and $\widetilde{V}_{\text{tb}}$ denote the returns on the banking and trading books, respectively. Assume that all returns are proportional to the current values. Suppose these are distributed as follows:

$$\widetilde{V}_{\text{tb}} \sim N(\mu, \sigma),$$

and

$$\widetilde{V}_{\mathrm{bb}} \sim N(\alpha\lambda, \alpha\hat{\sigma}).$$

Suppose the bank commits a capital of $K_c = kV^0_{\mathrm{tb}} = k$. Suppose also that the cost of capital is a linear function $C(k) = ck$, $c > 0$.

Whenever the trading book risk $\sigma > 0$, a breach occurs with probability

$$Prob(\widetilde{V}_{\mathrm{tb}} < -K_c) = \Phi\left(\frac{-k-\mu}{\sigma}\right)$$

where Φ is the standard normal distribution function. Note that here the probability of breach is independent of α.

Let C_R denote the reputational cost. As we argued above, the cost of reputation is proportional to $V^0_B = (1+\alpha)$. Assume that C_R is linear in V^0_B. We have:

$$C_R = RV^0_B = R(1+\alpha),$$

where R is a positive constant.

If the trading book risk $\sigma > 0$, a breach might occur. The bank earns a return of $\mu + \alpha\lambda$ whether a breach occurs or not, and loses $R(1+\alpha)$ if a breach occurs. Thus the expected return of the bank is given by

$$E\left(\widetilde{V}_B|\sigma > 0\right) = \mu + \alpha\lambda - \Phi\left(\frac{-k-\mu}{\sigma}\right)(1+\alpha)R - ck \tag{7.1}$$

On the other hand, if the bank undertakes no trading book risk, i.e. $\sigma = 0$, there is no chance of a breach and the issue of reputational cost does not arise. Then the expected return is given by

$$E\left(\widetilde{V}_B|\sigma = 0\right) = E\widetilde{V}_{\mathrm{bb}} - ck = \alpha\lambda - ck \tag{7.2}$$

Let us write the breach probability as simply Φ. From equations (7.1) and (7.2),

$$E\left(\widetilde{V}_B|\sigma > 0\right) \geq E\left(\widetilde{V}_B|\sigma = 0\right)$$

if and only if

$$\alpha \leq \alpha^* = \frac{\mu - \Phi R}{\Phi R}.$$

This implies the following result.

Result: *Banks with a relatively large banking book ($\alpha > \alpha^*$), would prefer to reduce their trading book risk to zero. Only banks with relatively small banking books would undertake risky trading strategies.*

Remark: These extreme conclusions are, of course, a result of this particularly simple set-up - but the insight is robust. The asymmetry in losses and gains introduced by reputational concerns induces a bank with a relatively small trading book to reduce its importance further by reducing trading book risk. On the other hand, banks with relatively small banking books have little to lose in terms of reputation, and these banks would therefore undertake higher trading book risk.

Banks with a large banking book relative to the trading book are the best candidates (from the point of view of social optimality) to bear greater trading book risks. Yet these are precisely the banks that would reduce their trading book risk, and possibly commit to very large trading book capital. On the other hand, banks with small banking books presumably have limited liability - they cannot be fined very high amounts once they have suffered a large loss on the trading book. Such banks would therefore care more about trading book profits than losses - they would tend to increase the size of the trading book risk.

Thus a perverse pattern emerges. Large banks with a large banking book relative to the trading book would be very loss averse, and would either make the trading book risk insignificantly small and possibly overcommit capital. In either case, since social optimality requires precisely these banks to take higher risk, reputational concerns generate inefficiency.

8 Conclusion: modifying PCA

We conclude by discussing possible remedies.

First, let us briefly review the results. Under a hard-link regime (with the exogenous link $K_{\text{reg}}(\cdot)$ mapping σ to capital requirement), the principal's optimum choice of σ^* can be enforced by choosing any payoff function increasing in V and a capital cover K such that $\sigma^* = K_{\text{reg}}^{-1}(K)$. Thus by choosing the right schedule of required capital, the regulatory choice of loss probabilities can be implemented.

Under PCA, if the manager's utility only depends on monetary payoff, the principal retains full control of the manager, and his optimum choice (K^*, σ^*) can be enforced by choosing $K = K^*$ and r^* such that $\sigma(r^*) = \sigma^*$. The choice of K^* and σ^* depends on the fine schedule. Thus by choosing the right schedule of fine, the regulatory choice of loss probabilities can be implemented.

However, if the manager also has career objectives - so that the manager places some weight q on a higher trading book standard-deviation (where q is unknown to the principal, who only knows the distribution of q), the agency problem generates higher expected losses. This is because, as we have shown, whenever the principal attempts to implement a $\sigma > 0$, there is a certain q^* such that for all types $q > q^*$ there is a jump in the variance undertaken. Thus the agency problem creates distortions in trading book risk.

Further, reputational concerns introduce distortions in the choice of trading book size relative to the banking book across the banking sector.

Modifying PCA to rectify the distortions

The reputational distortion arises because the regulation treats the trading book separately from the banking book. Any piecemeal regulation that attempts to punish trading losses would generate an asymmetry in the bank's evaluation of trading gains and losses, and make the bank loss averse. Of course, the obvious way to correct for this distortion is to regulate the whole bank under the same regulatory scheme.

Correcting for agency distortions is more complicated. In general, this is a problem of designing a mechanism to implement a certain objective given that various interacting agents have conflicting preferences[(13)]. Such a general approach could be very fruitful in this context, and while this is one of our research areas, an analysis along this line is beyond the scope of the paper.

However, there is another possible route - since the interaction between the regulator and the banks takes place repeatedly over time, we need not focus simply on static regulation. The key problem here is that on the one hand, maintaining flexibility makes it necessary to allow the banks to choose their own riskiness, and on the other hand, such flexibility might result in loss of control by the principal over the manager. A hard-link is inflexible, but it allows full control.

A loss of control occurs when managers of different types have different preferences for portfolio risk. In view of this, we might attempt to retain the flexibility and yet harden the soft-links under PCA in the following manner.

Consider the following scheme for any given bank:

[(13)]For a lucid discussion of the central issues in the implementation literature, see the survey by Moore (1992).

- Regulate according to PCA to start with.
- In any future period t, if there has been no breach in period $t-1$, regulate according to PCA.
- If a breach occurred in period $t-1$, adopt a hard-link approach for T periods (if VaR is econometrically problematic, adopting the standardized approach would do just as well - or any other hard-link regime that would put limits on managerial risk-taking), at the end of which switch back to PCA.

Such a scheme would help eliminate the agency distortion. The reason is that the manager must trade-off σ today with σ tomorrow(14). Suppose the manager is of a type that puts a high weight on portfolio risk (a high q, in terms of our parametrization). Suppose he takes a very high risk strategy in period t, and large losses occur. In a static context, limited liability implies that the manager would not care about the losses. But now there are other consequences. Since the manager puts a high weight on risk, unless he discounts the future heavily, he would care about the risk he can undertake in period $t+1$ and after. Higher risk in period t increases the chances of facing a hard-link regime for T periods that would put limits on managerial risk-taking. Thus there is now a trade-off. This helps reduce the agency distortion.

The policy is simple enough - a violating bank must go through a "probationary" phase during which its risks would be very inflexibly controlled. This approach maintains the flexibility of PCA, while hardening the links on punishment paths.

In future research, we hope to explore these issues further and shed light on optimal regulation.

(14)Of course, such a scheme would only work if the expected duration of the manager's employment is not very short.

Appendix A: Some Proofs

A.1 Regulatory control under a hard-link regime

The objective of the regulator is to specify p such that

$$Prob(V_0 + \tilde{V} < V_L) = p,$$

and the regulatory capital is

$$K_{reg} = V_0 - V_L.$$

Let $\tilde{Z}$ denote the standard normal variable. Thus $\tilde{Z} = (\tilde{V} - \mu V_0)/(\sigma V_0)$. Also, let Φ denote the standard normal cumulative distribution. The regulatory objective can be rewritten as

$$Prob\left(\tilde{Z} < \frac{V_L - V_0(1+\mu)}{\sigma V_0}\right) = p,$$

which implies,

$$\frac{V_L - V_0(1+\mu)}{\sigma V_0} = \Phi^{-1}(p) = -\Phi^{-1}(1-p).$$

Thus,

$$V_L = V_0(1+\mu) - \sigma V_0 \Phi^{-1}(1-p).$$

This implies,

$$K_{reg}(\sigma) = V_0 - V_L = \sigma V_0(\Phi^{-1}(1-p) - \beta).$$

The principal chooses a payoff function for the manager $g_m(V)$ where $g'_m \geq 0$. Given the limited liability of the manager,

$$\pi_m(V) = \max[0, g_m(V)]$$

Note that without any additional constraints, given that the choice of σ by the manager is not contractable, the manager would choose the highest possible σ. However, given the regulatory rule, and given the K in place, the manager is constrained by the following inequality.

$$\sigma \leq K_{reg}^{-1}(K) = \frac{K}{V_0(\Phi^{-1}(1-p) - \beta)}$$

Given the payoff function, the above equation is satisfied with strict equality, and thus given $K_{reg}(\sigma) = \sigma V_0(\Phi^{-1}(1-p)-\beta)$, a loss of $V_0 - V_L$ would be exceeded with probability p. Thus this function implements the required regulatory objective.

For example, for $p = 0.01$, $K_{reg}(\sigma) = -\sigma V_0(\beta + \Phi^{-1}(0.01))$.

A.2 Deriving equation (5.2)

The expected utility of the manager depends only on expected payment. This is given by

$$E\hat{g}_m(r,\beta,\sigma) = \frac{2}{3}(1 + r\beta\sigma)\left(\Phi(\alpha_1) - \Phi(\alpha_2)\right) - \frac{2}{3}r\sigma\left(\phi(\alpha_1) - \phi(\alpha_2)\right) + \Phi(-\alpha_1)$$

where

$$\begin{aligned} \alpha_1 &= \frac{1}{2r\sigma} - \beta \\ \alpha_2 &= -\frac{1}{r\sigma} - \beta \end{aligned}$$

Note that the expected payment of the manager is a function of r and σ only through the term $r\sigma$. Let $\theta = r\sigma$. Now the expected payoff can be written as

$$E\hat{g}_m(r,\beta,\sigma) = \frac{2}{3}(1 + \beta\theta)\left(\Phi(\tilde{\alpha}_1) - \Phi(\tilde{\alpha}_2)\right) - \frac{2}{3}\theta\left(\phi(\tilde{\alpha}_1) - \phi(\tilde{\alpha}_2)\right) + \Phi(-\tilde{\alpha}_1)$$

where

$$\begin{aligned} \tilde{\alpha}_1 &= \frac{1}{2\theta} - \beta \\ \tilde{\alpha}_2 &= -\frac{1}{\theta} - \beta \end{aligned}$$

Note that $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ depends on r and σ only through θ. Using this, we see that $E\hat{g}_m(r,\beta,\sigma)$, too, depends on r and σ only through θ. Thus $E\hat{g}_m(r,\beta,\sigma) \equiv t(\theta,\beta)$.

A.3 The principal's payoff in the special case

The gross payoff of the principal is given by (since in equilibrium the expected payoff to the manager is equal to the reservation value of the manager, it does not matter whether we maximize the gross payoff of the principal or his payoff net of the managerial pay)

$$\pi_p = \tilde{V}(r, K_c) - C(K_c) - f(-K_c - \tilde{V}(r, K_c)).$$

The expected payoff is given by the following expression

$$(1 - H(-K_c))E(\tilde{V}|\tilde{V} \geq -K_c) + H(-K_c)E(\tilde{V} - f(-K_c - \tilde{V})|\tilde{V} < -K_c) - C(K_c),$$

where $H(\cdot)$ denotes the cumulative normal distribution. Using the fine function specified in section 5, and simplifying, we get

$$E\pi_p(\sigma, K_c, \beta) = \beta\sigma(1 + d\Phi(\gamma)) + d\sigma\Phi(\gamma) - d\sigma\phi(\gamma) - C(K_c) \tag{A.1}$$

where

$$\gamma = -\frac{K_c}{\sigma} - \beta,$$

and $\Phi(\cdot)$ is the cumulative standard normal distribution.

The principal maximizes his payoff with respect to K_c and σ, and enforces the optimum σ by choosing r such that $T_0/r = \sigma$. Given our assumption that $C(\cdot)$ is convex, the optimization is well-defined and has an interior solution.

A.4 Proof of proposition 2

To reduce notation, without loss of generality set $V_0 = 1$.

$$Eg_m(\tilde{V}) = \frac{1}{\sigma}\int_{-\infty}^{\infty} g_m(\tilde{V})h(\tilde{V})d\tilde{V},$$

where $h(\cdot)$ is the normal density with mean μ and variance σ^2. Differentiating with respect to σ,

$$\frac{\partial Eg_m(\tilde{V})}{\partial\sigma} = \frac{1}{\sigma}\int_{-\infty}^{\infty} g_m(\tilde{V})\left[\frac{\tilde{V}}{\sigma}\left(\frac{\tilde{V}}{\sigma} - \beta\right) - 1\right] h(\tilde{V})d\tilde{V},$$

The two roots of $\left[\frac{\tilde{V}}{\sigma}\left(\frac{\tilde{V}}{\sigma} - \beta\right) - 1\right] = 0$ are $A_L\sigma$ and $A_H\sigma$ where

$$\begin{aligned} A_L &= \frac{\beta - \sqrt{\beta^2 + 4}}{2} \\ A_H &= \frac{\beta + \sqrt{\beta^2 + 4}}{2}. \end{aligned}$$

Note that $A_L < 0$ and $A_H > 0$. Also, whenever $\tilde{V} < A_L\sigma$ or $\tilde{V} > A_H\sigma$, the expression is strictly positive, and strictly negative for $A_L\sigma < \tilde{V} < A_H\sigma$. Thus the best way to achieve the lowest possible value for $\frac{\partial Eg_m(\tilde{V})}{\partial\sigma}$ is to set $g_m(\cdot)$ such that it is positive only for $A_L\sigma < \tilde{V} < A_H\sigma$.

Accordingly, any optimal payoff function can be written as:

$$g_m(\tilde{V}) = \begin{cases} W > 0 & \text{for } A_L\sigma < \tilde{V} < A_H\sigma, \\ 0 & \text{otherwise} \end{cases}$$

Then the integral above is negative, and

$$\frac{\partial E g_m(\tilde{V})}{\partial \sigma} = \frac{M_0}{\sigma}$$

where $M_0 < 0$.

To show that M_0 does not change with σ:

$$M_0 = W \int_{A_L \sigma}^{A_H \sigma} \left[\frac{\tilde{V}}{\sigma} \left(\frac{\tilde{V}}{\sigma} - \beta \right) - 1 \right] h(\tilde{V}) d\tilde{V}. \tag{A.2}$$

Let $\tilde{Z} = (\tilde{V} - \beta\sigma)/\sigma$. Then we can write:

$$M_0 = W \int_{B_L}^{B_H} \left[\tilde{Z}(\tilde{Z} + \beta) - 1 \right] \phi(\tilde{Z}) d\tilde{Z}$$

where ϕ is the standard normal density function, and

$$\begin{aligned} B_L &= A_L - \beta = \frac{-\beta - \sqrt{\beta^2 + 4}}{2} \\ B_L &= A_L - \beta = \frac{-\beta + \sqrt{\beta^2 + 4}}{2}. \end{aligned}$$

Now,

$$\frac{M_0}{W} = \int_{B_L}^{B_H} \tilde{Z}^2 d\tilde{Z} + \beta \int_{B_L}^{B_H} \tilde{Z} d\tilde{Z} - (\Phi(B_H) - \Phi(B_L))$$

Calculating the truncated variance and mean, and simplifying,

$$\frac{M_0}{W} = \phi(B_L) \left(\frac{\phi(B_L)}{\Phi(B_L)} + B_L \right) - \phi(B_H) \left(\frac{\phi(B_H)}{\Phi(B_H)} + B_H \right) + \beta \left(\phi(B_L) - \phi(B_H) \right)$$

Since B_L and B_H only depend on β, M_0 is independent of σ. □

Appendix B: removing assumption 1

In section 3 we claimed that all results hold whenever assumption 0 is satusfied and that assumption 1 is merely a simplifying device. We discuss this is some detail here.

Suppose instead of assumption 1 we assume that

$$\mu = \psi(\sigma)$$

where $\psi(\cdot)$ is a continuous bounded function such that

$$\lim_{\sigma \to 0} \psi(\sigma) = 0$$

and there exists $\epsilon > 0$ such that $\psi(\cdot)$ is twice differentiable on $(0, \epsilon)$.

Hard-link approaches: First, note that the results about the hard-link approach are unrelated to assumption 1. Under a hard-link approach, portfolio risk is directly tied down by the capital level, as shown in equation (4.1). This resulty does not depend upon assumption 1. Thus proposition 1 is unchanged. The exact calculations of the principal's optimum level of σ change - but there is no qualitative change.

PCA: special case of $q = 0$: For PCA, in the special case $q = 0$ (section 5.1), we showed by constructing an explicit payoff function that the principal can retain full control. Using assumption 1, we showed that as r increases, the managerial choice of σ decreases - and that this allows the principal to implement any level of σ by the appropriate choice of r. If we use the more general assumption above, we can derive the same conclusion as follows. Approximate the function $\psi(\cdot)$ by a piecewise linear function. On each of the linear segments, the inverse relation between r and σ holds by the calculations in section 5.1. Taking limits, we can conclude that the inverse relation holds in this case as well.

PCA: genreal case: In section 5.2, the proof of proposition 2 uses assumption 1. We can construct a proof and show the tradeoff between control and returns replacing assumption 1 by the more general assumption above as follows.

Note that if there exists $q^* \in (0,1)$ given by

$$(1-q^*)E(g_m(\widetilde{V})|\bar{\sigma}) + q^*\bar{\sigma} = (1-q^*)E(g_m(\widetilde{V})|\sigma) + q^*\sigma$$

for all $\sigma \leq \bar{\sigma}$, then managers of type $q \in (q^*, 1]$ would choose $\sigma = \bar{\sigma}$. Let $\Delta E g_m$ denote $E(g_m(\widetilde{V})|\sigma) - E(g_m(\widetilde{V})|\bar{\sigma})$. From the above,

$$q^* = \frac{\Delta E g_m}{\Delta E g_m + (\bar{\sigma} - \sigma)}.$$

Note that q^* rises as $\Delta E g_m$ increases. Thus to increase control, $\Delta E g_m$ must be raised.

Now,

$$\Delta E g_m = \int_{-\infty}^{\infty} g_m(\widetilde{V}) d(H(\widetilde{V}|\mu, \sigma) - H(\widetilde{V}|\bar{\mu}, \bar{\sigma}).$$

Suppose V_L and V_H be the values such that $h(\cdot|\mu, \sigma) - h(\cdot|\bar{\mu}, \bar{\sigma}) > 0$ for $V_L < \widetilde{V} < V_H$ and $h(\cdot|\mu, \sigma) - h(\cdot|\bar{\mu}, \bar{\sigma}) \leq 0$ otherwise. Then any payoff function

$g_m(\cdot)$ that maximize control must set $g_m(\tilde{V}) = W > 0$ for $V_L < \tilde{V} < V_H$ and $g_m(\tilde{V}) = 0$ otherwise.

Then,

$$\Delta E g_m = \int_{V_L}^{V_H} h(\tilde{V}|\mu, \sigma) - h(\tilde{V}|\bar{\mu}, \bar{\sigma}) d\tilde{V}.$$

For any (μ, σ) with σ bounded away from 0, the integral is finite, and thus q^* is bounded away from 1. Now, $\psi(\cdot)$ is continuous and differentiable near 0. Thus for σ close to 0, differentiating $\Delta E g_m$ with respect to σ we get (M_1/σ) where M_1 (which is similar to M_0 given by equation (A.2)) is negative and as σ approaches 0, M_1 approaches a negative constant. Thus as σ goes to zero, $\Delta E g_m$ goes to $-\infty$, and q^* goes to 1. Thus the only way to approach full control is to reduce σ to zero, and thus, once again, the tradeoff emerges.

Finally, the results on **reputational distortions** arise from the asymmetry of profits and losses due to reputation, and do not depend on assumption 1.

References

Besanko, D and Kanatas, G (1996), 'The regulation of bank capital: do capital standards promote bank safety?', *Journal of Financial Intermediation,* Vol. 5, pages 160-83.

Bliss, R (1995), 'Risk-based bank capital: issues and solutions', Federal Reserve Bank of Atlanta, *Economic Review,* September/October, Vol. 80, pages 32-40.

Campbell, T, Chan, Y and Marino, A (1992), 'An incentive based theory of bank regulation', *Journal of Financial Intermediation,* Vol. 2, pages 255-76.

Chan, Y, Greenbaum, S and Thakor, A (1992), 'Is fairly-priced deposit insurance possible?', *Journal of Finance,* Vol. 47, pages 227-45.

Daripa, A (1997), 'Lenders who must borrow: underinvestment in aggregate equilibrium and the role of trade credit', Birkbeck College, *Institute of Financial Research working paper.*

Daripa, A, Jackson, P and Varotto S (1997), 'The pre-commitment approach to setting capital requirements', Bank of England and SIB, *Financial Stability Review,* Autumn, pages 42-50.

Dewatripont, M and Tirole, J (1993), *The prudential regulation of banks,* MIT Press, Cambridge, Massachusetts.

Dimson, E and Marsh, P (1992), 'Capital requirements for securities firms', *Journal of Finance,* Vol. 50, pages 1219-33.

Giammarino, R M, Lewis, T R and Sappington, D (1993), ' An incentive approach to banking regulation', *Journal of Finance,* Vol. 48, pages 1523-42.

Jackson, P (1995), 'Risk measurement and capital requirements for banks', *Bank of England Quarterly Bulletin,* May, pages 177-84.

Jackson, P, Maude, D and Perraudin, W (1996), 'Bank capital and value-at-risk', *Working Paper,* Birkbeck College.

Kupiec, P H (1995), 'Techniques for verifying the accuracy of risk measurement models', *Journal of Derivatives,* Winter, pages 73-84.

Kupiec, P H and O'Brien, J M (1995a), 'The use of bank trading risk models for regulatory Capital Purposes', Federal Reserve Board, *Finance and Economics Discussion Paper,* March.

Kupiec, P H and O'Brien, J M (1995b), 'A pre-commitment approach to capital requirements for market risk', Federal Reserve Board, *Finance and Economics Discussion Series,* July, No. 95-34.

Kupiec, P H and O'Brien, J M (1995c), 'Recent developments in bank capital regulation of market risks', Federal Reserve Board, *Finance and Economics Discussion Series,* December, No. 95-11.

Kupiec, P H and O'Brien, J M (1997), 'The pre-commitment approach: using incentives to set market risk capital requirements', Federal Reserve Board, *Finance and Economics Discussion Series,* March, No. 97-14.

Marshall, D and Venkatraman, S (1997), 'Bank capital standards for market risk: a welfare analysis', Federal Reserve Bank of Chicago, *Working Paper,* April, *mimeo.*

Moore, J (1992), 'Implementation, contracts and renegotiation in environments with complete information', Cambridge University Press, *Advances in Economic Theory: Sixth World Congress,* Vol I, pages 182-282.

Prescott, E (1997), 'The precommitment approach in a model of regulatory banking capital', Federal Reserve Bank of Richmond, *Economic Quarterly.*

Rochet, J (1992), 'Capital requirements and the behaviour of commercial banks', *European Economic Review,* Vol. 36, pages 1137-78.