

A NEW APPROACH TO CAPITAL BUDGETING FOR FINANCIAL INSTITUTIONS

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The classic approach to capital budgeting—the one MBA students have been taught for the last 30 years—is premised on the idea that a company’s incremental investment decisions should be independent of its pre-existing capital structure. That is, the hurdle rate for any new project should depend only on the characteristics of that new project, and not on the inherited financial policy of the company evaluating the project. Similarly, the hurdle rate should also not be influenced by the company’s risk management policy, or by the nature of any previous (physically unrelated) assets it already has on the balance sheet.

In a paper recently published in the *Journal of Financial Economics*, we argue that this approach may not be appropriate for banks and other financial institutions.¹ More specifically, we suggest that discount rates based on the standard Capital Asset Pricing Model (CAPM) may understate the true economic costs of illiquid bank investments—those which impose on a bank risks that, although ultimately diversifiable by shareholders, cannot be readily hedged by the bank and therefore require it to hold more equity capital.

In principle, our general point applies to any company attempting to manage the risks associated with illiquid (and therefore unhedgeable) assets. Nonetheless, we think it is particularly useful for addressing the problems facing financial institutions. This is because getting the cost of capital right for any given instrument is very likely to be a first-order consideration for a financial institution. In contrast, for many industrial companies doing capital budgeting, the uncertainties associated with projecting cashflows on their physical assets may be so large as to swamp any modifications in discount rates that our method might suggest.

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1. Although we use the term “bank” throughout for shorthand, we have in mind not just commercial banks, but other types of intermediaries as well, e.g., investment banks, insurance and reinsurance companies, etc. Indeed, many of the applications that we discuss below are set in the context of these other institutions.

THE LINK BETWEEN BANKS' INVESTMENT, CAPITAL STRUCTURE, AND RISK MANAGEMENT POLICIES

One of the fundamental roles of banks and other financial intermediaries is to invest in illiquid assets—assets which, because of their information-intensive nature, cannot be frictionlessly traded in the capital markets. The standard example of such an illiquid asset is a loan to a small or medium-sized company. A more modern example is the credit-risk component of a foreign exchange swap. Even if the currency risk inherent in the swap can be easily laid off by the dealer bank, the same is not likely true of the credit risk.

At the same time that they are investing in illiquid assets, most banks also engage in active risk management programs. Holding fixed its capital structure, a bank has two broad ways to control its exposure to risk. First, it can offset some risks simply via hedging transactions in the capital market. Second, for those risks where direct hedging transactions are not feasible, the other way for the bank to control its exposure is by altering its investment policies. Therefore, with illiquid risks, the bank's capital budgeting and risk management functions become linked.

To see this point more clearly, return to the example of the foreign exchange swap. If a dealer bank is considering entering into such a transaction, its own aversion to currency risk should not enter into the decision of whether or not to proceed. After all, if it doesn't like the currency risk embodied in the swap, it can always unload this risk in the market on fair terms. Thus with respect to the tradeable currency risk, the risk management and investment decisions are separable. The same is not true, however, with respect to the illiquid credit-risk component of the swap. If the bank is averse to this risk, the only way to avoid it is by not entering into the swap in the first place.

This reasoning suggests that if the bank is asked to bid on the swap, its pricing should have the following properties. First, the pricing of the swap should be independent of the bank's own attitudes toward currency risk—the bank should evaluate currency risk in the same way as any other market participant, based only on the risk's correlation with

systematic factors that are priced in the capital market. Second, however, the swap's pricing *should* depend on the bank's own attitude toward the credit risk. Thus if the bank already has a portfolio of very highly correlated credit risks, it might bid less aggressively for the swap than another institution with a different balance sheet, all else equal. This should hold true even if the credit risk is uncorrelated with factors that are priced in the capital market.

Although this sort of approach to the pricing of bank products may sound intuitively reasonable, it differs substantially from the dominant paradigm in the academic literature, which is based on the classical finance assumptions of frictionless trading and absence of arbitrage. In the specific case of pricing the credit risk on a swap, the classical method boils down to a contingent-claims model of the sort pioneered by Robert Merton in the early 1970s.² This type of model—like any classical pricing technique—has the implication that the correct price for the swap is the same for any dealer bank, independent of the bank's pre-existing portfolio. Of course, this is because the classical approach by its very nature assumes away exactly the sorts of imperfections that make the bank's problem challenging and relevant. Indeed, it is only appropriate if either (1) the bank can frictionlessly hedge all risks—including credit risks—in the capital market; or (2) the Modigliani-Miller theorem applies, so that the bank has no reason to care about risk management.

Perhaps because the classical finance approach does not speak to their concerns with risk management, practitioners have developed alternative techniques for capital budgeting. One leading approach is based on the concept of RAROC (risk-adjusted return on capital). The RAROC method effectively assesses a risk premium in the form of a capital charge on investments that is equal to a measure of their "capital at risk" multiplied by a "cost of capital." However, although the RAROC approach has some intuitive appeal, it is not clear that it is the *optimal* technique for dealing with the sorts of capital budgeting problems facing financial institutions. That is, RAROC—as currently applied—is not derived from first principles to address the objective of shareholder value maximization. Consequently, it has some features that might be considered troublesome, and it leaves other issues potentially unre-

2. Robert C. Merton, "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance* 29 (1974), 449-470.

solved. For example, should “capital at risk” be calculated based on an investment’s total volatility, or on some sort of covariance measure? And once one has determined the amount of capital at risk, what is the right cost to assign to this capital? Should the cost of capital at risk depend on the strength of the bank’s balance sheet, or other related variables?

Our primary goal in this paper is to present a conceptual framework for capital budgeting that blends some of the most desirable features of both the classical approach and the RAROC-style bank-practitioner approach. To accomplish this goal, we describe a model that—like the classical approach—is squarely rooted in the objective of maximizing shareholder value in an efficient market. However, the model also incorporates two other key features: (1) there is a well-founded concern with risk management; and (2) not all risks can be hedged in the capital market. This allows us to capture the important intuition that *bank-level risk-management considerations should enter into the pricing of those risks that cannot be hedged*.

In order to rationalize banks’ concern with risk management, we assume that there are increasing costs to raising new external funds. For example, if a bank were to be hit with a negative shock that depleted its capital, and had to rebuild its balance sheet, it might be forced to issue new equity in a highly uncertain (“asymmetric information”) environment where bank management attaches a different value to the equity than outsiders. In an effort to avoid these problems in the first place, the bank will behave in a risk averse fashion.³

As will become clear, one key feature of this modelling approach is that it highlights a trade-off between (1) managing risk via ex ante capital structure policy and (2) managing risk via capital budgeting and hedging policies. Aside from engaging in hedging transactions, a bank has two other methods for controlling the risk of being caught short of funds. First, it can adopt a very conservative capital

structure. If there are no costs to holding a lot of capital, this will be the preferred way of dealing with the problem. In the limit when the bank holds a very large capital buffer, risk-management concerns will no longer enter investment decisions, and the model will converge back to the classical paradigm. Alternatively, if holding capital is costly (e.g., due to tax or agency effects), the bank can control its risk exposure by investing less aggressively in (i.e., charging a higher price for bearing) non-hedgeable risks. In this case, risk-management concerns will have a meaningful impact on capital budgeting policies. The bottom line is that in our framework, optimal hedging, capital budgeting and capital structure policies are jointly determined.⁴

In what follows, we begin by briefly describing the model that is presented in full in our original *JFE* paper, and discussing the model’s implications for banks’ hedging, capital budgeting, and capital structure decisions. Next, we provide several examples of how the basic framework can be applied to different sorts of capital budgeting problems facing financial institutions. Finally, we undertake a detailed comparison of our approach with the RAROC method.

THE MODEL: SET-UP

The model has three time periods, 0, 1, and 2. In the first two periods, the bank chooses its capital structure, and then makes capital budgeting and hedging decisions. These two periods are at the heart of our analysis. The last period is needed to close the model—to give the bank a well-founded objective function that incorporates both shareholder-value maximization as well as a concern for risk management.

Time 0: Bank Chooses Its Long-run Target Capital Structure

The bank enters time 0 with an initial portfolio of exposures. This portfolio will result in a time-2

3. This basic rationale for risk management is essentially the same as that presented by Froot, Scharfstein and Stein (1993) in the context of non-financial corporations. (See Kenneth A. Froot, David S. Scharfstein, and Jeremy C. Stein, “Risk Management: Coordinating Corporate Investment and Financing Policies,” *Journal of Finance* 48 (1993), 1629-1658.) It is also closely related to the banking models of Kashyap and Stein (1995) and Stein (1998), which emphasize the costs that banks face in raising non-deposit external finance. In what follows, we ignore any risk-taking incentives that might arise with government-provided deposit insurance. Thus our theory is most literally applicable either to financial institutions that are not insured commercial banks (e.g. investment banks) or to commercial banks that are sufficiently well-capitalized that one can for practical purposes safely ignore the incentive effects of deposit insurance. (See Anil Kashyap and Jeremy C. Stein,

“The Impact of Monetary Policy on Bank Balance Sheets,” *Carnegie-Rochester Conference Series on Public Policy* 42 (1995), 151-195; and Jeremy C. Stein, “An Adverse Selection Model of Bank Asset and Liability Management with Implications for the Transmission of Monetary Policy,” *RAND Journal of Economics*, forthcoming 1998.)

4. For other papers which investigate the linkages between capital budgeting and risk management, see Robert C. Merton and Andre F. Perold, “The Theory of Risk Capital in Financial Firms,” *Journal of Applied Corporate Finance* 5 (1993), 16-32; Robert C. Merton, “A Model of Contract Guarantees for Credit-Sensitive Opaque Financial Intermediaries,” Harvard Business School working paper, 1995a; and Robert C. Merton, “A Functional Perspective on Financial Intermediation,” *Financial Management* 24 (1995b), 23-41.

random payoff of $\mu_p + \varepsilon_p$, where μ_p is the mean and ε_p is a normally distributed shock. The only decision facing the bank at time 0 is how much equity capital to hold. Specifically, the bank can raise an amount of capital K , and invest the proceeds in riskless Treasury bills. Holding “financial slack” in this manner involves direct deadweight costs. These costs might in principle arise from a number of sources; for concreteness, it is useful to think of them as being driven by taxes. Thus the deadweight costs of holding an amount of capital K are given by πK , where π is the effective net tax on cash holdings.⁵

Although it involves deadweight costs, we will see below that banks typically opt to hold non-zero levels of capital. This is because holding capital allows banks to tolerate risks better, and thereby price their products more aggressively. Thus the question we ultimately wish to address with the time-0 analysis is this: what is the appropriate long-run “target” capital structure for the bank? In other words, how should the bank be seeking to position itself over the long haul—as a AAA credit, a BBB credit, or something in between?

Time 1: Bank Invests In New Products And Makes Hedging Decisions

At time 1, the bank faces two decisions. First, it has the opportunity to invest in a new product.⁶ The new product offers a random payoff of $\mu_N + \varepsilon_N$, where μ_N is the mean and ε_N is a normally distributed shock.

The second decision to be made at time 1 is how to hedge both the initial and new exposures. A key premise of the model is that not all risks can be hedged. As stressed above, the very existence of intermediaries such as banks is testimony to the fact that certain risks are somewhat information-intensive, and hence cannot be traded perfectly liquidly. To take a first cut at capturing this notion, we make the following decomposition. We assume that a bank’s exposures can be classified into two categories: (1) perfectly tradeable exposures, which can be unloaded frictionlessly on fair-market terms; and (2) completely non-tradeable exposures, which must be retained by the bank no matter what.

In terms of our previous notation, this amounts to decomposing both ε_p and ε_N (the risks on the pre-existing portfolio and the new product) as follows:

$$\varepsilon_p = \varepsilon_p^T + \varepsilon_p^N \quad (1)$$

$$\varepsilon_N = \varepsilon_N^T + \varepsilon_N^N \quad (2)$$

where ε_p^T is the tradeable component of ε_p , ε_p^N is the non-tradeable component, and so forth.

There are a number of different examples that help illustrate what we have in mind with this decomposition, and we will develop several of these examples in more detail shortly. For the time being, it may be helpful for concreteness to think of the new product as being an investment in a company whose stock is not publicly traded. Clearly, some of the risk associated with such an investment may be tradeable, to the extent that it is correlated with, say, the stock market as a whole, and hence can be hedged with something like a stock-index-based derivative. However, some of the idiosyncratic exposure associated with the investment cannot be laid off, at least not frictionlessly. This is what we are trying to capture.

Time 2: Bank Reacts To Its Cashflow Realization

As noted above, we need to build into the model a reason for the bank to care about the riskiness of its cashflows. To do so, we follow closely a model developed in a 1993 study by Froot, Scharfstein and Stein, henceforth “FSS.”⁷ In particular, we assume that after the risky cashflows on the pre-existing portfolio and the new product are realized, the bank has a further, riskless investment opportunity—for example, it might be able to extend some new loans. This investment can either be funded out of internal sources, or the money can be raised externally. The hitch is that there are increasing marginal costs to raising external finance. Again, these external-finance costs may be rooted in asymmetries of information between bank management and outside investors.

FSS demonstrate that in this setting, the bank will behave in a risk-averse fashion. The idea is that the bank wants to avoid very negative cashflow

5. The tax cost of holding equity-financed slack is just the mirror image of the tax advantage of debt finance.

6. We begin by focusing on the case where there is only one new product at time 1 for simplicity. However, it is easy to generalize the results to the case of multiple new products, as we do below.

7. Froot, Scharfstein and Stein (1993), cited in footnote 3.

The standard Capital Asset Pricing Model may understate the true economic costs of illiquid bank investments—those which impose on a bank risks that, although ultimately diversifiable by shareholders, cannot be readily hedged by the bank and therefore require it to hold more equity capital.

outcomes that force it to raise large amounts of costly external finance on short notice. Loosely speaking, the more difficult it is for the bank to raise external funds at time 2, the more risk averse it will be with respect to fluctuations in its cashflows.

Some Observations About The Structure Of The Model

If one were to leave time 1 out of the model, and keep only the parts corresponding to time 0 and time 2, we would be left with a very standard “pecking-order” story of corporate investment and financing.⁸ At time 2, the presence of increasing marginal costs of external finance can lead to underinvestment. This problem can be partially alleviated to the extent that a buffer stock of financial slack can be built up at time 0. Thus it may be desirable to hold such a buffer on the balance sheet, even if there are some costs to doing so.

What we have added to this basic pecking-order story are the ingredients that come into play at time 1. Specifically, the bank now has two other tools at its disposal—beyond simply holding financial slack—that it can use to offset the underinvestment distortions caused by costly external finance: (1) the bank can reduce its risk exposure by hedging more completely; and (2) the bank can also reduce its risk exposure by cutting back on the amount it invests in the new product. Thus overall, the bank optimizes by picking the right combination of capital structure, hedging and capital budgeting policies. It is in this sense that these three decisions are linked to one another.

ANALYSIS

Optimal Hedging Policy

Suppose the bank designs its risk management policy so as to maximize shareholder value. What should it do? Simply put, it should hedge out *all* the tradeable risks, on both the pre-existing portfolio and the new product. For example, if either the portfolio or the new product is exposed to interest-rate or currency risk, the bank should enter into

derivative transactions (swaps, etc.) that fully offset these risks.

It might be tempting to conclude that this prescription resembles that for a risk-averse individual. But this is not quite correct. In general, a risk-averse individual *will not* wish to completely shun systematic risk, as this involves a reduction in expected return. Rather, an individual will typically opt to bear some systematic risk. However, this is not true for a publicly traded bank in our set-up. A bank does not reduce *shareholder value* by sacrificing return in exchange for a reduction in risk, so long as the terms of trade are set in an efficient market—i.e., so long as the hedging transactions are zero-NPV from a capital-market perspective.

Capital Budgeting Policy: The Two-factor Model

The standard procedure for estimating a project's cost of capital is to use the CAPM. The CAPM can be thought of as a “one-factor” model in the sense that, in the standard application, the required rate of return on a new project is a function solely of the project's covariance with the market portfolio. Expressed in equation form, the hurdle rate for a new project N—which we denote by k_N —is given by:

$$k_N = r_F + \beta_N^M(r_M - r_F), \quad (3)$$

where r_F is the riskless rate (often approximated by a Treasury yield), β_N^M is the exposure of the new project to the market factor, and r_M is the expected return on the market portfolio.

But again, the use of the CAPM assumes away the financing frictions that are central to our model of a banking firm. In our *JFE* paper, we show that when these frictions are present, the hurdle rate contains a second factor:

$$k_N = r_F + \beta_N^M(r_M - r_F) + \beta_N^P Z, \quad (4)$$

where Z is the bank's price of unhedged risk, and $\beta_N^P = \text{cov}(\epsilon_N^N, \epsilon_P^N) / \text{var}(\epsilon_P^N)$. In words, this second factor boosts the hurdle rate by an amount that is proportional to the new project's “internal portfolio beta.”⁹

8. This is very much in the spirit of Myers (1984), Myers and Majluf (1984), and the large literature that has followed these papers. (Stewart C. Myers, “The Capital Structure Puzzle,” *Journal of Finance* 39 (1984), 575-592; and Stewart C. Myers and Nicholas Majluf, “Corporate Financing and Investment Decisions When Firms Have Information that Investors Do Not Have,” *Journal of Financial Economics* 13 (1984), 187-221.)

9. Strictly speaking, this hurdle rate is only correct if the new project being considered is small relative to the bank's pre-existing portfolio. We discuss this in more detail shortly.

This second beta is driven by the correlation of the new project's unhedgeable risks with the unhedgeable risks in the bank's pre-existing portfolio.

The bank's price of unhedged risk Z is the product of two factors: (1) the bank's risk aversion and (2) the overall variance of its unhedged portfolio.¹⁰ Importantly, the bank's risk aversion is an endogenous variable, unlike in the case of an individual decision-maker. In particular, this risk aversion—and hence the price of unhedged risk Z —will depend on the amount of capital K that the bank holds. When K becomes very large, Z converges to zero. In other words, with infinite capital, the bank becomes risk-neutral, as in the classical setting. This is because the probability of it ever having to seek costly external finance falls to zero.

An Example. As noted above, the most literal interpretation of our tradeable/non-tradeable risk decomposition would be to think of a group in a bank that invests in non-public companies, or slightly more generally, companies whose stock is sufficiently illiquid as to preclude easy hedging of the bank's position. To take a concrete illustration, a merchant banking group may have the opportunity to make a small, fixed-size investment in the equity of a private company, e.g., a real estate investment trust (REIT). How should it decide whether or not to go forward?

As in any valuation exercise of this sort, the group will have to do a discounted cash flow analysis of the REIT in question. The cashflow projections will be done in the usual manner. However, our results suggest that if risk management is a serious concern for the group's parent bank, the discount rate should differ from that used in a classical setting. Specifically, to calculate an appropriate discount rate, the group should start with the classical CAPM-based rate and then add a premium given by the second factor in equation (4) above. So, for example, if the bank's existing portfolio already contains significant correlated (and unhedgeable) real estate exposures, our second factor will lead it to set a higher discount rate, all else equal.

A Caveat: Large Investments. In traditional capital budgeting applications, the hurdle rate for an investment is independent of the investment's size. This is no longer true in our context. Indeed, our two-

factor model only applies literally if the project in question is sufficiently small that, if it were undertaken, it would have no discernible impact on the bank's overall portfolio.

To see why this complication arises, think back to our example of the proposed REIT investment. Suppose the bank has an existing portfolio of \$10 billion invested in a wide variety of assets. If the REIT investment is only \$10 million, it is a reasonable approximation to think of it as leaving the bank's aggregate portfolio unchanged. However, if the REIT investment is, say, \$500 million, taking it will alter the bank's portfolio in such a way as to make it more real-estate-sensitive. This in turn implies that the hurdle rate for further incremental real-estate investments goes up. The bottom line is that while our basic logic still applies, the hurdle rate for a large investment is an increasing function of the size of that investment.¹¹ Intuitively, a risk-averse bank wants to maintain a diversified portfolio. Large investments work against this diversification goal, and so must be evaluated more stringently.

Multiple Investments, Interdependencies, and Decentralization. Thus far, we have assumed that the bank only has the opportunity to invest in one new product. However, it is straightforward to extend the results to the case where the bank can invest simultaneously in multiple new products. If these new products are all "small" investments in the sense discussed above, one can apply the two-factor model of equation (4) to each one of the new products independently.

However, if the new products are not "small" investments, things become more complicated in this multi-investment setting than in the usual corporate capital budgeting framework. In the usual framework, investment decisions are independent of one another—holding fixed their cashflows, the appeal of one project does not depend on whether or not another project is undertaken. In our model, with multiple large investments, this no longer holds true. In fact, there are two distinct sources of interdependence.

First, there is what might be termed a "covariance spillover" effect. Holding fixed the bank's risk aversion, investment in any one product will be less (more) attractive to the extent that there is also a

10. In our *JFE* paper, we show how to calculate Z explicitly in terms of primitive parameters describing the bank's investment opportunities and its costs of external finance.

11. In our *JFE* paper, we give a precise analytical treatment of how to handle such large investments.

The right question is not whether or not the bank should centralize its decision-making, but rather *how often* headquarters should gather information and use this pooled information to help guide investment decisions.

significant investment made in another product with positively (negatively) correlated non-tradeable risk.

Second, and somewhat more subtly, there is what might be termed a “bank-wide price of risk” effect. Even if all the new products are uncorrelated with one another, investment decisions are in general interdependent because they can all influence the value of the bank’s aversion parameter, and by extension, the price of unhedged risk Z . Thus for example, if the bank takes a large, very risky position in one product, even if this position is completely uncorrelated with all others, this might raise Z and thereby make the bank less willing to take on any other risks.

These interdependencies imply that in order for the bank to make optimal investment decisions, these decisions must be centralized. If one thinks of individual product managers as observing the profitability of their own products but not of others, one cannot simply delegate the investment decisions to these managers, even under the strong assumption that there are no agency problems and that the managers would therefore act in the bank’s best interests with the information that they have. Rather, the information of the individual managers must be pooled.

As a practical matter, however, such centralized decision-making may present its own set of difficulties. This is likely to be especially true when decisions are made at very high frequencies, in which case the costs and delays associated with transmitting new information to headquarters each time an investment is considered made may be prohibitive. To take an extreme example, think of a bank with several hundred different traders who reevaluate their positions on an almost continuous basis. Clearly, in this sort of polar situation, complete centralization of decision-making is impossible.

This raises the question of whether one can approximate the full-information centralized solution in a decentralized setting where individual product managers cannot observe the profitability of other new products. As we have seen, decentralization poses no problem in the limiting case where all the investments in the new products are small, and where one can use the two-factor hurdle rate ap-

proach independently for each one. Of course to the extent that the investments in the new products are *not* small, this decentralized approximation will be an imperfect one.

Overall, this line of reasoning suggests that the right question is not whether or not the bank should centralize its decision-making, but rather *how often* headquarters should gather information and use this pooled information to help guide investment decisions. Loosely speaking, what we have in mind is a dynamic version of the model wherein each time headquarters gathers information, it can update its estimate of both Z , and the characteristics of the pre-existing portfolio. These updated estimates can then be passed back to individual product managers, who will use them to form hurdle rates and thereby do their best to approximate optimal incremental investment decisions on a decentralized basis over the interval of time before the next round of information-pooling.

Although we have not analyzed such a dynamic model formally, we suspect that following basic trade-off would emerge: on the one hand, shortening the interval between rounds of information-pooling should lead to smaller deviations from the full-information centralized solution. On the other hand, this will also clearly increase the costs of information transmission. The task is then to properly balance these two competing considerations.¹²

Optimal Capital Structure

Having discussed capital budgeting, we are now in a position to think about the capital structure decision. There is a simple trade-off at work: on the one hand, as noted above, a higher level of bank capital K reduces the bank’s effective risk aversion, and hence the price of unhedged risk Z . From an ex ante perspective, this allows the bank to lower its hurdle rates and invest more aggressively in products that promise an above-market return. On the other hand, a higher K also involves deadweight costs of πK due to agency or taxes.

To put it differently, the bank has two choices: it can hold more slack K as a buffer at time 0, or it can be forced (in an expected sense) to seek more

12. Again, we should emphasize that this informal story completely ignores any agency issues associated with delegating investment decisions to individual product managers. In reality, these considerations are likely to be very important. For example, for a given information set, a product manager may have a tendency

to take what the bank would view as excessive risks, because his reward structure is inherently a convex function of outcomes. In this case, decentralization may involve not only setting appropriate prices—i.e., hurdle rates—but also imposing position limits or capital constraints on individual managers.

financing later on, with the attendant costs. It should optimally set K so that the expected marginal costs of external finance at time 2 just balance the cost of holding more capital at time 0. In the limiting case where $\pi = 0$, and thus there are no deadweight costs of holding capital, the bank holds a very large amount. This eliminates the need for short-notice external financing later on, which in turn implies that Z converges to zero. Thus the bank behaves in a classical manner, doing capital budgeting according to a purely market-based model of risk and return (e.g., the CAPM). In contrast, as π increases above zero, the bank holds less capital, thereby raising its effective price of unhedged risk Z , and amplifying the deviations from textbook capital budgeting principles.

FURTHER APPLICATIONS

We have already briefly discussed one concrete application of our model. Here are a couple of others.

A Proprietary Trading Desk

Another useful application of our framework is to a proprietary trading operation located inside a larger financial institution. For simplicity, suppose we are thinking of a desk that trades actively in “linear” instruments such as futures and forwards. At first glance, it might appear that our approach would be of little use in thinking about such a desk. To the extent that all the instruments it deals in are relatively liquid, it can in principle hedge any risk it faces, and therefore our tradeable/non-tradeable risk decomposition would seem to have little bite.

However, one needs to be a bit careful with the interpretation of the words “non-tradeable.” Even if all the risks facing the desk are hedgeable in principle, this obviously cannot be what the desk does in practice—if it did hedge out all of its risks, it would have no business. In other words, being a trading desk by definition requires intentionally assuming certain exposures. Ostensibly, these exposures are justified by the desk’s ability to earn a positive return on average, even after adjusting for market-wide risk factors. The presence of such

positive (subjective) risk-adjusted returns makes such exposures “non-tradeable” in our sense.

Seen in this light, our framework can be helpful in thinking about two closely related questions facing the managers of a trading desk. First, there is the *ex ante* capital budgeting question: given a particular directional “view” about an asset, how aggressively should the desk invest in that asset? Second, there is the *ex post* performance measurement question: how can one evaluate whether the desk made enough of a profit to compensate for the risks it imposed on the bank as a whole?

The answers to both of these questions flow directly from our two-factor model. For example, if the desk is making a go/no-go decision on a small trade, the verdict should be to go ahead only if the trade offers a subjective expected return that exceeds the two-factor hurdle rate in equation (4).

Pricing Non-hedgeable Derivatives Positions

Our approach may also be useful in helping to price derivatives positions that a bank cannot hedge cost-effectively. For concreteness, suppose the bank is acting as a dealer and has been asked to write a put option on the equity of another firm. If the option can be effectively delta-hedged by trading in the underlying equity, we are in the case where all the risk is tradeable. Thus the option should be priced using standard methods—i.e., a Black-Scholes approach.

However, suppose instead that the firm in question is either privately-held, or only very thinly traded. More precisely, the current market value of the firm is observable, but because of either trading costs or short-selling constraints, it is infeasible to hedge the option. Thus if the bank writes the option, it must bear the associated exposure. What price should the bank now charge for the option?

In our *JFE* paper, we show that the solution to this problem is arrived at with a very simple trick. One takes a classical option-pricing model (such as Black-Scholes) and augments the dividend yield on the underlying asset by an amount equal to the second factor from our two-factor model, i.e., by $\beta_N^P Z$.¹³ Note that, as in the standard setting, the market’s expected return on the underlying asset does not enter into consideration.

13. The one slight complication has to do with early exercise. In the example above, the *holder* of the put option will generally attach a different value to the option than the bank. And the holder’s decision of when to exercise will be

determined so as to optimize value from *his* perspective. This exercise strategy must then be incorporated when valuing the option from the bank’s perspective.

In the context of our example of a bank writing a put, this logic implies that the bank will charge a higher price than indicated by a standard model. The intuition is straightforward: the put is written on a stock which the bank discounts at a rate $\beta_N^P Z$ higher than the market. Thus from the bank's perspective, the stock is worth less than in the open market and, accordingly, the put is worth more. The upward effect on the put's price is the same as would obtain if the option was fully hedgeable but written on a stock that paid an extra dividend of $\beta_N^P Z$.

More generally, the same method can be used to value a wide range of illiquid derivatives positions. For example, one might wish to value illiquid credit risks. Following Merton (1974), one could take the approach of modelling a bank's credit exposure to a firm as being equivalent to a short put position in the firm's market value. Of course, this basic type of model can be tailored along a number of dimensions, according to how one wants to treat issues of priority in bankruptcy, etc. But whatever the specific variant of the perfect-markets pricing model is chosen, our results suggest that it can be adjusted for illiquidity very simply, along the lines above.

COMPARISON WITH RAROC-BASED CAPITAL BUDGETING

As noted at the outset, an increasingly popular approach to capital budgeting among banks is based on the concept of RAROC, or risk-adjusted return on capital.¹⁴ Now that we have developed our own framework, and have worked through several examples, it is useful to see how it compares with RAROC. For simplicity, we will consider the case of a small, new investment opportunity. In this case, our model says that the appropriate, value-maximizing hurdle rate is given by the two-factor model of equation (4).

A Generic Description of the RAROC Approach

Different banks implement RAROC in different ways; we will discuss some of the variations momen-

tarily. However, the approach can be generically described as follows. Each investment under consideration is allocated a certain amount of capital. Multiplying the allocated amount of capital by a "cost" of capital yields a capital charge. The hurdle rate for the investment is then the relevant riskless rate, plus the capital charge. Translated into our notation, we have:

$$k_N^R = r_F + E_N^R(k^E - r_F), \quad (5)$$

where k_N^R is the RAROC required return for the new investment, E_N^R is the amount of capital the RAROC model allocates to this investment, and k^E is the cost of capital as computed by the RAROC model. In all variants of RAROC of which we are aware, the capital allocation E_N^R is related to a measure of the investment's risk. Thus RAROC can be thought of as a one-factor risk-pricing model—not the CAPM to be sure, but an alternative one-factor model.

Comparing equation (5) with equation (4), we can see that our model will coincide with the RAROC approach only if the following three conditions are satisfied:

(1) The investment in question must have a beta with respect to the market factor of zero—i.e., it must be that $\beta_N^M = 0$. Or said differently, if the bank uses RAROC to evaluate an investment, this investment must be considered on a *post-hedged* basis, where all the market-factor risk has already been hedged out.

(2) One must be able to express the capital charge E_N^R for the new investment as a linear function of that investment's beta with respect to the bank's existing portfolio—i.e., one must be able to write $E_N^R = \zeta \beta_N^P$, for some parameter ζ .

(3) Finally, it must be that $\zeta(k^E - r_F) = Z$, where Z is the bank's price of unhedged risk.

Pitfalls in the Implementation of RAROC

The three conditions above highlight different ways that one can go wrong—at least relative to our model's implications for value-maximizing behavior—in applying a RAROC approach to capital budgeting. We now discuss each of these in turn and,

14. The RAROC concept was developed at Bankers Trust in the late 1970s. For recent descriptions of how it can be used for capital budgeting, see the following articles: Edward Zaik, John Walter, Gabriela Kelling and Christopher James, "RAROC at Bank of America: From Theory to Practice," *Journal of Applied Corporate Finance* 9 (1996), 83-93; Christopher James, "RAROC Based Capital

Budgeting and Performance Evaluation: A Case Study of Bank Capital Allocation," University of Florida working paper, 1996; and Dennis Uyemura, Charles Kantor and Justin Pettit, "EVA for Banks: Value Creation, Risk Management and Profitability Measurement," *Journal of Applied Corporate Finance* 9 (1996), 94-133.

where possible, comment on the current state of practice as we understand it.

Pitfall #1: Not Adequately Separating Priced and Non-priced Risks. One of the key implications of our two-factor model is that a bank should evaluate investments according to *both* their correlation with the market portfolio *and* their correlation with the bank's existing portfolio. Taken literally, the one-factor RAROC approach does not allow for these two degrees of freedom. Of course, if the RAROC model is only used for investments that are zero-beta with respect to the market portfolio, then there will be no problem. But to see where things can easily go wrong, think back to our example of the proprietary trading desk. One can easily imagine situations where the desk increases its exposure to the market factor, without changing either its total volatility or its correlation with the rest of the bank's portfolio (perhaps because the rest of the bank is market-neutral). In this case, the required return for the desk should obviously go up, but a direct application of the standard RAROC methodology is unlikely to capture this effect.

Pitfall #2: Basing Capital Allocations on Measures of Variance Rather Than Covariance. As noted above, the amount of capital E_N^R allocated to an investment is typically related to some measure of that investment's risk. But in some applications of RAROC, the risk measure used is the investment's *total volatility*.¹⁵ This is at odds with value maximization; as we have shown, it makes more sense for the capital allocation to be driven by the investment's *covariance* with the rest of the bank's portfolio. Fortunately, the preferred covariance-based approach seems to be gaining some favor. For example, Chris James, in discussing the implementation of RAROC at Bank of America, writes that: "the amount of capital allocated varies with the contribution of the project to the overall volatility of earnings at B of A (the project's so called internal beta)."¹⁶ This is very much in the spirit of what emerges from our model.

Pitfall #3: Using An Incorrect "Cost" Of Capital. Even if the RAROC capital allocation is based on the appropriate sort of covariance measure, one still

has to come up with the right values of ζ and k^E . From the perspective of our model, the individual values do not really matter, so long as the two together satisfy $\zeta(k^E - r_F) = Z$. The most common practice seems to be as follows. First, ζ is chosen to ensure that the probability of the bank defaulting is less than some threshold level. For example, an article describing Bank of America's RAROC approach notes that B of A tolerates a default probability of only .03%.¹⁷

Second, the "cost" of capital, k^E , is typically set to equal the required return on equity for the bank's shareholders, as calculated, for example, from the CAPM.¹⁸ This latter calculation is, in the context of our model, a non sequitur. The fallacy can be most easily seen by considering the polar case where the bank—as suggested by our model—hedges all priced risks. In this case, the bank's shareholders are left only holding non-priced risks, so their required return on equity is simply the riskless rate r_F .¹⁹ But if this is true, then the RAROC method says that the capital charge should be *zero* for any values of ζ and E_N^R !

Simply put, shareholders' required return on the bank's equity bears no relationship to what we would ideally like to capture, which is the parameter Z . This parameter is in principle influenced by the *deadweight costs* of holding equity on the balance sheet, which is a very different concept than the required return. To consider another polar case, as the tax rate π goes to zero, so does Z . In this case, our model would imply that it is "costless" (in a deadweight sense) to hold equity, so there should be no mark-up at all for non-priced risks. Yet a RAROC model driven by the required return on equity might incorrectly continue to apply a markup.²⁰

CONCLUSIONS

This paper has stressed the linkages between banks' risk management, capital budgeting, and capital structure policies. In our model, all three of these policies are shaped by two related primitive frictions: first, it is costly for banks to raise new

15. See, e.g., Uyemura, Kantor and Pettit (1996).

16. James (1996), p. 11.

17. Zaik et al (1996)

18. Again, see Zaik et al 1996.

19. This is perhaps a more realistic description of a hedge fund than a commercial bank, but it suffices to illustrate our point.

20. In fairness to the RAROC method, our parameter Z , while theoretically more appropriate, is harder to estimate from readily available data. As we discuss in our *JFE* paper, to construct Z , one ultimately needs to draw on information about both the bank's investment opportunities as well as its marginal costs of external finance.

One of the key implications of our two-factor model is that a bank should evaluate investments according to *both* their correlation with the market portfolio *and* their correlation with the bank's existing portfolio.

external funds on short notice; and second, it is also costly for banks to hold a buffer stock of equity capital on the balance sheet, even if this equity is accumulated over time through retained earnings.

Given these frictions, bank-value maximization implies the following:

- banks should hedge any risks that can be off-loaded on fair-market terms;

- banks should also hold some capital as a device for absorbing those illiquid risks which cannot be hedged, but the optimal amount of capital is limited; and

- finally, given limited capital, banks should value illiquid risks much as an individual investor would—that is, according to their impact on overall portfolio risk and return—with the degree of risk aversion being a decreasing function of the amount of capital held.

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