The Term Structure of Discount Rates and Capital Budgeting Practice

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Abstract

Generally accepted expositions of NPV analysis for capital budgeting apply a constant discount rate across the life of a project. This fails to adequately reflect the temporal structure of risk for investments in real assets. We propose the use of time-varying discount rates that reflect, as a minimum modification, the term structure of interest rate risk. We propose additional adjustments for the estimated risk premia associated with idiosyncratic project risk (especially asset specificity) and information uncertainty. These adjustments are likely to result in a term structure of discount rates which is upward sloping with a decreasing gradient

Key Words

Capital Budgeting, Transaction costs Economics, Interest Rate Risk

Introduction

The recent managerial and applied economics literatures are replete with attempts to explain contemporary capital budgeting practices. Traditional finance theory asserts that the Net Present Value (NPV) rule is the optimal evaluation technique for firms considering investment in real and financial assets. Recent empirical evidence (e.g. Block, 2000; Graham and Harvey, 2001) suggests that although most large firms now employ NPV analysis as their primary means of investment appraisal, there remains widespread use of less theoretically sound techniques such as internal rate of return and payback period methods. These “inferior” methods are often used as a complement to NPV analysis, or less commonly as a substitute for full NPV analysis. The need to supplement NPV with payback or other analyses may signal a deficiency in the usual implementation of NPV.

We argue, as a fundamental explanation for this behaviour, that the standard NPV application described in current texts and guidelines fails to adequately reflect the temporal structure of risk in real asset investments.

The theoretical limitations of evaluating risky projects using the single risk-adjusted discount rate technique were first noted more than 30 years ago (see Robichek and Myers, 1966; Chen, 1967). Empirical evidence suggests, however, that the majority of corporations of all sizes continue to use this approach (Graham and Harvey, 2001). Many recent papers expound employment of a “real options” approach to capital budgeting problems (see, for example, Miller and Park, 2002; Farzin *et al*, 1998). Valuation of each possible outcome under the real options method is methodologically identical to standard NPV analysis and is subject to the same empirical limitations. Nonetheless, the approach we suggest generates outcomes consistent with real options based theories of capital budgeting.

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Traditional NPV models employ a static periodic discount rate throughout the project. While some contemporary academics (e.g. Bierman and Schmidt, 1993 pp. 397-99) note that risk-adjusted discounts rates may differ across the cash flows associated with a project, to our knowledge no attempt has been made to incorporate such effects into a general model.

We propose that the schedule of periodic discount rates applicable to real asset investments should normally be upward sloping, reflecting the firm's cost of capital and premiums for interest rate and liquidity risk, as well as the increasing risk attaching to opportunistic behaviour (arising with asset specificity) and bankruptcy risk as investment horizons expand.

The next section briefly identifies the capital budgeting problem and notes the role of certainty equivalents as a conceptually appropriate but seemingly impractical solution. We then examine the temporal structure of different components of risk adjusted discount rates and demonstrate our basic proposition. We conclude with a brief comparison of our approach with the popularly advocated real options approach.

Accounting for Risk in Capital Budgeting

Under complete certainty, the NPV of a given project is given by:

$$NPV_0 = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - I_0 \qquad (1)$$

where
C_t = the cash flow receivable in period t
r = the periodic risk-free discount rate or required return
I_0 = the initial investment required to purchase the asset

Where either the future cash flows of the project or the future returns on alternative investments are uncertain, a risk-averse investor must adjust their valuation method. A well-diversified investor facing risky asset returns described by known distributions of returns can calculate a "certainty equivalent" for each expected cash flow (uncertain periodic expected cash flows are reduced to the value of the certain cash flow that would yield the same utility to the investor). A certainty equivalent still can be estimated where risk is more complex. For a risk averse investor, the certainty equivalent cannot exceed the expected value of the uncertain cash flow. This theoretically appealing approach facilitates consideration of risk for individual cash flows but empirical evidence suggests that it is not widely used in practice (Block, 2000; Graham and Harvey, 2001). This may be attributed to the difficulty of estimating certainty equivalents but also may be due to decision makers being more comfortable with concepts such as interest rates or discount rates.

The alternative to the certainty equivalent approach is to account for risk by adjusting the discount rate applied to the expected cash flows. These alternatives are conceptually identical and mathematically linked. The usual NPV practice of adjusting the periodic discount rate by a constant premium yields the same result as the certainty equivalent approach only if the rate of increase in the riskiness of cash flows over time is constant (Chen 1967, p. 320). A problem in practice is the lack of intuitive appeal in this assumption of a constant rate of change in risk.

Accepting the evidence of a market preference for the modelling of risk via the discount rate, rather than by directly adjusting cash flows, we next consider a conceptual basis for estimating of appropriate discount rates across the life of real asset investment projects before proposing an elementary heuristic that is relatively simple to implement in most practical contexts.

The Components of Risk-adjusted Discount Rates

We review several factors that influence appropriate risk-adjusted discount rates for capital budgeting purposes. These factors are not necessarily independent, but this categorization allows us to focus on separable effects and articulate the relationships between the factors. Discount rates should reflect at least five factors:

- The investor's risk attitude
- The investor's cost of capital
- Interest rate risk
- Perceived risk for expected returns from the project
- Information uncertainty for projected cash flows

While the component of the discount rate that reflects an investor's risk attitude *may* be constant in relation to future payoffs, the other four components are very likely to be time varying. Most, we argue, are likely to be increasing in time. Following the Chen (1967) result, the rate of increase in collective risk with respect to time determines the appropriate shape of the discount rate schedule. There is little available empirical evidence in this regard and so we demonstrate the possible behaviour of most components analytically. Interest rate risk, however, can be demonstrated empirically as shown below.

The Investor's Cost of Capital and Interest Rate Risk

According to finance theory, the appropriate discount rate applicable in project evaluation is a function of the firm's cost of capital (Peirson *et al* 2002, p. 478). A firm's cost of capital is dependent on its capital structure and reflects the required returns to each source of finance. These required returns of debt holders and equity holders are influenced by the firm's asset structure and leverage (Peirson *et al* 2002, p.466). For the very well diversified firm, systematic risk and leverage will be the focus for investors but few firms are sufficiently diversified for this to prevail. For less diversified firms, the major non-systematic risk elements also should be considered. Similarly, the commonly employed assumption that investors are well diversified, which suggests that the firm need only consider systematic risk factors simply does not hold in all cases. Systematic risks do play a dominant role in risk-assessment, but not to the total exclusion of unsystematic risk.

An important time-varying component of systematic risk facing investors is the interest rate risk attaching to investments. This affects both an investing firm's perception of project risk and the firm's cost of capital. A firm investing in long-term projects requires long-term finance. The dual impact of interest rate risk is discussed below.

Graham and Harvey (2001, p.204) report that interest rate risk is the single most important factor considered by US firms when evaluating projects. The return on alternate investments is usually proxied by the current interest rate for a known term investment or bond. The potential for changes in future interest rates affects the evaluation of a project in two ways:

The firm's cost of capital is the primary determinant of the appropriate discount rate for use in project evaluation (Modigiliani and Miller, 1958; Peirson et al 2002, p. 478). Cost of capital is affected by investors' perceptions of the variability in the opportunity cost, caused by interest rate risk, of investing in this firm. This interest rate risk is partly a function of the firm's existing asset structure and the remainder is specific to the contractual nature of investors' claims on the firm. Investors in a firm's fixed-interest securities have the greatest exposure to interest rate risk, as there is no prospect of adverse interest rate movements being offset by changes in the magnitude of the cash flows from the investment.

In most circumstances, interest rate yields on default risk-free securities increase in time, but at a decreasing rate. A reason for this expected pattern lies in the compounding of the interest premia that compensates for the risk attributed to increasingly distant future periods. While risk necessarily increases in time, there is a reduction in the annualized interest premia to compensate for a particular risk level as the period over which the interest rate applies becomes longer (Chen 1967).

Regardless of any particular explanation for the phenomena, as an empirical observation, it appears well founded. Table One describes the average yield rates for US Treasury Bonds from 1983 to 2001 for 1, 2, 3, 5, 7 and 10 year bonds. The pattern of results for the six different maturity periods in each of the 19 years is consistent with the overall average graphed in Figure One. Clearly, the perceived interest rate risk is time-varying. Normally, longer term fixed cash flow securities with zero default risk trade at higher implied yields (i.e. higher implied discount rates) than similar short-term securities. Typically, this premium is described in texts as a liquidity premium, which is somewhat of a misnomer when considering the depth of the market in which US Treasury Bonds are traded. The premium represents an aversion to interest rate risk.

Table One: Percentage Yields on US Treasury Bonds 1983-2001

	1 Year	5 Years	10 Years
1983	9.57	10.80	11.11
1984	10.89	12.24	12.44
1985	8.43	10.13	10.62
1986	6.46	7.31	7.68
1987	6.76	7.94	8.38
1988	7.65	8.47	8.85
1989	8.54	8.50	8.50
1990	7.88	8.37	8.55
1991	5.86	7.37	7.86
1992	3.89	6.19	7.01
1993	3.43	5.15	5.87
1994	5.31	6.68	7.08
1995	5.95	6.39	6.58
1996	5.51	6.18	6.44
1997	5.63	6.22	6.35
1998	5.05	5.15	5.26
1999	5.08	5.54	5.64
2000	6.11	6.15	6.03
2001*	4.03	4.78	5.15

*2001 figures are calculated up to and including the month of August

All annual yields are the simple averages of the monthly yield statistics provided by the United States Federal Reserve.

The term structure of interest rates observed in financial markets is inextricably linked to the issuing firm's cost of debt. The firm's cost of debt is not only a component of the firm's weighted-average cost of capital, but also directly positively influences the firm's cost of equity (this is Modigliani and Miller's (1958) 'Proposition 2').

A Simple Example

To illustrate the effect of interest rate risk on project evaluation, consider the following scenario. A single project firm is considering an investment in a project with fixed $100 cash flows receivable in 1, 3 and 10 years time[1]. This firm is financed entirely by fixed-interest debt securities, issued at time zero. In order to match the maturity of the firm's assets and liabilities

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[1] The cash flow are assumed fixed so that we may focus attention on the effect of changes in the opportunity cost of funds.

(and facilitate the timely repayment of the debt) the firm issues 1, 3 and 10 year zero-coupon bonds. What is the magnitude of the return required by the investors in these bonds (and hence what is the firm's cost of debt for each debt security)? The yields (required returns) on the 1, 3 and 10 year bonds respectively describe the term structure. Using the data for 2001 from Table One, 1 year bonds would be issued at a yield of 4.03%, 3-year bonds at 4.78% and 10-year bonds at 5.15%, and these yields determine the weighted-average cost of capital for this firm.

Logically, when evaluating this project, the cost of capital used should reflect the term structure of the required return on capital, which in turn implies an upward sloping term structure of discount rates for project evaluation purposes. The cash flow schedule of a project prescribes the financing options in such circumstances. Cash flows at time 1 are discounted by 1.0403^{-1}, those in time 3 are discounted by 1.0478^{-3} and those occurring at time 10 are discounted at 1.0515^{-10}. Of course, it is mathematically possible to calculate a common periodic discount rate that precipitates the same NPV as the 'term structure of discount rates' here, but this common rate must be re-calculated whenever the timing or magnitude of the project's expected cash flows changes. A project's cash flows determine the financing term required. In a multi-product firm the same rule must apply in aggregate in the long run[2]. Failure to take account of the term structure of interest rates may distort investment incentives, by overstating the attractiveness of long-term projects that ultimately require long-term financing (assuming an upward-sloping yield curve).

If we relax the pure finance theory assumption that the firm is nothing more than a conduit between project cash flows and returns to investors, the essence of our argument remains unchanged. From the perspective of the company management, the appropriate risk adjusted rate can be viewed as measuring the expected returns on alternative investments available to the company (ie the opportunity cost of funds employed). The greater the term of a project, the greater the relative effect of an increase (during the life of the project) in the returns of alternative investments.

To some extent, expected cash flows from a risky real asset investment are subject to the same interest rate risk factors as securities. It follows that this risk be treated similarly in evaluating real asset investments; discount rates used across a project's life should be time varying (normally upward sloping). Some real asset investments embody a natural hedge against interest rate risk in that the future risky cash flows may be correlated with current interest rates, reducing the fall in present value of such cash flows when interest rates rise. Intuitively, this natural hedge is highly unlikely to perfectly insure the investor and empirical evidence suggests that such risk *does* impact on investment decisions (Graham and Harvey, 2001).

The extent to which interest rate risk should dominate the explanation of the term structure of interest rates is debatable. Quoted long-term interest rates cannot be perfectly separated into components representing future short-term rate expectations and interest rate risk premia. Consequently, there is continuing disagreement regarding the reasons for the term structure. However, the term structure remains highly relevant in determining an investor's cost of capital – if long term debt is more expensive than short-term debt, projects that encourage long-term debt funding should be evaluated in this light. Accordingly, we argue that a term structure of discount rates is the most appropriate base, to which we can add other risk premia, in estimating appropriate time-varying discount rates.

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[2] That is, it is possible (though not desirable) to finance an individual long-term project with short-term debt, but in the long-run it is not possible to finance all long-term projects with short-term debt.

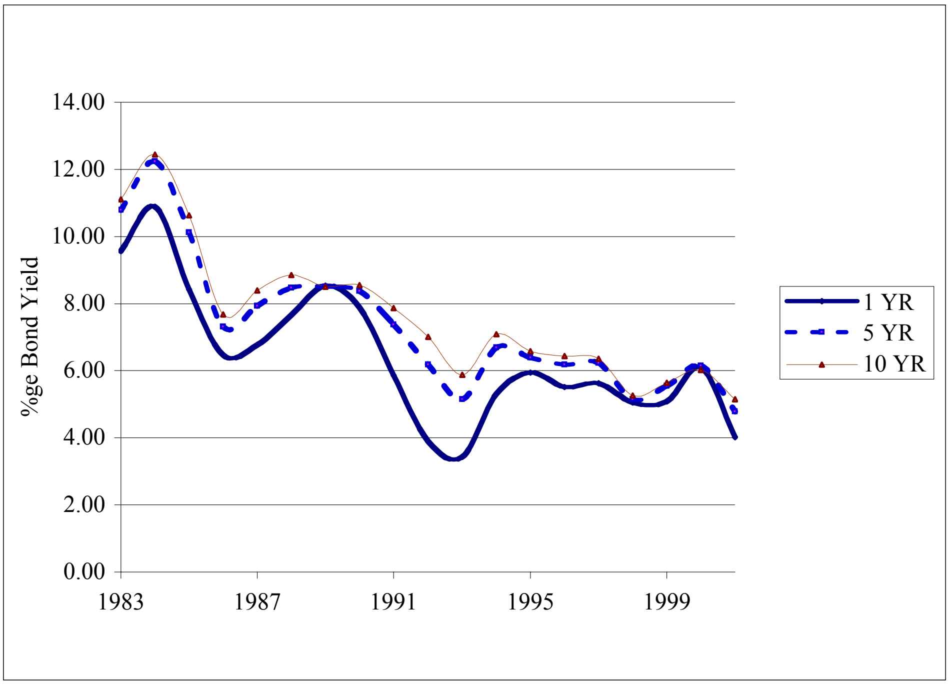

Figure One: Term Structure of US Bond Yields 1983-2001

Perceived Risk for Expected Returns from the Project

The risk for expected payoffs from a project may be identified by the variance of expected periodic cash flows. For example, following Gordon's (1962) stock valuation model, if the investor forms expectations of future payoffs as a Markov process, and the dispersion of the distribution of the future payoffs is a measure of the risk of these expectations, the risk of a future payoff expectation increases with time.

With current payoff or cashflows (C_0) and where the distribution of future cashflows has variance σ^2, the measure of risk (U) of the payoff expected for period t is given by:

$$U_t = \frac{\sigma\sqrt{t}}{C_0} \qquad (2)$$

For subsequent periods, we have:

$$U_{t+n} = \frac{\sigma\sqrt{t+n}}{C_0} \qquad (3)$$

so that $U_t < U_{t+1} \ldots < U_{t+n}$ (4)

Therefore, if the investor forms a Markov process for expected future cashflows and the variance of the future cashflows is the measure of risk, then the risk of future cashflows is increasing over time at a decreasing rate. This illustrative result, of course, is dependent on the process by which the investor forms expectations of future pay-offs and perceives risk. Other (unidentified) processes may yield risk measures that increase in time at an increasing rate.

Asset specificity and risk: Idiosyncratic time-varying risk components attach to most projects. To a varying extent, an investor's valuation of any real asset involves some element of specificity. Asset specificity, along with opportunism and incomplete contracts, is a critical element in the transaction cost economics (TCE) theory expounded by Williamson (1975) and others.

TCE focuses on problems relating to investments in specifically valued assets. Asset specificity is a condition that arises when assets are differentially valued between firms and markets. There are many potential sources of asset specificity. One such example is geographic specificity, which exists where one supplier (customer) has a significant cost advantage over all others because they are located in close proximity to a customer or supplier. Other sources of specificity include technological specificity, dedicated asset (or productive capacity) specificity and temporal specificity. See Williamson (1991, p.281) for a detailed explanation of these sources. (The source of asset specificity is not relevant to our argument, although technological specificity and dedicated asset specificity may present larger discounting effects). Specificity gives rise to quasi-rents, which equal the difference between the value of an asset in its current use and the asset's value in its next best use. With incomplete contracting and the threat of opportunistic behaviour these quasi-rents become appropriable and so prospective cashflows are further threatened.

Incomplete contracting refers to an environment in which it is not feasible to incorporate contractual terms for expected (and observable) performance for every possible future state. Contracting may be incomplete for a variety of reasons, such as ignorance of the range of possible future states, information search costs, and the cost of writing detailed contracts and observing and enforcing behaviour.

Opportunism refers to self-interested behaviour, in which individuals act with guile. This does not imply that all individuals always act opportunistically. It means that contracting parties cannot rely on unbounded promises of future performance if that performance cannot be costlessly verified and the other party punished if breach occurs.

The combination of asset specificity, uncertainty, opportunism and incomplete contracting precipitates an investment environment in which quasi-rents become (potentially) appropriable (Williamson 1985, p. 43-67). The appropriation of quasi rents is effected by imposing subsequent price variations on the owner of the specific asset through a practice known as hold-up (see Shailer and Wilson 2003 for an extended treatment of the interaction of these factors and their effect on asset valuation in an accounting context).

The threat of opportunistic behaviour with respect to these rents is an important source of risk to an investor's returns.

Even where trading partners always act in good faith, project risk still exists via the effect of asset specificity and the possibility of bankruptcy of trading partners. While some of this risk may be eliminated by diversification, a non-trivial amount of risk is not diversifiable when dealing with real firms and real assets. For the firm with a broad portfolio of contractual relationships subject to risk from specificity some contractual partners will exceed expectations of future performance (in their individual businesses) and some partners will suffer business failure. Unlike well-diversified share portfolios, the diversified contractor receives no necessary increase in return from their relationship with customers that exceed performance expectations (just as a creditor's returns are bounded by the promised repayments). The diversified contracting firm does bear losses associated with the business failure of contractual parties. Diversification of contractual relationships thus cannot be relied upon to eliminate risk from specificity.

The impact of asset specificity on discount rates depends on the perceived risk of hold-up occurring. This too is likely to be time-varying. How might such risk be anticipated? Klein *et al.*'s (1978) depiction of appropriable rents as the difference between value in its current use and its market value provides a basis for measuring the amount at risk over time. To illustrate, take the initial investment (I_0) as the initial measure of value in use (B_t) and the accounting depreciation of an asset as the diminution of its value in use.

For convenience, assume this process to be linear (straight-line depreciation) for a project of life N with a trivial salvage value so that:

$$B_{t+n} = B_t\left(1-\frac{n}{N}\right) \tag{5}$$

Assume also that a uniform decline in market value of the asset is approximated by:

$$M_t = M_{t-1} \bullet I_0^{-\frac{1}{N}} \tag{6}$$

The appropriable rents at time *t* are the differences between the market value and book value for the remaining life of the project:

$$\Re_n = \sum_{t=n}^{N}\left[B_t - M_t\right] \tag{7}$$

This is shown for the life of the project as the shaded area in Figure Two. Because the appropriable amount at any point is the remaining area, the amount at risk is necessarily decreasing in time. The opportunity to appropriate the rents depends on the occurrence of future states that allow any appropriation strategies. *Ex ante*, the range of possible future states is necessarily increasing in time, giving increasing cumulative probabilities for appropriation (the effect is more profound for projects with greater specificity or complexity). For example, assuming a simple binomial path to discrete future states where the probability of a hold-up state occurring is *r* and that the hold-up strategy subsequently persists, the cumulative probability of hold-up at *t*=0 is:

$$\sum_{t=0}^{N} r(1-r)^{t-1} \tag{8}$$

The net effect of the decreasing remaining appropriable rents and increasing probability of (or at least opportunity for) appropriation cannot be generalized. It is plausible that that the risk is increasing, at least in the near term of the project, but this cannot be assumed with confidence. Regardless, it is apparent that the risk is time-varying.

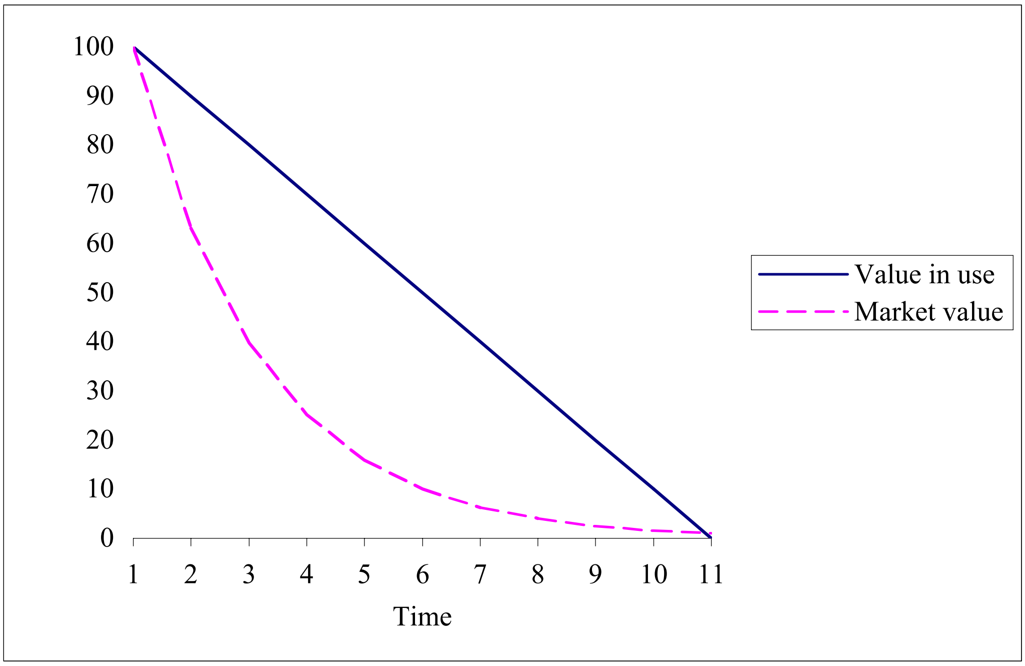

Figure Two: Appropriable Rents Proxied as the Difference between Book Value and Market Value

Information Uncertainty

Information uncertainty refers to a lack of confidence in the available information set; this may be because information is inadequate or observation disorderly. This uncertainty is necessarily increasing in time, as reflected in the real options literature where the option to delay investment has value because of the reduction in uncertainty obtained as pay-off becomes more proximate. This concept of uncertainty, and the resulting discounting of probabilities and estimated pay-offs, was recognized early in the development of theory concerning decision-making under uncertainty (with foundations in Knight, 1921), but has since largely been omitted (or subsumed in other parameters) in investment models.

Discussion

The above discussion establishes that risk affecting capital projects is time-varying. Failure to take account of the time-varying nature of risk systematically biases standard NPV analysis of capital projects. Notwithstanding our analytical argument, there is strong empirical evidence of time-varying risk premia in capital markets – normally longer-term securities are associated with higher required rates of return.

We recognize there may be practical impediments to assessing the term structure of some of the secondary causes of risk but discounted cash flow techniques can be greatly improved by at least taking account of the existing term structure of interest rates when deciding on the discount rates applicable to a capital project. We suggest that the adoption of the term structure of interest rates as the basis for the term structure of discount rates is a superior default to assuming a flat discount rate schedule.

For highly specialized assets, some attempt should be made to incorporate the additional time-varying risk premia. The estimation of these premia poses an empirical problem – but even an arbitrary estimate of the time-varying nature of discount rates can be no more biased than ignoring them.

A relatively recent development in the project evaluation literature involves the evaluation of the ‘real options’ embedded in an investment. While conceptually appealing, the real options approach requires that application of very sophisticated mathematical techniques and access to information that is beyond the capabilities of many firms. While we have not explicitly employed a real options approach, our suggested treatment of risk generates investment decisions consistent with the prescriptions of this paradigm. Highly specific assets imply that the *ex-post* option value to re-deploy the asset to alternative uses is relatively low. Investing in low specificity assets (rather than high specificity assets) possesses similar option value to that implied by deferring an investment decision until further information becomes available. We argue that the risk effect of the irreversibility of highly specific investments becomes more profound the greater the time to the expected receipt of cash flows as there is an increased risk that appropriation will occur. This effect is partially accounted for through the resulting fall in the expected value of future cash flows, but simultaneously, the dispersion of possible future cash flows increases with specificity. Intuitively, a real options approach would similarly assess an irreversible project whose profitability was contingent on the realization of far off cash flows subject to time-increasing risk due to strategic behaviour. While most real-options models assume risk-neutrality, assuming decision makers to be risk-averse would not compromise such analysis (Dixit 1992, p.110). To emphasize the similarity between the capital decision-making implications of our time-varying discount rate model and the real options approach, consider the following simple descriptive example.

Assume a firm that is evaluating the purchase of a new-technology machine while facing monopsonistic demand. The machine is specialized to the firm's existing product line and is expected to generate recurrent labor cost savings throughout its life. The machine is so specialized that it is has little value in alternate use. When evaluating this project, the firm should be conscious of the risk that quasi-rents may be either strategically appropriated or lost due to business failure of the firm's sole customer. An alternative to investment in the new technology is to continue production with existing, less specific, technology and forgo the potential future labor cost savings. Under many plausible cost conditions, continuing production using existing technology may appear, prima facie, sub-optimal. The evaluation of such a policy, however, must take account of the option value implied by the fact that future (higher) labor costs are not committed irreversibly at time zero. The firm can decide whether to 'invest' in these higher labor costs sequentially, upon the realization of future states.

Under our proposed regime, relatively specific assets would be evaluated using a 'steeper' term structure of discount rates, reflecting greater exposure of far off cash flows to the risk of appropriation or loss through failure of business partners. A real options approach would similarly 'penalize' the relatively irreversible investment (see, for example, Farzin *et al*, 1998), particularly if investors are assumed to be risk-averse. The potential advantage of our method is that it does not require a complete uprooting of existing capital budgeting practices – merely some fine-tuning.

While the focus of our paper has been to provide a basis for project evaluation subject to inter-temporal risk which can be applied using traditional or real options methodologies, a means of dealing with intra-temporal cash flow risk is detailed below. Recent research has demonstrated that betas are time varying, and that appropriate project betas normally increase with project duration (Cornell, 1999). This phenomena is explained by the fact that a firm's systematic risk is not simply a function of the sensitivity of its cash flows to market factors, but is also profoundly affected by common variation in future required returns (discount rates) (Campbell and Mei 1993; Cornell 1999).

Following Franks and Broyles (1979, p. 115-130) a practical approach is to add the estimation of project betas (scaled by the observed market risk premium) for each time period, adding these to the risk free rate implicit in the term structure.[3] Franks and Broyles' model measures project betas as the product of a series of non-diversifiable risk factors. At the simplest level, these risk factors represent revenue sensitivity and operational gearing. The revenue sensitivity factor calculates the relative level of revenue sensitivity of the project relative to the revenue sensitivity of the division (firm) with respect to a change in total market demand. Operational gearing is also a relative measure, representing the ratio of the degree of operating leverage of the project to that of the division. The product of these (and possibly other) risk factors estimates the effect of the project on the firm's systematic risk. The resulting risk-adjusted discount rate for each period thus reflects both the term structure of interest rates, and a premium relating to the systematic risk of the periodic cash flows.

The limitations of this approach are twofold. First, for many decision-makers (such as closely-held corporations), unsystematic risk may play a role in decision-making due to comparative advantages in diversification costs for some firms (over individuals) and second because unsystematic risk affects the probability of bankruptcy, which generates non-diversifiable deadweight losses (Aaker and Jacobsen, 1987). Notwithstanding these limitations, the Franks and Broyles model demonstrates one possible means of applying our logic. It should be noted however, that our approach may also be appropriated to real options analysis or any other NPV-based method of risk-assessment.

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[3] We are indebted to an anonymous reviewer of an earlier version of this article for this suggestion.

Conclusion

In the above discussion of time-varying risk factors in real asset investments, we have demonstrated the unserviceability of static risk-adjusted discount rate assumptions commonly employed in finance textbooks and in practice. We propose that a time-varying schedule of risk-adjusted discount rates be employed in capital budgeting analyses, particularly in the case of longer-term investments and investments characterized by significant degrees of asset specificity. At the very least, a schedule of discount rates mapping the extant term structure of interest rates observed in risk-free debt markets should form the basis of long-term capital budgeting. Where additional time-varying risk factors, such as the possible appropriation of quasi-rents are significant, the term structure of discount rates can be further adjusted to accommodate these factors. The estimation of the additional risk premia is potentially problematic and is affected by individual decision maker's attitudes to risk. This empirical problem is, however, common to all attempts to quantify the effects of uncertainty.

A possible criticism of our approach is that too many subjective judgements are required to estimate the appropriate term structure. Our approach is no more subjective than the status quo – the implicit assumption that risk is monotonically increasing at a constant rate. We contend that capital budgeting practice can be improved the educated application of the principles espoused above.

References

Aaker, D.A. and Jacobsen, R. (1987), "The Role of Risk in Explaining Differences in Profitability", *Academy of Management Journal*, Vol. 30, No. 2, pp. 277-296.

Bierman, H. and Smidt, S. (1993), *The Capital Budgeting Decision*, Prentice-Hall, Upper Saddle River New Jersey.

Block, S (2000), "Integrating Traditional Capital Budgeting Concepts into an International Decision-Making Environment." *The Engineering Economist*, Vol. 45, No. 4, pp. 309-325.

Campbell, J.Y. and Mei, J. (1993), "Where do Betas Come From? Asset Price Dynamics and the Sources of Systematic Risk", Review of Financial Studies, Vol. 6, No. 3, pp. 567-592.

Chen, H.Y. (1967), "Valuation Under Uncertainty." *Journal of Financial and Quantitative Analysis*, Vol. 2, No. 3, pp. 313-325.

Cornell, B. (1999), "Risk, Duration, and Capital Budgeting: New Evidence on Some Old Questions", *Journal of Business*, Vol. 72, No. 2, pp. 183-200.

Dixit, A.(1992), "Investment and Hysteresis." *Journal of Economic Perspectives*, Vol. 6, No. 1, pp. 107-132.

Farzin, Y.H., et al. (1998), "Optimal Timing of Technology Adoption." *Journal of Economic Dynamics and Control*, Vol. 22, pp. 779-99.

Franks, J.R. and Broyles, J.E. (1979), *Modern Managerial Finance*, John Wiley and Sons.

Gordon, M. (1962), *The Investment, Financing and Valuation of the Corporation*, Irwin, Homewood Illinois.

Graham, J.R. and Harvey, C.R. (2001), "The Theory and Practice of Corporate Finance: Evidence from the Field." *Journal of Financial Economics*, Vol. 61, pp. 1-28.

Klein, B., Crawford, R. and Alchian, A. (1978), "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process", *Journal of Law and Economics*, Vol. 21, pp. 297-326.

Knight, F.H. (1921), *Risk, Uncertainty and Profit*, University of Chicago Press, Chicago.

Miller, L.T. and Park, C.S. (2002), "Decision Making Under Uncertainty - Real Options to the Rescue?" *The Engineering Economist*, Vol. 47, No. 2, pp. 105-51.

Modigliani, F. and Miller, M. (1958), "The Cost of Capital, Corporation Finance and the Theory of Investment", *American Economic Review*, Vol. 48, No. 3, pp. 261-97.

Peirson, G., Brown, R., Easton, S. and Howard, P (2002), *Business Finance*, 8th ed. McGraw-Hill Irwin.

Robichek, A.A. and Myers, S.C. (1966), "Conceptual Problems in the Use of Risk-Adjusted Discount Rates." *Journal of Financial and Quantitative Analysis*, Vol. 21, No. 4, pp. 727-730.

Shailer, G. and Wilson, M. (2003), "A Revised Lesson for Accounting Measurement from Transaction Cost Economics", *Australian Accounting Review*, Vol. 13, No. 1, pp. 66-73.

Williamson, O.E. (1975), *Markets and Hierarchies: Analysis and Antitrust Implications*. Free Press, New York.

Williamson, O.E. (1985), *The Economic Institutions of Capitalism*, New York, Free Press.

Williamson, O. E. (1991), "Comparative Economic Organization: The Analysis of Discrete Structural Alternatives." *Administrative Science Quarterly*, Vol. 36, No. 2, pp. 269-96.