Pillar 1 vs Pillar 2 under Risk Management

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Abstract

Under the New Basel Accord bank capital adequacy rules (Pillar 1) are substantially revised but the introduction of two new dimensions to the regulatory framework is, perhaps, of even greater significance. This paper investigates the complementarity between Pillar 1 (risk-based capital requirements) and Pillar 2/PCA and, in particular, the role of closure rules with costly recapitalization when banks are able to manage their portfolios dynamically. A feature of our approach is to consider the costs as well as the benefits of capital regulation in a way that accommodates the behavioral response of banks in terms of their portfolio strategy and capital structure and, further, the extent to which capital rules are effective, i.e., the extent to which banks can "cheat".

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1 Introduction

Under the New Basel Accord bank capital adequacy rules (Pillar 1) are substantially revised but the introduction of two new dimensions to the regulatory framework is, perhaps, of even greater significance. Pillar 2 increases the number of instruments available to the regulator: (i) intensifying monitoring; (ii) restricting the payment of dividends; (iii) requiring the preparation and implementation of a satisfactory capital adequacy restoration plan; (iv) requiring the bank to raise additional capital immediately. Pillar 3 enhances disclosure (that is, publicly available information). This paper focusses on Pillar 2 and asks how regulators should use the discretion that this new approach provides.

If regulators are able to enforce a risk-based capital requirements rule at all times, then both failure and, consequently, calls on the deposit insurance fund can be effectively eliminated. In this case the details of the rule are of little importance because, as soon as capital reaches some lower threshold[1] the regulator simply has to force the bank to invest entirely in riskless assets. Under these conditions additional regulatory instruments such as Pillars 2 and 3 would have no role[2]. Thus, the design of capital requirements is a significant problem only in the case when the regulator is either unable to observe the bank's portfolio perfectly or lacks the power to force changes in its composition. In this event, and if they are able to change their portfolio composition over time, i.e., engage in risk management, banks may deliberately deviate from compliance with capital adequacy rules, in other words,

[1]The conclusion that continuous monitoring and perfect liquidity would eliminate the possibility of default rests on the assumption of asset price continuity, i.e., the absence of jumps. In the context of a single obligor this assumption is indeed critical but, for banks with large well diversified portfolios, the conclusion is much more robust in the sense that a jump in the value of a claim on a single counterpart would have only a small effect on the value of the portfolio of a whole.

[2]A similar point is made by Berlin, Saunders and Udell (1991) who point out that, with perfect observability, even capital requirements are redundant and could be replaced by a simple closure rule: "A credible net-worth closure rule for banks relegates depositor discipline to a minor role. Indeed, a totally credible and error- and forbearance free closure rule removes any need for depositors to monitor bank risk at all since they would never lose on closure".

they may "cheat". Under these circumstances instruments such as Pillar 2 and Pillar 3 may not be redundant. Our paper focuses on the interaction between Pillar 1 and Pillar 2 when banks are able to use risk management to "cheat" in relation to capital requirements.

We construct a model of bank behavior in which banks manage their portfolios in the interests of their shareholders subject to the constraints imposed by regulation. These constraints include not only capital requirements but actions on closure and recapitalization taken by the regulator under the new Pillar 2.

An important feature of the model and one that distinguishes our approach from a number of earlier studies, is that banks may recapitalize and that their choice of the capital structure is endogenous.

The model is also multiperiod, which means that banks are concerned about survival as well as exploiting deposit insurance and are allowed to manage their risk dynamically. This last point is important for several reasons. Among these are that dynamic portfolio choice ("risk management") changes the impact of (a) capital requirements and (b) Pillar 2 discretion on both bank risk taking and the ability of banks to "cheat".

In our analysis we wish to address the trade-off between the costs and benefits of the regulatory framework. Thus we need to consider not only measures of the negative externalities associated with bank failure but also some measure of the cost of regulation imposed by constraining bank activity. Thus we include the probability of bank closure and the value of deposit insurance liabilities as measures of the negative externalities of bank risk taking and the average investment in risky assets and the average capital utilization as, respectively, measures of bank activity, to reflect the negative externality of reduced activity induced by regulation, and the private costs associated with high capital levels.

The main innovation in our paper is to introduce a framework for analyzing the impact of Pillar 2. In our model Pillar 2 is represented as a threshold level such that, if a bank's capital falls below this level at the time of an audit, it must either recapitalize or face closure. This view of Pillar 2 is similar to the concept of Prompt Corrective Action promulgated by the FDIC. This additional constraint on the bank's capital position gives the regulator an extra degree of freedom. In this sense is therefore a simple constraint on leverage. However, we also consider the case where a bank that recapitalizes at the Pillar 2 threshold level incurs a fixed cost. This cost may be thought of as an increase in compliance costs brought about by more intensive scrutiny on the part of the regulator or, simply, as a "fine". We show that the effects of Pillar 2 intervention depend (a) on the level of the threshold, (b) the size of the recapitalization cost, (c) the level of risk based capital requirements and (d) the extent to which banks are able to avoid complete compliance with these rules ("cheating").

Our paper focuses on two main questions:

(i) How should regulators use the enhanced discretion for intervention that Pillar 2 provides (closure rules, dividend restrictions, recapitalization, etc.) while taking into account banks' ability to revise their portfolios dynamically?

(ii) How does the answer to the previous question change when banks are able, at least to some extent, to avoid complete compliance with capital regulation.

The paper is organized as follows. Sections 2 and 3 describe the New Basel Accord and its main advantages and drawbacks. Section 4 describes the model and characterizes the bank's optimal investment decisions. Section 5 introduces costs of recapitalization and examines the effects on dynamic portfolio management. Section 6 extends the analysis introducing risk-based capital requirements (Pillar 1). Section 7 presents the results of the interaction between Pillar 1 and Pillar 2. Section 8 concludes.

2 The New Basel Accord: a brief description

In the early 1980's, as concern about the financial health of international banks mounted and complaints of unfair competition increased, the Basel Committee on banking Supervision initiated a discussion on the revision of capital standards. An agreement was reached in July 1988, under which new rules would be phased in by January 1993. The Basel accord of 1988 explicitly considered only credit risk and the scheme was based entirely on capital requirements. These requirements, still in force, comprise four elements: (i) the definition of regulatory capital, (ii) the definition of the assets subject to risk weighting, (iii) the risk weighting system, and (iv) the minimum ratio of 8%[3].

[3]Following its introduction, the Accord has been fine-tuned to accommodate financial innovation and some of the risks not initially considered. For example, it was amended in 1995 and 1996 to require banks to set aside capital in order to cover the risk of losses arising from movements in market prices. In 1995 the required capital charge was based on the "standard approach" similar to that applied to credit risk. The standard approach defines the risk charges associated with each position and specifies how any risk position has to be aggregated into the overall market risk capital charge. The amendment of 1996 allows banks to use, as an alternative to the standard approach, their internal models to determine the required capital charge for market risk. The internal model approach allows

When the Accord was introduced in 1988, its design was criticized because too crude and for its "one-size-fits-all" approach[4]. Given these shortcomings, together with the experience accumulated since the Accord was introduced, the Basel Committee considered a revision of the current accord (Basel Committee (1999, 2001, 2003)).

The proposed new accord differs from the old one in two major respects. First it allows the use of internal models by banks to assess the riskiness of their portfolios and to determine their required capital cushion. This applies to credit risk as well as to operational risk and delegates to a significant extent the determination of regulatory capital adequacy requirements. This regime is available to banks if they choose this option and if their internal model is validated by the regulatory authority. Second, by adding two additional "pillars", alongside the traditional focus on minimum bank capital, the new accord acknowledges the importance of complementary mechanisms to safeguard against bank failure. Thus, the new capital adequacy scheme is based on three pillars: (i) capital adequacy requirements (Pillar 1), (ii) supervisory review (Pillar 2) and (iii) market discipline (Pillar 3).

With regard to the first pillar, the Committee proposes two approaches. The first, so called "standardized" approach, adopts external ratings, such as those provided by rating agencies, export credit agencies, and other qualified institutions. The second approach, called the "Internal rating-based approach", allows the use of internal rating systems developed by banks, subject to their meeting specific criteria yet to be defined and validation by the relevant national supervisory authority. The internal ratings approach is also divided in two broad approaches: the "advanced" and the "foundation". The former gives some discretion to banks in choosing the parameters that determine risk weights, and consequently, in determining their capital requirements. The foundation approach, in contrast, provides little discretion[5].

a bank to use its model to estimate the Value-at-Risk (VaR) in its trading account, that is, the maximum loss that the portfolio is likely to experience over a given holding period with a certain probability. The market risk capital requirement is then set based on the VaR estimate. The main novelty of this approach is that it accounts for risk reduction in the portfolio resulting from hedging and diversification.

[4]The main criticisms were, among other things, (i) the capital ratio appeared to lack economic foundation, (ii) the risk weights did not reflect accurately the risk of the obligor and (iii) it did not account for the benefits from diversification. One of the main problems with the existing Accord is the ability of banks to arbitrage their regulatory capital requirements (see Jones (2000) and exploit divergences between true economic risk and risk measured under the Accord.

[5]In addition to revising the criteria for the determination of the minimum capital associated to the credit risk of individual exposures, the reform proposals advanced by

As far as the second Pillar is concerned, the proposals of the Basel Committee underline the importance of supervisory activity, such as reports and inspections. These are carried out by individual national authorities who are authorized to impose, through "moral suasion", higher capital requirements than the minimum under the capital adequacy rules. In particular, Pillar 2 emphasizes the importations of the supervisory review process as an essential element of the new Accord (see Santos (2001)). Pillar 2 encourages banks to develop internal economic capital assessments appropriate to their own risk profiles for identifying, measuring, and controlling risks. The emphasis on internal assessments of capital adequacy recognizes that any rules-based approach will inevitably lag behind the changing risk profiles of complex banking organizations. Banks' internal assessments should give explicit recognition to the quality of the risk management and control processes and to risks not fully addressed in Pillar 1. Importantly, Pillar 2 provides the basis for supervisory intervention and allows regulators to consider a range of options if they become concerned that banks are not meeting the requirements. These actions may include intensifying the monitoring of the bank; restricting the payment of dividends; requiring the bank to prepare and implement a satisfactory capital adequacy restoration plan; and requiring the bank to raise additional capital immediately. Supervisors should have the discretion to use the tools best suited to the circumstances of the bank and its operating environment. (New Accord: Principle 4: 717).

Finally, the third Pillar is intended to encourage banks to disclose information in order to enhance the role of the market in monitoring banks. To that end, the Committee is proposing that banks disclose information on, among other things, the composition of their regulatory capital, risk exposures and risk-based capital ratios computed in accordance with the Accord's methodology.

In the light of these objectives, the Basel Committee has articulated four principles: (1) Each bank should assess its internal capital adequacy in light of its risk profile, (2) Supervisors should review internal assessments, (3) Banks should hold capital above regulatory minimums, and (4) Supervisors should intervene at an early stage. In particular Pillar 2 increases the number of instruments available to the regulator.

The descriptions of the second and third Pillars by the Basel Committee are not as extensive or detailed as that of the first. Nevertheless, it is significant that for the first time in international capital regulation, supervision and market discipline are placed at the same point of the hierarchy as the

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the Committee introduce a capital requirement for operational risks, which is in turn determined using three different approaches presenting a growing degree of sophistication.

regulatory minimum. In discussing the second Pillar the proposal states that: "The supervisory review process should not be viewed as a discretionary pillar but, rather, as a critical complement to both the minimum regulatory capital requirement and market discipline."

In this paper we analyze the effects of Pillar 2 intervention and in particular, the interaction between Pillar 2 and Pillar 1. We characterize Pillar 2 as a threshold level of leverage such that a bank with higher leverage than this threshold at the time of an audit is required either to recapitalize or to close. If a bank recapitalizes it incurs a cost. This characterization is therefore firmly in the spirit of both PCA and Basel II.

We show first that Pillar 2 intervention has an impact on the frequency of bank failure and the value of deposit insurance liabilities only when regulators are unable to force banks to comply with Pillar 1 risk based capital requirements at all times. This may arise, for example, as the result of monitoring costs. If banks always comply with risk based capital requirements then both failure rates and the present value of deposit insurance liability (PVDIL) go to zero[6].

However, if banks do not always comply with Pillar 1 capital requirements, Pillar 2 may have a role by inducing banks to manage their portfolios so as to reduce the likelihood of incurring recapitalization costs. A central issue that we explore in the paper is the interaction between the level of risk based capital requirements (Pillar 1), the threshold leverage level (Pillar 2) and the degree of non-compliance with Pillar 1 rules.

3 Advantages and main drawbacks of the New Accord

The Basel Committee's proposals can be seen as an attempt to address some of the drawbacks of the previous capital adequacy scheme. In particular, the New Accord represents an advance in three main areas. First, with the objective of making capital requirements more risk sensitive, it introduces a more accurate framework for the assessment of risk, in particular credit risk. Although the new proposals have undoubtedly raised the level of the analysis of credit risk from the first Accord, there remain some important questions about some aspects, e.g., how the correlation of credit exposures is treated. Moreover, for the first time the rules explicitly include operational risk as

[6]Unless there are jumps in the value of the portfolio of bank assets.

one of the determinants of required capital (Pillar 1). The new rules will also enhance the role of banks' internal assessments of risk as the basis for capital requirements. Second, the new accord represents an attempt on the part of regulators to lower the impact of capital regulation as a source of competitive inequality by reducing the opportunity for regulatory arbitrage. Third, the new accord enhances the role for regulatory review and intervention (Pillar 2) and market discipline (Pillar 3).

Introducing an extension to the current Accord, that concentrates only on capital requirements, Basel II is more consistent with the consensus of the literature on asymmetries of information that, in general, it is advantageous to consider a menu-based approach rather than a uniform "one-size-fits-all" rule[7]. The limitations of a simple capital adequacy approach in our paper arise when bank portfolios are imperfectly observable by the auditor and banks are able to engage in dynamic portfolio management .

Nonetheless, it appears that the new Accord does have some significant weaknesses and, among these, we draw particular attention to the following.

A major problem – long present in the literature – in assessing developments in banking regulation, and financial regulation in general, is that there is little discussion, and certainly no consensus, on the objectives that the regulator should pursue (Dewatripont and Tirole (1993)). The two most commonly cited justifications for bank regulation, and capital regulation in particular, are (i) the mitigation of systemic risks (see Goodhart et. al (1998), and Benston and Kaufman. (1996) among others) and (ii) the need to control the value of deposit insurances liabilities (see Merton (1997), Genotte and Pyle (1991), Buser, Chen and Kane (1981), Chan, Greenbaum, and Thakor (1992), Diamond and Dybvig. (1986) among others). Indeed the authors of the Basel II proposals refer to their " .. fundamental objective ... to develop a framework that would further enhance the soundness and stability of the international banking system ..".

It might seem curious to an outsider that the new Basel II accord is so little concerned with the systemic issues that have for so long been seen as central to the design of bank regulation. Nonetheless we find the same view expressed repeatedly by the regulators in describing the goals of the new accord. For example the quotation below, which comes from the BIS itself, addresses what we would regard as some of the central questions in bank

[7] See Kane (1990) and Goodhart et al. (1998) for a discussion of the principal-agent problems that can arise between regulators and regulated and Hauswald and Senbet (1999) for the design of optimal banking regulation in the presence of incentive conflicts between regulators and society. For other analysis of the interplay between capital regulation and monitoring of the bank by a regulator, see Campbell, Chan and Marino (1992) and Milne and Whalley (2001).

regulation and does so without any reference to systemic costs:

> *"Why are banks subject to capital requirements?*
>
> Nearly all jurisdictions with active banking markets require banking organizations to maintain at least a minimum level of capital. Capital serves as a foundation for a bank's future growth and as a cushion against its unexpected losses. Adequately capitalized banks that are well managed are better able to withstand losses and to provide credit to consumers and businesses alike throughout the business cycle, including during downturns. Adequate levels of capital thereby help to promote public confidence in the banking system.
>
> *Why is a new capital standard necessary today?*
>
> Advances in risk management practices, technology, and banking markets have made the 1988 Accord's simple approach to measuring capital less meaningful for many banking organizations.
>
> *What is the goal for the Basel II Framework and how will it be accomplished?*
>
> The overarching goal for the Basel II Framework is to promote the adequate capitalization of banks and to encourage improvements in risk management, thereby strengthening the stability of the financial system. This goal will be accomplished through the introduction of "three pillars" that reinforce each other and that create incentives for banks to enhance the quality of their control processes". (BIS, 2004)

The connection between the objective of enhancing the "soundness and stability" of the banking system and the specifics of the proposal, particularly in relation to systemic risk, are unclear. More broadly, the Basel II Accord is almost silent on the presence of externalities such as systemic failure and contagion which would be regarded by many as the principal justification for regulatory intervention (Berlin, Saunders and Uddell (1991), Allen and Gale (2003)). Without externalities, decisions, e.g., on capital structure, that are optimal from the private perspective of bank owners would also be socially optimal and, in this case, there would be no need for regulation.

The "externality-free" view of regulation that Basel II appears to espouse is also reflected in Pillar 3. This seeks to "encourage market discipline by developing a set of disclosure requirements that allow market participants to assess key information about a bank's risk profile and level of capitalization" (Basel Committee (2004)). However, it is unclear what impact greater transparency would have. If capital requirements are set without reference to the social costs of failure, i.e., regulatory capital requirements coincide with privately optimal levels of capital, then banks are, in any case, incentivized to maintain these levels and greater transparency would have little effect. If capital requirements do reflect the social costs of failure, i.e., are higher than those banks would choose privately, then it is not clear how disclosing to a private counterparty, a deficit against regulatory capital requirements would give the bank any incentive to increase capital.

When systemic costs are taken into account, optimal regulatory design involves trading off the social benefits of, for example, a lower frequency of failure with the private costs of achieving this. But when systemic issues are excluded from the analysis, there is no trade-off because the interests of private owners and social welfare coincide. In this case the prescriptions of the regulator are those that the bank would optimally choose for itself and the regulator becomes as sort of "super consultant" helping to promote "good practice" and "sound analysis". These objectives are, perhaps, worthy but it is unclear why this type of activity needs to be promoted within a legal framework such as Basel II. For example, the Basel Committee states that it "believes that the revised framework will promote the adoption of stronger risk management practices by the banking industry". While undoubtedly desirable, it is not clear how improving management practice in the area of risk management addresses the broad objectives of "soundness and stability" or, indeed, that banks themselves are not in a better position to decide on the appropriate level of investment in risk management.

The absence in the Basel Accord of any substantial discussion of costs is a major omission.[8] For example, if the costs imposed by capital requirements were small while the social costs of failure were significant, required capital should be set to sufficiently high levels that the incidence of bank failure would be minimal. The fact that no bank regulator proposes such a regime suggests that they at least consider that the costs imposed by capital regulation are significant. Certainly the US House of Representatives Committee on Financial Services (USHRCFS) has reservations about the costs

[8] References to the cost of capital requirements by the Basel Committee are rare. Among the small number of examples, the following quotation makes an implicit reference to cost when it refers to the possibility that capital level might be "too high":

"The technical challenge for both banks and supervisors has been to determine how much capital is necessary to serve as a sufficient buffer against unexpected losses. If capital levels are too low, banks may be unable to absorb high levels of losses. Excessively low levels of capital increase the risk of bank failures which, in turn, may put depositors' funds at risk. If capital levels are too high, banks may not be able to make the most efficient use of their resources, which may constrain their ability to make credit available". (BIS, 2004) imposed by capital requirements: "We are concerned that the bank capital charges created by Basel II, if implemented, could be overly onerous and may discourage banks from engaging in activities which promote economic developments"[9].

In our analysis we reflect the trade-off between, on one hand, the public and private costs of failure and, on the other, the costs imposed by regulation. Ideally, alternative designs for Basel II would find the best trade-offs between these costs using a general equilibrium approach. In the absence of such a model we focus on four outcome variables that are plausible candidates for the arguments of the welfare function that might be derived from an equilibrium model.

The first is the PVDIL: the cost of insuring deposits. The second is the frequency of bank closure which we regard as an index of the systemic cost of failure. All else equal, a low frequency of failure would promote confidence in the banking system and enhance the efficiency of the payments mechanism (see Diamond and Dybvig (1986))

Third, there is a widely held view, reflected in the concerns expressed by the USHRCFS, that high levels of capital impose a cost on banks. In our analysis we use the average level of bank capital as a measure of this cost.

Finally, we wish to capture the positive externalities that may arise from banking activity, e.g., bank lending. Clearly, a capital requirements regime that was so onerous as substantially eliminates banking activity would also reduce both the frequency of failure and the PVDIL to zero. A former chairman of the London Stock Exchange once referred to this approach as the "regulation of the graveyard". The quotation above from the USHRCFS suggests that they share these concerns and so we also report the average level of risky assets held as a proxy for banks' contribution to economic activity through lending.

The Basel Committee has attempted to assess the potential impact of the new Accord on capital requirements for different types of banks in a variety of countries by carrying out "Quantitative Impact Analysis" (QIS). These entail each bank recalculating capital requirements for its current portfolio under the new Accord. However, the QIS calculations were conducted under ceteris paribus assumptions and did not attempt to take into account any behavioral response on the part of banks to the new Accord. One of the aims of this paper is to provide a framework within which the behavioral response of banks to changes in regulation might be studied.

[9] US House of Representatives Committee on Financial Services letter to the chairmen of the Federal Reserve and the FDIC, the Comptroller of the Currency and the Director of the Office of Thrift Supervision, 3 November 2003.

Pillars 2 and 3 are major innovations in the new Accord and represent an explicit recognition that capital supervision involves more than capital requirements. Pillar 2, in particular, adds an important instrument to the bank regulator's armory and allows for some discretion over important elements such as closure, dividend payments and recapitalization. Pillar 3, by encouraging transparency, attempts to capture the benefits of market discipline. However, two important issues remain. First, as other authors (see Saidenberg and Schuermann (2003), von Thadden (2003)) have pointed out, there is a substantial imbalance between the detail provided by the Committee on Pillar 1, on one hand, and Pillars 2 and 3 on the other. The focus of the Committee's attention seems clear. Second, and more important, there is no discussion of the inter-relation between capital rules, and market discipline and the rules governing closure, dividend payments and recapitalization.

The main aim of this paper is to try to provide a framework within which to analyze the relations between capital requirements and closure, dividend payments and recapitalization. Descamps, Rochet and Roger (2003) have also drawn attention to the importance of this issue.

One aspect of the objectives of Basel II is to ensure that "... capital adequacy regulation will not be a significant source of competitive inequality among internationally active banks". However trying to make regulation neutral with respect to competition ("the level playing field") is a more demanding objective. First, regulation almost inevitably effects competition because it affects bank costs. Second, if the regulator attempts to design capital requirements, say, by finding the optimal trade-off between private and social costs, then capital rules will almost inevitably vary across banks unless they are all identical in term of their social costs (e.g., of failure). Differentiation of this kind – e.g., between large banks and small banks – is not found in the Basel II rules or, indeed, in other capital adequacy regimes. It appears that the pressure on regulators for "equal treatment" among banks dominates a more fine-tuned approach to regulatory design

4 The model

4.1 Timing and assumptions

In our model a bank is an institution that holds financial assets and is financed by equity and deposits.

Bank shareholders and depositors: Shareholders are risk neutral, enjoy limited liability and are initially granted a banking charter. The charter permits the bank to continue in business indefinitely under the control of its shareholders unless, at the time of an audit, the regulator is preventing to do so because the bank is in violation of regulation such as capital requirements. In this case the charter is not renewed, the shareholders lose control of the bank and the value of their equity is zero.

If the bank is solvent at time $t-1$, it raises deposits[10] D_{t-1} and capital kD_{t-1}, $k>0$ so that total assets invested are:

$$A_{t-1} = (1+k)D_{t-1}. \tag{1}$$

The deposits are one-period term deposits paying a total rate of return of r^d. Thus, at maturity the amount due to depositors is:

$$D_t = D_{t-1}(1+r^d). \tag{2}$$

At this point, if the bank is "solvent", the accrued interest, $r^d D_{t-1}$, is paid to depositors and deposits are rolled over at the same interest rate.

Regulators and audit frequency: We assume that audits take place at fixed times $t = 1, 2, ...$ The government guarantees the deposits and charges the bank a constant premium per dollar of insured deposits. This premium is included in the deposit rate [11] r^d.

Portfolio revisions and investment choice: Between successive audit dates there are n equally spaced times at which the portfolio may be revised. Setting $\Delta t \equiv 1/n$, the portfolio revisions dates, between audit dates t and $t+1$, are therefore:

$$t, t+\Delta t, t+2\Delta t, \ldots.., t+(n-1)\Delta t, t+1. \tag{3}$$

For simplicity we assume that the bank may choose between two assets: a risk free bond with maturity $1/n$, yielding a constant net return $\widehat{r}$ per period of length $1/n$ (r per period of length 1) and a risky asset yielding a gross random return $R_{t+j\Delta t}$ over the period $(t+(j-1)\Delta t)$ to $(t+j\Delta t)$[12]. Returns on the risky asset are independently distributed over time and have a constant expected gross return of $E\left[R_{t+j\Delta t}\right] \equiv (1+\widehat{a})$, where $\widehat{a}$ is the net expected return per period of length $1/n$ (a per period of length 1). Notice that we assume that, at each portfolio revision date, the bank is allowed either to

[10] We take the volume of a bank's deposits as exogenous.

[11] Equivalently, we may interpret this arrangement as one where the depositors pay the deposit insurance premium and receive a net interest rate of r^d.

[12] This means that we do not address the issues related to portfolio diversification as in Boot and Thakor (1991).

increase or decrease its investment in the risky asset, i.e. the risky asset is marketable.

In our model we assume that the only source of bank rent is the deposit insurance, i.e. $r^d = r = a$. This may appear to be a very pessimistic view of banking as in this case a bank's only activity is to try to exploit deposit insurance. However, we know that when banks have other sources of rents this acts as a natural curb on excessive risk taking and capital requirements will be less necessary. In our framework the banks that are most likely to default are those without other significant sources of rents who will try to hold as little capital as possible.

Portfolio choice: Let $w_{t+j\Delta t}$ denote the percentage of the portfolio held in the risky asset at time $t + j\Delta t$ with the remainder invested in the "safe" security. We limit the leverage that the bank can take on by imposing a no-short selling constraint ($0 \leq w_{t+j\Delta t} \leq 1$) on both the risky and safe assets[13]:

$$0 \leq w_{t+j\Delta t} \leq 1 \; \forall \; t \in [0, \infty] \, , \forall \; j \in [0, n-1] \, . \tag{4}$$

The bank's portfolio management strategy is represented as a sequence of variables $\Theta = (\theta_0, \theta_1, ., \theta_t, ., \theta_\infty)$ with:

$$\theta_t = \left(w_t, w_{t+\Delta t}, .., w_{t+j\Delta t}, .., w_{t+(n-1)\Delta t} \right) \text{ for all } 0 \leq t \leq \infty \tag{5}$$

and $0 \leq j \leq n-1$, where θ_t represents the strategy between audit dates t and $t+1$ and Θ the collection of these sub-strategies for audit dates $1, 2, \ldots, t, \ldots \infty$.

Intertemporal budget constraint: The intertemporal budget constraint is given by:

$$A_{t+(j+1)\Delta t} = \left[w_{t+j\Delta t} R_{t+j\Delta t} + (1 - w_{t+j\Delta t})(1 + \widehat{r}) \right] A_{t+j\Delta t}, \tag{6}$$

and so the bank's asset value at the audit time $t+1$ is:

$$A_{t+1} = \prod_{j=0}^{n-1} \left[w_{t+j\Delta t} R_{t+j\Delta t} + (1 - w_{t+j\Delta t})(1 + \widehat{r}) \right] A_t \tag{7}$$

[13]It may not be immediately apparent that a non negativity constraint on the risky asset would ever been binding. However, under the assumptions that we introduce below (limited liability) we show that the bank will be risk preferring in some regions and would short the risky asset if they could.

Bank closure rule (transfer of control from shareholders to supervisor) Most of the previous literature has assumed a the closure rule under which banking authorities deny the renewal of the banking licence and close the bank if its net worth (asset value minus deposits) is negative at the end of a period, that is if the asset value is lower than the threshold point represented by the deposit value (Marcus (1984), Keeley (1990), Hellman, Murdoch and Stiglitz (2000), Pelizzon and Schaefer (2004)). This closure rule induces the bank to be "prudent" when the bank has a sufficiently high rent from deposit insurance, interest ceilings or monopoly power in the deposit or asset market. Such a closure policy serves as a mechanism that both manages bank distress ex-post and may also have a disciplinary effect on ex-ante actions. A major drawback of this approach, however, is that shareholders who wish to provide capital to re-establish solvency are prevented from doing so. Among the problems raised by this assumption is the question of whether, by refusing to allow recapitalization, the government would be "illegally" expropriating the property of bank shareholders.

Thus, in this paper we consider the case where the banking authorities, instead of closing the bank or intervening and assuming control (for equityholders this is the same as closing the bank), allow recapitalization by shareholders and renewal of the licence if, after recapitalization, the volume of capital meets a given minimum threshold level, $\widehat{k}$[14]. This threshold level is in the spirit of the intervention level for Prompt Corrective Action[15] (PCA) or Pillar 2.

The idea of an early intervention can be used to fix a trigger point for intervention in management and transfer of control from shareholders to the depositors' representative, the supervisory authority.

The minimum capital requirement $\widehat{k}$ is independent of the portfolio composition that the bank chooses after recapitalization. It therefore acts as a

[14] A typical situation is where bank losses are covered by bank merges and acquisition. In our framework, it is the same if capital is replenished by old or new shareholders, the key point is that old shareholders do not lose the 100% of the franchise value. Dewatripont and Tirole (1993) state that this closure policy is very common in US (73,8%).

Another rescue policy documented by Dewatripont and Tirole (1993) is the "open bank assistance" policy also called "bail out". In a bail out the bank liquidates the defaulted assets, the government covers the shortfall to the depositors whose claims are in default, and the bank is not closed. This rescue policy is assimilable to our closure rule if shareholders still maintain a proportional claim on the bank franchise value. It is also assimilable to the government takeover when the bank is completely nationalized.

[15] The prompt corrective action scheme is in effect in the US since the passage in 1991 of the Federal Deposit Insurance Improvement act. The scheme defines a series of trigger points based on a bank's capitalization and a set of mandatory actions for supervisors to implement at each point.

traditional leverage constraint and is distinct from a risk-based capital requirement.

Under this rule equityholders have an option to retain the banking licence. They will exercise this option when there is an amount of capital, $k^* > \widehat{k}$, such that the volume of capital the bank shareholders need to raise, $k^*D + D_t - A_t$ is lower than the value of equity, S , after recapitalization.

More formally, let the indicator variable I_t represent whether the bank is open ($I_t = 1$) or closed ($I_t = 0$) at time t:

$$I_t = \begin{cases} 0 \text{ if } \prod_{s=0}^{t-1} I_s = 0 \\ 0 \text{ if } \prod_{s=0}^{t-1} I_s = 1 \text{ and } S < k^*D + D_t - A_t \\ 1 \text{ if } \prod_{s=0}^{t-1} I_s = 1 \text{ and } S > k^*D + D_t - A_t = \Psi \end{cases} \tag{8}$$

with $I_0 = 1$.

Dividend policy and capital replenishment: With this new feature, the shareholder cash flow (a dividend, if positive or equity issue amount, if negative) is:

$$d_t = \begin{cases} A_t - D_t - k^*D \text{ if } S \geq D_t + k^*D - A_t \\ \quad 0 \qquad \text{otherwise} \end{cases} \tag{9}$$

4.2 The problem

The bank chooses its investment policy θ_t^*, (i.e. the percentage $w_{t+j\Delta t}^*$ invested in the risky asset at each time $t + j\Delta t$) and the level of capital after recapitalization, k^*. The value of equity is given by the present value of future dividends:

$$S_0 = \sum_{t=1}^{\infty} (1+r)^{-t} E\left[d_t\left(\theta_t, k\right)\right] \tag{10}$$

The problem faced by the bank is to choose the policy $\{\theta_t^*, k^*\}$ that maximizes the franchise value, defined as the difference between the value of equity and the amount of capital, k^*, provided by shareholders at time 0.

$$\{\theta_t^*, k^*\} \in \arg \max_{\{\theta_t\}_{t=0}^{\infty}, k} F = \sum_{t=1}^{\infty} (1+r)^{-t} E\left[d_t\left(\theta_t, k\right)\right] - kD \tag{11}$$

subject to (4) and where dividends, d_t, are defined in (9).

This problem is time invariant at any audit time because, if the bank is solvent at audit time t, then, since the distribution of future dividends is identical at $t+1$, the portfolio problem faced by the bank is also identical at each audit time if the bank is solvent. This means that the value of equity at time t, conditional on solvency, is given by[16]:

$$S_t = \begin{cases} \sum_{t+1}^{\infty} (1+r)^{-(s-t)} E\left[d_s\right] = (1+r)\left\{E\left[d_{t+1}\right] + S_{t+1}\right\} \text{ if } I_{t+1} = 1 \\ 0 \text{ if } I_{t+1} = 0 \end{cases}, \tag{12}$$

This quantity is constant at each audit time when the bank is solvent and can be written as[17]:

$$S(\theta^*, k^*) = \frac{E\left[d(\theta^*, k^*)\right]}{r + \pi(\theta^*, k^*)} \tag{13}$$

where $\pi(\theta^*, k^*)$ is the probability of default at the next audit. Thus, the value of equity is equal to the expected dividend divided by the sum of risk free rate and the probability of default. In other words, the value of equity has a character of a perpetuity where the discount rate is adjusted for default[18].

Using (9), (12) and (13) it is straightforward to show that the $PVDIL$ of the bank can be written as:

$$\frac{E\left(Put\right)}{r + \pi(\theta^*, k^*))} = PVDIL, \tag{14}$$

[16]Note that d_{t+1} and $S_{t+1}$are functions of the portfolio strategy, θ_t, and the level of capital, k, but, for sake of notational clarity, we suppress this dependence.

[17]For details see Pelizzon and Schaefer (2004).

[18]A similar relation obtained in a number of models of defaultable bonds (see Lando (1997) and Duffie and Singleton (1999))

where "*Put*" represents the payoff on a one-period option held by the bank on the deposit insurance scheme, i.e.:

$$E_{t-1}\left(Put\right) = \int_{0}^{D_t - F} (D_t - A_t) f(A_t) dA_t \equiv E\left(Put\right)$$

4.3 Bank's optimal policy

In this section we show that the disciplinary effect of the franchise value vanishes when closure rules allow costless recapitalization. The feedback effect of alternative closure policies on the incentives of bankowners to avoid financial distress warrants closer attention, a point emphasized by the wide range of such policies that regulators actually employ.[19]. This result is summarized in the following lemma.

LEMMA 1: When recapitalization is allowed (and $F < D$), the optimal policy for the bank is the riskiest policy, irrespective of the sources of the franchise value.

Proof.

See the Appendix A.

■

This result (already proved by Suarez (1994) for the case with deposit rents only and Pelizzon (2001) for different sources of rents) is drive by the form of the payoffs associated with one-period decisions. Under the simple rule described above where closure takes place when the asset value is lower than the threshold point represented by the deposit value, the payoff to shareholders at the time of an audit, when the bank continues, is given by the sum of the dividend cash flow, d (which is negative in the case of recapitalization) and the value of the equity in continuation, S. If, at the time of an audit, the bank is closed when $A_t < D_t$ the payoff to equityholders is zero. This is illustrated in Figure (1).

[19]See Dewatripont and Tirole (1993) for a comparison of rescue policies employed in the developed economies of the United States, Japan, and European Nordic countries. Legislation in general calls for increasingly strict sanctions against banks as their capital levels deteriorate (see for example the Prompt Corrective Action) but still permits some regulators discretion concerning the closure of banks. See also Gupta and Misra (1999) for a review of failure and failure resolution in the US thrift and banking industries.

[Insert FIGURE (1) about here]

In contrast, when recapitalization is allowed even when the value of assets is below that of liabilities, shareholders' total payoff is given by the sum of value of equity S and the dividend cash flow d when the value of equity after recapitalization is higher than the amount of capital contributed ($S > A_t - D_t + k^*D$), and zero otherwise. Figure (2) shows the total payoff in this case.

[Insert FIGURE (2) about here]

Figures (1) with (2) differ for asset values between $D_t + k^*D - S$ and D_t. The non-convexity of the total payoff as a function of the asset value in the first case explains shareholders' aversion to risk when F is sufficiently high. Conversely, the convexity of the total payoff in the second case induces risk-loving.

As Lemma 1 states, in the case of a convex payoff function, the optimal portfolio strategy for bank is always to invest entirely in the risky asset. The option to recapitalize in this case not only induces the bank to choose the most risky strategy but also affects the probability of default and the value of deposit insurance liabilities (Pelizzon (2001)).

5 Costs of Recapitalization

Thus, the case of a convex payoff function analyzed by Suarez (1994) allows recapitalization but leads to the prediction that banks always seek to maximize risk. As a characterization of actual bank behavior this approach probably has very limited descriptive power. As mentioned above, the approach taken in the earlier literature induced prudence on the part of banks but only by expropriating the positive franchise value that insolvent banks ($A < D$) would have had if allowed to recapitalize.

In this paper we follow Suarez (1994) in allowing recapitalization for all values of A but with a frictional cost. The presence of these costs reintroduces concavity into the bank's payoff function and, depending on the parameters, this is sufficient to induce prudence on the part of the bank. Figure (3) shows the payoff to shareholders as a function of the asset value where the bank incurs a variable cost of replenishing the bank's capital[20] to a level k^*.

[20] Our model does not explain why equity is relatively expensive. This can be because

[Insert FIGURE (3) about here]

There is a second cost that banks incur when they recapitalize. This is a fixed cost that is related to the PCA/Pillar 2 intervention threshold $\widehat{k}$. Our interpretation of this cost is as an increase in the direct and indirect costs of compliance that come about as a result of the regulator increasing its intensity of monitoring. This may be viewed in terms of increased direct compliance costs, diversion of management time, restrictions on new business activities etc. This situation is illustrated in Figure (4) where, for simplicity, we suppress the variable cost of recapitalization that was illustrated in Figure (3).

[Insert FIGURE (4) about here]

Note that in our analysis the impact of the threshold $\widehat{k}$ on the shareholders' payoff comes entirely from the cost imposed on the bank rather than the specifics of the action taken by the regulator (inspections, detailed auditing etc.).

In the analysis below we first analyze bank behavior when banks are subject only to a minimum capital requirement, $\widehat{k}$ with a fixed cost, C. Next we introduced risk-based capital requirements (Pillar 1) and analyze the interaction between the Pillar 2/PCA intervention policy $\{\widehat{k}, C\}$ and Pillar 1 capital requirements. A key aspect of our analysis of Pillars 1 and 2 is to investigate the effect on both shareholder wealth and regulatory outcomes of banks' ability to manage their risk dynamically.

5.1 Optimal Bank Policy with Costs of Recapitalization

We now consider the effect on bank behavior of the recapitalization costs described above. In this section we deal with the case with leverage-based capital requirements only and, in the next section, introduce risk-based capital requirements.

As described earlier we assume that a PCA, triggered by a fall in the bank's capital to the threshold level $\widehat{k}$, imposes fixed cost C on the bank's shareholders. In addition, when a bank recapitalizes it incurs a variable cost

of tax rules, agency costs of equity, and in the case of banks a comparative advantage in the collection of deposit funds (Taggart and Greenbaum (1978)). For other motivations of expensive bank costs of capital see Boot (2001) and Berger et al. (1995).

equal to a fraction v of the amount of capital raised. Taking these costs into account, the dividend paid by the bank becomes:

$$d_t = \begin{cases} A_t - D_t - k^*D \text{ if } A_t \geq D_t + k^*D \\ (A_t - D_t - k^*D)(1+v) - C \text{ if } S \geq D_t + k^*D - A_t \text{ and } A_t < D_t + k^*D \\ 0 \quad \text{otherwise} \end{cases} \tag{15}$$

The benchmark case with no transaction costs has been described earlier. In this case, whether or not it is able to manage its portfolio dynamically, the optimal strategy for the bank is to maximize its portfolio risk. With either fixed or variable recapitalization costs the bank has, in general, an incentive to manage the risk of its portfolio dynamically.

We introduce the possibility of portfolio revision in our model by allowing, as discussed earlier, a bank that is solvent at time t to revise its portfolio at times t, $t + \Delta t$, $t + 2\Delta t$,.. up to the next audit date $t + 1$. We are not able to solve this problem analytically and therefore provide numerical solutions for a number of cases.

Figure (5) shows the solution to this optimization problem when the bank is able to revise its portfolio four times between annual audit dates[21]. The parameters used are: $D = 100$, $\widehat{k} = 4\%$, $C = 1$, $v = 0$, $r = 5\%$, $\sigma = 10\%$, the endogenous optimal level of capital, k^*, is equal to 4%.

[Insert FIGURE (5) about here]

Panels (a), (b) and (c) show the optimal investment in the risky asset as a function of A/D at revision dates 1 (panel (a)), 2 (panel (b)) and 3 (panel (c)). At time zero the optimal portfolio is entirely invested in the risky asset. Panel (a) shows that at date 1, i.e., at $t + \Delta t$, the optimal solution is not long always boundary and, for a wide range of values, the investment in the risky asset is substantially less than 100%. Panel (b) shows that at date 2, i.e., at $t + \Delta t$, for asset values greater than $(1 + k^*)D$ the strategy is similar to portfolio insurance, i.e., as the asset value falls towards $(1 + k^*)D$ the proportion of the portfolio invested in the risky asset is reduced. In this range, the strategy is dominated by the need to reduce the fix costs of recapitalization. For asset values below $(1 + k^*)D$ the bank "gambles for

[21]Starting with an arbitrary franchise value at audit date $t+1$ we solve for the franchise value at date t using backward induction and a multi-nominal approximation to the log-normal distribution (with 100 points). We than iterate until the franchise values at dates t and $t+1$ are equal.

resurrection" and maximizes its investment in the risky asset to increase the value of the deposit insurance put. The portfolio strategy at date 3 (Panel (c)) is similar to the date 2 strategy but more extreme.

As shown in Pelizzon and Schaefer (2004), this strategy has a significant effect on the distribution of the bank's asset at audit time. Figure (6) compares the distribution of the asset value at the audit date with and without risk management.

[Insert FIGURE (6) about here]

As shown in Figure (6) a result of the discontinuity in the portfolio policy is that the distribution is bimodal with one mode above $(1+k^*)D$ and the other below. The shape of this distribution, compared to the distribution generated without portfolio management, allows us to understand the effect of the portfolio policy on the probability of default and the value of deposit insurance. In particular, as shown in Pelizzon and Schaefer (2004), under risk management the one-to-one relation between π and PVDIL is no longer guaranteed. Indeed, with portfolio revision the asset risk is, in some states, lower than the maximum and so the average risk is also lower. We might expect, therefore, that both π and PVDIL would be lower in the latter case. In fact, while the probability of default is indeed lower, the PVDIL is higher. As mentioned above, this occurs because the shape of the distribution in these two cases is different. The rents earned by the bank are generated by exploiting the deposit insurance and so, to exploit this source of rents to the maximum, the bank uses risk management to increase the expected loss in those cases where the bank does default while simultaneously increasing the probability of survival and therefore the length of time the shareholders expect to receive dividends before closure.

A consequence of our analysis is that the value of deposit insurance is affected by banks' ability to engage risk management; ignoring this feature is likely to lead to an understatement of the cost and unreliable conclusions about the consequences of bank capital regulation. This observation is central to the analysis performed in the remainder of this paper.

6 Risk Based Capital Requirements (Pillar 1)

Under the 1988 Accord a bank's required capital was a linear function of the amount invested in risky assets. More recent rules rely on the VaR (Value-at-Risk) framework. In our model we assume that capital requirements are proportional to the amount invested in the (one) risky asset. Thus our approach is obviously consistent with the earlier Accord. Moreover, because there is only one risky asset, the portfolio VaR depends simply on, w_j, the amount invested in the risky asset and thus our characterization of capital rules is also consistent with the more recent VaR based approach.

We assume a VaR based capital rule in which the required level of capital is proportional to the VaR of the portfolio $K_R = \alpha VaR(A)$, where K_R is the required capital given the portfolio composition of bank's asset. In our framework this may be written as:

$$k_R = \lambda w_j \frac{A_j}{D_j} \tag{16}$$

where k_R is the required amount of capital expressed as a percentage of deposits and λ is the required capital per unit of investment in the risky asset. In the case with constant portfolio positions and normally distributed asset values, for example, λ is the product of (i) the number of standard deviations defining the confidence level, (ii) the volatility of the rate of return on risky assets and (iii) the scaling factor λ.

Under this rule, which we imply in the paper, the bank's investment in the risky asset at each portfolio revision date, w_j, is constrained according to:

$$w_j \leq k_j \frac{D_j}{A_j} \frac{1}{\lambda} \equiv \overline{w}(k_j, \frac{D_j}{A_j}, \lambda) \tag{17}$$

where $\overline{w}$ represents the maximum permissible investment in the risky asset for a given ratio of deposits to assets and to a percentage of capital k_j defined as:

$$k_j = \frac{A_j - D(1+r)^{1/n}}{D}. \tag{18}$$

One of the main objectives of our paper is to analyze the effects of capital regulation on bank risk taking. However, our analysis to this point assumes an environment that is entirely unregulated except for the periodic audits when, if the percentage of capital is lower than $\widehat{k}$ the bank must either recapitalize or is closed. Between audits, however, we have assumed that the bank has complete freedom to choose the risk of its portfolio even if insolvent.

In practice banks are required to observe capital requirements continuously through time and face censure, or worse, if they are discovered, even ex-post, to have violated the rules. However, if (i) asset prices are continuous, (ii) capital rules are applied continuously through time and (iii) capital rules force banks to eliminate risk from their portfolio when their capital falls below a given (non negative) level, a bank's probability of default becomes zero[22].

With continuous portfolio revision the only way to avoid this unrealistic conclusion is to assume – perhaps not unrealistically – that banks are able to continue to operate, and to invest in risky assets, even when in violation of either, or both, the leverage/PCA constraint $\widehat{k}$ and the risk-based capital requirements (RBCR). Without some assumption of this kind the analysis of the effect of capital requirements in a dynamic context is without content. However, in order to say something about the effects of capital requirements in this case, we must also say something about the extent to which banks are able to deviate from regulatory constraints on leverage and exposure to risky assets. In other words, we have to make assumptions about the extent to which banks are able to "cheat".

We consider two different levels of "cheating":

1. *One-Period capital requirements (OP)*: Here, capital requirements are binding only when there is an audit; at all other times the bank faces no constraints on its portfolio. Moreover, irrespective of its portfolio composition prior to audit, any solvent bank may reorganize its portfolio to meet capital requirements but is then constrained to hold this portfolio up to the next portfolio revision date. In all other periods the portfolio is unconstrained. In this highly ineffective capital requirements regime, a regulator is able to monitor and control the activities of banks only at the time of an audit.

$$0 < w_t \leq k\frac{D}{A}\frac{1}{\lambda} \text{ and } 0 < w_{t+j\Delta t} \leq 1 \tag{19}$$

2. *Lower Bound capital requirements*: Between two audit dates, the maximum exposure of the bank to the risky asset is the greater of (i) the level determined by its capital at the earlier audit date and (ii) the exposure based on its actual capital at the time. Here, the capital requirements regime is much more effective than under the "One-Period" rule. Its main deficiency is that banks are able to conceal any decrease in capital from the level observed

[22] As mentioned above, in this setting, the relevant assumption is the absence of jumps in the value of the entire portfolio, a much less stringent constraint than the absence of jumps for any single claim in the portfolio.

by the regulator at the previous audit date and are therefore able to invest in the risky asset up to an amount determined either by this amount or their actual capital, whichever is higher.

$$w_j \leq \max(k_j \frac{D_j}{A_j} \frac{1}{\lambda}; k \frac{D}{A} \frac{1}{\lambda}) \equiv \overline{w}_m \tag{20}$$

It is worth noting that these rules are different only when banks are able to engage in risk management since, otherwise, banks choose their portfolios only on the date of audit date when, under both regimes, they comply with capital requirements.

We now ask how the introduction of risk-based capital requirements and PCA/Pillar 2 affects risk taking when banks are able to engage in risk management and when capital requirements are imperfectly enforced.

7 Results

We study the effects of these two different cheating regimes in terms of the four output variables. We analyze first the impact of risk-based capital requirements (RBCR), as described above, when recapitalization is subject to proportional costs and then introduce PCA/Pillar 2.

In our model at each audit date the bank chooses its level of capital taking into account the constraints that RBCR place on its decisions. The endogeneity of the bank's capital decision, together with the opportunity for insolvent banks to recapitalize[23] is critical and differentiates our approach from much of the previous literature on RBCR (see Rochet (1992), Marshal and Venkatarman (1999), Dangle and Lehar (2003)).

Figure (7) shows the effect of changing λ, the required capital per unit of investment in the risky asset, on the bank's optimal choice of capital, k^*.

[23]Surprisedly, little research on banking treats either the level of capital or the franchise value as endogenous and little research takes into account either the dynamic risk management or the options to recapitalize or close. An analysis of endogenous capital closely related to our own is Froot and Stein (1998). They assume convex costs of capital issue and examine the implications for bank risk management, capital structure and capital budgeting. But they do not allow for bank regulation or deposit insurance and, since theirs is a static model, they are unable to explore the potential implications of an endogenous franchise value. Another is Milne and Whalley (2001) but they do not consider risk-based capital requirements.

[Insert FIGURE (7) about here]

In the previous section we found that, for the parameters considered, without regulation and with deposit insurance as sole source of rent, the bank always chooses the lowest level of capital. This conclusion holds whether or not the banks engages in risk management.

Under RBCR the bank must chooses a level of capital simultaneously with a dynamic portfolio strategy. This policy also depends on the RBCR regime, i.e., the extent to which it is able to "cheat". As we show below, both the level of capital, k^*, and the dynamic strategy are strongly affected by the RBCR parameter, λ, and the "cheating" regime.

RBCR introduce a trade-off between the level of capital, k^*, and the investment in risky assets, w. For a given value of λ, a higher level of capital allows a higher investment in the risky asset and thus a higher franchise value but, at the same time, a higher level of capital increases the value of bank assets and so reduces the value of the deposit insurance put and, therefore, the franchise value. Changing either λ or the RBCR regime ("cheating") changes the trade-off and, therefore, the optimal choice of capital.

It could be argued that cheating on the part of banks is also endogenous but, for these purposes, we regard the cheating regime as exogenous. Figure (7) shows that, under OP, RBCR are so ineffective that banks optimally choose a zero level of capital. In this case, in general, banks wish to invest as much as possible in the risky asset and, when λ is low, they choose the minimum[24]. Because banks wish to maximize their holding in the risky asset, when λ is low they increase k^* as λ increases from 1% to 3%. But when λ is increased beyond 3% the effect of increasing (these admittedly highly ineffectual) capital requirements is to decrease the amount of capital that banks choose to hold. In terms of the trade-off between w and k^* the bank initially increases capital to maintain the investment in the risky asset and, for λ>3% then reduces capital and reduces the average investment in the risky asset.

Under the Lower Bound RBCR regime, however, the trade-off is different, although the precise outcome depends on the (variable) cost of recapitalization. For the parameters considered, and because under LB RBCR are more effective, the bank increases its level of capital, k^*, in order to maintain its

[24] This may appear to be a rather pessimistic view of bank behavior since, in this case, a bank's only activity is to try to exploit deposit insurance. Two caveats should be made, however. First, banks' willingness to take risk is, in general, reduced when there are costs to recapitalisation. Second, when banks have other sources of rents, e.g, from assets or deposits, these also act as a natural curb on excessive risk taking. In both cases CR will be less necessary.

investment in the risky asset.

At this point we might consider for a moment the possibility that the extent of cheating is endogenous. When λ is low ($\lambda < 3\%$) the reduction in the value of the bank's equity (and therefore its franchise value) from adopting the more restrictive LB regime is also low. However, for high values of λ, and as the cost of recapitalization increases, the reduction in equity value gives the bank a strong incentive to choose the less restrictive regime and "cheat more".

Figure (8) shows the effect of changing λ on our second output variable, the value of deposit insurance liabilities, PVDIL.

[Insert FIGURE (8) about here]

The effect of changing the capital requirements parameter, λ, on PVDIL can be easily understood in terms of its effects on k^*. We consider first the case when the RBCR regime is ineffective (OP). As Figure (8) shows, when banks are able to manage their portfolio dynamically and therefore optimally choose very low levels of capital, increasing λ is ineffective as a means of reducing the value of deposit insurance liabilities. In other words, because, for values of $\lambda > 3\%$, the marginal impact of increasing λ on the amount of capital that banks actually hold is small, its impact on PVDIL is also necessarily small.

However, under the more effective LB regime, increases in λ are much more effective in reducing PVDIL. In this case banks choose to increase their capital in order to maintain their investment in the risky asset and this increase in capital reduces PVDIL. Allowing for the behavioral response on the part of banks is critical to a proper evaluation of the effects of changes in regulation (λ) and, in the "Quantitative Impact Analysis" (QIS) carried out by the Basel Committee, the behavioral response was ignored. Our results also emphasize that the behavioral response itself depends on the way the formal rules actually work in practice, i.e., the scope they give for banks to cheat.

The results for the probability of bank closure π, the third output variable, are consistent with the first two. Figure (9) shows, once again, that when RBCR are ineffective, increasing λ does not reduce the probability of failure. As before the results for OP have two regimes. For $\lambda < 4\%$, firms "voluntarily" comply with capital requirements and so an increase in λ decreases π. For $\lambda \approx 4\%$, however, the level of capital, k^*, falls to almost zero and π increases. For higher levels of λ firms also hold almost no capital and π remains high. Under, LB, on the other hand, π falls monotonically as λ increases. As we point out below, however, this result does not come about because, as λ increases, banks reduce reduce their investment in the risky asset but because they hold higher levels of capital. However, when the cost of recapitalization is high the opposite applies and π falls as λ increases because banks' holdings of the risky asset are lower.

[Insert FIGURE (9) about here]

The last output variable that we consider is the average investment in the risky asset. As described earlier, we use this variable as an (imperfect) measure of the volume of credit services provided by banks. In the absence of such a measure we might conclude that the optimal regulatory design was a capital requirements regime so stringent that banks effectively eliminate risky assets (e.g., loans) from their balance sheets.

The results here are interesting and, perhaps, not immediately obvious from those just discussed. Under the ineffective OP regime, Figure (10) shows that increasing λ reduces the average investment in the risky asset even when it has little effect on the amount of capital held. Under LB rule, however, the average investment in the risky asset is approximately constant for all values of λ between 1% and 10%. If the objective of capital regulation is to moderate bank risk taking – the cost of deposit insurance and the frequency of failure – while maintaining bank lending activity, then it is interesting to see that both the former and the latter are more favorable under a more effective capital requirements regime. It might be imagined that, as capital requirements becomes less effective, banks respond by decreasing capital and increasing their investment in the risky asset. In fact, in our setting, a less effective capital requirements regimes does indeed lead to reductions in capital but also to reductions in the volume of risky assets held.

[Insert FIGURE (10) about here]

7.1 Pillar 1 and Pillar 2 (PCA)

Finally, we consider how PCA/Pillar 2 affects the impact of λ on our four output variables. Recall that, in our framework, PCA/Pillar 2 acts as a minimum capital requirement or maximum leverage constraint at the time of an audit. As described earlier, if a bank violates the PCA constraint at audit and chooses to recapitalize it incurs a fixed cost. Figure ((11) shows the relation between each of the four output variables and λ. In our calculations, $\widehat{k}$, the minimum capital level is set at 4%.

[Insert FIGURE (11) about here]

In the case of the OP regime the effect of PCA on capital is simple: without PCA banks hold almost no capital; with PCA they hold the PCA minimum. Under LB the effect depends on the level of λ. When PCA is binding, for low levels of λ, $k^* = 4\%$. for high levels of λ, when the value of k^* that banks choose in the absence of PCA is much higher than 4%, and so introducing PCA has no effect. But when $\lambda \approx 4\%$, the introduction of PCA increases k^*, in some cases to values higher than 4%, as a result of the effects of the fixed cost of recapitalization.

The effects of PCA/Pillar 2 on PVDIL mirror those on capital. Under the OP regime, the increase in capital brought about by PCA/Pillar 2 produces a marked reduction in the PVDIL. Under the LB regime, there is a reduction in PVDIL for all values of λ: large for low values of λ and small for high values. Overall, then, PCA does a good job in reducing PVDIL. When there is a great deal of cheating, PVDIL is reduced substantially. With little cheating the effects are more modest except where PCA/Pillar becomes a binding constraint at audit.

Without PCA/Pillar 2 the capital decision under OP has two regimes: voluntary compliance for low levels of λ and almost zero capital for high λ. Under PCA/Pillar 2 in our calculations, there is just one regime as PCA/Pillar 2 becomes a binding constraint. As a result, the two regimes for the probability of failure, π, becomes one regime under PCA/Pillar 2 with an almost constant level of π for all values of λ. For low values of λ, π is somewhat higher than without PCA/Pillar 2; for high levels it is somewhat lower. Under the LB regime π is higher for all values of λ as a result of the fixed cost of recapitalization. Under PCA/Pillar 2 a firms that has a capital ratio less than the threshold value $\widehat{k}$ incurs a recapitalization cost and will choose to only if this cost is less than the franchise value.

The results on investment in the risky asset can also be understood in terms of those obtained earlier. Under PCA/Pillar 2 firms hold more capital but incur a cost in recapitalization and, in general, reduce their holding of risky assets to avoid this cost. The one exception is under OP for high values under λ where, without PCA/Pillar 2, the optimal trade-off is to hold almost no capital and a low level of risky assets. Under PCA/Pillar 2 the level of capital is higher and banks are therefore able to increase their holdings of the risky asset without incurring excessive recapitalization costs. This reinforces our earlier point that compliance can leads to higher investment in risky assets.

8 Conclusion

This paper investigates the complementarity between Pillar 1 (risk-based capital requirements) and Pillar 2/PCA and, in particular, the role of closure rules with costly recapitalization and where banks are able to manage their portfolios dynamically.

A feature of our approach is to consider the costs as well as the benefits of capital regulation and to do so in a way that accommodate the behavior response of banks in terms of their portfolio strategy and capital structure and, further, the extent to which capital rules are effective, i.e., the extent to which banks can "cheat".

We measure the effects of capital regulation, for both Pillars 1 and 2, in terms of four output variables that we use as proxies for the costs and benefits – both private and social – of capital regulation.

In our analysis we make the perhaps extreme assumption that the only source of rents in the banking system is generated by deposit insurance. In this setting, we know from Merton's (1977) static model that banks will choose the portfolio with the maximum risk. However, we show that in a multiperiod setting, taking into account the option for costly recapitalization, banks have an incentive to manage their portfolios dynamically. Without the fixed costs associated with Pillar 2/PCA intervention, we show that, in general, RBCR induce a bank to hold more capital unless it is able largely to avoid the constraints that the RBCR rules impose, i.e., that they are able to cheat. If a bank can choose the extent to which it cheats, it has an incentive to cheat more when the levels of RBCR are high.

In our results we distinguish between a regime where RBCR are relative ineffective and where they are effective. When RBCR are effective they reduce the cost of failure as measured by the probability of closure and the PVDIL. Importantly, when RBCR are effective we find that the level of investment in risky assets is relatively unaffected by the level of RBCR. On the other hand when they are ineffective we find that increasing capital requirements reduces banks' investment in risky assets and increases the probability of failure.

The second question that we address is whether an intervention rule in the spirit of PCA/Pillar 2 and based simply on leverage rather than portfolio risk, is effective in conjunction with RBCR. We show that PCA/Pillar 2 is indeed effective in reducing PVDIL: substantially when RBCR are ineffective and more modestly when RBCR are more effective. When banks cheat a great deal and RBCR are high, PCA/Pillar 2 induces banks to increase capital, reduces the probability of closure and increases the investment in risky assets. However, when RBCR are more effective PCA/Pillar increases the probability of bank closure and decreases the amount invested in risky assets.

In summary, Pillar 2/PCA may help to penalize the "lemons" in the banking system. However, it is important that, in deciding on the parameters that determine how this form of intervention is implemented, regulators take into account the differential effect that PCA/Pillar 2 has on banks that are more effectively regulated versus those that are not.

Appendix

Proof of LEMMA 1:

Assuming that the risky asset distribution is lognormal and constant portfolio proportion imply that:

$$S = (1+r)^{-1} \int_{D_t + kD - S}^{\infty} (A_t - D_t - kD - S)\, f(A_t) dA_t$$

Clearly this is the value of a call option; increasing the investment in the risky asset the bank rises the volatility of the asset A_t and so the value of equity (i.e. the value of the call option).

Q.E.D.

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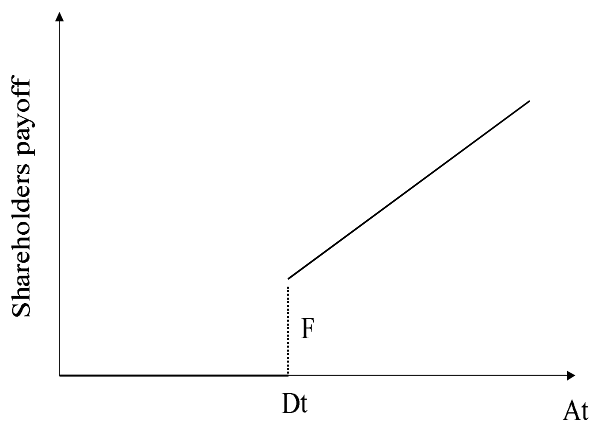

Figure 1: **Shareholders payoff without the option to recapitalize**
This Figure shows the shareholders payoff at next audit time under threshold closure rule.

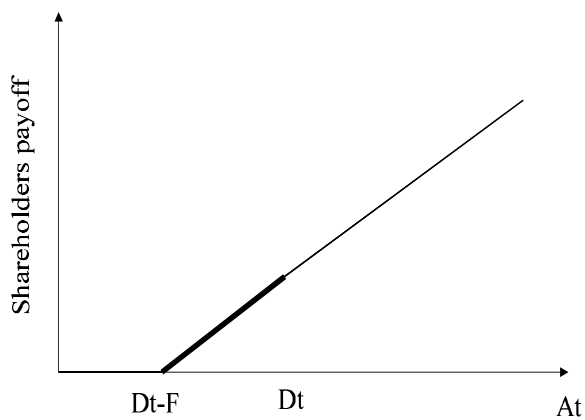

Figure 2: **Shareholders payoff *with* the option to recapitalize**
This Figure shows the shareholders payoff at next audit time under option to recapitalize closure rule.

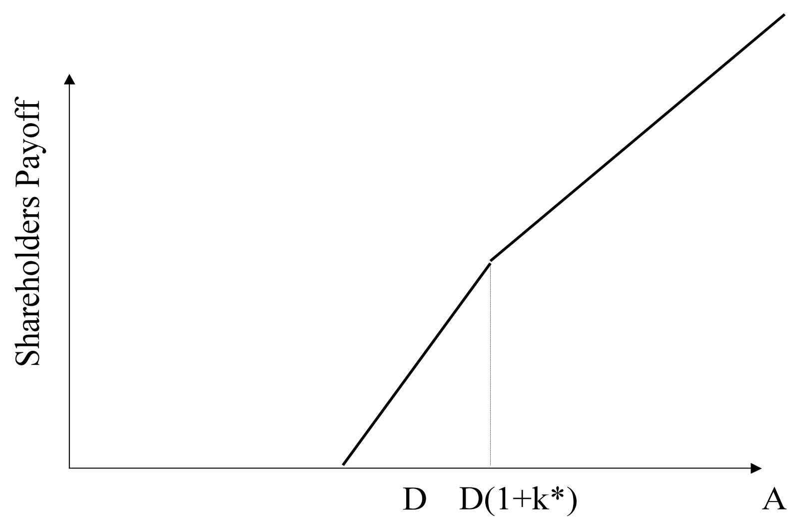

Figure 3: **Shareholders payoff with proportional costs**
This Figure shows the shareholders payoff at next audit time under option to recapitalize closure rule and proportional costs of recapitalization.

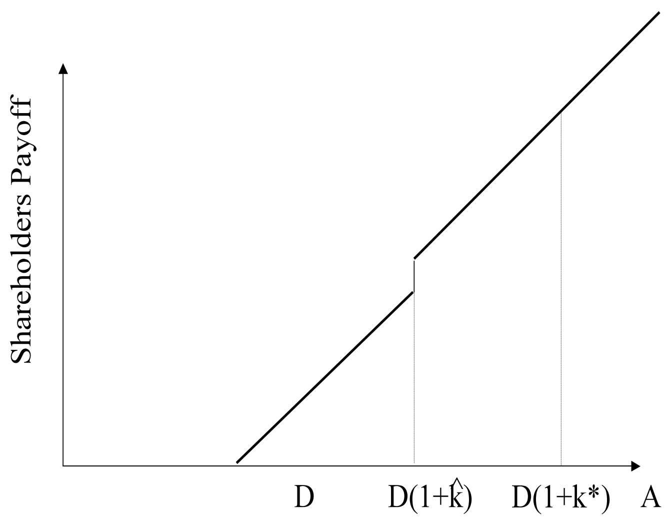

Figure 4: **Shareholders payoff with fix costs**
This Figure shows the shareholders payoff at next audit time under option to recapitalize closure rule and Pillar II/PCA fix costs of recapitalization.

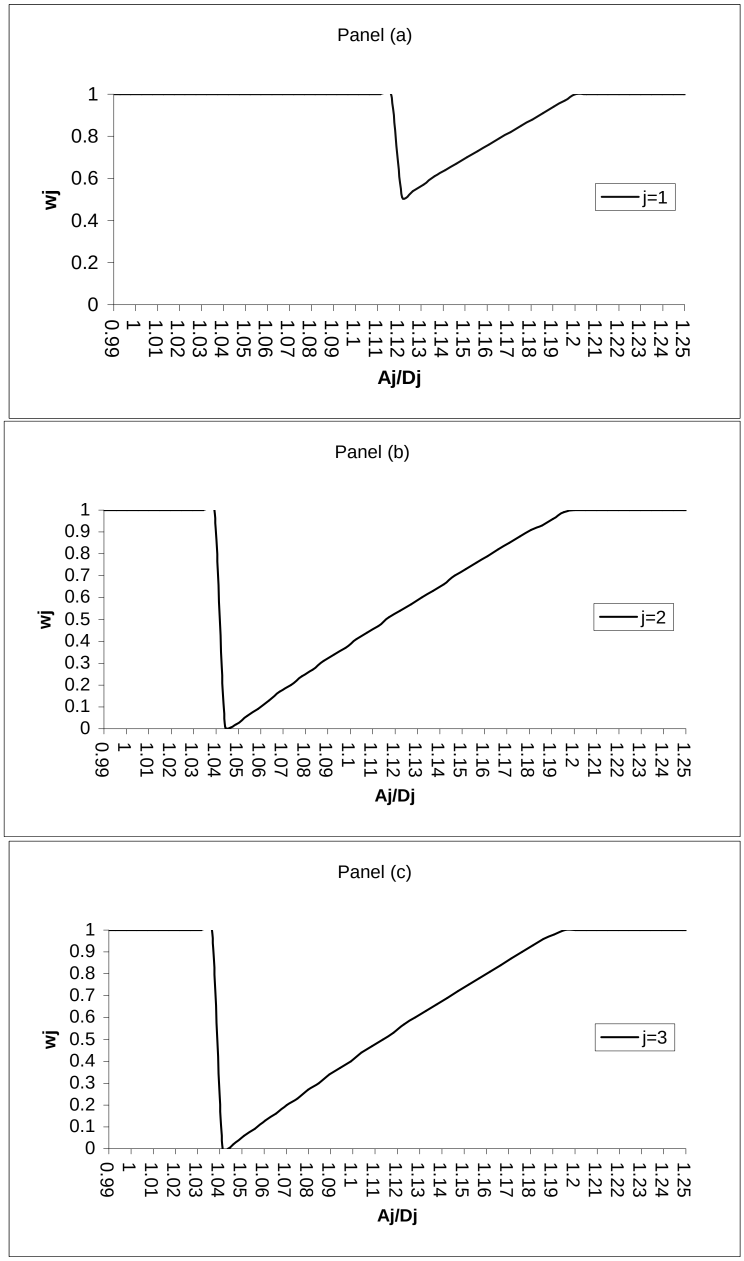

Figure 5: **Optimal portfolio strategies and the distribution of asset value**

This Figure plots the optimal strategies conditional on time to audit and the distribution of asset value at different times. We consider an audit frequency of one year. The parameters used are: $D = 100$, $k = 5\%$, $n = 4$, $r = 5\%$, $\sigma = 10\%$, $C = 1$.

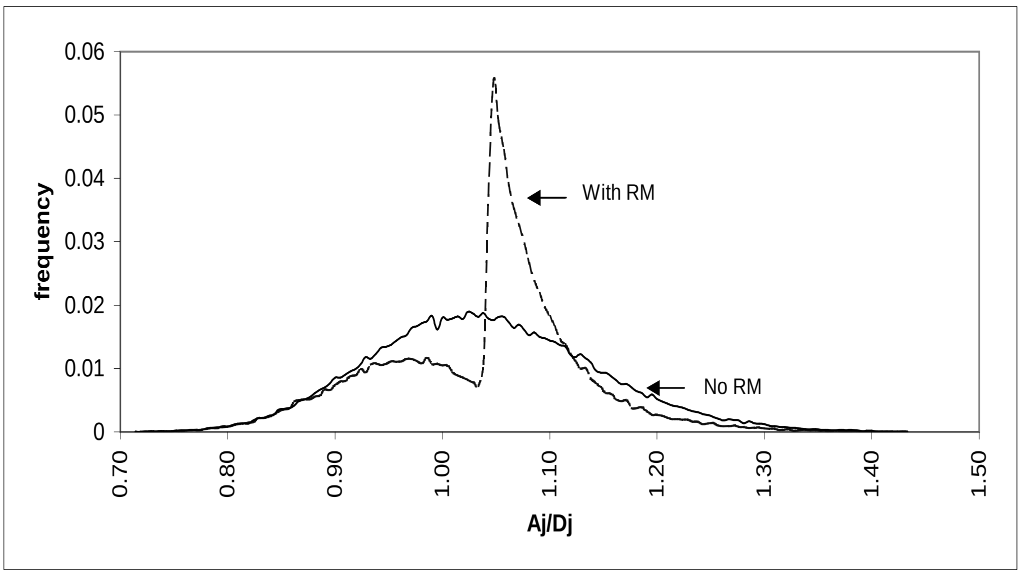

Figure 6: **Bank asset distribution**

This Figure plots the distribution of the asset value at the audit date for two portfolio policies. The first is the optimal dynamic policy, the second is a policy that invests 100% of the portfolio in the risky asset. The parameters used are: $D = 100$, $k = 5\%$, $n = 12$, $r = 5\%$, $\sigma = 10\%$, $C = 1$.

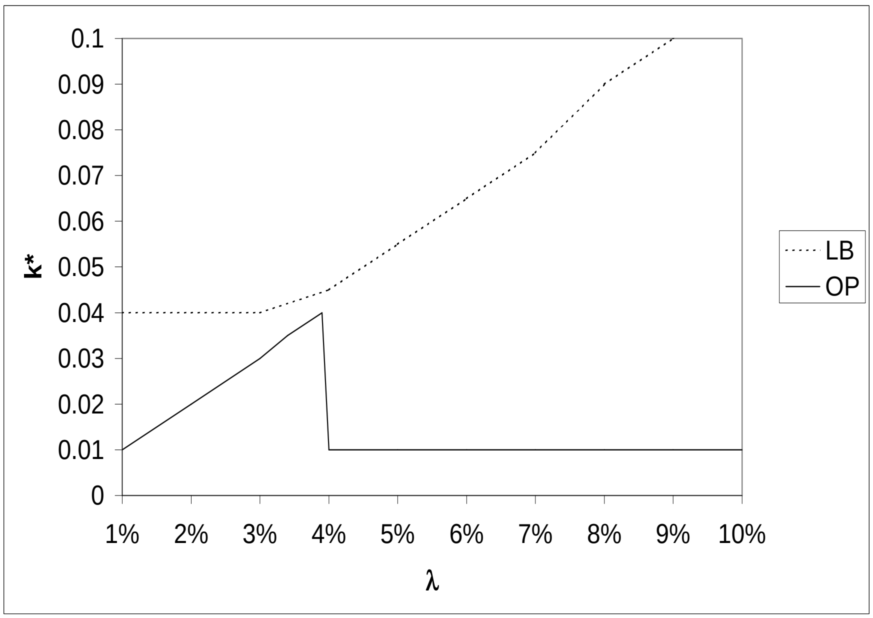

Figure 7: **Endogenous level of capital**

This Figure plots the effect of changing the required capital per unit of investment in the risky asset (λ) on bank's optimal choice of capital k^*. The parameters used are: $D = 100$, $k = 5\%$, $n = 4$, $r = 5\%$, $\sigma = 10\%$, $v = 5\%$.

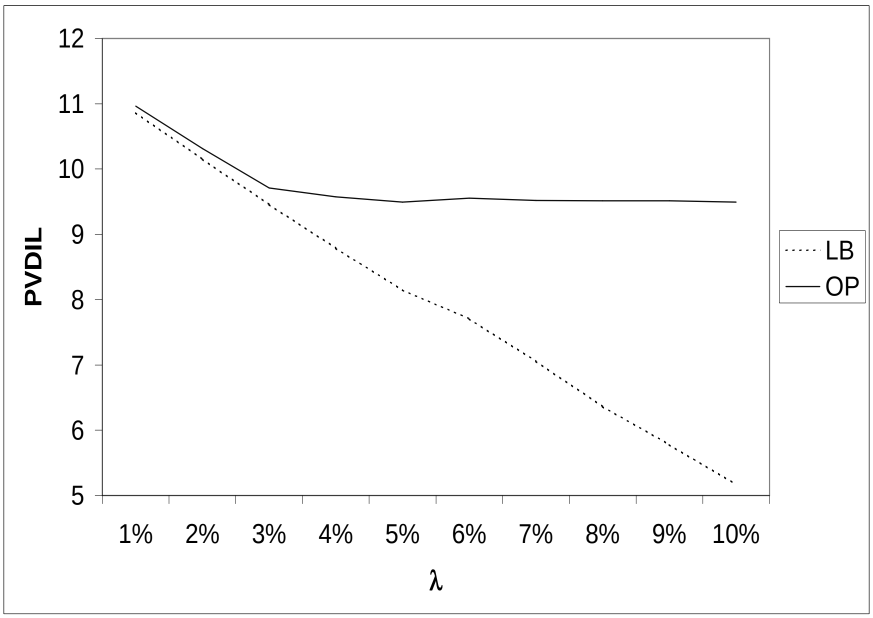

Figure 8: **Present Value of Deposit Insurance Liability**
This Figure plots the effect of changing the required capital per unit of investment in the risky asset (λ) on the cost of the deposit insurance. The parameters used are: $D = 100$, $k = 5\%$, $n = 4$, $r = 5\%$, $\sigma = 10\%$, $v = 5\%$.

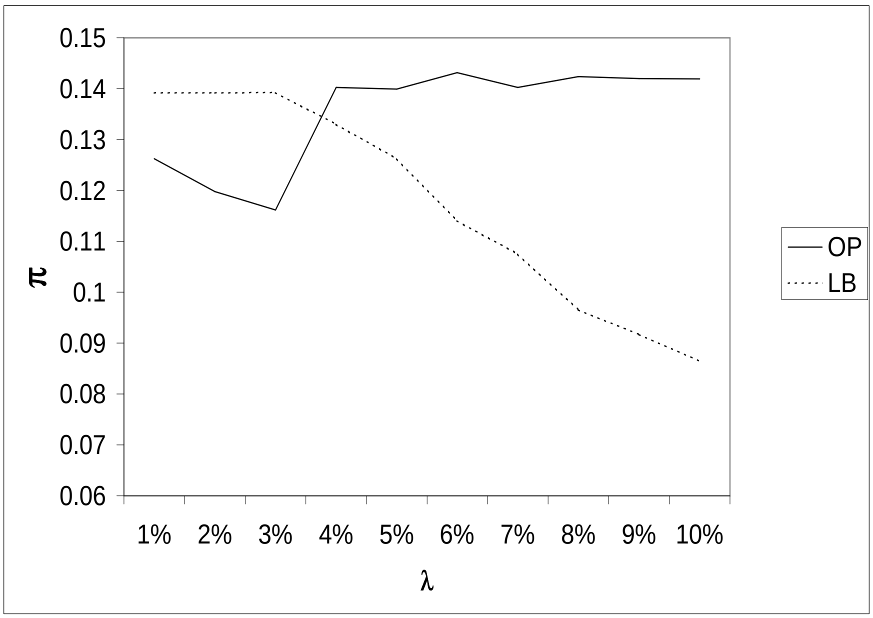

Figure 9: **The probability of bank closure**

This Figure plots the effect of changing the required capital per unit of investment in the risky asset (λ) on the probability of bank closure. The parameters used are: $D = 100$, $k = 5\%$, $n = 4$, $r = 5\%$, $\sigma = 10\%$, $v = 5\%$.

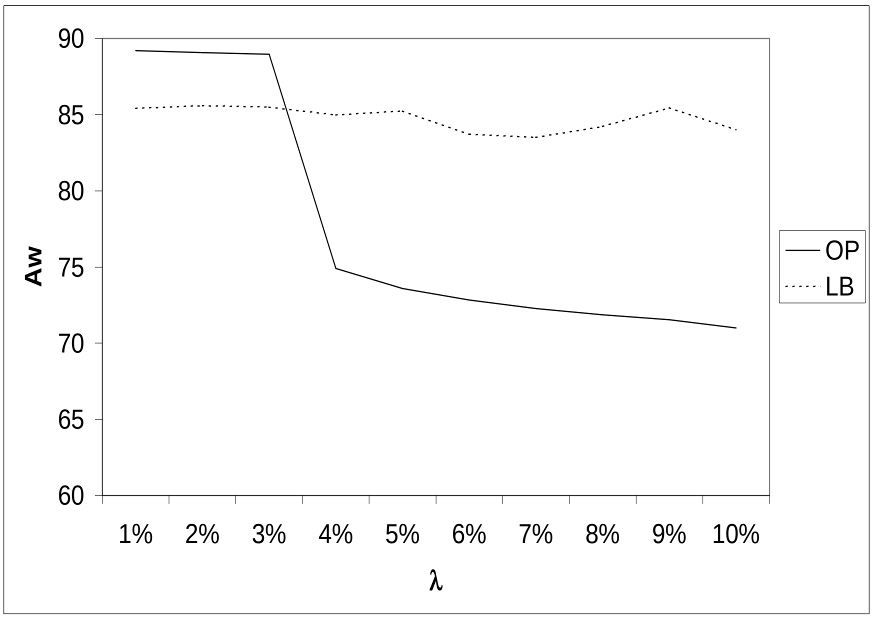

Figure 10: **Average investment in the risky asset**

This Figure plots the effect of changing the required capital per unit of investment in the risky asset (λ) on the average investment in the risky asset. The parameters used are: $D = 100$, $k = 5\%$, $n = 4$, $r = 5\%$, $\sigma = 10\%$, $v = 5\%$.

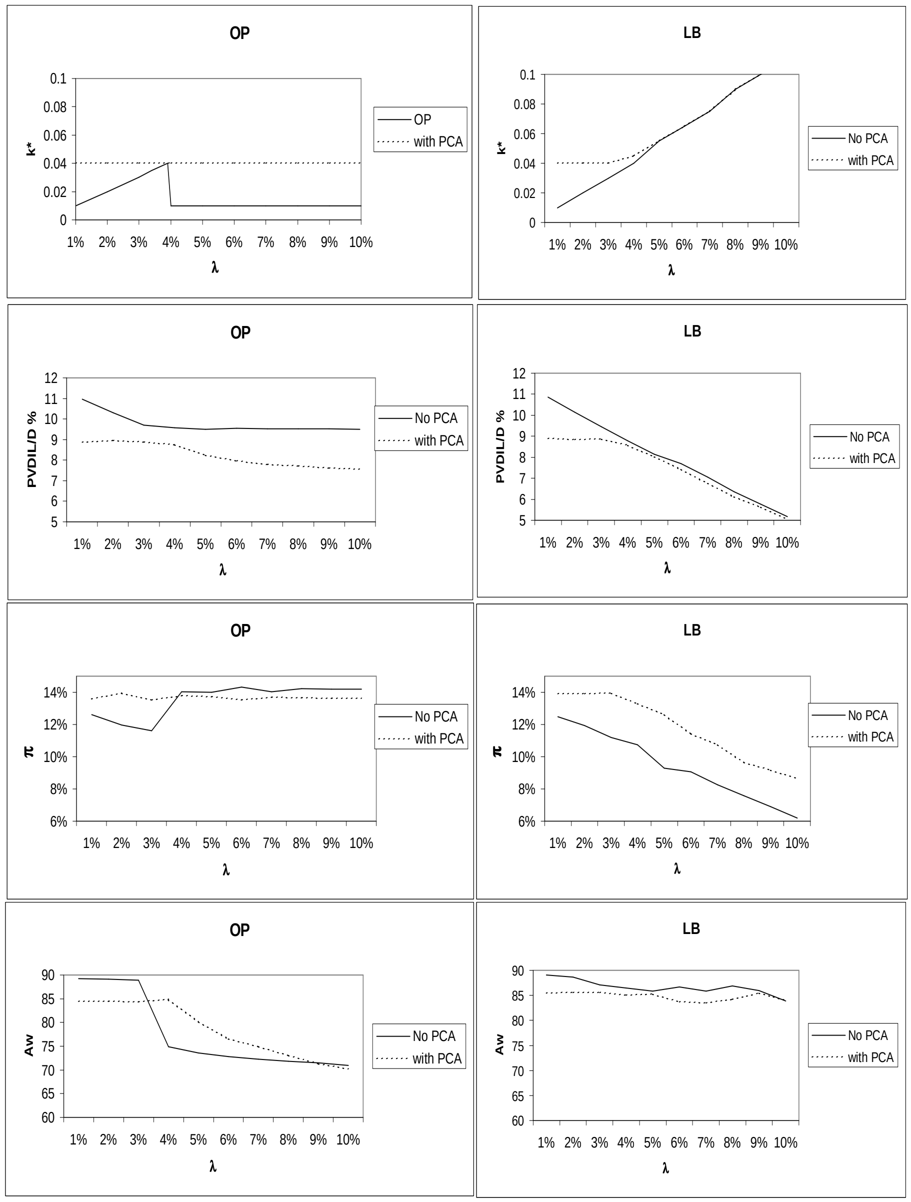

Figure 11: **Pillar 2/PCA**

This Figure plots the effect of changing the required capital per unit of investment in the risky asset (λ) on the four output variables under Pillar 2/PCA. The parameters used are: $D = 100$, $k = 5\%$, $n = 4$, $r = 5\%$, $\sigma = 10\%$, $v = 5\%$, $C = 1$.