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# Design of Risk Weights

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**Abstract**

Banking regulations set minimum levels of capital for banks. These requirements are generally formulated through a ratio of capital to *risk-weighted* assets. A risk-weighting scheme assigns a weight to each asset or category of assets and effectively functions as a linear constraint on a bank's portfolio choice; it also changes the incentives for banks to hold various kinds of assets. In this paper, we investigate the design of risk weights to align regulatory and private objectives in a simple mean-variance framework for portfolio selection. By setting risk weights proportional to profitability rather than risk, the regulator can induce a bank to reduce its overall level of risk without distorting its asset mix. Because the regulator is unlikely to know the true profitability of assets, we introduce an adaptive formulation in which the regulator sets weights by observing a bank's portfolio. The adaptive scheme converges to the same combination of weights and portfolio choice that would hold if the regulator knew the asset profitability. We also investigate other objectives, including steering banks to a target mix of assets, adding robustness, mitigating procyclicality, and reducing system-wide risk in a setting with multiple heterogeneous banks.

## 1 Introduction

Capital requirements for banks are intended to ensure that banks have adequate capital to withstand large losses in the assets they hold. The simplest type of capital requirement limits a bank's overall leverage by putting an upper bound on the ratio of a bank's total assets to its equity. Since the 1980s, most regulatory capital requirements have instead been formulated as a percentage of *risk-weighted* assets, with the objective of aligning a bank's capital cushion with the riskiness of its assets.

A risk-weighting scheme assigns a risk weight to each type of asset or group of assets, such as residential mortgages, corporate loans, securities, and so on. Risk-weighted assets, in their simplest form, are then calculated by taking a linear combination of a bank's investments across categories, using the risk weights as coefficients. Required capital is then set at a fixed fraction (e.g., 8 percent) of the risk-weighted sum. See Section 2 for details and background.

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This is a rather curious scheme, if we consider that risk is not ordinarily considered additive. One might construe the additive formulation as conservative, but capital requirements affect which assets a bank chooses to hold, so the choice of risk weights affects a bank's asset mix and not just the overall risk of its portfolio. A risk-weighting scheme may be conservative in its effect on overall risk and yet introduce unintended distortions in the levels of different kinds of lending activities.

This paper undertakes a theoretical investigation into the design of risk weights. Our goal is to understand what types of objectives can be achieved by imposing linear risk-weight constraints. We work within a simple model of portfolio selection based on various mean-variance objectives. This simple setting provides a high degree of tractability, which makes the implications of the results easier to interpret.

The theoretical underpinnings of risk weights have not received a great deal of attention. Pyle [28] and Hart and Jaffee [20] provide early formulations of a financial institution's portfolio problem using mean-variance optimization; Hart and Jaffee [20] associate a reserve requirement with each asset that functions much like a risk weight, but they take these requirements as given. Koehn and Santomero [24] and Kim and Santomero [23] use the mean-variance framework to argue that a simple leverage limit can actually increase risk, and Kim and Santomero [23] go on to derive risk weights that preclude this outcome. Their formulation is critiqued by Keeley and Furlong [22] for assuming that a bank can buy and sell its own equity the way it trades in any other asset. In this respect, our formulation is closer to Rochet [31, Chapter 8], in that we treat the level of capital available to a bank as fixed. Using a mean-variance analysis, Rochet [31, p.244] proposes setting the risk weight for each asset proportional to its systematic risk, as defined through the capital asset pricing model. Calomiris [11] and Morgan and Ashcraft [27] propose tying capital requirements to the interest rates banks charge on loans because higher rates should reflect higher risk. This approach implicitly takes the view that the risk weight for an asset should reflect only the risk in that asset, without consideration of the effect on portfolio mix. See Santos [32] and VanHoose [36] for surveys of research on capital requirements and many additional references.

Gordy [17] analyzes the connection between a linear risk-weighting scheme and a value-at-risk measure for portfolio credit risk, based on the internal ratings based approach introduced under Basel II capital requirements (BCBS [7]). He shows that in an "asymptotic single risk factor" version of the portfolio model, a value-at-risk based capital requirement is equivalent to a linear risk-weighting scheme. Repullo and Suarez [30] analyze implications of this framework for bank portfolio choice. Shin [33] interprets value-at-risk based capital constraints from the perspective of mean-variance optimization.

The empirical literature on bank capital requirements is extensive, but most of it focuses on the

level of bank capital rather than the validity of risk weights. An exception is Cordell and King [12] who compare regulatory risk weights with market-based risk weights derived from the performance of bank stocks. Recent studies comparing risk-weighted assets with the market risk of banks include Acharya, Engle, and Pierret [2], Das and Sy [13] and Vallascas and Hagendorff [35].

For our investigation, we take a risk-weighting scheme to have two primary interlinked objectives: to limit the overall risk in a bank portfolio and to do so without an unintended distortion of the mix of assets held by the bank. The first of these objectives is common to all capital regulation, but the second is specific to a risk-weighting scheme because risk weights implicitly assign prices (in terms of additional capital) to asset categories and thus inevitably create incentives for banks to choose some assets over others. As a starting point, we suppose that the regulator would prefer not to change the mix of assets — just the overall levels — before we consider the more general case in which the regulator seeks to steer banks toward a different mix.

Our first main result (in Section 3) shows that this objective can be achieved — surprisingly, the ideal risk-weights turn out to have little to do with risk and are instead proportional to the profitability (expected excess return) on each asset. With these weights, the regulator can limit the bank's overall risk; Kim and Santomero [23] arrive at a similar conclusion in their formulation, but their result does not appear to be well known. Moreover, we show that this choice of weights leaves the relative mix of assets in the bank's portfolio unchanged from the relative mix the bank would choose in the absence of a risk-weight constraint. If the regulator does want to change the asset mix as well as the overall risk level, we identify the set of target portfolios the regulator can induce the bank to hold through suitable choice of risk weights.

Setting risk weights proportional to asset profitability has attractive theoretical properties but is difficult in practice because the regulator is unlikely to have good information on expected returns. We therefore analyze an *adaptive* implementation in which the regulator sets weights based on observing a bank's portfolio. Changing the weights changes the bank's choice of portfolio which leads to a further change in weights. The result is an iterative process. We show that the process converges to an equilibrium in which the risk weights and the bank's portfolio coincide with the values they would have if the regulator knew the profitability of each asset. The details of this adaptive process are specific to our model, but we view the main insight from this analysis as more broadly applicable: to compensate for imperfect knowledge about bank assets, the regulator should increase the risk weight for an asset category as banks increase their positions in that category. These results are in Section 4.

Banks face multiple capital constraints, including an overall leverage ratio and, more recently, constraints based on stress tests. In Section 5, we extend our analysis to consider multiple con-

straints, and we connect the extension with a robustness interpretation.

A significant concern with risk-based capital requirements is that they are *procyclical*. In an economic downturn, defaults become more likely, so loans become riskier, forcing banks to hold more capital and thus reduce lending, aggravating the economic downturn. In Section 6, we show that our basic approach to the design of risk weights can be modified to mitigate procyclicality. In the simplest case, these "macroprudential" risk weights are still proportional to asset profitability, but the constant of proportionality changes to mitigate procyclicality.

Finally, in Section 7 we consider a system-wide objective for the regulator in a model with multiple heterogeneous banks. Banks differ in the set of assets to which they have access. We show that a single set of risk weights can ensure that all banks meet a regulatory risk limit. Using a common set of risk weights implicitly imposes a capital surcharge on banks that participate in a wider range of activities, which is consistent with heightened capital requirements for global banks. This effect can be offset through a simple multiplier based on portfolio concentration.

## 2 Background on Risk Weights

Nearly all of the various capital adequacy measures defined in the international standards set by the Basel Committee on Banking Supervision (BCBS [6, 7, 9]) are based on a bank's risk-weighted assets. These measures include, in particular, ratios for Tier 1 and Tier 2 capital, total capital, common equity Tier 1 capital, and core Tier 1 capital. These ratios differ in the scope of capital they include in the numerator, but they all take risk-weighted assets as the denominator.

A capital standard based on risk-weighted assets was introduced in the 1988 Basel Accord [6], now generally referred to as Basel I. The accord sought to harmonize capital requirements internationally and set a minimum capital standard of 8 percent of risk-weighted assets. It put forward three reasons for risk-weighting that remain relevant today: ensuring comparability across banking systems with different structures, incorporating off-balance-sheet exposures, and not deterring banks from holding assets that carry low risk. The accord did not, however, lay out any principles by which the risk weights would be set.

The Basel I rules allow just five weights: 0 percent, 10 percent, 20 percent, 50 percent, and 100 percent, in increasing order of "riskiness." For example, sovereign exposures have a 0 percent weight for OECD countries and 100 percent for non-OECD countries; short-term loans to other banks carry a 20 percent risk weight; first-lien residential mortgages for owner-occupied housing carry a 50 percent risk weight, and all corporate loans carry a 100 percent risk weight. The weight for off-balance-sheet exposures is determined by the type of counterparty — sovereign, bank, or corporate. The 1988 accord includes general discussion of risk categories, but, again, it does not

provide principles to support the relative magnitudes of the weights.

In response to the growing importance of trading activities in large banks, the 1996 amendment to Basel I expanded capital requirements to include capital charges for market risk. The amendment's standardized approach assigned risk weights to various categories of assets, covering specific risk associated with, for example, a particular issuer, and general risks from interest rates, exchange rates, and similar broad market factors. As one would expect, the risk weights introduced suggest an effort to align the weights with perceived risk — the risk weights for debt securities increase with maturity, for example. However, the amendment does not provide underlying principles that would imply a particular relative weighting across risk categories like interest rates, equities, currencies, and commodities.

For banks with advanced internal risk management procedures, the amendment offered an alternative approach, and this alternative would appear to be the first attempt to make a rigorous connection between risk and regulatory capital in banks. Under the internal models approach, a bank estimates a value-at-risk (VaR) for its trading activities, which is simply the first percentile of the profit and loss distribution over a ten-day horizon. The VaR is scaled and then added to the risk-weighted assets of the banking book (calculated from the original Basel I weights); the overall capital requirement is then 8 percent of the total. The net effect of this procedure is to assign a risk weight to the trading book that is proportional to its VaR. If we go a step further and assume that VaR is roughly proportional to portfolio standard deviation,[1] then the risk weight for the trading book is proportional to its standard deviation.

The internal models approach marks a departure from earlier schemes in that the regulator does not explicitly assign a risk weight for each asset. Instead, the regulator specifies the rules for calculating the risk weight for a set of assets and leaves it to the bank to carry out the calculation.

This perspective is also important for Basel II [7], which revisited the calculation of risk-weighted assets in the banking book. The standardized approach under Basel II is, for the most part, based on tables of fixed risk weights for various types of exposure, though with greater differentiation of risk categories than Basel I. But the internal ratings based approach instead defines procedures by which banks themselves are to calculate risk weights for various types of lending activities. The procedures are complicated but, at their core, they take the risk weight for a category of loans to be proportional to a VaR figure for the portfolio of those loans. A significant current concern is the wide disparity in the application of the internal ratings based approach across large banks; see, for example, Le Leslé and Avramova [25], European Banking Authority [14], and many accounts in the financial press.

[1] This does not require a normal distribution; rather, it assumes that the shape of the distribution remains stable so that the first percentile remains at a fixed number of standard deviations from zero.