Do We Need CAPM for Capital Budgeting?

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A key input to the capital budgeting process is the cost of capital. Financial managers most often use the CAPM to estimate the cost of capital for which they need to know the market risk premium. Textbooks advocate using the historical value for the US equity premium as the market risk premium. The CAPM as a model has been seriously challenged in the academic literature. In addition, recent research indicates that the true market risk premium might have been as low as half the historical US equity premium during the last two decades. If business finance courses have been teaching the use of the wrong model along with wrong inputs for 20 years, why has no one complained? We provide an answer to this puzzle.

The classic rule for making capital budgeting decisions is to take projects with positive *Net Present Value* (NPV). Consider a project that generates an annual, real cash flow of 100,000 forever, starting one year from now. The initial investment is 1,600,000. To decide whether to invest in this project or not, we discount all future cash flows and subtract the initial investment to get the NPV. The decision rule is then simple: If the NPV is positive, take it; if the NPV is negative, leave it. The current textbooks used in all major MBA courses advise financial managers to calculate the cost of capital based on the *Capital Asset Pricing Model* (CAPM). The project's cost of capital is the rate investors require to undertake the investment, and we should discount all future cash flows at this rate. The cost of capital in the CAPM equals the riskfree rate plus a risk premium. The CAPM asserts that the only relevant risk measure for a project is it *beta*. The beta factor times the excess return of the market over the riskfree rate determines the risk premium of the investment.

A key input for the CAPM is the excess return of the market over the riskfree rate, the market (equity) risk premium. The common practice has been to use the historical average return over a long period as a measure of what investors expect to earn. As a proxy for the market portfolio, a broad equity market index is applied. For the US the average market risk premium of the S&P 500 was 7.43% during the post-war period, whereas the real riskfree rate (six-month commercial paper) was 2.19%. Assuming that the project beta is 1.0 and the firm is 100% equity financed, the cost of capital is 2.19% + 1 X 7.43% = 9.62% and the NPV of our project is negative:100,000/ 0.0962 - 1,600,000 = -560,499. We would decide against investing.

However, a new strand of literature starting with Blanchard (1993) takes a forward-looking perspective to determine the market risk premium. Instead of taking an average over a past period, these studies infer the rate that justifies the current stock market index level given the expected dividends or earnings of all companies in the index. The evidence from this literature suggests that the market risk premium has been only about 2-4% during the last two decades, substantially below the average return of 7.43% for 1951-2000. If we take the value of 2.55% as the equity premium, the estimate that Fama and French (2001) obtain, the NPV of the same

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project is positive: 100,000/0.0474 - 1,600,000 = 509,705. A manager who follows the textbook recommendation and uses a cost of capital of 9.62% based on historical averages would have missed an opportunity to increase shareholder value by half a million dollars.

A recent survey by Graham and Harvey (2001) finds that three out of four CFOs use the CAPM as the primary tool to assess cost of capital. Why do managers continue to use the CAPM along with the historical average market risk premium to estimate cost of capital when the evidence indicates that this practice leads to gross overestimation of the cost of capital? In this paper, we provide an answer to this question.

We take the stand that the cost of capital is not a critical input for arriving at the right decision in those situations where managers use the CAPM. To understand why that may be the case, we need to distinguish between valuing projects and selecting the right project at the right time. While precise estimate of cost of capital is necessary to value a project, it may not be needed for deciding which projects to fund at a given point in time. For example, consider a firm that has several attractive positive NPV projects, but can undertake only one of them due to organizational capital being in limited supply in the short run. In that case, it would be sufficient to identify the project that has the highest NPV for making the right decision. A manager who uses too high a value for cost of capital would still undertake the right project as long as the NPV computed using the wrong cost of capital is positive and ranks the projects in the right order.

The earlier literature on capital budgeting viewed financial capital as being in limited supply and textbooks discussed capital rationing extensively. Capital rationing has received little attention in the more recent literature, especially in the post Modigliani-Miller era, for good reasons. In a well functioning capital market, the cost of capital will adjust to equate supply and demand for financial capital. By definition, projects that are not funded must be those with a non-positive NPV. Hence, financial capital is always available at the right price (cost of capital). In our view, what is rationed is not financial capital but managerial talent and organizational capital. Managers with superior skills will always have future positive NPV investments in the pipeline. This creates situations where the firm has to decide whether to take up a project today or wait for a better project in the future. In such situations, the project on hand must be sufficiently attractive for the firm to undertake it immediately (i.e., its NPV must be higher than a target level NPV > 0.) Equivalently, the firm may compute NPV using a hurdle rate that is sufficiently higher than the cost of capital and take only those projects that have a positive NPV computed using the hurdle rate. We show that in such situations precise estimation of the cost of capital is not critical. As long as a reasonable hurdle rate that is sufficiently higher than the cost of capital is used the firm would make nearly optimal decisions. The capital budgeting decision would be fairly insensitive to the estimated cost of capital and the estimates of the riskiness of future projects.

This may explain why managers get by with imprecise estimates of the cost of capital. Our conjecture is consistent with the findings reported in published surveys. Poterba and Summers (1995) find that the average hurdle rate used by companies at the time of the survey in Fall 1990 was 12.2% in real terms. This is even higher than the historical real return on equity of 9.62% over the period 1951-2000, which itself appears to be much higher than what the true risk premium probably was.

The rest of the paper is organized as follows. Section I overviews the difficulties involved in using the CAPM. Section II explains why the cost of capital may not be a critical input based on the theory of real options. Section III extends the analysis to continuous time and demonstrates that, when the firm has substantial real options, the project selection decision will, in general, be near optimal even when the wrong cost of capital is used. Sections IV and

V discuss the implications for capital budgeting and the past and current practice in the field. Section VI concludes.

I. Challenges to Using the CAPM

Textbooks in the 1950s and 60s recommended using the historical average return on a firm's stock or a group of comparable companies for determining the cost of equity capital. The CAPM developed by Sharpe (1964) and Lintner (1965) provided an alternative. According to the CAPM, the cost of capital of a project can be predicted from knowledge of the beta of the project and the market risk premium. In a typical core finance course, top MBA programs spend on average about 10-20% of the class time on present value concepts and another 30-40% on portfolio theory/CAPM and capital budgeting (Womack, 2001). However, since the critique by Fama and French (1992), there is consensus in the academic literature that the CAPM as taught in MBA classes is not a good model—it provides a very unreliable estimate of the cost of capital. There are more difficulties. Recent studies reveal that there may be substantial disagreement regarding what the market (equity) risk premium is. It may be substantially smaller than the values advocated in textbooks.

A. The CAPM May Not Be a Good Model

The CAPM became the preferred model for determining the cost of capital following the classic studies by Black, Jensen, and Scholes (1972) and Fama and Macbeth (1973) showing strong empirical support for it. Combining all NYSE stocks during the period 1931-65 into portfolios, Black et al. (1972) found that the data are consistent with the predictions of the CAPM. Fama and Macbeth (1973) examined whether knowing other characteristics of stocks—in particular, the squared value of beta and the idiosyncratic volatility of returns—in addition to their betas would help explain the cross section of stock returns better. Confirming the CAPM, they found that knowledge of beta was sufficient, using return data for NYSE stocks from 1926 to 1968.

There have been many academic challenges to the validity of the CAPM as applied in practice. The first serious challenge came from Banz (1981) who provided empirical evidence that stocks of smaller firms earned a higher return than predicted by the CAPM. He showed that firm size does explain cross-sectional variations in average returns on NYSE stocks during 1936-75.The general academic reaction to Banz (1981) was that since the CAPM was only an abstraction from reality, expecting it to hold exactly would be unreasonable. Since small firms constitute less than 5% of the total market capitalization Banz's findings were not viewed as being economically important. The CAPM continued to be the chosen model for classroom use.

The greatest challenge to the CAPM came from Fama and French (1992). For the period from 1963-90, using a similar procedure as Fama and MacBeth (1973) and ten size classes and ten beta classes, Fama and French (1992) find no systematic relation between return and risk as measured by beta. The regression analysis suggests that the size of a company and the book-to-market equity ratio do better than beta in explaining cross-sectional variation in the cost of equity capital across firms.[1] These findings could not be dismissed as being economically insignificant and lead to the question: Can beta be saved? The findings by

[1]Stattman (1980) was the first paper to document the positive relation of US stock returns and book-to-market ratios.

Fama and French (1992) have been scrutinized as well. Notable are the replies by Amihud, Christensen, and Mendelson (1992), Black (1993), Breen and Korajczyk (1993), and Kothari, Shanken, and Sloan (1995). The evidence against the interpretation of Fama and French (1992) can be summarized as follows: i) The data and, hence, the estimated coefficients are too noisy, ii)the size effect is simply a sample period effect, and iii) the data used for the studies contain a survivorship bias. Jagannathan and Wang (1996) question the use of a broad stock market as the adequate market portfolio. By adding the growth rate of labor income as a proxy for human capital return, and allowing betas to change over time, they find stronger support for the CAPM. While this may revive the CAPM, the revived version may not resemble the one that has been taught in MBA classes. Stulz (1999) pursues another line of argument that questions the use of CAPM for capital budgeting. This lack of empirical support for the CAPM can be recapitulated in the words of Campbell, Lo, and MacKinlay (1997, p. 217): "There is some statistical evidence against the CAPM in the past 30 years of US stock-market data. Despite this evidence, the CAPM remains a widely used tool in finance."

B. What Is the Market Risk Premium?

How should we measure the market risk premium? First, we need to identify the market portfolio of all assets in net positive supply. Typically, the portfolio of all stocks traded in the US is used as a proxy for the market portfolio. Second, we need to measure what investors expect to earn on that portfolio. A standard approach is to use the average return earned by the market portfolio over a long period of time in the past. For example, although they take no official position and list two reasons why history may overstate the risk premium, Brealey and Myers (2000, p. 160) "believe that a range of 6 to 8.5 percent [in real terms] is reasonable for the United States. We are most comfortable with figures toward the upper end of the range." Welch (2000) surveys 226 financial economists and finds an average estimate of 6.7% for a five-year horizon and roughly 7% for longer time horizons.

There is a lot of uncertainty about what the historical equity premium is. Siegel (1992) constructs a risk free rate series for the nineteenth century. The average realized real return on short-term risk free investments from 1800 to 1888 was 5.5% and 0.87% during 1889-1978, whereas the real return on equity was 7.49% and 7.79% during the corresponding two periods. Consequently, the equity premium of 1.99% (arithmetic mean) during the nineteenth century was significantly lower than the 6.92% of the twentieth century. The gap widens if we include more recent data. For the period 1926-1998, Siegel (1998, 1999) reports an average equity premium over treasury bills of 8.6%. Jorion and Goetzmann (1999) conclude that the success of the US stock market from 1921-1996 is rather exceptional compared to 39 markets around the globe. Conditioning on the best performing market may be misleading and raises the problem of survivorship bias. Dimson, Marsh, and Staunton (2002) collected data of 16 countries over the last 101 years and estimate a global, historical equity premium of 6.2% relative to treasury bills. Computing the equity premium for 92 overlapping decades, the arithmetic mean drops to 5.1% across all 16 countries. The authors try to avoid what they call the "easy data bias" and include turbulent periods, like the 1920s or the Second World War, for which it is difficult to collect data. They document that the composition of the stock index changed substantially over time. For example, in 1900, railroad stocks accounted for63% of the total market value of publicly traded stocks in the US whereas in 2000 they account for only an insignificant 0.2%. This is explained by the decline of the railroad industry along with today's higher fraction of the national output that is due to firms whose stocks are traded in organized exchanges. The consumption basket has also changed substantially over time. For example in the UK, the Cost of Living Index in 1914 contained just 14 items including candles and corset lacing—a larger fraction of the services and goods consumed was home produced in the early part of the century.

Blanchard (1993) chooses a different approach. Instead of looking at a historic period, he computes the equity premium using a forward-looking approach. He infers the expected equity premium from a dynamic version of the Gordon (1962) growth model. Blanchard (1993) concludes that the equity premium steadily decreased from the early 1950s, with a transitory increase in the 1970s that he attributes to inflationary trends, to a premium around 2-3%.

Wadhwani (1999) applies different assumptions for the input variables of the Gordon growth model and then calculates the implied risk premium that justifies the index level of the S &P thinspace500. In the first scenario, he uses the yield on Treasury Inflation-Protected Securities (TIPS) of 3.7% to approximate the real interest rate, the long-term growth rate of real dividends over the 1926-1997 period of about 1.9% p.a., and a dividend yield of 1.65%. To justify the index level of the S &P (at 1150) the implied risk premium is negative -0.15%. This is an extremely low value compared to the historic average of 7% over the 1926-97 period[2] or his ex-ante estimate for the same period of 4.3%. Under the following assumptions, the implied equity risk premium increases to 3.2%: i) TIPS contain a premium for lack of liquidity and, hence, a lower value for the real interest rate of 3% might be justified; ii) the dividend yield has to be adjusted for stock buybacks andcash-financed merger/acquisition/ LBO activity; iii) the earnings growth over the next six years is 14%. This value, far higher than the average, should reflect the I/B/E/S 1997 consensus.[3]

Jagannathan, McGrattan, and Scherbina (2001) use a modification of the classical Gordon growth model that allows the expected dividend growth rate to changeover time. The two datasets they use to derive the equity premium cover the major US stock exchanges (NYSE, AMEX, and Nasdaq), and all stocks that are held by US residents as reported by the Federal Reserve System Board of Governors to account for stocks that are not publicly traded. Although including not publicly traded stocks increases the equity premium, the bottom line remains the same. The US equity premium has dramatically declined from an average of 8.90% during the fifties to an average of 3.98% during the nineties.

Fama and French (2001) compare the sum of the average dividend yield and average growth rate in dividends with the average return on stocks. Over long horizons, the two averages should have similar means. They do except for the post war period when the latter is substantially larger than the former. They conclude that the equity risk premium has come down during the post war years. Claus and Thomas (2000), Bansal and Lundblad (2000), and Siegel (1999) provide evidence that this is not only a pure US phenomena—the equity risk premium has come down around the world.

When taken together, these studies of the historical equity premium and forward-looking models question the validity of the folk wisdom that the longer the length of the time series, the more reliable would be the predictions of the future based on historical averages. The current view among academics is that we need a valuation model to forecast what to expect from stocks in the future.

The views of academics are reflected in some of the more recent textbooks. Benninga and Sarig (1997) is the first textbook to explicitly recommend a forward-looking methodology in

[2]Brealey and Myers (2000) report an average real return on S&P 500 stocks of 9.7% over the period 1926-1997. The real return on government bonds for the same period is 2.6%. The difference is about 7%, the value Wadhwani (1999) uses for his analysis.

[3]The mean outstanding forecast of institutional brokers (I/B/E/S: Institutional Brokers Estimate System) for the S&P 500.

the spirit of Blanchard (1993). Grinblatt and Titman (2002) caution the reader against estimating the equity premium from historical excess returns. Van Horne (2002) expresses his preference for ex-ante estimates of the equity premium. He suggests to use consensus estimates of security analysts or economists and acknowledges that the equity risk premium could be anywhere from 3 to 7%. Brigham and Ehrhardt (2002, p. 429) mention that “for our consulting, we typically use a risk premium of 5 percent, but we would have a hard time arguing with someone who used a risk premium in the range of 4.5 to 5.5 percent. The bottom line is that there is no way to prove that a particular risk premium is either right or wrong, although we are extremely doubtful that the market premium is less than 4 percent or greater than 6 percent.” Ross, Westerfield, and Jaffe (2002, p. 273) state that “financial economists find this [the average risk premium in the past] to be a useful estimate of the difference to occur in the future.”

There is overwhelming evidence in the academic literature that business schools have been teaching a model that may not be of much value when it comes to estimating the cost of capital for a project. In addition, studies that take a forward-looking perspective suggest that the historic average return on equities substantially overstates the market equity premium. As a consequence, some textbooks have revised their prescriptions. If managers in fact followed the mainstream textbook prescription and used the historical average on equities of 7.43% as the market risk premium, their cost of capital estimates would have been off the mark by a large margin. Does this mean that managers would have turned down many profitable investment opportunities that they should have otherwise taken up during the last two decades? We argue that managers probably were right in turning down these apparently profitable investment opportunities because by doing so they positioned themselves to be able to take up even better investment opportunities that showed up later on in time.

II. Capital Budgeting Decisions and Hurdle Rates

Each manager, dependent on his skills and the overall limitations of managerial and organizational capital within the company, faces an opportunity set of alternative projects. Taking a project today may preclude taking another attractive project in the near future. In that case, deciding against a positive NPV project might be advantageous and the question is when should the manager accept a project. The opportunity to acquire an investment in the future is a real option. In contrast to most examples in the real options literature, we do not have in mind a tree cutting example—given that you own a forest when is it optimal to cut the timber (see e.g., Brealey and Myers, 2000, pp. 134/35 and 625-27, or the review of the real options literature in the capital budgeting survey by Brennan, 2001).[4] The simple example in the introduction illustrated that to value a project it is critical to use a precise estimate of cost of capital. In this section, we show that for a company that has real options it is not critical to estimate the cost of capital precisely in order to make the right project selection decision. As long as the company selects a reasonable hurdle rate above cost of capital, that has to be cleared before a project is launched, the decisions will be nearly optimal.

A. Distinguishing Between Net Present Value, Intrinsic Value, and Enterprise Value

The *net present value* (NPV), V_t, of a project that a manager has available at a point in time,

[4]This situation resembles more the classical secretary problem in the optimal stopping literature. Freeman (1983) and Ferguson (1989) provide an in-depth review of the classical secretary problem.

t, that produces an infinite stream of cash flows C_t each period, $\{C_t, C_t, C_t, \ldots\}$, and requires an initial investment I is defined as:

$$V_t = \frac{C_t}{r} - I \tag{1}$$

where r is the appropriate discount factor given the risk characteristics of the project.

Since a negative NPV project need not be undertaken, define the intrinsic value, W_t, of the project as follows:

$$W_t = \max\,[V_t, 0] \tag{2}$$

Suppose the manager expects to get projects at different points in time with *Vt* drawn from some probability distribution, and he can only successfully manage a limited number of projects—what seems to be a natural assumption? In this case, it is well known that taking the first positive NPV project that comes along is not necessarily optimal. It may pay off to wait for a better, alternative project. Let *enterprise value*, F_t, denote the value of the firm that takes this value to waiting into account and comes up with an optimal policy for undertaking projects. The real options literature examines the special case where the same project can be undertaken at different points in time and the NPV of the project depends on the time at which it is implemented. In our setting, the projects that become available at different points in time may be different. This does not fit into any of Trigeorgis' (1993) common real options categories. Define the *time value of the option*, Ot, as the difference between the enterprise value and the intrinsic value (i.e., $O_t = F_t - W_t$.)

B. The Optimal Decision May Not Be Critically Dependent on the Cost of Capital: A Two-Period Example

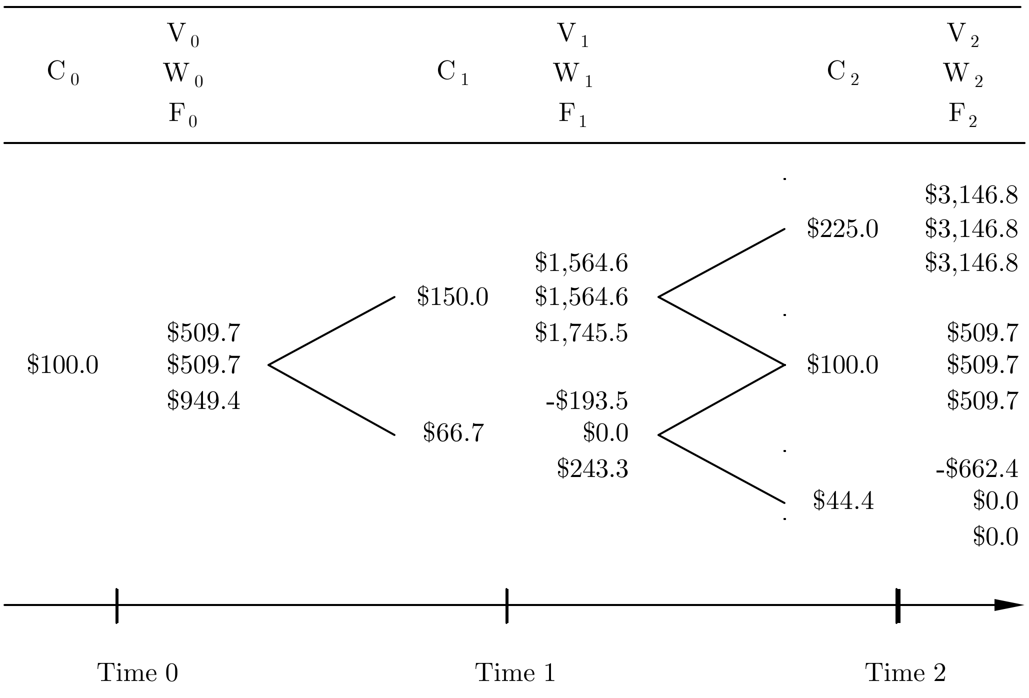
Consider the situation of a skilled manager. Every period she gets an opportunity to invest in one infinitely-lived project with a per period cash flow of C. If she takes the project, she is tied to that project for the rest of her life. Today at time $t = 0$, she has a project that generates a perpetual stream of cash flows of 100 (in thousands of dollars) each period, starting at $t = 1$. The project requires an initial investment of 1,600 and the beta factor of the project is 1.0. This is the situation of the simple example in the introduction. If we believe that the forward-looking equity premium number given in Fama and French (2001) of 2.55% is correct, the cost of capital from the CAPM equals $r = 4.74\%$ (in real terms). From Equation (1) the net present value of undertaking the project today is $V_0 = 509.7$. As long as the net present value is positive, the intrinsic value W_0 in Expression (2) is the same.

The manager can also decide to wait for a maximum of two periods. If she waits and forgoes the investment opportunity on hand, she will get with equal probability a new project next period with a NPV that can be 50% higher or 33.3% lower (corresponding to a discrete geometric process). Therefore, waiting for two periods opens up three possible investment opportunities. The probability to receive an infinite stream of cash flows of 225.0 or 44.4 per period is 25% each, the probability for the outcome 100.0 per period is 50%. Figure I displays the corresponding binomial tree.

The enterprise value at each time can be calculated working backwards in the tree. At time 2, there is no further option to delay the project. Hence, at each state the enterprise value

Figure I. Binomial Tree When the Cost of Capital is 4.74%

The probability of an up move or down move is 50%. C_t denotes the cash flows you will get in the different states. V_t is the value of the project, W_t the intrinsic value, and F_t the enterprise value that includes the option to delay the investment decision. The discount factor is r = 4.74%, the value Fama and French (2001) derive from the dividend growth rates of the real S&P for the period 1951-2000.



equals the intrinsic value, the value to launch the project at time $t = 2$. In the up-up state with a perpetuity paying C = 225.0 per period the net present value is $V_2^{up,up}$ = 3,146.8, and $V_2 = W_2 = F_2$. In the down-down state C = 44.4, the net present value is - 662.4, and the intrinsic value and enterprise value $W_2 = F_2 = 0$. The calculation of the enterprise value prior to time $t = 2$ is illustrated for the down state after one period. Given an infinite stream of cash flows of 66.7 and an initial investment of 1,600, the net present value V_1^{down} = - 193.5, the intrinsic value W_1^{down} = 0, and the enterprise value F_1^{down} = 0.5 times 509.7/ $(1 + r)$ + 0.5 X 0 = 243.3. Today, at time $t = 0$, the enterprise value is F_0= 949.4. The time value of the option, $O_0 = F_0 - W_0$ = 949.4 - 509.7 = 439.7, gives the opportunity cost of investing now instead of waiting. The time value of the option in this example is almost as large as the intrinsic value of the project itself.[5] In the situation in Figure I, we should wait for two periods since in the up state the value to wait for another period is still positive. Now consider two other values for the cost of capital. The value r = 6.51% is the cost of capital if we use the forward-looking equity premium of Fama and French (2001) implied by earnings forecasts, and r = 9.62% is the cost of capital based on the realized real equity premium over the period 1951-2000. It can be verified that the optimal decision does not change when cost of capital, r, equals 6.51% or

[5]As W_0 gets closer to zero, the fraction $F_0 - W_0 W_0$ goes to infinity.

9.62%, as shown in Figures II and III, except in the second node from the top at time $t = 2$. The key insight from these figures is that although the project's net present value in the different states differ substantially depending on the specific value used for the cost of capital, the optimal decision remains almost the same.[6]

C. High Hurdle Rates Capture the Option Value

Alternatively, to account for the option to take an alternative investment opportunity in the future, the manager can use a high hurdle rate to discount the cash flows and invest whenever the net present value is positive. In the above example, any hurdle rate between 9.38% and 14.06% will lead to the same investment decision as the real option approach. If we define the hurdle premium as the difference between the hurdle rate and the cost of capital and assume cost of capital is 4.74%, then the hurdle premium is aslarge as the cost of capital. Given the uncertainty associated with the cost of capital, managers may choose a hurdle rate that is near optimal for a range of costs of capital.

III. Precise Estimate of the Cost of Capital May Not Be Necessary for Making the Right Decision

The two-period example in the previous section may seem contrived, but MacDonald (1999) shows that for a given cost of capital, a wide range of hurdle rates will result in decisions that are close to the optimal decision based on dynamic programming. In what follows, we extend McDonald (1999)and show that a single, high enough hurdle rate will result in near optimal decisions for a wide range of values for the cost of capital. This would explain why a manager may continue to use the same hurdle rate even though the cost of capital has changed by a substantial amount. The investment decision is also fairly insensitive to the volatility parameter that determines the distribution of future investment opportunities one gives up by deciding not to wait and take the project on hand.

A. The Optimal Hurdle Rate in a Continuous-Time Framework

We assume that at any time, t, the manager can take up a project that is available immediately by investing an amount I, or wait and take a look at another project at date $t + dt$. The projects are infinitely lived. The project that becomes available at date t has an initial cash flow rate, C_t, that changes over time according to the stochastic process with drift α and standard deviation σ given below:[7]

$$\frac{dC_t}{C_t} = \alpha dt + \sigma z(t) \tag{3}$$

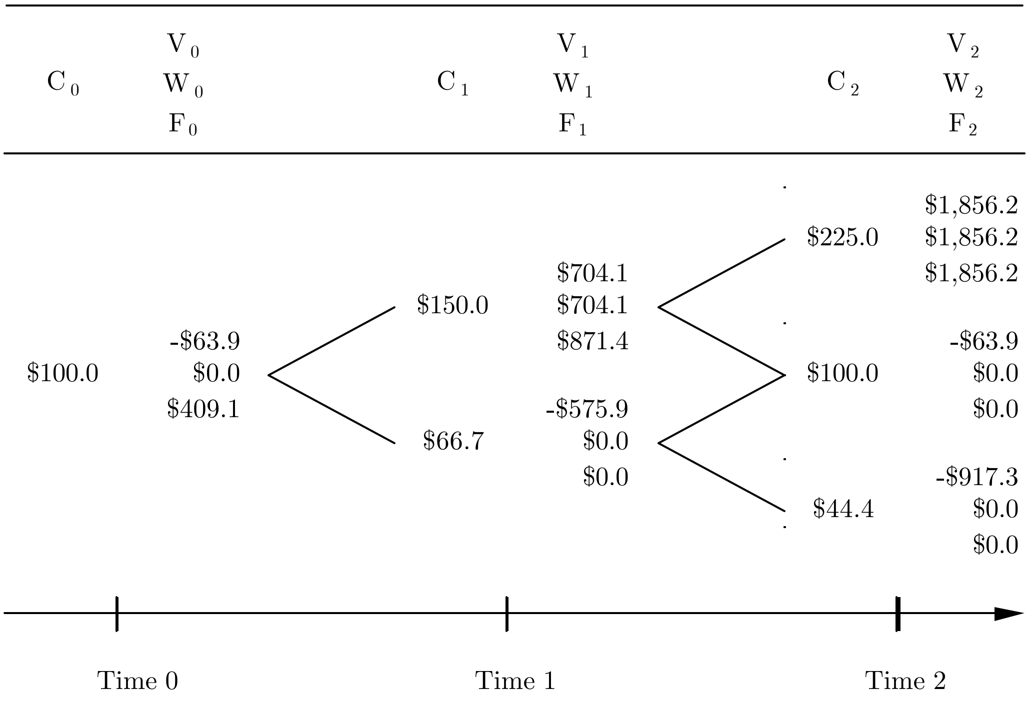
The net present value, V_t, of the project that becomes available at date t computed using a cost of capital, r, is the value of a perpetuity with initial cash flow rate C_t that grows over time at the rate a as described in Equation (3), minus the initial investment I that is required to undertake the project, i.e.:

[6]The example can easily be extended to include a penalty for waiting.

[7]The original version in McDonald and Siegel (1986) describes the stochastic process for the value of the project. The project value V is a perpetuity and proportional to C. Therefore, the results are equivalent.

Figure II. Binomial Tree When the Cost of Capital Is 6.51%

The discount rate is r = 6.51%, corresponding to the estimate of Fama and French (2001) based on earnings growth rates from 1951-2000.

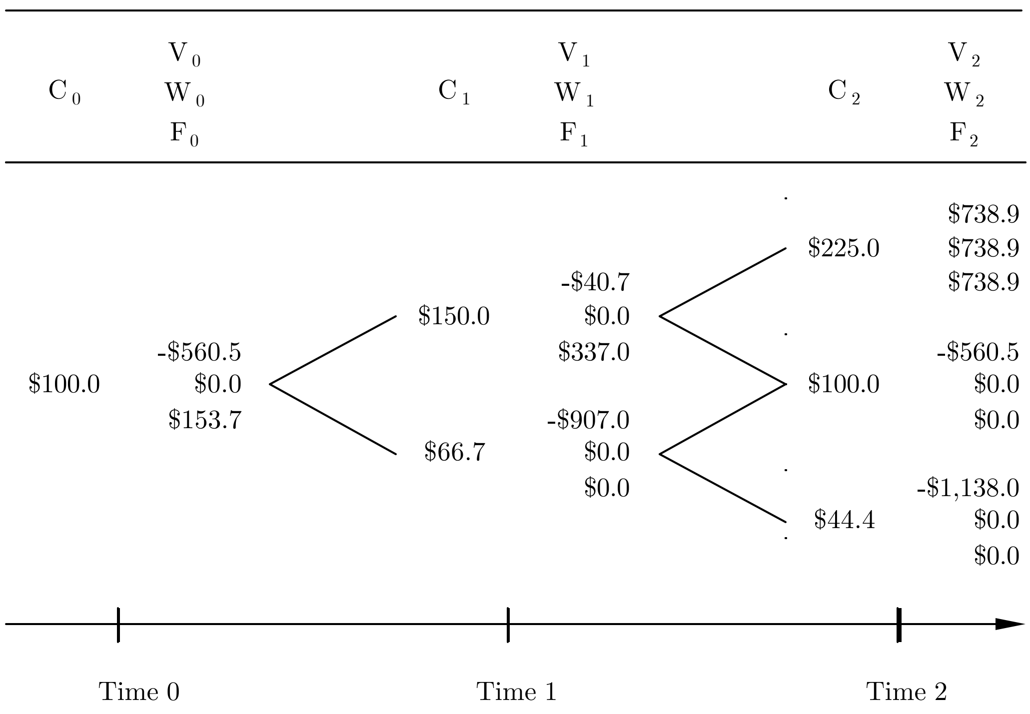


$$V_t = \frac{C_t}{r - \alpha} - I \tag{4}$$

Suppose the manager decides to wait. He will have another infinitely-lived project available at date $t + dt$. It will have an initial cash flow rate of C_{t+dt} and it will also change over time according to the stochastic process given in Equation (3). Furthermore, the initial cash flow rate of the project that becomes available at time $t + dt$, C_{t+dt}, is related to the initial cash flow rate, C_t, of the project that was available at date t by Equation (3), (i.e., $C_{t+dt} = C_t + \alpha C_t dt + \sigma C_t \sqrt{dt} z(t+dt)$), where $z(t + dt)$ is a standard Normal random variable. It is well known that the optimal policy for the manager is to undertake the project that becomes available at date t if and only if its net present value computed using the cost of capital exceeds a hurdle level, NPV*. We refer to the optimal policy as the net present value rule. Future cash flows—and this holds also for the project value as it is a linear transformation—are log normally distributed with variance that increases linearly with time. The growth rate of the cash flows cannot be above the cost of capital forever, otherwise the value of the project would be infinite (i.e., the cost of capital r must be strictly larger than α). Given the above geometric Brownian motion process, the net cash flows are always positive. In that case, the net present value rule is

Figure III. When the Cost of Capital Is 9.62%

The discount factor is set to the average realized return on the S &P index from 1951-2000 of r = 9.62%.



equivalent to the following hurdle rate rule: Invest in the project if the internal rate of return, R_t, of the project that becomes available at date t exceeds the hurdle rate, h.[8] The internal rate of return is the discount rate at which the discounted present value of project cash flows minus the investment required to undertake the project equals zero, i.e.:

$$R_t = \frac{C_t}{I} + \alpha \tag{5}$$

Under the hurdle rate rule, the manager will undertake the project that becomes available at date t if the present value of the project computed by discounting at the hurdle rate is positive. The hurdle rate will, in general, be substantially higher than the cost of capital r.

The enterprise value when the manager follows the optimal hurdle rate rule is given by the solution to a dynamic programming problem. The solution in this real option framework was first introduced by McDonald and Siegel (1986). For a detailed exposition of the mathematical derivation, see Dixit and Pindyck (1994). The enterprise value, F (omitting the subscript t), is

[8] Dixit (1992) shows that for time-homogeneous cash flows the requirement of positive NPV can be replaced by a lower bound for the internal rate of return of the project.

given by:

$$F(h)=\left(\frac{h-r}{r-\alpha}\right)\left(\frac{C}{h-\alpha}\right)^{b_1} I^{1-b_1} \tag{6}$$

where b_1 is:

$$b_1=\frac{1}{2}-\frac{\alpha}{\sigma^2}+\sqrt{\left[\frac{\alpha}{\sigma^2}-\frac{1}{2}\right]^2+\frac{2r}{\sigma^2}} \tag{7}$$

Maximizing Equation (6) with respect to the hurdle rate h, McDonald (1999) shows that the optimal solution is:

$$h^* = \alpha + (r-\alpha)\frac{b_1}{b_1-1} \tag{8}$$

Since $b_1 > 1$ and $\alpha < r$, the optimal hurdle rate is always strictly higher than the cost of capital r. Inserting the optimal hurdle rate in Equation (6) returns the maximum enterprise value.

The comparative statics are discussed in McDonald (1999) and can be summarized as follows:

i) The higher the growth rate a, the more valuable it is to defer the investment, and hence *F* left (*h* right) increases;

ii) the option value increases the greater the uncertainty about future changes in cash flows s. This is the standard option pricing intuition;

iii) the higher the cost of capital, the lower is the present value of distant cash flows and it is less attractive to postpone the project. The value of the option decreases with increasing *r*.

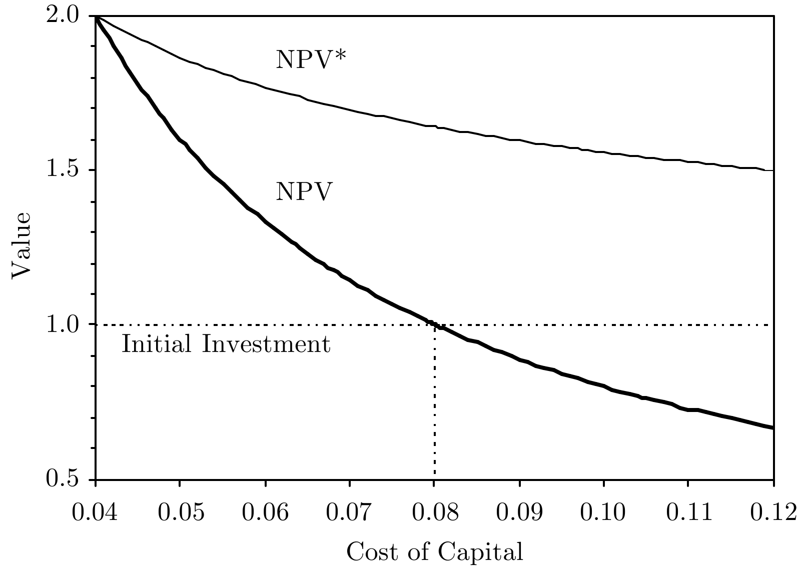
B. The Same Hurdle Rate May Work for a Wide Range of Cost of Capital

Next, we discuss the sensitivity of the enterprise value to changes in the cost of capital. We take the position of a financial manager and—say using CAPM—we calculate the cost of capital. Applying the result from the real options literature we calculate the optimal hurdle rate from Equation (8). Figure IV plots the NPV as a decreasing function of the underlying cost of capital. If there is no uncertainty ($\sigma = 0$) and the growth rate of the expected cash flows is zero, the manager would either take the project now or never. Consequently, if the NPV of the project today is positive and the internal rate of return above the cost of capital, then the manager would undertake the project. Assuming the project requires an initial investment $I = 1$ and the instantaneous cash flow is $C = 0.08$ with an expected growth rate of $\alpha = 0$, the project has zero NPV if the cost of capital is 8%. In case the growth rate α is positive, it may even be optimal for the manager to wait in the deterministic case. The present value of the project taken up at some future point in time decreases over time at the rate $e^{-(r-a)T}$ whereas the present value of the initial investment decreases at a higher rate e^{-rT}.[9] With volatile cash flows, the optimal strategy is to invest when the NPV of the project clears the target level NPV*. The top line that plots NPV* in Figure IV is based on a volatility parameter $\sigma = 20\%$. Below a cost of capital of 4%, NPV > NPV*

[9]Real options can take other forms. Berk (1999) considers the case where waiting resolves uncertainty about the level of interest rates.

Figure IV. A Project's Net Present Value and the Optimal Value for NPV*

The expected growth rate of the cash flow process is $\alpha = 0$ and its volatility $\sigma = 20\%$. The graph shows the net present value (NPV) of a project with $C = 0.08$ and initial investment $I = 1$ as a function of cost of capital. It is optimal to take a project immediately only if the NPV exceeds the trigger value NPV*.



and, thus, the manager would launch the project that is available immediately.

Figure V compares the NPV with the enterprise value. Suppose a manager decides not to follow the optimal hurdle rate rule and decides to take up the first project he gets that has a positive NPV. When the cost of capital is just below 8% such a manager would be giving up shareholder value of 18.02% of the initial investment, the difference between F and W. This value decreases to 4.39% if cost of capital is 12%

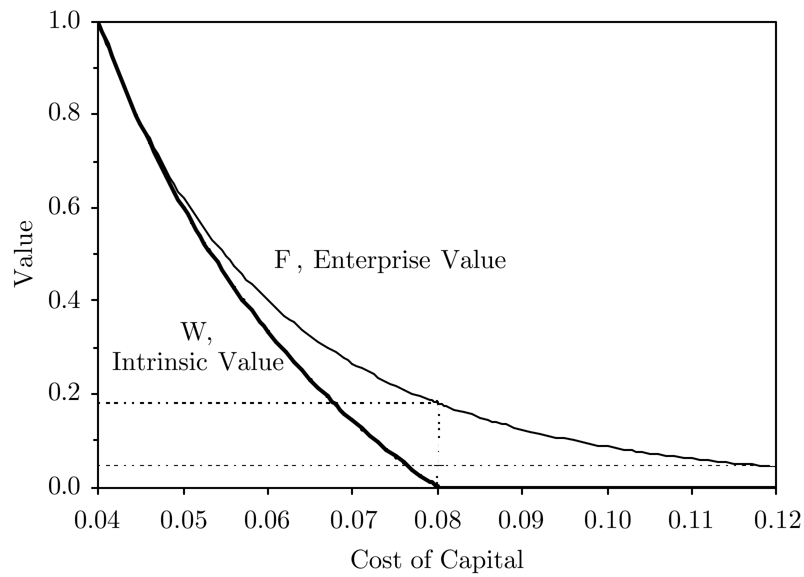
What if the manager tries to follow the optimal hurdle rate rule, but makes a mistake while estimating the cost of capital? How much of the value of the investment opportunity will such a manager miss? We answer this question by calculating the optimal hurdle rate for a given cost of capital. From this we can infer the maximum enterprise value in Equation (6). The question is then how far off could we be with a wrong estimate for the cost of capital and still capture most of the enterprise value. Figure VI shows the bandwidth of hurdle rates that still pick 90% of the enterprise value. Given the above calibration with estimated cost of capital of 8%, the optimal hurdle rate is $h^* = 13.12\%$. When the manager uses a hurdle rate of 13.12% the true cost of capital can be anywhere in the range of 5% to 10% and the manager would still capture 90% of the enterprise value. The result is independent of the choice of the investment costs. Even if we require that 95% of the enterprise value is captured the bandwidth of hurdle rates is wide with lower and upper bounds of 6% and 9.5%, respectively.

C. The Same Hurdle Rate May Work for a Wide Range of Values for the Volatility Parameter Characterizing Real Options

Figure VII plots the optimal hurdle rate as a function of the volatility parameter σ. As

Figure V. Intrinsic Value Versus Enterprise Value

The parameters of the cash flow process are $\alpha = 0$ and $\sigma = 20\%$. The graph plots the intrinsic value if we take a project with cash flows $C = 0.08$ and initial investment $I = 1$ immediately, and the enterprise value. The enterprise value at cost of capital of $r = 8\%$ is 18.02% of the initial investment and 4.39% at $r = 12\%$.



above, the growth rate is set to $\alpha = 0$, the instantaneous cash flow to $C = 0.08$, and the initial investment is normalized to 1 and stays constant over time. Now we fix the cost of capital at 8% and vary the volatility. For the deterministic case with $\sigma = 0$, the simple NPV decision rule using the cost of capital is the optimal solution to the investment problem. Given the cost of capital of 8%, the optimal hurdle rate increases to 13.12% if the volatility is $\sigma = 20\%$. The optimal hurdle rate is a convex function of the underlying uncertainty of future cash flows s. Assume that the manager estimates the volatility to be 20% and hence the optimal hurdle rate $h^* = 13.12\%$. If in fact the true volatility of the underlying cash flow process deviates from the manager's estimate and he uses a hurdle rate of 13.12% he would still capture 90% of the enterprise value if s is in the range from 13% to 34%. As long as the manager has future investment opportunities, the sensitivity of the enterprise value to changes in the volatility of the underlying cash flows is moderate.

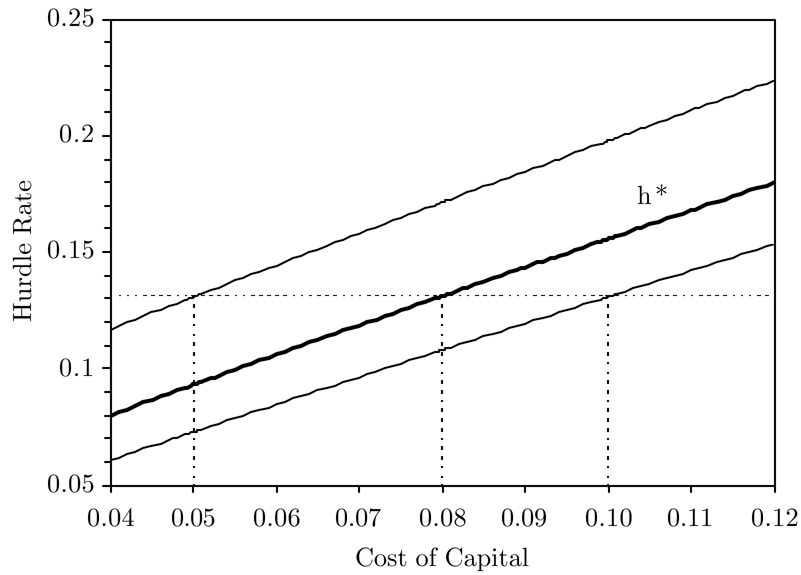
The wide areas where 90% and more of the enterprise value is captured in Figures VI and VII shows that the capital budgeting decision is insensitive for many combinations of cost of capital and volatility. Therefore, the knowledge of the true underlying cost of capital is far less important than traditional NPV calculations would suggest. This explains why using a high hurdle rate makes sense. As long as the volatility of the cash flows is high—(i.e., the option value is high)—a wide range of hurdle rates would lead to near optimal decisions.

IV. Empirical Implications

Our theory predicts that managers who do not change the optimal hurdle rate in response to

Figure VI. Range of Cost of Capital Capturing 90% of the Enterprise Value When the True Cost of Capital Is 8%

The bold line shows the optimal hurdle rate h^* as a function of cost of capital. The parameters of the underlying cash flow process are $\alpha = 0$ and $\sigma = 20\%$. The two thin lines indicate the range of hurdle rates that, at a given cost of capital, still capture 90% of the enterprise value. The optimal hurdle rate for cost of capital $r = 8\%$ is $h^* = 13.12\%$.



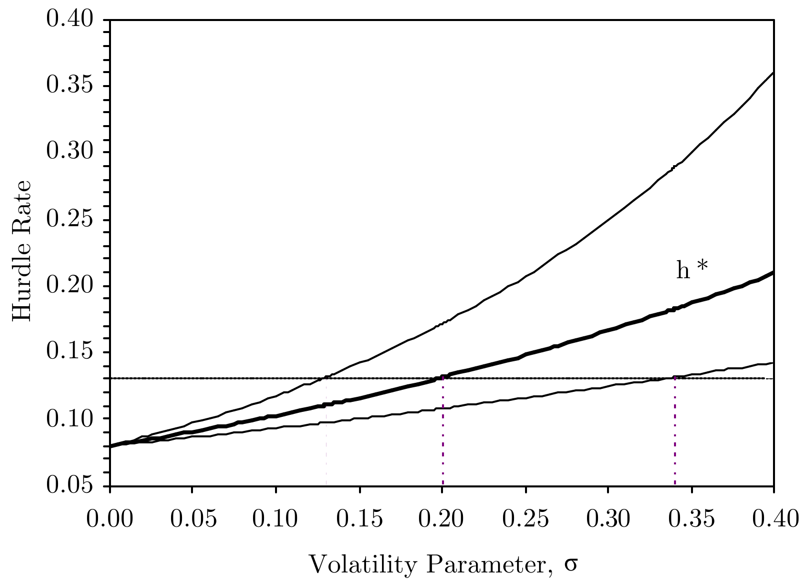
changes in the cost of capital may still be making near optimal capital budgeting decisions. The magnitude of the hurdle premium can be as large as the cost of capital and will depend on project specific characteristics.

Traditional cost of capital calculations would suggest that companies in the same sector face similar systematic risks and, thus, would apply similar discount rates to evaluate their projects. Therefore, the high variation in hurdle rates within the company and industry sectors found in surveys indicates that hurdle rates are not directly linked to the cost of capital. For example, using a sample of 228 companies Poterba and Summers (1995) find that only 12% of the variation in the hurdle rates can be explained by the industry sector. A simple linear regression of the real hurdle rates of all 228 companies on their beta factor (a proxy for the cost of capital) further reveals that the beta of a firm is by no means significant in explaining the hurdle rate.

Depending on the availability of managerial resources, the hurdle premia within a firm and across companies may vary considerably. Some types of projects are more likely than others to require the use of skilled manpower or the use of special purpose facilities that take time to build and consequently face organizational constraints. Firms would use relatively high hurdle rates for such projects even though the systematic risks in such projects are no different than that for other projects. Consider a single company. A positive NPV project of small size and/or low complexity can be administered successfully by lower management

Figure VII. Range of Volatility Parameters Capturing 90% of the Enterprise Value When the True Volatility Is 20%

The bold line shows the optimal hurdle rate h^* as a function of the volatility parameter σ. The expected growth rate of the cash flow process is $\alpha = 0$ and cost of capital is fixed at $r = 8\%$. The two thin lines indicate the range of hurdle rates that, for a given volatility of the cash flow process, still capture 90% of the enterprise value.



requiring little skilled manpower. In this case the hurdle premium may even be zero. In contrast, a project—usually large and of a high degree of complexity—that will lock in much of the organizational facilities if undertaken would prevent the firm from taking another similar project in the near future. In this case, the option to wait is more valuable. This can explain the large variation in hurdle rates used within firms reported by Poterba and Summers (1995). In their survey the average difference between the highest and lowest hurdle rate used within a company is 11.2%.

In equilibrium, the marginal project that is accepted will be a zero NPV project (i.e., the associated hurdle rate will be the same as the cost of capital.) This does not mean that the average of the hurdle rates used within a firm or across firms would equal the cost of capital. Typically, surveys are biased toward including larger and relatively more successful firms. These firms are more likely to have organizational capital in short supply resulting in the use of a higher hurdle rate. The fact that surveys report average hurdle rates far above cost of capital may in part be due to this selection bias. When the cost of capital comes down unexpectedly the collection of projects that have a positive NPV will typically increase. If the set of investment opportunities facing old well established firms do not change these new lower NPV projects will be taken up by new entrants.

The volatility of the stream of cash flows is a key determinant of the option value of waiting and, thus, of the opportunity set. When changes in the cost of capital do not affect the opportunity set, managers may get by using the same hurdle rates since they would be nearly optimal. Hence, hurdle rates may vary much less than the cost of capital over time. This is consistent with the evidence from surveys.

Brigham (1975) investigated the question how often companies change their hurdle rate. Thirty-nine percent revise their hurdle rates less than once a year. Another 32% of the respondents stated that the frequency they adjust the hurdle rate "depends on conditions." In most cases, the accompanying comments indicate that these companies "revise rates to reflect product and capital market conditions, with revisions generally occurring less than once a year." Gitman and Mercurio (1982) asked the same question and find that 50%of the companies adjust the capital costs "when environmental conditions change sufficiently to warrant it." In addition, 11% re-estimate cost of capital each time a major project is evaluated. Twenty-two percent of the 177 respondents revise cost of capital annually and 13% less frequently than annually. The qualitative part is repeated by Bruner, Eades, Harris, and Higgins (1998). They conclude that for very large ventures cost of capital may be recalculated every time, otherwise only major changes in the economy induce companies to revise their hurdle rates.

Our conjecture is that firms earn more than the cost of capital because of resources that are unique to that firm and cannot be competed away immediately. Such firms would typically be firms of larger size, with patents, copy rights, brand name and other protections.[10]

We show in the last section that for those companies the capital budgeting decision is fairly insensitive to the estimated cost of capital and the estimates of the riskiness of future projects. What about firms for which cost of capital is critical—firms that do not have much real options? Such firms are likely to rely on other methods that bring in market information ina timely manner. This view is consistent with the findings in Graham and Harvey (2001) indicating that smaller firms are less likely to use the CAPM to determine the cost of capital.

V. Practice in the Field

Earlier, we mentioned that the CAPM continues to be widely used in the field. In this section, we provide a brief overview of the surveys reported in the literature supporting that conclusion and discuss the extent to which the various findings in the surveys are consistent with the empirical implications of our theory. Table I summarizes the main contributions in the survey literature on capital budgeting.

Istvan (1961) triggered a number of surveys on the cost of capital techniques used by major US firms. He interviewed with top-ranking executives of 48 companies. The sample included major corporations with capital expenditures of over $8 billion for plant and equipment in 1959, almost one fourth of the nation's aggregate $33 billion. Istvan's survey documents that in the late fifties, financial decision makers overwhelmingly disregarded the use of discounted cash flow methods. The techniques that were most widely used are payback period and simple rate of return, in essence the reciprocal of the payback period. The payback period was often defended by executives as a measure that does not require any long range estimates and is, thus, implementable. Table I includes the number of companies that are surveyed (*N*) and the response rate (*RES*). For the survey by Istvan (1961), no response rate is reported as he did not send a questionnaire to companies, but interviewed directly with financial executives. The number of companies that denied to be interviewed is not reported. The column *TV* shows the fraction of the sample companies using capital budgeting techniques that account for the time value of money.

Klammer (1972) surveys a sample of 369 large manufacturing companies (from Compustat)

[10] Baldwin (1982) develops a model for companies with market power, where investment decisions affect the existing or future opportunity set, and investments are not reversible in the short run. In such situations it may be optimal for a firm to accept projects only if they clear a threshold level NPV*.

Table I. Overview of Surveys

N is the number of companies that are surveyed by sending a questionnaire. For surveys that use interviews with specific companies no response rate (*RES*) is reported. *TV* measures the fraction of companies that use capital budgeting techniques that account for the time value of money. *WACC* is the percentage of companies that use weighted cost of capital. *CAPM* is the overall percentage of companies that use CAPM to determine the equity cost of capital. *h* is the average cost of capital or hurdle rate used.

Authors	*N*	*RES*	*TV*	*WACC*	*CAPM*	*h*[a]
Istvan (1961)	48[b]		15%			
Klammer (1972)	369	50%	67%			
Fremgen (1973)	250	71%	76%			
Brigham (1975)	33		94%	61%		
Petty and Bowlin (1976)	500	45%	77%			
Gitman and Forrester (1977)	268	38%	66%			~14%
Schall, Sundem, and Geijsbeek (1978)	407	46%	86%	46%		11.4%[c]
Gitman and Mercurio (1982)	1000	18%		83%	30%	14.3%
Moore and Reichert (1983)	500	60%	86%			12.2%
Bierman (1993)	100	74%	99%	93%		
Poterba and Summers (1995)	1000	23%				12.2% (real)
Bruner, Eades, Harris, and Higgins (1998)	27		96%	93%	85%	~12.4%[d]
Graham and Harvey (2001)	4440	9%			74%	

[a]Nominal rate if not noted otherwise.
[b]149 executives in 48 companies.
[c]After tax rate. The pre-tax rate is 14.3%
[d]The average equity premium is ~7%, plus the 20-year US Treasury bond yield in 1998 of 5.4%.

with sizable continuing capital expenditures. By the late sixties, a majority were using discounting techniques as the primary project evaluation standard, followed by accounting rate of return, and payback period or its reciprocal. The payback rule was the most popular secondary technique. Fremgen (1973) sent a questionnaire to 250 randomly picked business firms (excluding financial institutions like banks and insurance companies); the response rate was 71%. His study confirmed the results of Klammer (1972) with 76% of the firms using discounted cash flow and internal rate of return methods. However, the internal rate of return was by far more popular than the net present value calculation. Fremgen's survey includes an analysis of the frequency with which multiple internal rates of return were encountered due to a mixed sequence of cash in- and outflows. The evidence indicates that most companies only "rarely" or at most "fairly frequently" encounter such projects. Brigham (1975) also used a questionnaire to determine what capital budgeting technique is the standard for large industrial and utility companies. In addition, current and former participants of MBA and executive program classes provided answers to the questionnaire. The sample is, therefore, biased towards larger firms, and the questionnaire was answered by financial staff that might favor "academic techniques" taught in standard MBA courses at that time. This study was different in that it provided for multiple answers to the question regarding the capital budgeting technique used by the firm. When compared to the previous studies, the 33 sample companies used net present value or internal rate of return (94%) more often. Sixty-one percent used a hurdle rate based on the cost of capital and53% adjusted the hurdle rate for risk differentials among projects. The fraction of companies that use a weighted average cost of capital—61% in the survey of Brigham—is reported in column (*WACC*) of Table I. Two out of the sample of 33 firms used only the payback and/or accounting rate of return.

Seventy-four percent of the companies used payback together with other criteria.

The respondents to the survey of Gitman and Forrester (1977) were 103 large, rapidly growing businesses. The internal rate of return was the dominant choice, and payback was commonly used as a secondary capital budgeting technique. The survey by Schall, Sundem, and Geijsbeek (1978) asked which capital budgeting technique large US firms use. They sent a questionnaire to 407 firms and had a response rate of 46.6%. The most popular decision rule was payback, although only 2% used it as the only criterion. In general, 86% of all respondents indicated the use of more than one capital budgeting technique. Forty-six percent of the firms that applied a discount rate used a weighted average cost of capital, and only 8% used the risk free rate plus a premium for their risk class. The average after-tax discount rate used was 11.4%. The authors conclude that, when compared to Fremgen (1973), the sophistication of risk analysis has increased. The results also indicate a slightly positive correlation between the level of sophistication and firm size. Moore and Reichert (1983), who survey 298 Fortune 500 firms find that 86% of firms surveyed use time-adjusted capital budgeting techniques. Bierman (1993) finds that all 74 responding Fortune 100 companies use some form of discounting, and 93% calculate the weighted average cost of capital.

During the two decades following the survey of Istvan (1961), the use of screening techniques that disregard the time value of money decreased considerably. By the late 1970s financial executives are familiar with discounted cash flow analysis, although they still may use other techniques like the payback period as well.

B. What Discount Rate Is Used in Practice?

The empirical literature of the sixties and early seventies addressed the choice of capital budgeting techniques by companies. None of the surveys provided specific information about the implementation of the cost of capital practices. Gitman and Forrester (1977) were the first to actually ask about the level of cost of capital or cutoff rate. Sixty percent of the 95 respondents had a nominal cost of capital between 10 and 15%, and another 23% a cost of capital of 15-20%. The average, nominal cost of capital (or hurdle rate) is denoted as h and shown in the last column of Table I. The approximate value for the average, nominal cutoff rate of the 103 companies is14%.[11] Gitman and Mercurio (1982) refined the grid ranges for the level of the cost of capital. They mailed a questionnaire to the chief financial officer of each firm in the 1980 Fortune 1000 listing. The 177 usable responses are primarily large manufacturing firms. For risk analysis, besides the dollar size of the project, the payback period played an important role for many companies. The mean of the overall cost of capital from all the respondents was 14.3% (in nominal terms), with 65% in the range of 11 to 17%. More than half indicated that the cost of capital varied by no more than 2 to 4% during the two preceding years. Thirty percent of the respondents use CAPM to determine the cost of capital (see column *CAPM* in Table I). Gitman and Mercurio (1982) conclude that “the respondent’s actions do not reflect the application of current financial theory.”

Poterba and Summers (1995) sent a questionnaire to all Fortune 1000 companies and received 228 answers. As in previous surveys, the large fraction of respondents are manufacturing companies. Their main finding is that the average hurdle rate applied by the sample companies is 12.2% in real terms, which is substantially higher than the average rate of return on debt or equity over the last several decades. Their results also indicate that depending on the

[11]On p. 69, Exhibit 9, Gitman and Forrester (1977) summarize the responses: 9.5% use a rate of 5-10%, 60% a rate of 10-15%, 23.1% a rate of 15-20%, and 7.4% a rate higher than 20%. The approximate average value is computed as 0.095 X 0.075 + 0.600 X 0.125 + 0.231 X 0.175 + 0.074 X 0.225 approx 14%.

project, hurdle rates used within a company vary substantially. The average difference between the highest and lowest hurdle rates was 11.2%. Lower hurdle rates were common for large strategic projects. The answers in the study of Bruner, Eades, Harris, and Higgins (1998) confirm that weighted average cost of capital is widely used. They also point out the disagreement in the implementation of the CAPM. In contrast to Poterba and Summers (1995), the average equity risk premium used was 6%, a value that is low when compared to the suggested value in many textbooks. Graham and Harvey (2001) find that 73.5% of the 392 respondents use the CAPM to estimate the cost of equity capital. This finding is in contrast to the survey of Gitman and Mercurio (1982) a decade before, where the dividend discount model was as popular as the CAPM that was used by less than a third of the sample companies.

C. The Answers to the Questionnaires May Be Biased

The answers to the surveys could be biased due to the *social desirability hypothesis* that is well documented in the psychology literature (see e.g., Singer and Presser, 1989 or Tanur, 1992). Responses from financial managers that went through an MBA program tend to be biased in favor of the methods that were taught in the MBA program. This can explain why in all recent surveys companies answer that they use CAPM together with many other decision criteria. Overall, the surveys provide overwhelming evidence that financial decision making is more and more based on the CAPM. The quantitative answers to the cost of capital or hurdle rate used are all in the range of 11-15%. This is close to the nominal historical average CAPM based estimate of the cost of capital, but far higher than any ex-ante estimate. This is consistent with our conjecture.

VI. Conclusion

The capital budgeting process plays an important role in most corporations. The textbook approach to capital budgeting involves computing the net present value of projects using the cost of capital as the discount rate and choosing the projects that maximize firm value. The predominant approach to estimating the cost of capital is to use the CAPM. The CAPM itself has been challenged in the recent academic literature. In addition, there is disagreement about what is a reasonable value for the market risk premium, a key input to the CAPM. The academic consensus is that the historical average market risk premium may overstate the true market risk premium by as much as a factor of two. This raises the question why managers report in surveys that they use the CAPM and do not complain about its shortcomings.

In this paper, we provide an explanation that assumes that managerial and organizational capital is rationed by firms. Managers of such firms cannot take every positive NPV project that comes along. It would sometimes be optimal to wait for a better investment opportunity to show up. Using results from the real options literature, we show that by using a hurdle rate that is higher than the cost of capital along with traditional NPV calculations, a manager can take into account the value of the option to wait. The opportunity cost of managerial talent that is in short supply and the type of project opportunities the firm faces determine the hurdle premium (i.e., the difference between the hurdle rate and the project cost of capital.)

Our explanation is consistent with the rather wide range of hurdle rates used within a company and the lack of correlation between betas and hurdle rates in the cross section reported in Poterba and Summers (1995). Errors in the estimation of the cost of capital are unlikely to be critical for firms with substantial real option component. Other reasons that would justify the use of a discount rate that is higher than the cost of capital have been put forward in the corporate finance literature (see e.g., Stein, 2001). They rely on agency costs and asymmetric information between shareholders and financial decision makers. The presence of these other explanations only strengthens our argument regarding as why accurate determination of the cost of capital may not be critical for project selection. Further research is needed to assess the relative importance of the various hypotheses that have been advanced to explain why managers may use a discount rate far higher than the cost of capital.■

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