Apples and pears? the comparison of bank economic and prudential capital

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Abstract

This paper compares economic capital, the risk-adjusted performance measure widely used by banks, with prudential capital measures such as those imposed by bank regulators. We identify sufficient conditions to compare performance using return on prudential capital. These conditions are implausibly strong, suggesting that prudential and economic capital are unconnected. We also examine the impact of regulatory requirements on bank capital structure, performance measurement, and loan decisions showing that regulatory requirements have only minor impact on bank behavior. We conclude that economic and regulatory capital are different measures of risk with no reason for their alignment.[96 words]

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1 Introduction

One of the most important developments in bank risk management over recent years has been the adoption of risk-adjusted performance measurement of RAPM. The most widely used generic RAPM is 'return on economic capital' r_{EC}.[1] This takes the following form,

$$r_{EC} \equiv \frac{\text{Expected Revenues} - \text{Costs} - \text{Expected Losses}}{\text{Economic Capital}} \tag{1}$$

where: Expected revenues are the anticipated receipts from the business activity, costs are the anticipated costs and expected losses is the expected level of losses (arising amongst other reasons from loan default, loss of capital value, and operational problems). Economic capital is the measure of the risk-associated with the exposure. r_{EC} is thus a measure of the 'risk-return' trade-off offered by the individual exposure and manager's risk-return preferences can be imposed across the institution by choosing an appropriate hurdle rate for r_{EC}.

It is also common to use a 'value-added' variation of the RAROC formula as an indicator of the amount of shareholder value created by business activity:

$$\text{value} = (r_{EC} - r^*)\text{Economic Capital} \tag{2}$$

The principal challenge to applying such performance measures is the measurement of risk associated with each exposure i.e. determining the economic capital to be included in the denominator of this calculation. One widely used approach associates economic capital with the capital set aside to cushion against the possibility of unexpectedly high losses arising from the entire range of bank risks, including market, credit and operational. In order to assess these prudential risks, many banks conduct a 'bottom up'

[1] Matten (2000, pp 146-166) describes several different RAPM.

calculation for some specified tail probability and time horizon, incorporating value at risk (VaR) for market risk, measures of credit value at risk and similar measures for operational and other risks, thus putting the returns of very different risk business on a comparable, risk-adjusted basis.[2]

A common choice is a time horizon of one year and a loss threshold of 99.97% or 99.98% i.e. economic capital should be enough to cover bank losses occurring in all but 2 or 3 out of 10,000 years. A justification for this parameter choice is that it corrresponds to the historical *cross-sectional* performance of AA rated corporate bonds. Moody's and Standard and Poor's databases indicate that average annual default on US AA corporate bonds over the past fifty yearshas been around 0.02% or 0.03%. Banks typically need to maintain a credit rating of AA in order to maintain their counterparty standing in wholesale and interbank markets. These choice of economic capital parameters are therefore consist with this business requirement. Measuring economic capital on this basis thus helps bank management estimate the amount of capital necessary to support each of their major activities and, with appropraite allowance for the benefits of diversification, to determine the overall leverage for the bank as a whole.

Economic capital is used not just to assess prudential risks but also to compare business lines across the institution and as an input to compensation systems and product prices i.e. to the *allocation* of capital across the bank using (1). This is why these bank systems are often described as systems of economic capital allocation. One justification for practicing such capital allocation is that shareholders provide the prudential capital of the bank and so bank activities should be chosen to achieve or surpass some target return on shareholder capital.

[2] For a more detailed description of credit value at risk see Ong 1999.

Allocating equity capital on the basis of the risk of individual business units seems pointless in the classical theoretical paradigm of "frictionless" capital markets (one with perfect information and without taxes, bankruptcy cost or conflicts between managers and shareholders). Of course, in real world, banks and other financial intermediaries add value precisely through their ability to reduce such market frictions. In this situation systems of RAPM can add value.

Capital allocation is a useful discipline in order to increase returns on equity and hence help ensure that bank activities are creating value for shareholders. However, as we will demonstrate, only in exceptional circumstances is return on prudential capital an appropriate measure of risk-return trade-offs. Banks are increasingly choosing not to allocate prudential capital, but rather allocating some other measure of risk that better reflects shareholder risk-return preferences. i.e. it needs to be understood that prudential and economic capital are *not* equivalent.

The emergence of economic capital allocation has been a principal driver of the new Basel accord on bank capital adequacy (Basel II). One of the main goals of the new accord has been to achieve a closer alignment of economic and regulatory capital. Misalignment of economic and regulatory capital is thought to have distorted business decisions and encouraged the use of financial transactions such as securitisations to reduce regulatory capital without alterning bank exposure to downside risks.[3]

The objective of the present paper is to present a coherent analysis of the relationship between economic capital (the risk-return trade-offs chosen by banks) and measures of prudential capital, including regulatory bank capital requirements. Section 2 reviews some relevant literature. While eco-

[3] See Jones (2000) for illustration of this practice of "Regulatory Capital Arbitrage".

nomic capital has become a core concept for both bank risk managers and regulators, there has been relatively little academic research on the topic and something of a divide between academic and pracitioner thinking. Section 3 presents the core analysis of the relationship between economic and prudential capital, i.e investigating when it is possible to enhance (maximise) the shareholder value of the financial institution using return on prudential capital as a performance metric. Section 3.1 introduces the assumptions of our model. Proposition 1 of Section 3.2 is our key finding. We use a general arbitrage argument to derive necessary and sufficient conditions for the use of return on prudential capital as a risk-performance measure. This section also illustrates our findings with computations of return on prudential capital for arithmetic and log-normal return distributions. We compare our findings with those of Crouhy et. al. (1999) which are a (near) special case of our own results. Section 3.3 extends the analysis to the case of a bank with limited shareholder liabilty and a bank with 100% deposit insurance (i.e. incorporating the Merton (1973) and Merton (1974) assumptions). We find that for banks with low target default probabilities, these generalisations make little difference.

Section 4 [not in this version] presents a related analysis, the impact of bank regulatory capital on bank. Section 4.1 states the additional modelling assumptions, incorporating an endogenous choice of default probability (prudential capital) depending on franchise value, tax and agency costs, and the regulatory capital requirement. Section 4.2 obtains the model solution. Section 4.3 presents some illustrative results. Section 5 summarises our contribution and draws policy conclusions, especially in relation to the operation of Pillar 1 (capital modelling) and Pillar 2 (capital assessments) in the new Basel accord. In particular we note that the modelling systems applied in these pillars can be expected to yield divergent measures of economic and prudential capital, but this divergence is entirely appropriate, banks and supervisors need not be concerned about divergences between the two.

2 Previous analysis of bank economic capital

This section reviews previous analysis of capital allocation, covering both academic and practitioner perspectives. According to Schroeck (2002) since early 1990s the financial institutions have been very focused on designing systems to measure the risk that is involved in their different lines of business. The purpose of such measurement systems is to determine the amount of capital that is necessary for each business unit and thus determine the equity capital required by the bank as a whole. In this framework the bank can define the profitability of businesses with different capital requirements and different sources of risk. These capital-based capital allocation systems are known as Risk Adjusted Return On Capital or RAROC.

As noted by James et. al. (1996) one goal of these capital allocation systems is to help optimise capital structure i.e. find the proportion of equity to assets that minimizes the bank's cost of funding. [4]They are in otherwords addressing the tradeoffs between the benefits of leverage (the tax shield provided by tax-deductible interest payments and the the motivation on managers to operate as efficiently as possible) against the costs of leverage (which as emphasized by Merton and Perold (1993) differ from industrial companies because their customers are often also their largest liability holders and as a consequence, a high credit rating is generally essential

[4]If its returns are less than perfectly correlated with the bank's returns its economic capital is reduced.

for bank to be major swaps dealer, to underwrite securities or to compete effectively in the corporate banking and deposit markets.) In extreme cases, extensive use of debt financing can lead to default and a costly reorganization. Although, many of the bank's businesses do not mark their portfolios to market on a regular basis and as a result the volatility of market values cannot be defined.For these businesses, the volatility in economic earnings is used instead. If RAROC of a particular business is higher than the cost of equity-shareholders' minimum required rate of return-the unit creates value for the shareholders.

This can be related to theoretical models of capital market frictions. As Froot and Stein (1995) point out, faced with an increasing cost of raising external funds banks will behave in a risk-averse fashion. Specifically, a business unit's contribution to the overall cash flow volatility of the bank will be an important factor in the capital budgeting decision. Capital structure, risk management and capital budgeting are inextricably linked together. Froot and Stein (1998) demonstrate that the hurdle rate for investments in new project can be represented as a two factor hurdle rate, namely the covariance of the return on the tradable component with the market R_m and the correlation on the non tradable component of the new risk $\left(\mu_i^N \right)$ with the non-tradable risks of the existing portfolio.[5] We are able to reproduce this

[5] The two factor model can be represented as: $\mu_i = \gamma cov\left(\mu_i^T, R_m \right) + Gcov\left(\mu_i^N, R_P^N \right)$, $\mu_i = (1) + (2)$, where: component (1) represents the first factor and, like the standard CAPM, describes the covariance of the return on the tradable component $\left(\mu_i^T \right)$ with the market R_m; component (2) represents the second factor and, like in the modified version of CAPM which considers the non marketable asset, is based on the correlation on the non tradable component of the new risk $\left(\mu_i^N \right)$ with the non-tradable risks of the existing portfolio $\left(R_P^N \right)$, multiplied by G (the bank's risk aversion factor that depends on the Economic Capital).

result in a capital allocation framework (see Section 4 where we introduce the tradeoff between franchise value and tax benefits of leverage). When combined with this federal insurance subsidy, depositors' further reduction of their required interest rates for the liquidity and convenience of demand and time deposits is an added incentive for banks to use this form of leverage. Because capital budgeting in the Froot and Stein model is driven by an exposure's impact on portfolio risk and return, decentralised implementation becomes a problem if the pre-existing portfolio cannot be treated as fixed for all time.

Thus, for example, if several new investment opportunities arrive at once, the optimal allocation to each must be jointly determined. This requires a well informed central planner operating out of the headquarters. The whole issue of centralisation versus decentralisation should also be investigated with respect of full versus asymmetric information and in presence of capital adequacy restriction.

There are nevertheless several well known problems with risk adjusted return on capital as a performance measure. Stoughton and Zechner (1999) argued that discussions with practitioners support the view that corporates CFOs as well as their counterparts at financial institutions view capital budgeting, risk management and capital structure as being inextricably linked. Crouhy, Turnbull and Wakeman (1999) find that the conventional RAROC hurdle rate depends upon the volatility of returns, i.e. any fixed RAROC hurdle will be biased for some exposures. Consider a generic portfolio that has a non-zero, strictly positive, mark-to-market value, and the risk manager has access to a risk-free asset investment opportunity. It is easy to show that, under these weak conditions, an infinite positive RAROC can be achieved by liquidating the entire portfolio immediately and investing the proceeds in the risk-free asset. This strategy would generate positive realised returns with no capital at risk, implying an infinite RAROC. As also shown by Wilson (1992) and James et. al. (1996), traditional RAROC can be thought of as a one factor pricing model, hence conflicting with the capital market frictions model of Froot and Stein (1998).

In this model the risk driver factor is the market:

$$\mu_i = \gamma \mathrm{cov}\left(\mu_i, R_m\right) + \lambda \mathrm{cov}\left(\mu_i, R_P\right)$$

where γ is the market unit price of risk for the (market) priced factor R_m the return of (market) price factor λ is the unit cost for volatility of the bank's cash flows and R_P is the return on the bank's existing portfolio. μ_i is the hurdle rate or required return for project i. The market is by definition a tradable component and this is the reason of the absence of the super-script T.

Stoughton and Zechner (1999) showed that optimal equity capital allocation is based on a business unit's contribution to the institution's total capital requirement and can be decomposed into two parts : the economic capital and the risk adjustment term. The economic capital term is measured by the divisional Incremental Value at Risk (IVaR). The sum of the IVaRs is equal to the institution's overall VaR. In the case of multiple business units ,the Economic Capital is equal to a price of risk multiplied by the division's own standard deviation. The risk adjustment term is a constant related to the economic value added (EVA) at the optimal investment level. They also declared that the right definition of RAROC involves in the numerator the business unit's expected return minus an adjustment factor and in the denominator an economic capital amount equal to the unit's IVaR. This adjustment reflects both the economic valued added (EVA) at the optimal risk level and risk externalities imposed by one business unit to the IVaR of other business units.

The two factor model can be represented as: $\mu_i = \gamma cov\left(\ \mu_i^T, R_m\right) + Gcov\left(\ \mu_i^N, R_P^N\right)$, $\mu_i = (1) + (2)$, where: component (1) represents the first factor and, like the standard CAPM, describes the covariance of the return on the tradable component $\left(\ \mu_i^T\right)$with the market R_m; component (2) represents the second factor and, like in the modified version of CAPM which considers the non marketable asset, is based on the correlation on the non tradable component of the new risk $\left(\ \mu_i^N\right)$with the non-tradable risks of the existing portfolio $\left(\ R_P^N\right)$, multiplied by G (the bank's risk aversion factor that depends on the Economic Capital). $R_m\ \left(\ \mu_i^N\right)$Extending to many new products means we have to incorporate the covariance of each new non-tradable exposure whit other exposure, the optimal mix of new and old investments will thus depend on this variance covariance matrix.

One of the key implications of the Froot and Stein two factor model is that a bank should evaluate investments according to both their correlation with any priced market factors and their correlation with the bank existing portfolios. Under traditional RAROC the amount of capital allocated is related to a measure of the investment's risk such as its total volatility, but from prospect of a bank value maximization it makes more sense to be driven by the covariance with the rest of the bank's portfolio. Many financial institutions have now recognised the usefulness of this approach. For example James (1996), in discussing the implementation of RAROC at Bank of America writes "the amount of capital allocated varies with the contribution of the project to the overall volatility of earnings at Bank of America (the projects so called internal beta). Even if the RAROC capital allocation is based on the appropriate covariance measure, one need to came up, first, whit the right measure of bank tolerated default probability. For example according to Zaik and al. (1996) at Bank of America a default probability of 0,03% is tolerated, and, second, with the appropriate cost of capital. Following Zaik and al. (1996) the hurdle rate is typically set to equal the required return on equity of the bank's shareholders, which could be calculated from the standard CAPM. This latter calculation is inconsistent within the Froot and Stein framework. In fact, in the polar case where the bank hedges all risks, the bank's shareholders are left only holding non-priced risks, so their required return on equity is simply the risk-less rate. But, if this is true, the traditional one factor RAROC method says that the capital charge should be zero for any target default probability and cost of equity capital value.

Crouhy, Turnbull and Wakeman (1999) argued that the definition of risk inside the financial institutions has moved away from a market definition to one that is purely firm specific. In particular, one of the most appealing features of the traditional RAROC methodology is that of avoiding to calculate the beta for the business. If a Business Unit's RAROC is higher than the cost of capital (or the cost of bank's equity) –the minimum rate of return required by shareholders- then the unit is deemed to be adding value to shareholders. Consequently, the implicit assumption is that the RAROC measure adjusts the risk of a business to that of a firm's equity. If a firm is considering investing in a business, it can compute the RAROC for the business and compare it with the firm's cost of equity capital. But Crouhy, Turnbull and Wakeman (1999) showed that maintaining the probability of default constant is inconsistent with a constant expected return on equity and vice versa thus showing that RAROC cannot be directly compared with the firm's cost of equity capital.

The primary objective of Bank of America system is to assign equity capital to business units (and ultimately to individual credits) so each BU has the same cost of equity capital. This process implies that investments in riskier projects or BUs (measured by the projects contribution to the overall volatility of the market value of the bank) will be required to use less leverage than investments in less risky BUs. Crouhy, et al. prefer an adjusted RAROC defined as:$Adj.RAROC = \frac{RAROC - R_f}{\beta_E}$, where $\beta_{\mathrm{E}}$is the systematic risk of equity and $\mathrm{R}_f$is the risk-free interest rate

It is easy to show that the adjusted RAROC is just equal to the expected excess rate of return of the market portfolio. But this ignores the tradable and non-tradable risk factor component identified by Froot and Stein. Then making a new investment project, only for zero net present value project the RAROC of the existing shareholders equals the RAROC of new shareholders and the RAROC of sum of the two classes of shareholders. In appendix 2 a numerical example of this limiting case is shown. The zero NPV relationship provides some credence for comparing RAROC to the firm's cost of equity capital for stand-alone projects (see Zaik and al. 1996). Bank of America's policy is to capitalise each BU in a manner consistent with an AA credit rating, based on the unit's stand alone risk, but also including an adjustment for any internal diversification benefits provided by the unit. Each of these individual capital allocations are then aggregated to arrive at the optimal level of equity capital for the entire bank.

Crouhy, Turnbull and Wakeman (1999) in the first appendix of their paper, pag 32, showed this result. Crouhy, Turnbull and Wakeman (1999) also found that their adjusted RAROC, unlike conventional RAROC, is insensitive to changes in volatility. If, as described by Zaik and al. (1996) a generic financial institution follows Bank of America's use of a fixed hurdle rate, than it would pick up high volatility and high correlation projects. Suppose the NPV decreases; this implies that the numerator in RAROC decreases and then denominator increases, and hence RAROC decreases. Crouhy, Turnbull and Wakeman (1999) showed also that the RAROC of a loan, when assuming the cost of borrowing for the bank is the risk-free of interest, varies as the volatility of the firm's risky assets change, even though the probability of default for the firm and the bank are held constant. It is also an increasing or decreasing function of the volatility of the firm's risky assets depending upon its credit rating; for low credits, RAROC increases as volatility increases.

3 Capital structure and cost of equity with constant default probability

This section investigates the relationship between shareholder value and the risk adjusted return on capital (r_{EC}). We determine the conditions under which return on prudential capital is a valid performance measure and hence when economic and prudential capital should be fully aligned. Previous work of Crouhy and al (1999) is closely related, their results emerging as a special case of our own.

The analysis of the present section assumes a fixed target default probability that determines the bank's capital choices. In the following Section 4 this assumption will be relaxed, allowing us to examine the impact of regulatory capital requirements, franchise value, agency costs, and taxes on shareholder value and the risk adjusted return on capital (r_{EC}).

3.1 Notation and modelling assumptions

We consider a bank considering the choice of whether or not to invest in a loan asset $A^i(t)$ over the period $t = 0$ until $t = T = 1$. This loan asset is one of a number of potential loan assets i.e. $i \in (1, 2, \ldots, I)$, but only one of these loan assets is available to the bank. As long as we are referring only to this single asset, we drop the superscript i.

If it proceeds, the bank finances this investment by issuing debt with a market value of $D(t)$. Shareholders are subject to unlimited liability i.e. this debt is risk-free.[6] The bank market value balance sheet is then:

$$A(t) = E(t) + D(t), \quad \text{with} \ \ t \in [0, 1] \tag{3}$$

where $E(t)$ is the market value of equity at time t. The risk free rate of interest is r_f and we have $D(1) = D(0)(1 + r_f)$

End period asset returns $A(1)$, net of all costs, are uncertain and continuously distributed. We will assume that all asset risks are tradeable in liquid markets and the returns on the asset are a (possibly non-linear) function of one aggregate priced market risk factor z.[7] $A(1) = R_A + \alpha_1(z) + \alpha_2\phi$ where ϕ is the specific asset risk after regressing $A(1)$ on $\alpha_1(z)$. We can assume that the returns are a linear function of ϕ since this factor is specific to asset A^i. z and ϕ have the bivariate joint density function $f(z)g^i(\phi^i)$ with $\int_{-\infty}^{+\infty} zf(z) = \int_{-\infty}^{+\infty} \phi g(\phi) = 0$ and $\int_{-\infty}^{+\infty} z^2 f(z) = \int_{-\infty}^{+\infty} \phi^2 g(\phi) = 1$ and with ϕ uncorrelated with z.

R_A is the expected absolute return on the bank's asset while $r_A = R_A/A(0) - 1$ is the expected rate of return.

[6] Sub-section 3.4 relaxes this assumption

[7] The assumption of a single pricing factor is inessential (we could instead work with an arbitrary number of n priced factors) but simplifies our exposition.

Markets are complete so the market value of the bank asset can be expressed as a linear function of the aggregate (priced) risk factor:

$$A(0) = (1 + r_f)^{-1} \left(R_A + \int \alpha_1(q(z))\mathrm{d}z \right) \tag{4}$$

where $q(z)$ is the risk-neutral linear pricing function.

$w = \alpha_1(z) + \alpha_2\phi$, the random component of asset returns, is a continuous random variable with density function given by:

$$h(w) = \int_{\infty}^{\infty} f(\alpha_1^{-1}(w - \alpha_2\phi))g(\phi)\mathrm{d}\phi \tag{5}$$

with corresponding cumulative density $H(w) = \int_{\infty}^{w} h(w)\mathrm{d}w$.

The bank is insolvent if $A(1) = R_A + w < D(1)$. The bank chooses its capital structure (the amount of debt $D(1)$) so that the probability of insolvency is maintained at a target level p^*. This requires that

$$D(1) = R_A + H^{-1}(p^*) \tag{6}$$

and since the banks debt is risk-free we have $D(0) = (1 + r_f)^{-1}D(1)$ and the (prudential) capital of the bank, measured at market values, is given by:

$$E(0) = A(0) - (1 + r_f)^{-1} \left(R_A + H^{-1}(p^*) \right) \tag{7}$$

Suppose that the bank asset requires total funding of $L(0)$ (in the case of a lending operation $L(0)$ corresponds to the book value the loan portfolio, but the funding requirement can equal zero or even be negative if the bank is undertaking business such as the writing of options). The funding provided by equity holders is $L(0) - D(0)$ and the investment creates value if $A(0) - D(0) > L(0) - D(0)$ i.e. if $A(0) > L(0)$. A marginal project, one that neither adds to nor subtracts from shareholder value is one where $A(0) = L(0)$.

Finally return on prudential capital (measured at market value, or also at book value for a marginal investment opportunity) is given by:

$$r_{PC} = \frac{R_A - (1 + r_f)D(0)}{E(0)} - 1 \tag{8}$$

Note that all expected costs (the costs of debt, anticipated loan losses etc.) are deducted from the numerator while all adjustment for risk comes through the denominator, higher risk opportunities are associated with higher prudential capital $E(0)$.

3.2 Conditions for the alignment of economic and prudential capital

The following proposition expresses a condition for applying a single hurdle rate for return on economic capital.

Proposition 1 *Consider a bank with unlimited shareholder liability. The rate of return on prudential capital takes the same value r^* for any marginal investment opportunity (one where $A^i(0) = L(0)$, drawn from a set of potential opportunities indexed by $i \in (1, 2, \ldots, I)$* ***if*** *the distribution of asset returns w^i for any given i can be expressed as a mean-preserving spread of a single underlying asset return distribution w^0.*

Proof

Consider a mean-preserving spread of the underlying asset return distribution, so that $w^1 = kw^0 = k\alpha_1(z) + k\alpha_2\phi$.

The denominator of the RAROC performance measure r_{PC}, the prudential capital required to protect against w^1 can then be rewritten as:

$$
\begin{aligned}
PC^1 &= A(0) - D(0) \\
&= (1+r_f)^{-1}\left(R_A + \int k\alpha_1(q(z))\mathrm{d}z\right) - (1+r_f)^{-}1\left(R_A + kH^{-1}(p^*)\right) \\
&= (1+r_f)^{-}1\left(\int k\alpha_1(q(z))\mathrm{d}z - H^{-1}(p^*)\right) \\
&= kPC^0
\end{aligned}
$$

i.e. prudential capital increases in proportion to k.

The numerator of the RAROC performance measure r_{PC}, the prudential capital required to protect against w^1 can also be rewritten as:

$$
R_A - (1+r_f)D(0) = R_A - \left(R_A + kH^{-1}(p^*)\right) = kH^{-1}(p^*)
$$

and this also increases in proportion to k

Since both numerator and denominator increase in proportion to k, the ratio of these two, the return on prudential capital r_{PC} for a marginal investment opportunity is unaffected by a mean-preserving spread in asset returns.

QED □

Corollary In this case, where all possible asset return distributions are mean-preserving spreads of a single underlying return distribution, then a single hurdle rate r^* for return on prudential capital r_{PC} can be used as a guide to whether investment in bank asset $A^i(0)$, $i \in (1, 2, \ldots, I)$ creates shareholder value. The shareholder value created by the investment opportunity is given by:

It should be apparent that the sufficient conditions for applying a RAROC hurdle given in Proposition 1 are very strong. They imply that the degree of skewness of all bank investments is the same, in order that tail risk (i.e. prudential capital) can be a sensible measure of the cost of risk to shareholders.

In practice banks must make choices for investment opportunities that differ greatly in their degree of skewness. Regulatory capital requirements, too, must allow for considerable variation in the skewness of bank returns and supervisors will wish to impose high capital requirements for risks which they believe have a relatively high prudential risk, even if this is viewed as an excessive penalty for risk by bank owners and managers. Economic capital (the shareholders and managers measure of risk) will not be generally aligned with prudential measures of risk such as the capital requirements imposed by bank regulators.

3.3 Two illustrative examples

This subsection presents the impact of increasing variability of asset return on the RAROC measure, for two standard cases, that of arithmetic and lognormal returns. These two cases are explored in more detail in Milne and Onorato (2006) and in Crouhy et. al. (1999) respectively.

In these illustrations we assume quadratic investor utility, so that the pricing function $q(z)$ becomes the capital asset pricing model, with the rate of return on the bank's asset given by:

$$r_A - r_f = \beta_{A,M} \left(r_M - r_f \right) = \tag{9}$$

with $\beta_{A,M}$ the beta of the return on asset A with the market M and $r_M(t)$ is the market return at time t.

Figure 1 shows the impact of increasing the standard deviation of asset returns on the RAROC on a marginal investment opportunity. The horizontal line (RAROC constant) is the case of the arithmetic normal distribution, explored by Milne and Onorato (2006). This case satisfies the necessary condition of Proposition 1 i.e. an increase in the standard deviation of returns is an mean-preserving spread in the return distribution.

The second line, sloping upwards, is that of the log-normal distribution of returns, analyzed by Crouhy et. al. (1999). In their case the distribution or returns has a right hand skew. An increase in the standard deviation of returns results in a less than proportionate increase in downside tail risk. The sufficient condition of proposition 1 does not apply. The denominator of the expression for return on economic capital rises less than proportionately to the increase in asset returns (the numerator). Hence RAROC rises as σ increases.

In practice many bank assets have a left- rather than a right-hand skew of returns. Our proposition 1 suggests that in such a case, as the distribution of returns widens (as the quality of exposure deteriorates), prudential capital will increase more than proportion to the increase in required asset return and hence that the RAROC hurdle will decline with increasing risk.

3.4 Limited liability with risky deposits

Unlimited liability is a simple and transparent special case. But our results also apply to the case of limited liability with risky deposits.

Proposition 2 *In the case of shareholder limited liability, provided that debt holders are fully liable for any losses not borne by shareholders and the bank is able to pre-commit its asset choice at the time it issues debt, then Proposition 1 continues to hold.*

Proof

Standard deviation of asset returns σ and RAROC[†]

[†] Parameters: $r_f = 0.05$, $\rho - > 0.2$, $\Phi = 1.5$

End-period debt $D(1)$ is determined as before by p^* through equation (6). The credit riskiness of debt now reduces the current market value by an V_{put}, the present market value of the put option on banks assets written by deposit holders:

$$D(0) = (1 + r_f)^{-1} D(1) - V_{put} = (1 + r_c)^{-1} D(0) \tag{10}$$

Here r_c is the implied interest rate on credit risky debt. The present value of equity then becomes:

$$E(0) = A(0) - D(0) + V_{put} \tag{11}$$

while the expected absolute return on equity is given by:

$$R_E = R_A - (1 + r_c)D(0) + (1 + r_f)V_{put} \tag{12}$$

Substituting into the right hand side of (11) and (12), all terms in V_{put} cancel. Neither the expected return nor the amount of required prudential capital is affected by the presence of risky debt. It follows immediately that the return on prudential capital for each project is also unaffected by limited liability in this case with risky debt and so Proposition 1 continues to apply. QED □ This result reflects the completeness of markets. Debt holders must be compensated for bearing default risk and since this compensation is paid by equity holders, the outcome is that neither the market value of equity nor the expected return on equity is affected by limited liability. The precommitment assumption is needed because otherwise the bank could increase the value of V_{put} after raising debt finance, hence transferring wealth from debt to equity holders (an agency cost of debt as in Myers (1977)).

3.5 Limited liability with 100% deposit insurance

The presence of deposit insurance increases both the return to equity holders and the absolute return to equity holders. As indicated by the following proposition, this can be expected to increase the return on equity available to the marginal project.

Proposition 3 *In the case of shareholder limited liability with 100% insured bank debt, then a mean-preserving spread in the returns on an available asset* *implies an increase in the hurdle rate applied and Proposition 1 no longer applies.*

Proof The return on prudential capital of the marginal project is now given by:

$$r_{PC} = \frac{-H^{-1}(p^* + (1 + r_f)V_{put}}{A(0) - (1 + r_f)^{-1}(R_A + H^{-1}(p^*) + V_{put}} - 1 \qquad (13)$$

and since

4 Prudential capital and the choice of capital structure

This section to be added in the next draft.

5 Conclusions and further research

This paper analyses the relationship between return on prudential capital (RAROC) and shareholder value and the related issue of the alignment of economic and regulatory capital. Our principal result is developed in Proposition 1 of Section 3.2. There we show that return on prudential capital can be used as a valid measure of contribution to shareholder value, when all bank asset returns distributions belong to a single 'family', each a mean preserving spread (or contraction) of each other. Otherwise a constant RAROC hurdle will only emerge if changes in the shape of the distribution by conincidence offset by changes in the degree of correlation with aggregate priced risk factors. Overall this shows that prudential capital and bank measures of loan risk (economic capital) are unconnected. Generally differences in the skewness of loan return distributions are to be expected and these will alter the relationship between prudential and regulatory capital. This suggests that the goal of "aligning" economic and regulatory capital, which was one of the motivations for the development of the new Basel accord, is misplaced. Regulatory (or prudential) capital and economic capital are different measures developed for different purposes. This may be a useful finding for bank supervisors seeking to develop the new procedures for capital assessment to be applied under Pillar 2 of the new accord. Supervisors should avoid imposing any requirement that allocated capital for business performance measurement be the same as bank assessed capital for prudential purposes. There are many good reasons, including both relativcely large tail risk and lack data in order to precisely estimate tail risks, as to why prudential capital should be much larger than actual allocated economic capital. This seems to fit with practice in many leading banks that do not in fact allocate economic capital calibrated to an extreme tail probability, such as 99.97%, instead using a much lower probability threshold for allocation or even using basic summary measures of the distribution of returns such as the standard deviation. Comparison of prudential and economic capital does indeed seem to be a comparison of apples and pears.

References

1. Aguais D. Scott, Forest Jr. R. Lawrence (2000) The future of Risk-Adjusted Credit Pricing in Financial Institutions, The RMA Journal.

2. Ahn, M. J. and Falloon, W.D. (1991) Strategic risk management, Chicago.

3. Banfield, Eric (2003) What is Economic Capital? A quick guide to the differences between Economical Capital and Regulatory Capital, Chicago.

4. Bansal A., Kauffman R.J., Mark R.M. and Peters E. (1993) Financial risk and financial risk management technology, Information and Management, pp: 267-281.

5. Basle Committee on Banking Supervision (1988) International convergence of capital measurement and capital standards, Basle: Switzerland.

6. Basle Committee on Banking Supervision (1995) An internal model-based approach to market risk capital requirements, Basle: Switzerland.

7. Basle Committee on Banking Supervision (1996) Amendment to the capital accord to incorporate market risks, Basle: Switzerland.

8. Basle Committee on Banking Supervision (1998) Operational risk management, Basle: Switzerland.

9. Basle Committee on Banking Supervision (1999) A new capital adequacy framework, Basle: Switzerland.

10. Basle Committee on Banking Supervision (1999) Banks' interactions with highly leveraged institutions, Basle: Switzerland.

11. Bauer, W. (1998) Implementing and managing risk-adjusted return on risk-adjusted capital, Bank Treasurer Manual, Sheshunoff Information Services.

12. Beaver, W.H. and Parker, G. (1995) Risk Management, problems and solutions, McGraw-Hill, New York.

13. Berger A. N., Herring R.J. and Szego G. P. (1995) The role of capital in financial institutions, Journal of Banking and Finance19, pp. 393-430.

14. Bralver Charles, Kuritzkes Andrew, Risk Adjusted Performance measurement in the trading room, Oliver, Wyman & company, Journal of Applied Corporate Finance.

15. Brealey R.A. and Myers S.C. (2000) Principles of Corporate Finance, 6^{th} edition, McGraw Hill, New York.

16. Briys, E. and Crouhy, M. (1993) Playing against the devil: Managing financial risks for better corporate return, European Management Journal, pp. 304-312.

17. Carty, L. and Fons, J. S. (1993) Measuring changes in credit quality, Moody's Investors Service, Special Report.

18. Chau Tien (2004) Optimal Capital Structure and Hedging, GTNews, China.

19. Coopers & Lybrand and the British Bankers' Association (1997) Operational risk management survey.

20. Copeland T., Koller T. and Murrin J. (1990) Valuation: Measuring and managing the value of companies, McKinsey & Company, Inc., 13: 375-397.

21. Crouhy, M. and Galai, D. (1986) An economic assessment of capital requirements in the banking industry, Journal of Banking and Finance 10, pp. 231- 241.

22. Crouhy, Turnbull and Wakeman (1999) Measuring Risk-adjusted performance, Journal of Risk, Vol 2 no 1, Fall, pp. 5-35.

23. Crouhy Michel, Galai Dan, Mark Robert (2000) Risk Management, McGraw-Hill.

24. Damodaran, Aswath Corporate Finance, second edition.

25. Damodaran, Aswath (2000) Investment Valuation: Tools and techniques for determining the value of any asset, 2nd edition, Wiley, New York.

26. Damodaran website.

27. Damodaran A. (2002) Concept Checks: EVA.

28. Drzik John, Nakada Peter and Schuermann Til (1998) Risk Capital Measurement in financial institutions, Part I, ERisk.

29. Drzik John, Nakada Peter and Schuermann Til (1998) Risk Capital Measurement in financial institutions, Part II, ERisk.

30. Falkenstein, Eric (1997) Accounting for Economic and Regulatory Capital in RAROC Analysis, Bank Accounting and Finance, Volume 11 no 11, Fall 1997.

31. Fortune, New York (1997) Debate: Duking It Out over EVA Gary Hamel; Al Ehrbar. August 4^{th}.

32. Froot, K. and Stein, J. (1998) Risk Management, Capital Budgeting and Capital Structure Policy for financial institutions: An Integrated Approach, Journal of Financial Economics, 47: 55-82.

33. Giles Tim and Milne Alistair (2003) An alternative view of the Basel II, rules for calculating regulatory capital, Working paper.

34. Harris M., Kriebe, C. and Raviv, A. (1982) The Capital Budgeting Process, Incentives and Information, Journal of Finance.

35. Hull, J. (2003) Options, Futures, and Other Derivatives, 5^{th} edition, Pearson education international.

36. Jameson, Rob (2001) Between RAROC and a hard place, ERisk.

37. Kimball, R. (1997) Innovations in Performance Measurement in Banking, New England Economic Review.

38. Kisgen Darren (2003) Credit Ratings and Capital Structure, University of Washington, School of Business Administration.

39. KPMG (2003) Basel II- A closer look, Managing Economic Capital.

40. Matten, Chris (2001) Managing Bank Capital, 2nd edition.

41. Merton, R. and Perold, A. (1993) Theory of risk capital in financial firms, Journal of Applied Corporate Finance, 6: 16-32.

42. Millbourn, Todd (1997) EVA's charm as a performance measure, Financial Times.

43. Modigliani, F. and Miller, H. (1958) The cost of capital, corporation finance and the theory of investment, American Economic Review 48, pp. 261-297.

44. Moody's Investors Service (1995b) Moody's credit ratings and research, New York.

45. Mussman, M. (1996) In praise of RAROC, Balance sheet.

46. Myers C. Stewart, The Search for Optimal Capital Structure, MIT.

47. Onorato, Mario (2004) How to use risk adjusted performance measurement to efficiently allocate economic capital, Working Paper.

48. Reichelstein, S. (1997) Investment decisions and managerial performance evaluation, Review of Accounting Studies, 2: 157-180.

49. Schroeck, Gerhard (2000) Risk Management and Value Creation in financial institutions, Wiley.

50. Stern, Joel M. (2000) EVA and Strategic Performance Measurement, Global Finance 2000, New York.

51. Stewart, G. Bennett (1994) EVA: Fact and Fantasy, Stern Stewart & Co, Journal of Applied Corporate Finance, volume 7 no 2.

52. Stoughton, M. Neal and Zechner, Josef (1999) Optimal Capital Allocation using RAROC and EVA, Working paper.

53. Stulz, Rene M. (1996) Rethinking risk management, Journal of Applied Corporate Finance, vol. 9 number 3, pp. 8-24.

54. Stultz, R. (1998) Derivatives, risk management and financial engineering, Southwestern Publishing.

55. Thomson, James B. (2001) PSAF, Economic Capital and the New Basel Accord, Federal Reserve Bank of Cleveland.

56. Tully, Shawn (1993) The Real Key to creating wealth, Fortune.

57. Uyemura D., Kantor C. and Pettit J. (1996) EVA for Banks: Value creation, risk management and profitability measurement, Journal of Applied Corporate Finance.

58. Villani E. (2004) Optimal Bank Capital Structure, Diversification and Managerial Incentive Schemes, Working Paper, Universita di Brescia.

59. Wilson, Thomas C. (1992) RAROC remodeled, Risk Magazine, Vol. 5 number 8, September 1992, pp. 112-119.

60. Wilson, Thomas C. (1996) Calculating risk capital, in Carol Alexander (ed) The Handbook of Risk Management and Analysis: Vol. I, Chichester: John Wiley & Sons, Inc, pp. 193-232.

61. Wilson, T.C. (2002) Overcoming the Hurdle: Integrating the Shareholder/ Debtholder-Perspectives, Mercer Oliver Wyman, New York.

62. Wilson, T.C. (2002) Cost of capital for financial institutions, Working paper, Mercer Oliver Wyman.

63. Wilson, T.C. (2003) Valuation, earnings volatility and cost of capital, Working paper, Mercer Oliver Wyman.

64. Zaik E., Walter J., Kelling G. and James C. (1996) RAROC at Bank of America: from theory to practice, Journal of Applied Corporate Finance.

65. (2000). Economic Capital Survey Results, Boston.

66. (2003) Capital and Risk: New evidence on implications of large operational losses, Federal Reserve, Bank of Boston.

67. (2003) Specialty Guide on Economic Capital, Version 1.4.

68. www.bis.org/publ/bcbsca

69. www.pages.stern.nyu.edu