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Bank capital regulation as an incentive mechanism: Implications for portfolio choice ☆

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Abstract

This paper contrasts the conventional interpretation of prudential capital regulation as a system of ex ante enforcement ('hard wired') with an alternative interpretation as a system of sanctions for ex post violation ('incentive based'). Under the incentive based interpretation risk-weightings affect portfolio choice only when assets are illiquid. Under both interpretations, the medium term impact on portfolio allocation depends upon the relative costs of debt and equity finance. Viewing enforcement as incentive based suggests there is relatively less need to match risk weightings accurately to portfolio risk. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

1.1. Bank capital regulation as an incentive mechanism

Virtually all analysis of the impact of bank capital regulation assumer that capital regulations are hard wired into the decision making of banks, i.e. that prudential capital requirements are binding constraints on bank behaviour. [1] But this assumption is unrealistic. Bank supervisors have only limited resources and are unable to monitor continuously the position of the banks. Even when they observe a breach of regulations they do not acquire absolute control over the operation of the bank concerned. All that is available to them is a range of interventions such as involvement in the management process, public rebuke, and – the ultimate weapon – withdrawal of the banking license. [2]

The view that capital is directly controlled by regulators is moreover inconsistent with even the most casual analysis of bank balance sheets. See Table 1 which reports summary statistics for the Basel risk weighted total capital ratios recorded in the Fitch-IBCA 'Bankscope' database of bank accounting data.

Banks almost always hold capital in excess, often substantially in excess, of regulatory requirements. Where regulatory requirements are breached they are often breached by a margin. Almost never do banks hold exactly the minimum amount of regulatory capital.

For these reasons the standard analysis, convenient as it is, must be considered suspect. An alternative account, suggested by Milne and Elizabeth Whalley (1999, 2001), is to view prudential capital regulations as an incentive mechanism, with some penalty imposed on the bank in the event of a breach. [3] These penalties need not be monetary. Any form of regulatory intervention will

[1] This hard wired assumption appears in virtually all the journal literature, including Kahane (1977), Koehn and Santomero (1980), and many subsequent papers. See Freixas and Rochet (1997, Sections 8.3.3 and 9.5.1) for a review.

[2] The nature and operation of sanctions vary considerably from one jurisdiction to another. In the US these operate under the framework of the 1991 FDICIA act, detailing a scale of actions for increasingly severe declines of capitalisation. In other countries regulatory intervention is more a matter of supervisory judgement. Ultimately however supervisory power rests on the threat of public rebuke and the legal powers of the supervisors including in extremis the removal of the banking license.

[3] This is an 'incentive mechanism' in a loser sense than the phrase is used in much of the economic literature on regulation. The optimality of bank regulation as an incentive mechanism is not addressed. For a discussion of optimality of bank regulation see Giammarino et al. (1993), who address the trade-offs between achieving financial safety and soundness via insurance of deposits and via bank capital regulation. Nor is it being argued that bank regulation is incentive compatible, in the sense that it induces banks to reveal hidden information or take actions desired by the regulator.

Table 1
Distribution of Basel risk weighted total capital ratio

	Required minimum level 8%			
	1999	1998	1997	1996
Number of banks	2456	2453	2232	2110
1 percentile	6.0	6.9	7.3	7.4
5 percentile	9.0	9.1	9.0	9.0
10 percentile	10.0	9.9	9.9	9.7
25 percentile	11.0	10.9	11.0	11.0
Median	12.7	12.9	13.2	13.1
Mean	16.4	16.8	16.7	16.9

All OECD banks reporting ratio to Fitch-IBCA.
Source: Fitch-IBCA CD-ROM database, August 2000.

impose costs on bank management and shareholders, including *inter alia* diversion of scarce management time to engage in negotiations with regulators; equity dilution in the event of an emergency infusion of capital; and loss of credit standing leading to an increased costs of funds when capitalisation approaches minimum levels.

In the continuous time setting examined in Milne and Elizabeth Whalley (1999, 2001), the incentive effects of imposing a penalty when banks breach the regulatory capital requirement induces banks to hold a buffer of free capital over and above this regulatory requirement. [4] This is therefore one explanation for the fact that observed capital holdings typically substantially exceed minimum levels. [5] The present paper takes this perspective a step further and examines the implications of such an incentive mechanism for bank portfolio choice. It turns out that the portfolio impact of capital regulation differs in a number of important respects from that predicted by a conventional assumption of hard wired capital regulation.

Viewing capital regulation as an incentive mechanism also indicates that, provided the penalties for breach of capital requirements are heavy enough, reduction of bank portfolio risk can be achieved with relatively crude risk

[4] It turns out, moreover, that bank attitudes towards risk then depend upon the buffer of capital in excess of the regulatory minimum, not on the absolute level of capital. In this continuous time set up moral hazard emerges, even with 100% deposit guarantees, only when capital declines below the regulatory minimum.

[5] The Basel Committee (1999) attributes the holding of capital in excess of required regulatory levels to 'market discipline' i.e. pressure from debt holders and rating agencies. This however does not explain excess capital holdings by smaller banks who do not borrow on interbank markets or issue securities.

weightings or even simple leverage based capital requirements. There may, in other words, be scope to shift the principal responsibility for risk management away from regulators and onto the banks themselves through incentives for self-discipline. This possibility has not been explored in the current consultations on the reform of the 1988 Basel accord (see Milne and Elizabeth Whalley, 2001).

This paper is organised as follows. The following two sections discuss bank portfolio choice, contrasting the results that emerge from the conventional assumption of direct control over bank capital requirements (Section 2) with those that emerge when capital regulation operates as an incentive mechanism of this kind (Section 3). Section 4 explores some illustrative examples, discussing implications both for the operation of bank asset and liability management and for the issue of regulatory capital arbitrage. Section 5 offers concluding remarks. Formal model solution is provided in the Appendix A.

1.2. Modelling assumptions

The following assumptions are maintained throughout the analysis. A bank invests in a range of risky assets and liabilities (negative assets) $a_0^1, a_0^2, \ldots$ at the beginning of the period (indexed by $_0$) subject to the net worth constraint $C_0 = a_0^s + \sum_i a_0^i$. Here a_0^s is the holding of the safe capital certain asset (cash).

Central to the subsequent analysis is a distinction between realisable and unrealisable returns. Realisable returns are those received either in the form of cash flows or from the revaluation of assets that can be sold in a liquid market. Realisable returns can be measured at market value. Unrealisable returns are end period value of assets that cannot be sold in a liquid market. These unrealisable returns are measured according to standard accounting conventions. This is appropriate in the present context because, for assets that cannot be realised in liquid markets, accounting conventions are used to assess compliance with prudential capital requirements.

The expected value of realisable returns on asset i is denoted by r^i. The total return (realisable and unrealisable) is $r^i + \mu^i$. These expected returns are multiplicative factors, so for example an expected return of 5% on a liquid asset is represented by $r^i = 1.05$. The distribution of realisable and unrealisable returns on asset a^i is represented respectively by the two zero-mean random variables ε^i and θ^i.

There is a safe cash asset offering a certain realisable return of r^s. All returns on cash are realisable and certain, so $\mu^s = \varepsilon^s = \theta^s = 0$. Cash borrowing also costs r^s. The equivalence of cash borrowing and lending rates reflects a further assumption of unlimited shareholder liability. The analysis abstracts from

Table 2
Illustration of possible returns on different assets and liabilities

Asset	Liability			
	Expected returns		Standard deviations	
	Realisable r^i	Unrealisable μ^i	Realisable σ_{ε^i}	Unrealisable σ_{θ^i}
'Cash' ($i = s$)	1.05	0.0	0	0
Government bond	1.06	0.0	0.02	0
Equities	1.09	0.0	0.05	0
10% Loan	0.20	0.9	0.02	0.01
4% Deposit	0.04	1.0	0	0.03

considerations about the credit worthiness of the bank and neglects the possibility of bank moral hazard. [6]

Table 2 indicates how this division between realisable and unrealisable gains night operate for some typical bank assets and liabilities. Note that withdrawal of deposits, because it reduces the cash reserves and hence liquidity of the bank, is a regulatory risk. Therefore $\sigma_{\theta^i} > 0$.

Assuming that all realisable returns are converted into cash, then assets evolve according to [7]

$$a_1^s = r^s a_0^s + \sum_i (r^i + \varepsilon^i) a_0^i, \tag{1}$$

$$a_1^i = (\mu^i + \theta^i) a_0^i. \tag{2}$$

Shareholders are risk-neutral maximising the expected value of end of period net worth. [8] In the absence of any penalty imposed on shareholders, expected net worth is given by

$$E(C_1) = E\left(a_1^s + \sum_i a_1^i\right) = C_0 + r^s a_0^s + \sum_i (r^i + \mu^i) a_0^i. \tag{3}$$

[6] This is an important but separate subject. The justification for ignoring it is that most banks have sufficient charter value or expected net worth that the impact of limited liability on the cost of liabilities and on incentives to take risks is relatively unimportant. For a 'first pass' on the question of how incentive based bank capital regulation affects portfolio this is a reasonable approach.

[7] Appendix A shows that conversion of all realisable returns is an optimal policy for the specifications assumed in this paper.

[8] This assumption is made for analytical convenience. A fixed discounting of expected returns would also be appropriate were there complete markets for the risks on bank balance sheets. The more realistic assumption of risk averse shareholders and with incomplete markets would introduce an additional incentive for banks to reduce balance sheet risk.

In the short run C_0 is treated as exogenous. For medium run analysis it is assumed that shareholders are willing to provide additional capital, provided it offers an expected return of $\rho > r^s$. C_0 is then a further endogenous choice variable and the expected excess return to shareholders is $E(C_1) - \rho C_0$.

For expositional simplicity it is assumed that the distribution of returns around their expected values are independent of the amount of assets on the balance sheet. Expected unrealisable returns are also independent of the amount of assets. Expected realisable returns on the other hand are iso-elastic functions of the corresponding amounts on the balance sheet:

$$\frac{\partial(r^i - r^s)}{\partial a^i} a^i = -1/v^i.$$

Here v^i is the interest rate semi-elasticity of demand for asset or liability i, with $v^i > 0$ in the case of assets and $v^i < 0$ in the case of liabilities. [9]

2. Hard wired capital requirements

In this section it is assumed that asset choices are made subject to the beginning of period hard wired risk weighted regulatory capital constraint $C_0 \geqslant \sum w^i a^i$. The relative values of the different risk weights w^i correspond to the risk weightings suggested by requirements such as those of the Basel 1988 accord.

2.1. Short run portfolio allocation with exogenous capital

In the short run capital is exogenous, with the bank inheriting a net worth of C_0 at the beginning of the operating period. The banks decisions can be modelled as a standard Lagrangian maximisation incorporating the capitalisation constraint (see Appendix A for details). This reveals two possible solutions depending on whether or not the capital constraint binds:

(1) If the capital constraint is not binding then investment takes place in each asset up to the point at which the marginal return $r^i - 1/v^i$ from a small increase of the holding of asset a^i equals the marginal funding cost r^s: i.e. when

$$r^i = r^s - \mu^i + 1/v^i. \tag{4}$$

In this case the analysis corresponds to the standard Monti–Klein model of a monopolistic bank, and capital weights have no impact on the portfolio decision.

[9] This final assumption is introduced simply to constrain the size of the bank balance sheet. It is not essential to the principal results of the paper. The iso-elastic specification is based on the standard Klein–Monti model of bank interest rates. See Freixas and Rochet (1997) for detailed discussion and references.

(2) If the capital constraint binds then the marginal cost of funds must be adjusted to take account of the shadow price of the capital constraint times its risk-weighting, so we have

$$r^i = r^s - \mu^i + 1/v^i + \lambda w^i. \tag{5}$$

Increasing of risk weighting w^i on asset i now leads to a reduction in holding of asset i. The magnitude of this effect will depend upon how tightly the capital constraint binds. There will also be an impact on the shadow price of capital but the sign of this effect is ambiguous – it may increase or reduce other assets and liabilities. If the interest elasticity of asset demand is sufficiently large the overall effect will be to reduce the shadow price of capital and reduce holdings of other assets and liabilities.

According to this conventional analysis the impact of capital weightings on short run portfolio decisions depends upon the capital position of the bank. If it is struggling to meet with regulatory capital requirements then it reduces holdings of those assets with regulatory capital weightings. If the bank is capital rich then the weightings have no impact.

2.2. Medium term portfolio allocation with endogenous capital

In the medium term, when the bank can be expected to be able to raise additional capital through retained earnings or new issues, it is more appropriate to treat capital C_0 as endogenous. The bank's objective then becomes $E(C_1) - \rho C_0$. Assuming $\rho > r^s$, the holdings of asset a^i are financed at the margin through a weighted mix of capital C (with weight of w^i) at cost ρ and the safe asset (with weight $1 - w^i$) at a cost of r^s. [10] With this marginal cost of funds we have

$$r^i = r^s - \mu^i + 1/v^i + w^i(\rho - r^s). \tag{6}$$

Thus, in the medium term allowing for adjustments in capitalisation, a higher risk weighting for an asset will always lead to a lower holding of that asset in the bank's portfolio, but the size of this impact will depend upon the margin between the costs of equity capital and wholesale borrowing $(\rho - r^s)$.

This formulation reveals a parallel between medium term bank portfolio allocation decisions and the standard analysis of the impact of the weighted average cost of capital. [11] If the assumptions of frictionless capital markets

[10] If $\rho = r^s$ then the bank can raise an unlimited amount of capital and invest this in cash without cost to shareholders. The regulatory capital requirement never binds and has no medium term impact on portfolio choice.

[11] The parallel is masked by different conventions over the use of the term 'capital'. For bankers and bank regulators 'capital' means prudential or equity capital. In the context of capital budgeting for non-financial corporations capital means all sources of long-term funding whether from debt or equity.

underlying the Modigliani and Miller (1958) proposition are accepted, then the margin between the costs of equity capital and wholesale borrowing vanishes and regulatory capital weightings will have no impact on portfolio allocation. In practice capital market frictions such as taxation and costs of recapitalisation will have an impact on bank returns – but it remains an open question for empirical study as to how large a gap between costs of equity capital and wholesale borrowing these frictions can explain.

3. Regulation as an incentive mechanism

This section replaces the assumption that regulators can directly impose an ex ante constraint on the banks capitalisation C_0 with an incentive mechanism in which regulators monitor end period net asset value C_1 and impose a fixed (monetary) penalty of χ is imposed on shareholders if the capital requirement is found to be breached (i.e. if $C_1 < \sum w^i a_1^i$). Returns to shareholders are thus given by

$$V = \begin{cases} C_1 & \text{if } C_1 \geqslant \sum w^i a_1^i, \\ C_1 - \chi & \text{if } C_1 < \sum w^i a_1^i, \end{cases} \tag{7}$$

and the bank's decisions are taken so as to maximise $\mathbb{E}\{V\}$. This can be expressed as

$$\mathbb{E}\{V\} = \mathbb{E}\{C_1\} - \chi F(z)$$

where $F(z)$ is the cumulative distribution function for $z = C_1 - \sum w^i a_1^i$ the buffer of free capital at the end of the period assuming that the bank avoids regulatory sanction wherever possible through realisation of all realisable returns. Now, instead the portfolio decision being made subject to a binding constraint, it rests on a calculation of the probability F of the constraint binding and on the expected penalty χ when a breach occurs.

3.1. Short-run impact on portfolio allocation

In order to investigate the short run impact on portfolio allocation, we revert to the assumption that capital C_0 is exogenous. Now the required interest rate on asset i can be expressed in terms of the probability density $f(z)$ evaluated for the event of a breach just taking place ($z = 0$) (see Appendix A for derivation):

$$r^i = r^s - \mu^i + 1/v^i + \frac{\chi f(0)}{1 + \chi f(0)} \left[w^i \mu^i - \mathbb{E}(\varepsilon^i + (1 - w^i)\theta^i)|_{z=0} \right]. \tag{8}$$

What does this equation tell us?

(a) As with hard wired capital regulation the impact depends upon the level of capitalisation. However instead of there being two regimes (constraint binding and constraint not binding) there are instead a continuum of possible outcomes. Amongst these outcomes three cases can be usefully distinguished, according to the magnitude of $f(0)$ the marginal probability of a capital breach:

1. If it is well capitalised capital or has strong cash flow then $f(0)$ will be very small and the risk weightings will have little impact on portfolio decisions.
2. If the bank is both short of capital and has poor cash flow, the probability of breach of the capital regulations is both fairly high and very much dependent upon the portfolio decisions of the bank. $f(0)$ is large and risk weightings will have a substantial impact on the banks portfolio decision.
3. In the extreme case of a failing bank (one of the 'walking dead') that finds it almost impossible to avoid a breach of the capital regulations regardless of its portfolio decisions, then $f(0)$ is once again small and the weightings have little impact on portfolio choice.

(b) The risk weightings affect the portfolio decision to invest asset i only so far as the returns on asset i are unrealisable ($\mu^i > 0$). Regulatory risk weightings create no disincentive to hold liquid and realisable assets because in the event of difficulties in satisfying the regulatory capital constraint they can easily be sold. The regulatory risk-weightings penalise only holding of illiquid assets that cannot be easily realised before a regulatory audit.

Conventional wisdom holds that the Basel 1988 risk weightings distorted portfolio allocation away from highly rated corporate liabilities (weighted at 100%) and towards OECD government debt (zero weighted). But lines of credit or loans to such highly rated corporates can be easily realised (for example through failure to renew a facility, through loan sale, or via a securitisation). In the event that a bank, at some point in the future, breaches minimum regulatory capital requirements it can always reduce its exposure to large credit worthy corporates and hold OECD government debt instead. This flexibility of making portfolio readjustments implies that lending to large credit worthy corporates will be unaffected by regulatory risk weightings. Only where portfolio readjustment is relatively costly or impossible, for example loans to small and medium-scaled enterprises, will regulatory risk weightings affect portfolio choice.

(c) The decision to invest in asset i now depends not just on expected returns on that asset (r^i, μ^i), but also the joint distribution of returns on the bank's entire portfolio. Specifically, an asset will be relatively unattractive if it has relatively low returns in circumstances where the regulatory capital constraint is just breached ($\mathbb{E}\{\varepsilon^i + (1 - w^i)\theta^i|_{z=0}\} \ll 0$). This is a form of induced risk aversion that operates separately from the regulatory risk-weightings and depends upon the covariance of returns of asset i with the entire portfolio of the bank. [12] This finding parallels that of Froot and Stein (1998) who find that costs of raising external capital induce additional risk aversion in a bank's capital budgeting decision.

This final term is a form of self-discipline. Even in the absence of asset specific risk weighting ($w^i = w$ for all assets) the bank still has an incentive to avoid investment in assets that are likely to trigger a breach of the regulatory capital requirement. The strength of this incentive will depend the magnitude of the penalty χ and (as discussed above) on the capitalisation and expected earnings of the bank through their effect on $f(0)$.

3.2. Medium run impact on portfolio allocation

The analysis of capital regulation operating as an incentive mechanism can be completed by returning to the case of medium run portfolio allocation, where capital is treated as endogenous. Capital C_0 in period 0 is now raised until the marginal expected cost of infringing the capital regulations ($-\chi\partial F/\partial C_0 = \chi f(0) r^s$) equals the marginal financial cost of substituting equity for debt finance:

$$\chi f(0) r^s = \rho - r^s. \tag{9}$$

This further first order condition implies that the required rate of return on asset i is given by

$$r^i = r^s - \mu^i + 1/v^i + \frac{\rho - r^s}{\rho}\left[w^i\mu^i - \mathbb{E}(\varepsilon^i + (1 - w^i)\theta^i)|_{z=0}\right]. \tag{10}$$

Many of the conclusions established in the previous subsection still continue to hold. Regulatory risk weightings affect portfolio choice only to the extent that assets returns are unrealisable. The bank still has an incentive, operating independently of regulatory risk weightings, to reduce holdings of assets that threaten to trigger a regulatory breach. What has now changed is that in the medium term the impact of capital regulation on the portfolio decision now depends on the margin between the costs of debt and equity finance ($\rho - r^s$) but no longer depends on the magnitude of the penalty for breaching the capital regulation χ. This is because banks increase their capitalisation to reduce the expected future costs of a capital breach.

[12] The final term in $w^i \ll 1$ and so will have only a minor impact on the portfolio decision.

4. Illustrative examples

This section presents a series of examples, illustrating and to some extent extending the findings of the previous two sections.

4.1. Example 1: Short versus long run and the regulatory 'credit crunch'

Consider the case of a bank holding two kinds of assets, corporate loans (a^1) and municipal loans (a^2). For the purposes of this example assume that interest rate elasticities, risk, and liquidity characteristics of the two types of loan are similar. Initially there are no regulatory capital requirements. The bank has been operating in this situation for some time and adjusted its capital to a desired medium run level. Suppose that the bank is then operating with the following balance sheet:

Assets	\$mn	Liabilities	\$mn
Corporate loans	50	Interbank borrowing	97
Municipal loans	50	Equity	3
Total	100		100

Risk weighted capital requirements are now introduced requiring the bank to hold 8% capital against corporate loans, compared to the current ratio (computed using its total equity) of 6%. In the short run, whether it seeks to observe the capital requirement ex ante or ex post, the bank contracts its lending (the 'regulatory credit crunch'). According to the hard wired view of bank capital regulation, as modelled in Section 2.1, this will result in a short term 33% reduction of holdings of corporate loans but the credit crunch will not impact on other assets. The incentive based view modelled in Section 3 suggests that *both* elements of the bank balance sheet will be reduced (the relative reductions in the holdings of the two assets will depend upon how important these asset categories are in raising the probability of a future breach of the capital requirement).

In the medium term, under both interpretations of the impact of bank capital regulation, the bank is able to raise new capital and the regulatory credit crunch unwinds. But there is still some permanent reduction of asset holdings, compared to the counterfactual where no capital requirements are introduced, as long as the cost of equity capital exceeds the rate of interest on interbank borrowing.

4.2. Example 2: Liquid versus illiquid assets

Consider a portfolio decision similar to that explored in example 1, except that now the assets differ because one offers returns that are completely realisable, while the other offers a mix of cash flow payments and unrealisable returns. Asset a^1 is a short maturity moderate risk asset (corporate paper) with μ relatively low (because of the lines of credit provided by other banks and guaranteeing the repayment of principal at maturity). Asset a^2 is longer maturity commercial lending, perhap to the same companies, for which μ is high. The bank balance sheet is as follows:

Assets	\$mn	Liabilities	\$mn
Corporate paper	50	Interbank borrowing	90
Company loans	50	Equity	10
Total	100		100

Under the interpretation of capital regulation as an ex ante enforced constraint, risk weighted capital requirements do not alter the relative holding of the two assets. In contrast, under the interpretation of capital regulation as an incentive mechanism, the introduction of regulatory risk weights will shift the bank's portfolio towards the relatively liquid shorter maturity corporate paper.

4.3. Example 3: Regulatory capital requirements and capital budgeting according to RORAC criteria

Practitioner analysis in the banking industry (e.g. Matten, 2000) typically recommends making capital budgeting (line of business) decisions based on 'RORAC' or 'return on economic capital' criteria. [13] A standard approach, taking into account regulatory capital requirements, is to adopt a procedure such as the following:

1. First a 'capital at risk' calculation is conducted determining the amount of equity capital required to support a particular business activity according to the distribution of losses over some defined time horizon and tolerance level. This calculation may be conducted on a stand alone basis or, in a more sophisticated implementation, allow for covariance of returns across the entire portfolio of the institution.
2. Second a regulatory capital requirement is computed based on the standard risk weightings.
3. The economic capital tied up in the business activity is then taken to be the higher of these two calculations (capital at risk from step 1 or regulatory capital from step 2).
4. Finally a business activity is deemed worth pursuing if it generates a return on this economic capital (i.e. a RORAC or 'Return On Risk Adjusted Cap-

[13] There is considerable and confusing variation in terminology. For example the term RAROC is also often used instead of RORAC. See Matten (2000) for further discussion.

ital') that exceeds some threshold (often related to target return on shareholder equity).

This procedure reflects the conventional hard wired assumption that regulatory capital requirements must be obeyed ex ante. [14] For most areas of bank business returns are sufficiently variable that economic capital is always computed from step 1 of this calculation i.e. from the capital at risk calculation not the regulatory capital requirement. But in certain relatively low risk business areas, e.g. secured trade credit or residential mortgage lending, computations of 'capital at risk' can be much less than regulatory capital requirements and economic capital requirements are therefore typically equal to regulatory capital requirements.

RORAC calculations of this kind are a useful rule of thumb. While ignoring some determinants of shareholder value that appear in standard academic models, such as the ability of shareholders to diversify risk through their own portfolio allocation, they are easier for practitioners to understand and implement than a full discounted cash flow analysis with an appropriate project specific discount rate. But viewed from an incentive based perspective, this standard approach for incorporating regulatory capital requirements on a product by product basis, biases bank decisions away from relatively low risk value adding activities that put relatively little capital at risk but require high levels of regulatory capital. A better approach, suggested by the incentive based analysis pursued in this paper, is to incorporate regulatory capital requirements for the institution as a whole into the calculation of capital risk i.e. directly into step 1 of this procedure and ignoring step 2. The amount of capital at risk will then be the level of capital reserves that would be required to reduce the probabilities of *both* insolvency *and* a breach of regulatory capital requirements for the institution as a whole, over the planning horizon for each capital budgeting decisions, to desired threshold levels.

Such an approach merits further study. The threshold would have to be some weighted average of the probability of insolvency and of the probability of a capital breach. For simplicity perfect correlation of returns across the bank might be assumed, ignoring any diversification of risk on the balance sheet. A more sophisticated calculation would allow for balance sheet diversification. Adopting an approach of this kind, the level of capital at risk or economic capital used in the RORAC assessment of a capital budgeting decision will then depend on the buffer of regulatory capital the bank holds in excess of its regulatory minimum. When a bank is well capitalised and this buffer is large,

[14] This approach is actually stricter than required by prudential capital regulations, even when viewed as an ex ante mechanism, because it achieves observation of the regulations at the level of individual lines of business rather than for the bank as a whole. Surplus regulatory capital in one line of business is not offset against insufficient regulatory capital in another line of business.

regulatory capital requirements will have relatively little impact on business decisions. When the buffer is small and the bank is constrained by regulatory capital requirements then capital at risk will be significantly raised and regulatory capital requirements will have a big impact on the banks decisions.

4.4. Example 4: Regulatory capital arbitrage via a securitisation

For this final example, consider a securitisation driven by regulatory capital arbitrage i.e. one where the risks to the bank's returns remain unchanged, but where the bank has achieved a reduction of its regulatory capital requirement by moving some assets off balance sheet. This example assumes that the bank is responding to bank capital regulation as an incentive mechanism.

Suppose that this particular bank has the following balance sheet structure:

Assets	$mn	Liabilities	$mn
Credit card receivables	50	Deposits	40
Small business lending	50	Interbank borrowing	48
		Equity	12
Total	100		100

Assume also that the total capital ratio can be decomposed into components:

$$12\% = 8\% + 1\% + 3\%$$

where the 8% corresponds to the Basel 1988 requirements (both assets are weighted 100%), plus an additional 1% to cover the risk of losses on credit cards, plus an additional 3% to cover losses on small business lending. The bank holds this excess capital because it wishes to avoid regulatory sanctions.

The expected rate of return on credit card receivables (net of all funding and overhead costs) is 1%, while the standard deviation of these returns is 0.5%. The expected return on commercial property (again net of all funding and overhead costs) is 3% while the standard deviation of returns of these returns is 1.5%. There is perfect correlation of returns on the two types of assets.

The excess capital holdings represent two standard deviations of returns on the assets. Taken together with the protection offered by expected returns, returns would have to be some four standard deviations below their expected level in order for there to be a breach of the capital regulations. In order for net worth to fall to zero, returns would have to be some eight standard deviations below their expected level. Half of this protection is provided by the regulatory capital requirement and half by the buffer of expected earnings and excess capital.

Now suppose that the bank securitizes all its credit card receivables, using the money to reduce interbank lending and equity capital, but retaining all the risk of the credit card receivables through the credit enhancement of the securitisation (the holding of junior high risk liabilities of the special purpose vehicle created to hold the securitized assets). The new balance sheet is as follows:

Assets	\$mn	Liabilities	\$mn
Credit card receivables	0	Deposits	40
Small business lending	50	Interbank borrowing	2
		Equity	8
Total	50		50

This reduction of equity is what would be expected in order to maintain the same amount of excess capital against small business lending as before. The capital, as a % of risk weighted assets, can be allocated as follows into regulatory requirement and a excess buffer of free capital:

$$16\% = 8\% + 2\% + 6\%.$$

According to the risk weighted regulatory capital ratio this bank is less risky than before the securitisation. But the probability of a regulatory capital breach is in fact unchanged. And the risk of insolvency is actually considerably higher than before, requiring a decline of returns below expected level of only six rather than eight standard deviations below expected levels.

Concern over regulatory arbitrage of this kind has been one of the principal motivations for the current consultation over reform of the 1988 Basel accord. As this example indicates regulatory capital arbitrage may indeed increase insolvency risks even if banks hold an excess of capital over required capital requirements.

But does regulatory capital arbitrage increase the probability of bank insolvency to unacceptably high levels? If banks themselves have a lot to lose from an insolvency or breach of regulatory capital requirement then self-discipline will limit their incentives to increase balance sheet risks in this way. Assuming equity capital is costly relative to debt finance, securitisation will typically allow banks to increase risk relative to a situation where no securitisation is possible. But the risk of default may still be acceptably low from a systemic perspective and lower than would have been the case in the absence of capital regulation. Regulatory arbitrage does not completely neutralise the impact of bank capital regulation. Further empirical research is still needed to quantify how great a systemic problem is posed by regulatory capital arbitrage through securitisation.

This arbitrage is of greatest concern when relatively weak and undercapitalised institutions, with a high risk of insolvency, engage in securitisation. The hard wired perspective suggests this could be prevented by accurate tailoring of regulatory risk weightings to balance sheet risk. The 'incentive' perspective suggests otherwise: even accurate risk weightings do not effectively restrain risk taking by the weakest institutions.

The most realistic response to the threat of regulatory arbitrage may be therefore not be via adjustments to capital regulations but via direct restrictions, e.g. through a requirement that institutions that hold junior securities in securitisation special purpose vehicles must themselves have a AA credit rating.

5. Conclusions

The goal of this paper has been to study the incentive impact of capital regulation on bank portfolio choice. The analysis here assumes that capital requirements are monitored ex post and a penalty is imposed on the shareholders of the bank in the event of a breach. This perspective is contrasted with a conventional view of bank capital regulations as ex ante constraints which banks must always obey when making their portfolio allocation decisions.

The present paper and its predecessors are not a prescription for an alternative incentive based method of bank capital regulation replacing our current system of regulatory capital requirements. [15] The claim made here is rather that the usual analysis of the impact of bank capital regulation on bank behaviour is flawed because it does not treat banks as forward looking optimisers balancing the benefits of their lending decisions against the costs of a regulatory capital breach. Adapting the words of M. Jourdain, it seems that for more than a dozen years bank regulators have been operating an incentive based mechanism of bank capital regulation without even realising it.

This paper shows that an incentive-based perspective on bank capital regulation offers a number of novel insights into the portfolio response of banks to regulatory capital requirements:

(a) The impact of risk weightings on bank portfolios will depend upon both net worth and the expected profitability of the bank. Three situations arise:

1. Over the medium term healthy banks with sufficiently high expected profits will aim to increase their capitalisation to levels where the threat of a regulatory capital breach is small. In this case regulatory capital requirements will have a relatively minor impact on bank portfolio decisions. Additional measures to lower the tax costs of equity capital relative to debt will encourage higher levels of capital and further reduce the risk of insolvency and the impact of capital requirements on portfolio decisions.
2. In the short run however (following a period of losses or an increase in regulatory capital requirements) the threat of infringing regulatory capital requirements may have a significant impact on portfolio decisions.

[15] Such as the proposal for pre-commitment of capital to market risks analysed by Marshall and Venkataraman (1999) and Kupiec and O'Brien (1997).

3. Finally for the 'walking dead', institutions for which insolvency can only be postponed and not avoided, regulatory capital requirements will no longer be an effective restraint on behaviour.

(b) Interpreted as an incentive mechanism the impact of risk weighted capital on portfolio allocation depends on the liquidity of the assets concerned. To the extent that assets can be traded in liquid markets – or where the bank can otherwise realise value through for example loan trading, securitisation, or termination of a facility – then portfolio choice is unaffected by capital requirements. In the event of a decline of net worth that threatens a regulatory capital breach the bank can simple 'trade out' of their positions in these assets.

(c) It is often claimed that the risk weightings in the 1988 Basel accord bias bank portfolio choice away from exposure to highly rated corporates and towards OECD government liabilities. This claim appears suspect, since banks can easily reduce their exposures to AA and AAA weighted corporates when they are short of regulatory capital.

(d) The threat of sanctions for a regulatory capital breach induces risk averse behaviour. This effect does *not* require accurate weightings for credit or market risk – even a crude unweighted capital requirement will lead banks to reduce portfolio risk.

(e) Regulators can respond to concern about the level of prudential risk in the banking system by increasing the severity of penalties on management and shareholders for infringements of regulatory capital requirements. [16] This will increase the incentives for reducing portfolio risk and, over the medium term, lead to increased bank capitalisation.

(f) Asset securitisation may partially offset the impact of regulatory capital requirements on solvency risk. But the most effective regulatory response to this problem of regulatory capital arbitrage may be to place restrictions on the banks rights to hold junior claims on securitisation special purpose vehicles, rather than attempting to fine tune capital regulations for securitized risks.

(g) Banking practitioners also often seem to interpret regulatory capital as a binding constraint, for example recommending return on regulatory capital as a business performance measure whenever regulatory capital for a particular asset exceeds capital at risk. Modelling capital regulation as an incentive mechanism suggests that this procedure biases bank decisions away from relatively low risk activities. A better measure of business performance is an adjusted capital at risk, set so as to reduce both the probability of insolvency and the probability of a future breach of regulatory capital requirements for the institution as a whole to acceptable threshold levels.

[16] A wide range of sanctions are possible, not just fines on the bank. Other potential sanctions include reductions in management salaries or requiring a new equity issue that will dilute the interests of existing shareholders. The ability to impose such penalties are limited, ultimately, by the 'charter value' of the bank.

It is appropriate to conclude with a brief general discussion of the implications of this 'incentive based' view for the design of prudential regulation. The differences between the two contrasting views of capital regulation explored in this paper go deeper than the timing of regulatory intervention (ex ante versus ex post). The fundamental issue is whether it is the regulator or bank management are best placed to take primary responsibility for the detailed management of bank risks.

Behind the hard wired view of capital regulation is an assumption that bank management and shareholders lack either incentives or means to monitor and control risks. Detailed prescriptive rules must therefore be set to ensure appropriate standards are enforced. This was an appropriate response to the situation in the late 1980s when few banks had meaningful institution wide risk-management and when the business of banking was sufficiently straightforward that regulators could contribute substantially to the micro-management of risks. It may still be appropriate today for less sophisticated institutions (for example for the thousands of small community based institutions operating in Germany and in the United States) or for banks operating under financial distress with imminent threat of failure who care little about regulatory sanctions.

Nowadays however the major banks, accounting for the vast majority of bank assets, have healthy earnings streams and sophisticated systems of risk-management. They therefore have both the incentive and the capacity to model and quantify risks in much more detail than could ever be incorporated into any codified regulatory framework. [17] If this is accepted then an incentive based perspective becomes increasingly helpful to understanding the impact of prudential regulation. The task of the regulatory system becomes the setting of appropriate systems of rewards and penalties, so that bank risk management takes into account the wider social and systemic costs of bank failure. Direct control of bank risks is no longer the business of the regulator. Risk control becomes a matter of 'self discipline' rather than 'external discipline'. [18]

Furthermore, even if regulators did fully understand the risk profile of a bank it is unclear that it is appropriate for them to tailor prudential capital

[17] This is not to say that there are no weaknesses in these systems. Statistically based risk-management techniques, such as Value at Risk, are poorly equipped for modelling the extreme risks of bank failure (see for example Dowd (1998) for a detailed critique). But the banks are certainly better placed than the regulators to carry out detailed risk-management.

[18] This 'self-discipline' is not the same as 'market discipline', as discussed for example in the July 1999 and Jan 2001 Basel consultative papers or in proposals for the issue of subordinated debt offering some maximum level of yield relative to risk-free bonds (Calomiris, 1999). Greater use of market discipline implies a shift of responsibility for external monitoring of banks from supervisors to holders of marketable debt rather than from supervisors to shareholders and management.

requirements to this risk profile. Viewed from an incentive perspective risk weighting of capital requirements is a double jeopardy, penalising the holding of risky and illiquid assets twice over, once through the increased risk of a breach of the regulatory capital requirement and a second time through the weighting system itself.

Given that any imposed regulatory weighting system can correspond only poorly to the actual asset risks, an easily understood weighting system for regulatory capital, not much more complicated than that set out in the Basel 1988 accord and designed largely with smaller institutions in mind, could work reasonably well when compared to any proposed alternative. [19]

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Appendix A. Mathematical appendix

A.1. Notation and assumptions

For notational economy this appendix represents returns and balance sheet decisions as vectors. For example, expected realisable returns during the period on assets of class $1, 2, \ldots$ are represented by $\mathbf{r} = (r^1, r^2, \ldots)$ while the corresponding assets and liabilities (with a +ve sign for assets and a −ve sign for liabilities) are represented by $\mathbf{a} = (a^1, a^2, \ldots)$. Net realisable returns on all assets and liabilities (other than the safe investment asset) are given by the inner product $\mathbf{r}'\mathbf{a}$. Other vectors used in this appendix are: ε (the distribution of realisable returns), μ (expected unrealisable returns), θ (the distribution of unrealisable returns), and $\mathbf{w}$ (the regulatory risk capital weights).

[19] Current proposals for a shift to capital weights based on 'internal ratings' involve considerable additional costs relative to such a simple crude weighting system. These costs include the need for regulators to employ skilled individuals to evaluate the internal rating systems of the individual banks, the risk of regulatory distortion of internal ratings to ensure compliance with the requirements, the greater scope for forbearance via reclassification of assets when capital regulations are breached, and the well known problem that under a system of internal ratings capital requirements may be increased just when banks earnings are low. It is far from clear that current proposals for a shift to an internal ratings based system of capital regulation will prove to be cost effective.

Other notational assumptions are as follows: the expectations operator is $\mathbb{E}$. The holding of the safe asset (cash) is denoted by a^s which offers a return of r^s at the end of the investment period. The subscripts $_{0,1}$ denote the beginning and end of the period respectively. The balance sheet constraints at the beginning and end of the period are that net asset value (capital) satisfies $C = a^s + \mathbf{1}'\mathbf{a}$ (where $\mathbf{1}$ is the unit vector).

As described in the main text, the expected realisable returns on all assets (other than the safe asset) are iso-elastic functions of the absolute amount of the asset held: $\partial(r^i - r^s)/\partial a^i = -1/v$ with $v > 0$ in the case of assets and $v < 0$ in the case of liabilities. This ensures finite and non-zero solutions for all asset and liability holdings. Unrealisable returns and the distribution of both realisable and unrealisable returns are independent of the amount of the asset holding.

A.2. The conventional analysis: Exogenous capital

The optimisation problem is

$$\max_{\mathbf{a}_0} \mathscr{E} C_1 = r^s a_0^s + (\mathbf{r} + \mu)'\mathbf{a}_0 \tag{A.1}$$

subject to $C_0 \geqslant \mathbf{w}'\mathbf{a}_0$ and $a_0^s = C_0 - \mathbf{1}'\mathbf{a}_0$. Substituting out for the holdings of the safe asset a_0^s, the Lagrangian for this problem can be written

$$\mathscr{L} = \max_{\mathbf{a}_0}\{r^s(C_0 - \mathbf{1}'\mathbf{a}_0) + (\mathbf{r} + \mu)'\mathbf{a}_0 + \lambda(C_0 - \mathbf{w}'\mathbf{a}_0)\} \tag{A.2}$$

where the inequalities $\lambda \geqslant 0$ and $\mathbf{w}'\mathbf{a}_0 - C_0 \leqslant 0$ hold with complementary slackness.

The first order condition w.r.t. the beginning period investment in asset i (a_0^i) is then

$$-r^s + r^i + \mu^i - 1/v^i - \lambda w^i = 0 \tag{A.3}$$

yielding Eqs. (4) and (5) in the main text, depending upon whether or not the constraint $C_0 \geqslant \mathbf{w}'\mathbf{a}_0$ binds.

A.3. The conventional analysis: Endogenous capital

With a required return on capital of ρ the optimisation problem now becomes

$$\mathscr{L} = \max_{\mathbf{a}_0, C_0}\{(r^s - \rho)C_0 - r^s\mathbf{1}'\mathbf{a}_0 + (\mathbf{r} + \mu)'\mathbf{a}_0 + \lambda(C_0 - \mathbf{w}'\mathbf{a}_0)\} \tag{A.4}$$

yielding the additional first order condition w.r.t. C_0:

$$r^s - \rho + \lambda = 0.$$

Substituting for λ in Eq. (A.3) yields Eq. (6) in the main text.

A.4. Capital regulation as an incentive mechanism: Exogenous capital

The optimisation problem is now to maximise expected end-period net worth less the expected penalty:

$$\max_{\mathbf{a}_0} \Omega = \mathbb{E}\{C_1\} - \chi F(z)|_{z=0} = r^s\left(C_0 - \mathbf{1}'\mathbf{a}_0\right) + (\mathbf{r} + \mu)'\mathbf{a}_0 - \chi F(z)|_{z=0} \tag{A.5}$$

where $z = C_1 - \mathbf{w}'\mathbf{a}_1$ is the margin of free capital at the end of the period, over and above the minimum regulatory requirement, and $F(z)$ is the cumulative density function for z. Stochastic optimisations of this kind are not solved so routinely in the economics and finance literatures as the Lagrangian solution used above in the case of hard wired capital regulation. A more detailed analysis is therefore appropriate, supported by the following two lemmas:

Lemma 1. *An optimal policy is to always fully realise end-period capital gains, implying that*

$$z = r^s(C_0 - \mathbf{1}'\mathbf{a}_0) + (\mathbf{r} + \varepsilon + \mu + \theta)'\mathbf{a}_0 - \mathbf{w}'\mathbf{D}(\mu + \theta)\mathbf{a}_0 \tag{A.6}$$

where $\mathbf{D}(\mathbf{v})$ *represents the diagonalisation operator, forming a matrix with off-diagonal elements equal to zero* ($d_{i,j\neq i} = 0$) *and on diagonal coefficients corresponding to the elements of* $\mathbf{v}$ ($d_{ii} = v_i$).

Proof. As described in the main text, end-period asset holdings are divided into realisable gains $(\mathbf{r} + \varepsilon)$ – asset holdings valued at market prices that can be sold without loss on liquid securities markets – and unrealisable gains $(\mu + \theta)$ – asset holdings that cannot be sold and are valued according to accounting conventions. Realisation of gains reduces elements of $\mathbf{a}_1$ and has no impact on C_1. Since regulatory asset weightings are non-negative $(\mathbf{w} \geqslant \mathbf{0})$, a policy of fully realising all gains at end of the period reduces z to the smallest possible level for any given realisation of ε and θ and hence minimises $F(z)$. Once all realisable gains are converted into cash, $C_1 = r^s(C_0 - \mathbf{1}'\mathbf{a}_0) + (\mathbf{r} + \varepsilon)'\mathbf{a}_0$ while the vector of end-period assets is given by $\mathbf{a}_1 = \mathbf{D}(\mu + \theta)\mathbf{a}_0$. This yields the equation for z. $\square$

Lemma 2. *Let* $\zeta = (\varepsilon, \theta)$ *be the vector of all stochastic terms affecting end period returns. The cumulative density function* $F(z)$ *evaluated at a value* $z = x$ *can then be written*

$$F(z)|_{z=x} = \int_{\phi=-\infty}^{x} f(\phi) \int g(\zeta|\mathbf{z} = \phi)\,\mathrm{d}\zeta\,\mathrm{d}\phi$$

where $f(z) = \partial F(z)/\partial z$ *is the probability density function for* z *and* $g(\zeta|\mathbf{z} = \phi)$ *is the marginal probability density for* ζ *evaluated for* $z = \phi$*. Hence*

$$\left.\frac{\partial F(z)}{\partial a_0^i}\right|_{z=x} = -f(z)|_{z=x} \int \left.\frac{\partial z}{\partial a_0^i}\right|_{z=x} g(\zeta|\mathbf{z} = \mathbf{x})\,\mathrm{d}\zeta = -f(x)\mathbb{E}\left\{ \left.\frac{\partial z}{\partial a_0^i}\right|_{z=x} \right\}. \tag{A.7}$$

Proof. The first equation of this lemma follows from the definition of the marginal density. Since $\partial z/\partial a_0$ is a function of ζ the evaluation of $\partial F(z)/\partial a_0$ requires that the contribution of $\partial z/\partial a_0$ be computed as an integral over $\mathrm{d}\zeta$, as in Eq. (A.6). □

The first order condition for the maximisation in Eq. (A.5) w.r.t. the investment in a_0^i is

$$-r^s + r^i + \mu^i - 1/v^i - \chi \frac{\partial F(z)|_{z=0}}{\partial a_0^i} = 0. \tag{A.8}$$

Differentiation of Eq. (A.6) yields

$$\partial z/\partial a_0^i = -r^s + r^i - 1/v^i + \varepsilon^i + (1 - w^i)(\mu^i + \theta^i).$$

Substitution using Eq. (A.7) into Eq. (A.8) then yields

$$-r^s + r^i + \mu^i - 1/v^i + \chi f(0)\mathbb{E}\{ -r^s + r^i - 1/v^i + \varepsilon^i + (1 - w^i)(\mu^i + \theta^i)|_{z=0}\} = 0$$

which can be written (since r^s, r^i, v^i, and μ^i are non-stochastic)

$$-r^s + r^i + \mu^i - 1/v^i + \chi f(0)\left[-r^s + r^i - 1/v^i + (1 - w^i)\mu^i + \mathbb{E}\{\varepsilon^i + (1 - w^i)\theta^i|_{z=0}\}\right] = 0$$

and this in turn yields Eq. (8) in the main text.

A.5. Capital regulation as an incentive mechanism: Endogenous capital

The optimisation problem is now

$$\max_{\mathbf{a}_0,\mathbf{C}_0} \Omega = (r^s - \rho)C_0 - r^s\mathbf{1}'\mathbf{a}_0 + (\mathbf{r} + \mu)'\mathbf{a}_0 - \chi F(z)|_{z=0}. \tag{A.9}$$

As $\partial z/\partial C_0 = r^s$ the additional first order condition w.r.t. the level of initial capital C_0 is then

$$r^s - \rho + \chi f(0) r^s = 0$$

and substituting out for $\chi f(0)$ in the first order condition w.r.t. a_0^i yields Eq. (10) in the main text.

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