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ABSTRACT

A key input to the capital budgeting process is the cost of capital. Financial managers most often use the CAPM for estimating the cost of capital for which they need to know the market risk premium. Textbooks advocate using the historical value for the U.S. 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 U.S. 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 twenty years, why has no one complained? We provide an answer to this puzzle.

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1 Introduction

The classic rule for making capital budgeting decisions is to take projects that maximize shareholder value. In an ideal market where there are no capital constraints or constraints for any other input, shareholder value is maximized by choosing projects with positive *Net Present Value* (NPV).[1] A key input to computing the NPV is the project's cost of capital, which is the return investors would require on average to undertake the investment. To estimate the cost of capital correctly managers have to understand how investors assess project risk and determine the risk premium for investing in the project.[2] Recent surveys on capital budgeting techniques of major U.S. companies confirm that corporate managers use the *Capital Asset Pricing Model* (CAPM) as the primary tool for predicting how investors would assess the riskiness of the firm's investment opportunities.

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. The current textbooks used in all major MBA courses advise financial managers to calculate the cost of capital based on the CAPM. The CAPM asserts that the only relevant risk measure for a project is its *beta*. If we know the beta of the project, we can determine what expected return investors would require provided we know what the risk premium for the market as a whole is. 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.

What is the market risk premium?

For calculating the cost of capital using the CAPM it is necessary to know the market (equity) risk premium in addition to the beta of the project. Not only has the CAPM been proved wrong but recent studies show that we do not even know what the market risk premium is. The common practice has been to use the historical average return over a long period as a measure of what investors expected to earn. 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." Even financial specialists share the view that the equity premium is in this 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. A new strand of literature uses a forward-looking perspective to estimate what to expect from stocks in the future. There is evidence that the market risk premium has been substantially below the historical average return of 9.2%, probably for nearly two decades. Blanchard (1993), Wadhwani (1999), Claus and Thomas (2000), Fama and French (2001), and Jagannathan, McGrattan and Scherbina (2001) provide estimates of the real equity premium in the range of 1-3%.

The puzzle: Why there has been no complaint from practitioners?

To summarize, there is overwhelming evidence in the academic literature that for over two decades business schools have been teaching the wrong model – or at least recommending the use of the wrong inputs – for calculating the cost of capital. Why do practitioners not complain about the usefulness of the CAPM we teach them in MBA courses? In a recent survey by Graham and Harvey (2001) three out of four CFOs answered that they use the CAPM as the primary tool. However, Poterba and Summers (1995) find that the average hurdle rate used by companies is 12.2% in real terms. This is even higher than the historical real return of equity of 9.7% over the period 1926-1997 reported by Brealey and Myers (2000)[3], which itself appears to be much higher than what the true risk premium probably is. We take the stand that managers use a discount rate (*hurdle rate*) that is higher than the cost of capital but not directly related to it. Therefore the cost of capital is not critical in the financial decision making process and that is the reason no one has complained.

Our view is that managerial and organizational capital is in limited supply and this is one of the major constraints to be taken into account while deciding whether to undertake a project or not. Therefore, managers can not take up all projects with a positive net present value. By deciding to go ahead with an investment project the firm gives up the option to undertake an even more attractive project down the road since decisions are irreversible without incurring large costs. McDonald (1999) shows that managers who use a hurdle rate that is substantially higher than the cost of capital for computing net present values account for the value of the option to wait.

The capital budgeting decision thus depends on setting a *hurdle rate*. The hurdle rate consists of the *cost of capital* and a *hurdle premium*. According to the CAPM the cost of capital is a combination of the risk free rate and *equity premium*. The hurdle premium is project specific and can be a multiple of the cost of capital. The firm specific rationing of managerial and organizational skills and the type of project determine the magnitude of the real option to wait for another opportunity in the future and consequently the optimal hurdle rate to apply in the NPV calculation. Errors in estimating the cost of capital would not matter so long as managers use reasonable hurdle rates. Our reading of the published surveys is that managers make an effort to get the hurdle rate right so that they are able to choose the best projects. So long as the hurdle rate is higher than the cost of capital shareholders will have no incentive to complain – managers will also not complain that the CAPM gives the wrong cost of capital. It is just accident that the hurdle rate reported by most managers exceed the rather high cost of capital value computed using the CAPM as given in textbooks.

Alternatively, a manager can take the timing options involved into account by computing NPVs using a discount rate that is greater than or equal to the cost of capital and undertake only those projects whose NPV exceeds a chosen project specific target level that is strictly positive. The actual decision will in general not be sensitive to the discount rate used. However, the NPV target that a project must clear before it can be undertaken will depend on the discount rate. The advantage of using a hurdle rate is that modelling all possible future options is not necessary, which makes communications easier to understand. This would explain why practitioners say they use the CAPM and at the same time report average hurdle rates that are far higher than the cost of capital computed using the CAPM.

Managers may use a higher hurdle rate for reasons other than the one we have advocated above. In particular, the corporate finance literature suggests that agency conflicts and asymmetric information between the managers and shareholders would likely lead to underinvestment in project opportunities (Stein, 2001). Underinvestment is equivalent to choosing projects with positive NPV computed using a hurdle rate higher than the cost of capital.

The rest of the paper

The rest of the paper is organized as follows. Section 2 provides a brief overview of the difficulties involved in using the CAPM. Section 3 discusses the practice in the field and reviews the literature on capital budgeting surveys. Section 4 provides an explanation for the puzzle using the theory of real options. Section 5 discusses the implications of capital rationing. Section 6 provides a brief summary of the arguments advanced in the corporate finance literature as to why managers may not undertake all available positive NPV projects. Section 7 concludes.

2 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 riskiness of a security is captured fully by its *beta* where beta is the covariance between the return on the security and the return on the market portfolio of all assets in positive net supply divided by the variance of the return on the market portfolio. The cost of equity capital – i.e., the expected return investors require to invest in a security – equals the risk free rate plus a risk premium that is proportional to its beta. The constant of proportionality is the *market risk premium*. Hence the cost of equity capital can be calculated from knowledge of the beta of equity and the market risk premium.

Validity of the CAPM

The initial empirical studies supported the CAPM – a strong enough support given that the CAPM, like all models, is only an abstraction from reality. Using all NYSE stocks during the period 1931-65, Black, Jensen and Scholes (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 volatility of returns – in addition to their betas would help explain the cross section of stock returns better. Consistent with the predictions of 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 showing 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 percent of the total market capitalization Banz's findings were not viewed as being economically important. The CAPM continued to be the chosen model for class room use. The greatest challenge to the CAPM came from Fama and French (1992). They found additional systematic factors besides beta play an important role in explaining the cross section of expected stock returns: firm size and book-to-market ratio. For the period from 1963-90, using the same procedure as Fama and MacBeth (1973) and 10 size classes and 10 beta classes, Fama and French (1992) find no relation between return and risk as measured by beta. These findings could not be dismissed as being economically insignificant. This lead to the question: Can the beta be saved? The findings of Fama and French (1992) suggest 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.

There have been challenges to the findings by Fama and French (1992) as well. Notable among them are the ones 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 contains 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. 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."

What do we know about the market risk premium?

According to the CAPM the risk premium for investing in a financial asset is given by the product of its beta and the market risk premium. Therefore a critical input for using the CAPM 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 U.S. 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. This would not provide a good estimate if the market risk premium changes over time.

Blanchard (1993) chooses a different approach. Instead of looking at a historic period he infers the equity premium using a forward-looking approach. He computes the expected equity premium each period using 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 percent.

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 500. In the first scenario, he uses the yield on Treasury Inflation-Protected Securities (TIPS) of 3.7% to estimate 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[4] 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 and cash-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 IBES 1997 consensus.

Jagannathan, McGrattan and Scherbina (2001) use a modification of the classical Gordon growth model that allows the expected dividend growth rate to change over time. The two datasets they use to derive the equity premium cover the major U.S. stock exchanges (NYSE, AMEX and Nasdaq), and all stocks that are held by U.S. 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 on average, the bottom line is the same. The U.S. 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 U.S. phenomena – the equity risk premium has come down around the world.

These findings suggest that the historic average return on equities would substantially overstate what rational investors would have expected to earn over the long run for investing in equities during the last two decades. If managers in fact used the historical average risk premium on equities of 8.5% as the market risk premium, as advocated in text books and MBA courses, their cost of capital estimates would have been off the mark by a large margin. Despite the difficulties associated with using the CAPM, the usage of the CAPM in the field appears to have increased during the past two decades, as the next section shows.

3 Practice in the Field

Clearly there have been a number of challenges to the validity of the CAPM. What do practitioners think? How prevalent is the use of the CAPM in the industry? What discount rate do practitioners use and how does it compare to that suggested by the CAPM? There are a number of surveys that provide partial answers to these questions. There is a clear trend in the history of these surveys. During the 1970s evaluating projects started to be predominantly based on methods like the net present value that take into account the time value of money. During the 1990s the CAPM became the prevailing method to calculate the appropriate, risk-adjusted discount rate. Table 1 summarizes the main contributions in the survey literature on capital budgeting. The results of these studies are discussed in the subsections below.

Qualitative surveys of capital budgeting techniques

Istvan (1961) triggered a number of surveys on the cost of capital techniques used by major U.S. firms. He interviewed with top-ranking executives of forty-eight 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.[5] 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 1 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) 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 percent 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. However, 61% used a hurdle rate based on the cost of capital and 53% 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 1. Two out of the sample of 33 firms used only the payback and/or accounting rate of return. 74% 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 U.S. 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 all 86% of all respondents indicated the use of more than one capital budgeting technique. 46% 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.

In summary, 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.

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. 60% percent of the 95 respondents had a nominal cost of capital between 10 and 15 percent, and another 23% a cost of capital of 15-20%. The average, nominal cost of capital (or hurdle rate) is denoted as γ and shown in the last column of table 1. The approximate value for the average, nominal cutoff rate of the 103 companies is 14%.[6] 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 percent. More than half indicated that the cost of capital varied by no more than 2 to 4 percent during the two preceding years. 30% of the respondents use CAPM to determine the cost of capital (see column *CAPM* in table 1). 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 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.

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 historic average CAPM based estimate of the cost of capital, but far higher than any ex-ante estimate. In addition, the literature indicates that the average hurdle rate is surprisingly stable over a long time period from the mid 1970s, when the first quantitative survey is available, to the present.

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. So why were managers not concerned about the possibility that the CAPM may give the wrong cost of capital? Why were they not concerned that the historical average return on equities may overstate what rational investors would expect to earn on equity investments? We argue that the managers probably took the right decisions even though they may have overestimated the cost of capital. This is because they use a hurdle rate that is higher than the cost of capital to capture the option to wait. In the next section we make our arguments precise by appealing to the real options literature.

4 Net Present Value, Real Options, and Hurdle Rates

In this section we show why the hurdle rate is different from the cost of capital. We will also show that managers will most likely take decisions that are nearly optimal for a wide range of hurdle rates – i.e., it may not be necessary to get the hurdle rate exactly right. This is in contrast to the well recognized fact that net present value calculations are sensitive to the discount rate that is used. In what follows we first illustrate the sensitivity of the NPV calculations to the discount rate used. Next, we show that when waiting gives the option to take up more attractive investment opportunities, using a hurdle rate that is higher than the cost of capital enables the manager to take the right decision and any hurdle rate within a range will work equally well.

Net present value is sensitive to cost of capital

To understand the magnitude of the sensitivity involved consider the following hypothetical project that generates an annual cash flow of $C = \$100$ (in real terms), starting today. The project requires an initial investment of $I = \$1,700$ and the non-diversifiable risk of the project is comparable to the risk of the overall market, i.e. the beta of the project is 1. The NPV of this project is equivalent to a perpetuity minus the investment cost

$$V_t = C \times \left(1 + \frac{1}{\rho}\right) - I, \tag{1}$$

where ρ is the true discount factor for the given risk characteristics of the project.

If we apply the historic real discount rate of $\rho = 10.33\%$ over the time period 1950-1999 the NPV of the project is $\$100 \times \left(1 + \frac{1}{0.1033}\right) - \$1,700 = -\$631.9$ and we do not take the project. If instead we take the forward-looking equity premium derived from dividend growth rates as in Fama and French (2001) the discount factor is $\rho = 5.45\%$. Discounting all cash flows at this rate results in a positive NPV of \$234.9 and we would undertake the project. It would therefore appear that a manager who used the NPV rule together with a historic estimate of the equity premium as suggested in most standard textbooks would have turned down an attractive investment opportunity.

The real options literature can explain why using a discount rate that is higher than the cost of capital is a good strategy when waiting opens up better opportunities. Such a discount rate is typically referred to as the *hurdle rate*. Suppose undertaking the project precludes taking another more attractive project that may come up down the road. In that case not taking the project might be advantageous. This opportunity to acquire an investment in the future is a *real option*.

A two-period example

Consider the following situation where the annual cash flow either moves up by 50% or drops by 50% over the next period. Both events are equally likely, i.e. the probability of an up or down move is 0.5. If we undertake the project today, we will receive a stream of cash flows with an expected value of \$100 forever. If we wait one period, we will either get an infinite stream of \$150s or \$50s. If we wait yet another period we have three possible outcomes. Figure 1 shows the corresponding tree. The probability that the expected value of the cash flow per period, C, moves up in both periods is 0.25. In that case C would be \$225 each period. The probability that you will receive cash flows of \$75 is 0.5. Either we get a move up in the first period and down in the second, or first down and then up. The probability of getting \$25 is 0.25. We assume that the initial investment to launch the project is $\$1,700$ in all states.

The net present value today is $V_0 = \$234.9$. If we wait one year and move up to an annual cash flow of $C = \$150$, the present value to undertaking the project increases to $V_1 = \$1,202.3$.[7] In the down state the value of the investment opportunity is negative and we will not take the project. In every state, based on the NPV rule, the value of the project is

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

This is the net payoff if we apply the NPV rule. In the literature about *dynamic programming* this corresponds to the termination value. If we wait for two periods we only take the project if C moves up twice. The net present value of the project is then $V_2 = \$2,653.4$. In this two period example there is no option to further delay the project after two periods. If we denote F_t as the value of the project including the option to delay the project, F_2 is in all states at time 2 equal to the NPV of the project, Ω_2. Knowing that the value of the investment is $\$2,653.4$ if $C = \$225$ and $\$0$ otherwise, we can work backward. The option to delay the project at time 1, if we reach the up state with $C = \$150$, is $F_1 = 0.5 \times \$2,653/(1+\rho) + 0.5 \times \$0 = \$1,258.2$ in figure 1. In the down state $F_1 = \$0$. Working backwards to time 0, the option value is $F_0 = 0.5 \times \$1,258.2/(1+\rho) + 0.5 \times \$0 = \$596.6$. The difference $F_0 - \Omega_0 = \$596.6 - \$234.9 = \$361.7$ is the option to postpone the project. The option value is more than 1.5 times the net present value of undertaking the project today.[8] In other words, this option value is equal to the opportunity cost of investing now instead of waiting. Standard net present value calculations do not include this opportunity cost to delay the project and eventually abandon it. If we consider this opportunity costs, the net present value of the project is in fact negative, and we should wait. In the situation of figure 1 we should wait for two periods as in the up state the value to postpone the project is still positive.

High hurdle rates capture the option value

If we apply the standard NPV calculations and neglect the option to wait, the decision whether or not to undertake the project is sensitive to the discount rate. If we take the estimate from Fama and French (2001) based on earnings growth, $\rho = 6.88\%$, the NPV criterion implies that we should launch the project if C moves up to $150 after one period. This example is plotted in figure 2. Using the historic discount rate of $\rho = 10.33\%$ returns a third answer: According to the standard NPV rule only invest if C moves up twice. Figure 3 shows the two-period example for the discount rate $\rho = 10.33\%$.

However, taking into account the value of the option to postpone the investment returns the same answer for all trees shown in figures 1-3. At time 0 the option to wait, $F_0 - \Omega_0$, is positive and it is optimal do delay the project. If the cash flows move down, NPV and the option to further delay the project is zero and we will never launch the project. In the up state the option to wait is still positive and we wait another period. The optimal solution is to invest only when the uppermost state is reached at time 2. Using a high enough hurdle rate together with the standard NPV takes into account that waiting may be optimal. This explains why using the historic real return on the S&P of 10.33% provides the optimal investment decision in the above example.

Size of the hurdle premium

If we use the average hurdle rate of 12.2% as reported by Poterba and Summers (1995) the investment decision will be the same, independent of whether we apply the real options approach or the classical NPV criterion: Wait for two periods and invest if the cash flow moves to \$225, otherwise do not take the project. This scenario is shown in figure 4. A higher discount rate reduces the present value of future cash flows and increases the probability that according to the NPV criterion we do not invest today. In fact any hurdle rate between 9.76% and 15.25% together with the NPV rule will provide the same answer. Below 9.76%, the NPV in the up state at time 1, i.e. the present value of the expected cash flows of \$150 net of the initial investment of \$1,700, Ω_1, is positive and according to the NPV rule we would launch the project. Above 15.25%, even if C moves up to \$225, V_2 is negative and hence $\Omega_2 = 0$. This simple two-period example shows that using a high hurdle rate together with the standard NPV rule will lead to the same investment decision as the real option approach. In the case of low discount rates, the situation was different. Then the NPV became positive and we invest earlier, ignoring the opportunity cost of waiting. If we compare the hurdle rate of 12.2% with the higher of the two forward-looking estimates of the real S&P return in Fama and French (2001), 6.88%, we can get an idea of the magnitude of the hurdle premium: $12.2\% - 6.88\% = 5.32\%$. In this example the hurdle premium is even larger than the equity premium of 6.88% minus the real return on six-month commercial paper of 2.05%, that is 4.83%. Taking the minimum rate of 9.76% that is required to get to the same solution for the NPV rule and the real options approach, the hurdle premium is 2.88%.

The two-period example in this section may seem contrived – but McDonald (1999) shows that for a wide range of hurdle rates, the optimal decision based on dynamic programming will be the same as the one we would arrive at by choosing positive NPV projects when NPV is computed using a higher hurdle rate. This would explain why surveys find that managers use hurdle rates that appear high when compared to even the historical average return on equities. By using high hurdle rates, companies in fact indirectly account for the existence of timing options.

A more general version

We now discuss the more general result in McDonald (1999).[9] The cash flow follows a stochastic process

$$\frac{dC_t}{C_t} = \alpha dt + \sigma d\, z\left(t\right). \tag{3}$$

α is the expected growth rate of the cash flows and σ is the standard deviation. Knowing the process of the changes in the cash flow and assuming that the cash flows are infinite, we can determine the value of the project at each time. The value is equal to a growing perpetuity with growth rate α minus the initial investment I.

$$V = \frac{C}{\rho - \alpha} - I \tag{4}$$

ρ is the rate of return to discount cash flows with the risk characteristics described by the stochastic differential (3). This is the net present value of the project at each time ignoring the option to postpone the project. In this case the NPV rule is equivalent to an internal rate of return rule: Take the project if the internal rate of return R exceeds the fair discount rate ρ. 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 the project. The internal rate of return R is the discount rate that sets the discounted cash flows equal to zero. Replacing ρ with R and setting $V = 0$ we get:

$$R = \frac{C}{I} + \alpha$$

This is different from using a hurdle rate. If we base our financial decisions on a hurdle rate, we launch the project if the internal rate of return exceeds the hurdle rate. We will denote the hurdle rate as γ. The hurdle rate can be very different from the discount rate ρ.

Equation (4) is the value of the project based on standard NPV calculations. McDonald and Siegel (1986) derives the value of the project including the option to postpone the investment. For simplicity we replicate the special case where once undertaken, the scrap value of the project is 0 at any time. The investment is sunk costs and completely irreversible. McDonald and Siegel (1986) and Dixit and Pindyck (1994) show that the main conclusions do not change if we assume a positive scrap value. Define r as the real risk free rate. The problem is a dynamic program and the solution is[10]

$$F\left(C, \gamma\right) = \left(\frac{\gamma - \alpha}{\rho - \alpha} - 1\right)\left(\frac{C}{\rho - \alpha}\right)^{b_1} I^{1-b_1}, \tag{5}$$

where

$$b_1 = \frac{1}{2} - \frac{r - (\rho - \alpha)}{\sigma^2} + \sqrt{\left[\frac{r - (\rho - \alpha)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma^2}}. \tag{6}$$

Note that if the hurdle rate γ is equal to the discount rate ρ, the first term and thus the value of the project is zero.

There exists an optimal hurdle rate rule γ^* that maximizes the value of the project $F(C, \gamma)$. McDonald (1999) shows that the optimal hurdle rate rule is

$$\gamma_t^* = \alpha + (\rho - \alpha) \frac{b_1}{b_1 - 1}. \tag{7}$$

Sensitivity of the results

We can show that the value of the project, F, need not be sensitive to the choice of γ. Following McDonald (1999) we calculate the fraction of the maximum option value that we obtain by applying a hurdle rate γ:

$$\frac{F(C, \gamma)}{F(C, \gamma^*)} \tag{8}$$

Table 2 shows the fraction for different scenarios of the true underlying discount factor and the volatility of the cash flows. The expected real growth rate α in the stochastic process of the cash flows is set to zero. Remember that we assume that the non-diversifiable risk of the project is equal to the market risk, i.e. the beta factor of the project is 1. The cost of capital according to CAPM then equals the sum of the interest rate and the equity premium. The given estimates for the real interest rate and equity risk premium are taken from Fama and French (2001). We compare the scenario if the equity premium is derived from dividend growth forecasts with the realized equity premium over the period 1872-1999, and the two subperiods 1872-1949 and 1950-1999. The cost of capital is used as the discount rate ρ to determine the optimal hurdle rate γ^* in equation (7). The hurdle rate is set to $\gamma = 12.2\%$ as reported by Poterba and Summers (1995). The fractions show that if the true equity premium is much lower than the historic estimate, a hurdle rate of 12.2% captures more than 99% of the maximum option value for projects with a volatility of cash flows $\sigma = 40\%$. On the other hand, if the true discount factor is indeed equal to the historic estimate and the volatility of the project is high, a hurdle rate of 12.2% would only capture 56-83% of the option value. The most interesting case is the post war period with a historic average of the sum of the risk free rate plus equity premium of 10.33%. If the true discount factor is 5.45% and the volatility of the cash flows is 40%, we capture 99.32% of the option value, compared to only about half of the option value if the correct discount factor would be the historic average of 10.33%. Thus, if managers used a hurdle rate of 12.2% in their NPV calculations they might have taken into account a large fraction of the real option values, given the fact that the recent literature indicates that the equity premium has been far below the historic average. Compared to the cost of capital, a relatively high hurdle rate of 12.2% is successful in capturing most of the option value as long as the uncertainty of projects' cash flows is high.

Figure 5 shows which combinations of volatility and true underlying discount factor deliver how much of the option value. This is more general than the above table. The horizontal axis measures the volatility parameter σ and the vertical axis the true underlying discount rate ρ. The figure assumes that the expected growth rate of the cash flows is $\alpha = 0$, and the real risk free rate of return is $r = 2.05\%$ – the real rate of return over the period 1950-1999. The hurdle rate is again chosen to be 12.2%. The fraction of the optimal value that is captured by the hurdle rate decreases quickly if the hurdle rate is just slightly above the true underlying discount rate. If the two are equal we are back to standard NPV calculations and we do not account for the inherent options at all.

Consider the following example: The volatility of the stream of cash flows is $\sigma = 0.30$. At point A in figure 5 the hurdle rate equals the project's cost of capital, $\gamma = \rho$. Then the term $(\gamma - \alpha) / (\rho - \alpha)$ in equation (5) is one, the value of the option to invest $F(C, \gamma) = 0$, and hence the fraction of the option value that is captured $F(C, \gamma) / F(C, \gamma^*) = 0$. If the true discount factor corresponds to the historic value of 10.33% the fraction increases to 74%. Point B thus lies between the two contour lines that indicate all parameter constellations that produce a fraction value of 0.6 and 0.8, respectively. If the estimate of Fama and French (2001) of 5.45% applies we reach point C that accounts for 97% of the option value. We get a higher fraction of the option value if the underlying true discount factor is lower than what we might have guessed from the historic average.

If the true underlying discount factor is far below the hurdle rate, say 4% and the volatility of the project is low, the fraction quickly decreases. Is this a problem? The answer is no. If we get closer to a risk free investment, we have also better estimates of the required rates of returns available. The term structure of interest rates measures the expected return for each maturity. So we already have a forward-looking measure at hand. We do not have, and actually people never did in the fixed-income security segment, rely on historic rates to discount future cash flows. As the market for fixed-income securities is outstandingly liquid, we have excellent forward-looking rates available. Thus, the fact that picking the wrong discount rate if the volatility of the cash flows is low is a minor problem.

The wide area of 0.9 and higher confirms, that this is true for many combinations of volatility and discount factor. Therefore, the knowledge of the true underlying discount factor is far less important than traditional NPV calculations would suggest. This explains why using a high hurdle rate makes sense and in addition why practitioners have not complained about the CAPM being the wrong model. If we take into account the option to delay the project, the financial decision is no longer crucially dependent on an exact figure of the discount rate. As long as the volatility of the cash flows are high – i.e., the option values are high – a range of high hurdle rates would lead to near optimal decisions. The hurdle premium – the difference between the hurdle rate and the cost of capital – would also be large when compared to the equity risk premium.

5 Real Options and Scarce Managerial Resources

In the previous section we considered an example where there is one project and the decision was to choose the right time to undertake the project. Many machinery replacement decisions have features described in that example – waiting would give the opportunity to invest in more productive machinery.

There are other situations where waiting creates options. For example consider a situation where managerial talent is in limited supply within the firm. Hence the firm can only have a limited number of projects at a given point in time. The ability to take on additional projects depends on the menu of uncompleted projects that the firm already has on the plate.

Skilled managers and the secretary problem

In order to understand the issues involved let us consider the case where the manager can only pick one project. Once a project is picked it has infinite life. It requires the full attention of the manager to make it a success. The manager sees new promising projects appear at random times over the future. Projects have different level of attractiveness. When should the manager decide to take one of these projects? In other words: When is it optimal to stop waiting? We can interpret this situation as a special case of the classical *secretary problem*, a well-documented problem in the literature on optimal stopping.[11] We will make the following assumptions:

(i) The manager can only take one project. On the other hand she must take a project over the next year. She cannot wait forever.

(ii) Over the next year there will be on average one proposal each month. So the manager will receive $n = 12$ proposals.

(iii) The projects are proposed in a random order and each random order is equally likely. All projects can be ranked from best to worst without ties.

(iv) For simplicity, we assume that the manager gets a raise in her salary if she is able to pick the best project and no rise otherwise. This assumption makes the example a so-called *best-choice problem*.[12]

(v) Once a project is proposed by one of the departments the manager knows the relative rank among the projects that have been proposed. Based on this information she has to decide whether to take it or not. Once she rejected the project, it can no longer be undertaken later.

Assumption (iv) implies that the manager can only take a project if it is relatively best among those that have been proposed so far. We call such a project a candidate project. If we take a candidate project after j months, the probability that it is the best project overall is j/n. The solution is to reject the first j^* projects and then take the next available candidate project (if any). The optimal threshold rule that maximizes the probability of getting a salary increase is

$$j^* = \min \left[j \geq 1, \sum_{i=j+1}^{n} \frac{1}{i-1} \leq 1 \right]$$

and the probability is

$$P_j = \frac{j-1}{n} \sum_{i=j}^{n} \frac{1}{i-1}.$$

The optimal solution for $n = 12$ is to wait for $j^* = 5$ months and then take the next available candidate project. With a probability of 39.59% the manager will pick the top ranked project and receive a salary increase.[13]

The secretary problem can be traced back to a mathematical brain-teaser that Gardner (1960a) attributes to J. Fox and G. Marnie in 1958. A solution was sketched by Gardner

(1960b) and the above solution by backward recursion was first published by Lindley (1961). A complete derivation and the extension of the standard secretary problem to the infinite case is provided by Gilbert and Mosteller (1966). The literature became a field of its own. For a review of the literature the reader is referred to Freeman (1983) and Ferguson (1989).

Under a few assumptions, this example can be transformed in a problem that resembles the example in the previous section. Assume that the projects do not appear randomly but at fixed time intervals. Furthermore, the value of a newly proposed project is not random, instead the probability of having good or bad projects evolves over time. The manager will be rewarded proportionally to the net present value of the project she selects. Then the situation is similar to the two-period tree example. Of course, the decision of the manager will also depend on her utility function and risk aversion. The attitude toward risky projects of the company and her preferences for the riskiness of her salary can be very different.

The key insight however remains the same. If managerial time of a skillful manager is limited, she must decide when it is optimal to take a project. It may pay off to wait and not take the next best positive net present value project. It follows from the earlier discussions that the use of a hurdle rate that is higher than the cost of capital to compute NPVs and undertaking the project when it has a positive NPV computed this way is likely to lead to near optimal decisions.

Hurdle rates are project-specific

Even though the investment decision is not sensitive to the hurdle rate used, provided it is within a reasonable range, hurdle rates within a firm and across companies may vary considerably. Consider a single company. If it faces a positive NPV project of small size and/or low complexity, it can be administered successfully by lower management. In this case the hurdle rate need not to be chosen very high because the managerial constraint is not restrictive. In contrast, a project – usually large and of a high degree of complexity – that will absorb much of the managerial skills and organizational structures of the company, will lock in many resources and prevent the company 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 that Poterba and Summers (1995) find in the hurdle rates used by companies. The average difference between the highest and lowest hurdle rate used within a company is 11.2%. 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. However, even though their sample of 228 companies might be limited, they find that only 12 percent 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 further reveals that the beta of a firm is by no means significant in explaining the hurdle rate. The high variation in hurdle rates within the company and industry sectors indicates that the hurdle rates used are not directly linked to the cost of capital. Applying real options can explain why, dependent on the scarcity of managerial resources, the hurdle rates may vary and are not systematically linked to the cost of capital.

Often, financial decision makers talk about strategic investments. Poterba and Summers (1995) asked an open-ended question about the type of projects that are evaluated with high or low hurdle rates. The answers suggest that companies use low hurdle rates for *strategic projects*. These are usually projects that have a low internal rate of return or a negative NPV, but are undertaken anyway because the investment promises future opportunities. If we would model all the upcoming investment opportunities due to this strategic investment, we could calculate the option value of this investment. Because it is difficult to estimate the values of all possible upcoming investment opportunities and to assign probabilities how likely these will arise, companies seem to use a low hurdle rate that takes into account that the payoffs in the future are possibly higher than the strategic investment itself suggests.

Testable implication

Each manager, dependent on his skills and the overall limitation of managerial and organizational capital of the company, faces an opportunity set of projects. The volatility of the stream of cash flows is a key determinant of the option value of waiting and thus of the opportunity set. Assuming that changes in the cost of capital do not affect the opportunity set, the optimal hurdle rate does not change if cost of capital changes. Under this premise we expect hurdle rates to be fairly constant over time.

Brigham (1975) investigated the question how often companies change their hurdle rate. 39% 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%

reestimate cost of capital each time a major project is evaluated. 22% 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. This brief overview of the available evidence from questionnaire data suggests that the hurdle rates used do not change quickly. However, most striking from table 1 is the fact that since the mid 1970s the average hurdle rates remained in the same range. The big changes the literature on ex-ante estimates for the equity premium would suggest can not be found.

Why even the lowest hurdle rate reported in surveys may be strictly larger than cost of capital

In contrast to the existing literature on capital rationing we claim that human and organizational capital and not financial capital is what is being rationed. When capital markets are in equilibrium the project taken up by the marginal firm will have zero NPV computed using the cost of capital. Such firms will have relatively poorer investment opportunities to choose from. If we were to examine all firms in the economy we should find that the lowest hurdle rate that we observe equals the cost of capital. Surveys typically cover larger and more successful firms that have relatively more attractive investment opportunities. Such firms in general will use hurdle rates that are strictly greater than the cost of capital. Hence the lowest hurdle rate reported in surveys will in general be strictly higher than the cost of capital. The positive value created through undertaking attractive projects will in general be shared among the different stakeholders of the firm. One may therefore expect managers of firms that use a higher hurdle rate to earn larger compensation.

6 Agency Theory, Asymmetric Information and Hurdle Rates

So far we focused our attention on the explanations given in the *real options* literature as to why managers may use a hurdle rate higher than the cost of capital. The use of a higher hurdle rate is equivalent to taking up only those projects with NPVs that exceed some predetermined threshold value. The *corporate finance* literature provides examples where this may happen even when there are no benefits to waiting as assumed in the real options literature. This strand of literature typically uses the terms under- and overinvestment. If not enough resources are allocated to positive NPV projects (or a division with high productivity) – relative to the optimum in a first-best world – we have a situation of underinvestment and if capital resources are wasted in low productivity technologies, i.e. negative NPV projects, we have overinvestment. The former case is the one we are primarily interested in as underinvestment is equivalent to using a hurdle rate above cost of capital. This section summarizes the main contributions in agency theory and information asymmetry that explain higher hurdle rates. The references are biased towards contributions that explain why there is underinvestment.

When optimal hurdle rates are higher than cost of capital

Suppose the gross return on an investment I is an increasing, concave function, $f_1(I)$. The source of funds for the investment are internal or external. Internal resources m_1 are retained earnings and external resources m_2 are raised by equity- or debt-issues. The capital constraint therefore is

$$I = m_1 + m_2.$$

Absent agency costs and costs related to external financing the manager maximizes:

$$\max \left[\frac{f_1(I)}{1+r} - I \right] \tag{9}$$

Following Stein (2001) the above equation can be modified for agency problems and costs of external financing. This provides an oversimplified but intuitive framework to point out the main contributions of the literature on agency and information asymmetry that can explain why managers use high hurdle rates. Agency conflicts between the manager and the shareholders emerge because managers prefer to control large amounts of capital. Managers have a desire to build empires as the private benefits increase with the size of the project or division they control. However the manager's preferred size may be bigger than optimal. For simplicity, we assume that the benefits increase with gross investment only.[14] θ_1 measures the degree of the agency conflict and $\theta_1 f_1(I)$ is the additional term that enters the initial function to be maximized.

The firm's managers have private information that is not available to shareholders. Therefore, shareholders watch the actions of the managers and infer the private information available to the manager. This introduces frictions in raising capital externally. If we denote the degree of the external financing friction as θ_2 and model the costs of external funding as a function of the amount externally raised, $\theta_2 f_2(m_2)$ the objective function is[15]

$$\max\left[\frac{(1+\theta_1)\, f_1(I)}{1+r} - I - \theta_2 f_2\,(m_2)\right]. \tag{10}$$

Whether the adjusted maximizing function (10) results in underinvestment (or overinvestment) relative to the first-best solution of to (9) depends on the degree of the agency problem θ_1 and the costs of external financing θ_2 and the respective functions of investment and external funds.

Underinvestment due to information asymmetry between managers and shareholders

This subsection considers the effect of external financing costs, i.e. $\theta_2 > 0$ in equation (10). Managers act in the interests of shareholders. There are no agency conflicts between managers in control of the projects and shareholders and thus $\theta_1 = 0$. If internal resources are not sufficient to finance positive NPV projects funds have to be raised externally. If there are costs to external financing, maximizing (10) results in underinvestment and not all positive NPV projects will be financed. The hurdle rate that solves the maximization problem will be above cost of capital.

What is the nature of the costs associated with external financing? The market knows that managers have access to private information about the firm's prospective projects and thus the right value of the firm. This leads to an adverse-selection problem that was first pointed out by Myers and Majluf (1984), Myers (1984) and Greenwald, Stiglitz and Weiss (1984).[16] A manager who acts in the interest of the existing shareholders will issue equity when stocks are overvalued. Otherwise, existing shareholders would suffer from dilution because also new shareholders would benefit from the undervalued stock. Rational investors would therefore infer that the firm's shares are overvalued when they observe an equity issue. Share issues are being interpreted as bad news even if shares would be fairly priced, whereas share repurchases indicate that management believes the firm's shares are undervalued and thus reveals good news. Empirical evidence by Korajczyk, Lucas and McDonald (1990) on stock issues and Dann (1981) for share repurchases confirm that announcements of equity issues (share repurchases) have a negative (positive) price impact.[17] This adverse-selection problem leads to underinvestment. Kaplan and Zingales (1997) show that investments are always below or equal to the solution in an efficient market as in equation (9).

The impact of agency problems on investment

If we drop the assumption that the manager acts benevolent towards shareholders and assume that he acts in his own interest the effect on investment is no longer known. Depending on the degree of the agency problem the resource allocation may result in underinvestment or overinvestment. The term $\theta_1 f(I)$ in the maximization problem (10) is positive and the overall outcome may be lower or higher investments relative to the first-best solution.[18]

A large fraction of the agency literature is devoted to the empire building tendency of managers.[19] As the manager is not the ultimate owner of the entire firm, Jensen and Meckling (1972) argued that the manager will waste resources in his own interest and consume personal benefits. The desire to build an empire induces the manager to spend "free" cash in negative NPV activities instead of paying out dividends, as in Jensen (1986). Among others, Nickell (1996) and Jagannathan and Srinivasan (2000) provide empirical evidence that competition reduces this type of agency costs.

Given the results of the recent empirical literature Stein (2001) concludes: "A simple and appealing interpretation of these findings is that the unified model [equation (10)] with both empire-building and financing constraints is the right one, and that in many, but not all cases the parameters line up in such a way that the typical firm is in the underinvestment region, where the NPV of the marginal investment is positive." Underinvestment in turn means that the minimum hurdle rate that is used is above cost of capital. Agency theory and asymmetric information thus provides an additional argument why hurdle rates are usually strictly greater than cost of capital.

Why managers behave myopically

The model of Narayanan (1985) provides an explanation to the question why payback is widely used – despite MBA textbooks dissuade from using payback as a decision tool. Graham and Harvey (2001) find that 57% of the surveyed CEOs use payback "always or almost always" to evaluate projects. The intuition of Narayanan's model is based on the following assumptions: (i) The control of the firm by the manager and the ownership by shareholders are separated. The company is equity-financed only. (ii) The ability of the manager is unknown and shareholders can not observe the actions taken by the manager, but only the result. (iii) The manager has two alternatives: invest in projects with quicker or slower returns, i.e. projects with a short or long payback period. (iv) The wage of the manager is based on the current and past output.

Thus the payments are noncontingent.

Because the manager's wage is a function of his current and past performance he has an incentive to boost cash flows in the near future. Shareholders on the other hand are aware of this and in evaluating the manager based on the output of the firm they implicitly assume he has decided for shorter payback periods. Therefore, the manager faces a prisoner's dilemma. He will not get paid more by pursuing projects with short payback but he is forced to make myopic decisions. Another way of incorporating this additional preference for early returns (above the traditional time value of money) is to use a higher hurdle rate in calculating NPV. Although the author views the model as an explanation for the widespread use of the payback criterion it equivalently delivers a rationale for using hurdle rates above cost of capital in NPV calculations.[20]

Some empirical support can be found in Poterba and Summers (1995). On average CFOs responded that investment in long-term investments would increase by 20.7% if the stock market would correctly value these investments.[21] The managers' claim seems to be that the stock markets forces them to favor projects with shorter payback and thus a higher hurdle rate in the NPV calculations.

Agency conflicts and information asymmetry among divisions

Similar agency conflicts and situations of asymmetric information occur within a company. Harris, Kriebel and Raviv (1982) and Antle and Eppen (1985) were the first to model the capital budgeting process within a company assuming information asymmetries and agency costs.

Harris and Raviv (1996) and Harris and Raviv (1998) assume individual capital constraints for division managers. Headquarters maximize firm value and allocate capital. Division managers have additional information about the division's production technology. The additional information can be discovered by headquarters through a costly auditing process. Division managers like to build empires and prefer to administer large investments. In their model, headquarters have three means to discipline division managers to maximize overall firm value: (i) Audit strategy to discover the manager's private information, (ii) capital allocation among divisions, and (iii) the salary of the division manager. The resulting capital budgeting process sets an initial capital spending limit. Division managers may then approach headquarters to get more capital. Headquarters either allocate a compromise amount in between the initial limit and the capital requested by the division or audit the project. If the project is sound, the division manager gets allocated the requested amount, otherwise he is punished by getting nothing. The empirical implication is that divisions with high productivity might get underinvested whereas low productivity technologies receive too many funds; either because the initial spending limit is too high or a request that is not well-founded is partially assumed by allocating a compromise amount and not processing a costly audit procedure. Using a model similar to Harris and Raviv (1996), Bernardo, Cai and Luo (2001) find that applying the optimal managerial compensation mechanism always results underinvestment.

7 Conclusions and Directions for Future Research

The capital budgeting process plays an important role in most corporations. The textbook approach is to compute the net present value of projects using the cost of capital as the discount rate and choose the ones 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. There is some consensus that it is probably the wrong model to use. In addition, there is disagreement about what is a reasonable value for the market risk premium, a key input for using 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.

In spite of this, using the cost of capital derived from the CAPM as the discount factor in the net present value calculations is the standard in textbooks and MBA courses on corporate finance. This raises the question why managers do not complain about the shortcomings of this approach. We provide an explanation based on the fact that managerial and organizational capital is rationed within a company. This implies that managers can not take every positive NPV project that comes along. Hence, it may be optimal to wait for the best 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 option to wait. This may be one reason managers report a hurdle rate that is substantially higher than the cost of capital – the hurdle premium may be as large as the market risk premium itself. The opportunity cost of managerial talent that is in short supply and the type of project opportunities the firm faces determine the hurdle premium. This may explain the rather wide range of hurdle rates used within a company that Poterba and Summers (1995) report, and why beta does not explain hurdle rate variations. Errors in the estimation of the cost of capital are thus not pivotal. Still, managers who choose the right hurdle rate do better than the ones who choose the wrong hurdle rate.

Other justifications for using a hurdle rate that is higher than the cost of capital have been suggested in the corporate finance literature that rely on agency costs and asymmetric information between shareholders and managers. In our future research we plan to examine the extent to which the availability of real options and the presence of agency costs determine the magnitude of the hurdle premium within as well as across firms.

Notes

[1]The neo-classical agency theoretic view claims that shareholders are the ultimate owners of a company and managers do not necessarily work in the interest of the shareholders but in their own interest. Berle and Means (1932) and Fama (1980) describe the ownership of a company as a contract between the various stakeholders, including shareholders, managers and other employees. As long as managers are given the right incentives it is in their own interest to maximize firm value. Managers can then negotiate how the value added is to be split between the stakeholders. Competition forces companies to meet the cost of capital so that shareholders are satisfied. A complete survey of the literature on the problems of asymmetric information and agency is given in Stein (2001).

[2]If a firm's shares are publicly traded the shareholders (owners) can send messages through the stock market. Unfortunately, there are two difficulties that come in the way of using stock market reaction to announcements as a tool for making capital budgeting decisions: (i) Shareholders who know that managers will watch for adverse stock market reactions and take corrective actions will not have an incentive to sell their shares and incur the associated transaction costs. If they do not sell their shares stock prices do not react and managers will not take corrective actions. (ii) Managers will first have to make the investment decisions and then later watch to see if the stock market approved their decision. Many investment decisions can not be reversed without incurring large costs. It is not feasible to propose a project, wait for the reaction of the shareholders and then decide whether to undertake it or not. Therefore, the capital budgeting process plays a key role in most modern day corporations.

[3]This value is based on the *Ibbotson Associates Inc.,* 1998 Yearbook.

[4]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.

[5]Recorded by the *Department of Commerce* in that year.

[6]On page 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 $0.095 \times 0.075 + 0.600 \times 0.125 + 0.231 \times 0.175 + 0.074 \times 0.225 \approx 14\%$.

[7]Implicitly, we assume that the additional uncertainty over the next period is diversifiable risk. This allows us to use the same discount factor ρ in both periods.

[8]As V_0 gets closer to zero, the fraction $\frac{F_0 - \Omega_0}{V_0}$ will go to infinity.

[9]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.

[10]For a complete derivation see Dixit and Pindyck (1994).

[11]There are a number of other names for the same problem and extensions of it. One is the parking problem MacQueen and Jr. (1960): You drive along a street to your destination, say a football stadium. You want to park as close as possible to the football stadium entrance but most parking spaces are taken. Typically, the problem is formulated using a monotonic utility function: the closer you park to your destination, the higher the utility.

[12]The example can easily be extended to any other monotonic reward function of the rank of the selected project.

[13]If n is infinite the solution is to reject approximately the first 36.8% of the projects and then take the next candidate project. The probability of picking the best project is approximately $1/e$.

[14]Output would be an alternative measure.

[15]This is equivalent to equation (3) in Stein (2001).

[16]Harris and Raviv (1991) review extensions of the basic Myers-Majluf model.

[17]For an extensive survey on empirical work in this field see Hubbard (1998).

[18]Stein (2001) points out that it "would be wrong to conclude that empire-building tendencies necessarily lead to an empirical prediction of overinvestment on average".

[19]For references on empire-building see Stein (2001).

[20]The managerial behavior in Stein (1989) is driven by similar forces. In his model the manager has an incentive to increase current earnings. The market does not observe the manager's action but only the output and the market perceives his preference for high current earnings. In equilibrium the decisions of the manager are myopic as well.

[21]There is a lot of variation in the answers. However, more than 50% of the managers would increase long-term investments. The average of 20.7% is driven by the 7.3% of the CFO's that would expand investments by more than 50%. At the same time 81% of the respondents answer that they never decide not to undertake projects because the stock market did not correctly value long-term investments.

References

Amihud, Y., Christensen, B. J. and Mendelson, H. (1992). Further evidence on the risk-return relationship. Working Paper S-93-11, Salomon Brothers Center for Study of Financial Institutions, Graduate School of Business Adminitration, New York University.

Antle, R. and Eppen, G. D. (1985). Capital rationing and organizational slack in capital budgeting, *Management Science* **31**(2): 163–74.

Bansal, R. and Lundblad, C. (2000). Fundamental values and asset returns in global equity markets. Manuscript, Duke University.

Banz, R. W. (1981). The relationship between return and market value of common stocks, *Journal of Financial Economics* **9**(1): 3–18.

Berle, A. A. and Means, G. C. (1932). *The Modern Corporation and Private Property*, MacMillan, New York.

Bernardo, A. E., Cai, H. and Luo, J. (2001). Capital budgeting and compensation with asymmetric information and moral hazard, *Journal of Financial Economics* **61**: 311–44.

Bierman, H. J. (1993). Capital budgeting in 1992: A survey, *Financial Management* **22**(3): 1–24.

Black, F. (1993). Beta and return, *Journal of Portfolio Management* **20**(1): 8–18.

Black, F., Jensen, M. C. and Scholes, M. (1972). The capital asset pricing model: Some empirical tests, *in* M. Jensen (ed.), *Studies in the Theory of Capital Markets*, Praeger, New York, pp. 79–121.

Blanchard, O. J. (1993). Movements in the equity premium, *Brookings Papers on Economic Activity, Macroeconomics* (2): 75–118.

Brealey, R. A. and Myers, S. C. (2000). *Principles of Corporate Finance*, 6th edn, Irwin/McGraw-Hill.

Breen, W. J. and Korajczyk, R. A. (1993). On selection biases in book-to-market based tests of asset pricing models. Working Paper 167, Northwestern University.

Brigham, E. F. (1975). Hurdle rates for screening capital expenditure proposals, *Financial Management* (Autumn): 17–26.

Bruner, R. F., Eades, K. M., Harris, R. S. and Higgins, R. C. (1998). Best practices in estimating the cost of capital: Survey and synthesis, *Financial Practice and Education* **4**(3): 13–28.

Campbell, J. Y., Lo, A. W. and MacKinlay, A. C. (1997). *The Econometrics of Financial Markets*, Princeton University Press, Princeton, New Jersey.

Claus, J. and Thomas, J. (2000). Equity premia as low as three percent? Empirical evidence from analysts' earnings forecasts for domestic and international stock markets. Manuscript, Graduate School of Business, Columbia University.

Dann, L. Y. (1981). Common stock repurchases: An analysis of returns to bondholders and stockholders, *Journal of Financial Economics* **9**(2): 113–38.

Dixit, A. (1992). Investment and hysteresis, *Journal of Economic Perspectives* **6**: 107–132. 1.

Dixit, A. K. and Pindyck, R. S. (1994). *Investment Under Uncertainty*, Princeton University Press, Princeton, New Jersey.

Fama, E. F. (1980). Agency problems and the theory of the firm, *Journal of Political Economy* **88**(2): 288–307.

Fama, E. F. and French, K. R. (1992). The cross-section of expected stock returns, *Journal of Finance* **47**(2): 427–65.

Fama, E. F. and French, K. R. (2001). The equity premium. Working Paper, Graduate School of Business, University of Chicago.

Fama, E. F. and MacBeth, J. D. (1973). Risk, return and equilibrium: Empirical tests, *Journal of Political Economy* **81**(3): 607–36.

Ferguson, T. S. (1989). Who solved the secretary problem?, *Statistical Science* **4**(3): 282–96.

Freeman, P. R. (1983). The secretary problem and its extensions: A review, *International Statistical Review* **51**: 189–206.

Fremgen, J. M. (1973). Capital budgeting practices: A survey, *Management Accounting* **54**(11): 19–25.

Gardner, M. (1960a). Mathematical games, *Scientific American* (February): 150–153.

Gardner, M. (1960b). Mathematical games, *Scientific American* (March): 178–181.

Gilbert, J. and Mosteller, F. (1966). Recognizing the maximum of a sequence, *Journal of the American Statistical Association* **61**: 35–73.

Gitman, L. J. and Forrester, J. R. (1977). A survey of capital budgeting techniques used by major u.s. firms, *Financial Management* **6**(3): 66–71.

Gitman, L. J. and Mercurio, V. A. (1982). Cost of capital techniques used by major u.s. firms: Survey and analysis of fortune's 1000, *Financial Management* **11**(4): 21–29.

Gordon, M. J. (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* **61**: 1–28.

Greenwald, B., Stiglitz, J. E. and Weiss, A. (1984). Informational imperfections in the capital market and macroeconomic fluctuations, *American Economic Review* **71**(2): 194–99.

Harris, M., Kriebel, C. H. and Raviv, A. (1982). Asymmetric information, incentives and intrafirm resource allocation, *Management Science* **28**: 604–20.

Harris, M. and Raviv, A. (1991). The theory of capital structure, *Journal of Finance* **46**: 297–355.

Harris, M. and Raviv, A. (1996). The capital budgeting process: Incentives and information, *Journal of Finance* **51**: 1139–74.

Harris, M. and Raviv, A. (1998). Capital budgeting and delegation, *Journal of Financial Economics* **50**: 259–89.

Hubbard, R. G. (1998). Capital-market imperfections and investment, *Journal of Economic Literature* **36**: 193–225.

Istvan, D. F. (1961). The economic evaluation of capital expenditures, *Journal of Business* **36**(1): 45–51.

Jagannathan, R., McGrattan, E. R. and Scherbina, A. (2001). The declining U.S. equity premium, *Quarterly Review, Federal Reserve Bank of Minneapolis* .

Jagannathan, R. and Srinivasan, S. B. (2000). Does product market competition reduce agency costs? NBER Working Papaer 7480.

Jagannathan, R. and Wang, Z. (1996). The conditional CAPM and the cross-section of expected returns, *Journal of Finance* **51**(1): 3–53.

Jensen, M. C. (1986). Agency costs of free cash flow, corporate finance, and takeovers, *American Economic Review* **76**: 323–29.

Jensen, M. C. and Meckling, W. H. (1972). Theory of the firm: Managerial behavior, agency cost and ownership structure, *Journal of Financial Economics* **3**: 305–60.

Kaplan, S. N. and Zingales, L. (1997). Do investment-cash flow sensitivities provide useful measures of financing constraints?, *Quarterly Journal of Economics* **112**(1): 159–216.

Klammer, T. (1972). Empirical evidence of the adoption of sophisticated capital budgeting techniques, *Journal of Business* **45**(3): 387–97.

Korajczyk, R. A., Lucas, D. and McDonald, R. L. (1990). Understanding stock price behavior around the time of equity issues, *in* G. Hubbard (ed.), *Asymmetric Information, Corporate Finance, and Investment*.

Kothari, S., Shanken, J. and Sloan, R. G. (1995). Another look at the cross-section of expected stock returns, *Journal of Finance* **50**(1): 185–224.

Lindley, D. V. (1961). Dynamic programming and decision theory, *Applied Statistics* **10**(1): 39–51.

Lintner, J. (1965). The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets, *Review of Economics and Statistics* **47**: 13–37.

MacQueen, J. and Jr., R. G. M. (1960). Optimal persistence policies, *Operations Research* **8**: 362–80.

McDonald, R. L. (1999). Real options and rules of thumb in capital budgeting, *in* M. J. Brennan and L. Trigeorgis (eds), *Project Flexibility, Agency, and Product Market Competition*, Oxford University Press, London, chapter 1, pp. 13–33.

McDonald, R. and Siegel, D. (1986). The value of waiting to invest, *Quarterly Journal of Economics* **101**(4): 707–28.

Moore, J. S. and Reichert, A. K. (1983). An analysis of the financial management techniques currently employed by large U.S. corporations, *Journal of Business Finance and Accounting* **10**(4): 623–45.

Myers, S. C. (1984). The capital structure puzzle, *Journal of Finance* **39**(3): 575–92.

Myers, S. C. and Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics* **13**(2): 187–221.

Narayanan, M. P. (1985). Observability of the payback criterion, *Journal of Business* **58**(3): 309–323.

Nickell, S. J. (1996). Competition and corporate performance, *Journal of Political Economy* **104**(4): 724–46.

Petty, J. W. and Bowlin, O. D. (1976). The financial manager and quantitative decision models, *Financial Management* **5**(4): 32–41.

Poterba, J. M. and Summers, L. H. (1995). A CEO survey of U.S. companies' time horizons and hurdle rates, *Sloan Management Review* (Fall): 43–53.

Schall, L. D., Sundem, G. L. and Geijsbeek, W. R. (1978). Survey and analysis of capital budgeting methods, *Journal of Finance* **33**(1): 281–87.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk, *Journal of Finance* **19**(3): 425–42.

Siegel, J. J. (1999). The shrinking equity premium: Historical facts and future forecasts, *Journal of Portfolio Management* **26**(3): 10–17.

Singer, E. and Presser, S. (1989). *Survey Research Methods*, University of Chicago Press, Chicago.

Stein, J. C. (1989). Efficient capital markets, inefficient firms: A model of myopic corporate behavior, *Quarterly Journal of Economics* **104**(4): 655–69.

Stein, J. C. (2001). Agency, information and corporate investment. NBER Working Paper 8342.

Tanur, J. (1992). *Questions About Questions: Inquiries Into the Cognitive Bases of Surveys*, Russell Sage Foundation, New York.

Wadhwani, S. B. (1999). The US stock market and the global economic crisis, *National Institute Economic Review* (January): 86–105.

Welch, I. (2000). Views of financial economists on the equity premium and on professional controversies, *Journal of Business* **73**(4): 501–29.

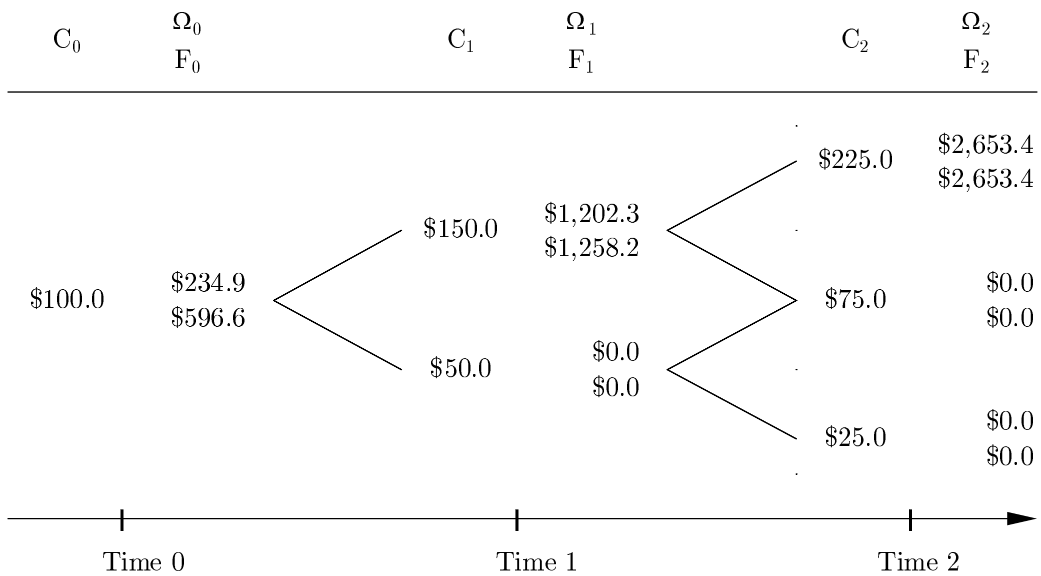

Figure 1: The probability of an up move or down move is 0.5. C_t denotes the cash flows you will get in the different states, Ω_t the net present value of the project if it is positive, otherwise $\Omega_t = 0$, and F_t the value of the project including the option to delay the investment decision. The discount factor is $\rho = 5.45\%$, the value Fama and French (2001) derive from the dividend growth rate of the real S&P for the period 1950-1999.

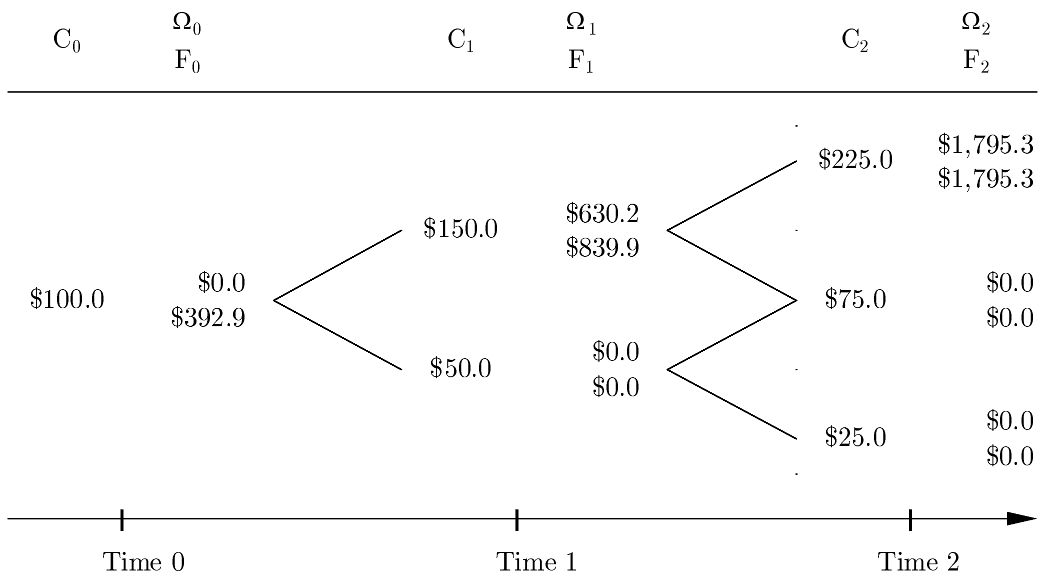

Figure 2: The discount factor is $\rho = 6.88\%$, corresponding to the estimate of Fama and French (2001) based on earnings growth rates from 1950-1999.

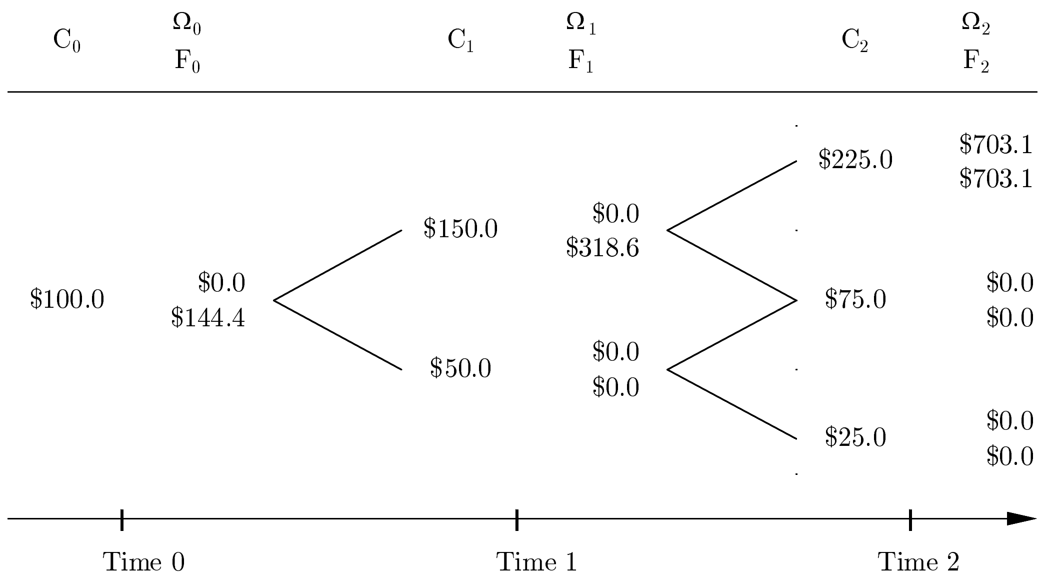

Figure 3: The discount factor is set to the average realized return on the S&P Composite Index from 1950-1999 of $\rho = 10.33$.

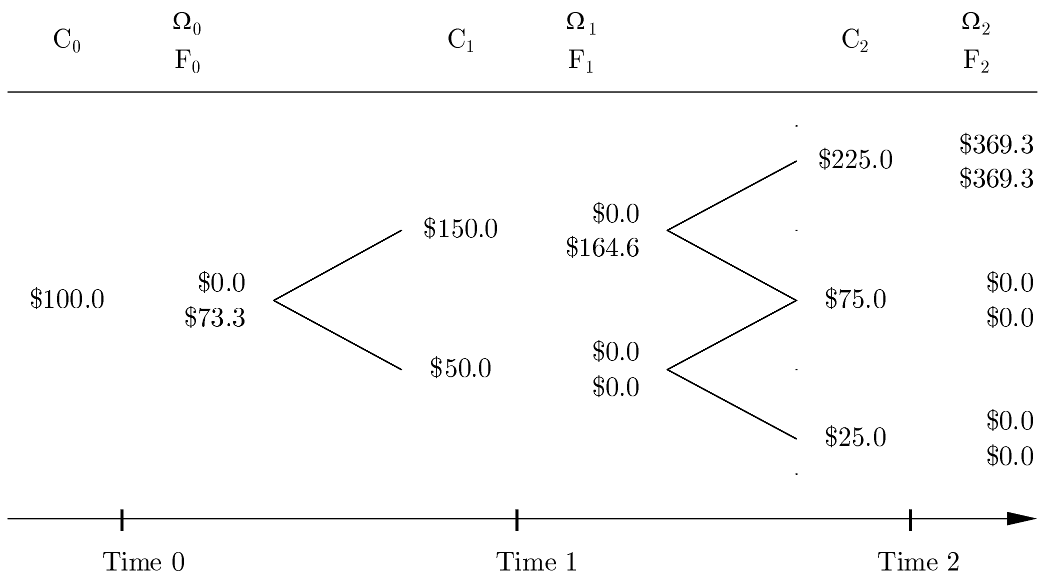

Figure 4: ρ is set to the hurdle rate 12.2%, the average hurdle rate used by the 228 companies in the survey of Poterba and Summers (1995).

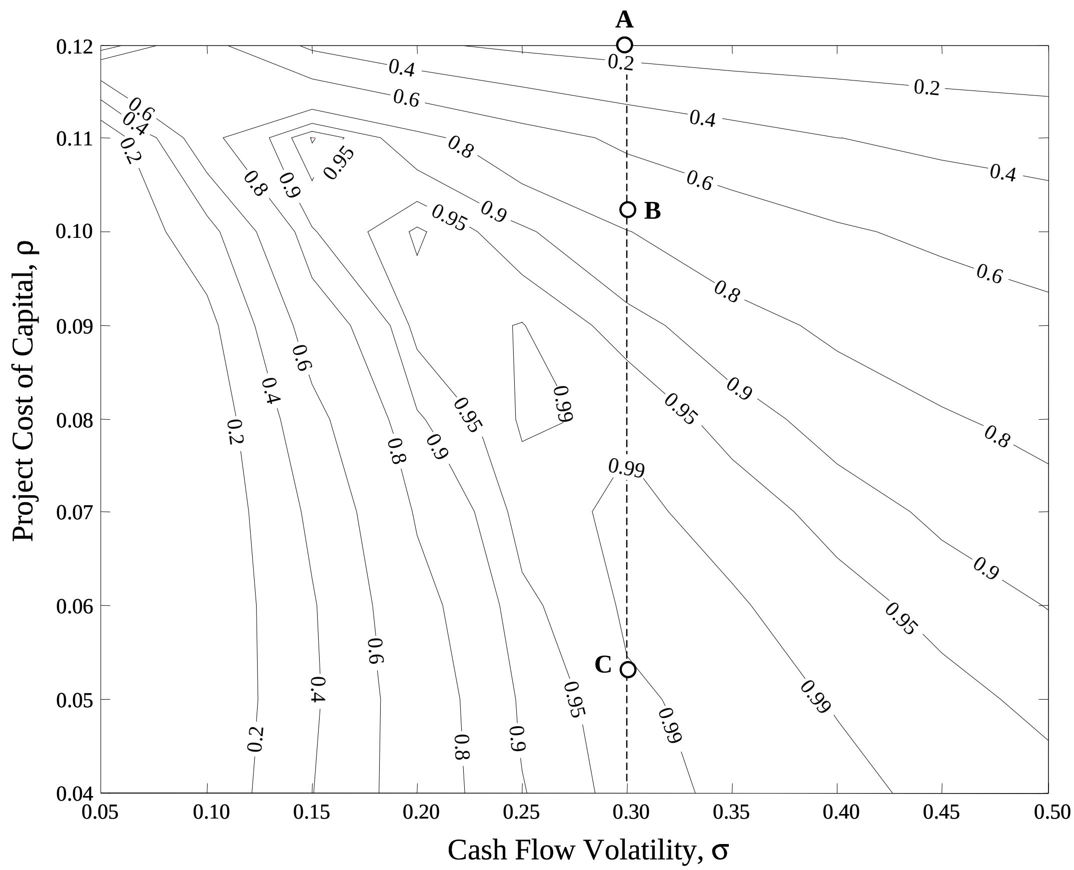

Figure 5: Fraction of the maximum option value as a function of the discount rate ρ and the volatility of the project's cash flows, σ. The real interest rate is set to $r = 2.05\%$, the realized return on six month commercial paper over the period 1950-1999. The hurdle rate is 12.2%.

Authors	N	RES	TV	$WACC$	$CAPM$	γ [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 U.S. Treasury bond yield in 1998 of 5.4%.

Table 1: 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. γ is the average cost of capital or hurdle rate used.

	r	Equity Premium		ρ	Volatility σ		
		RH	RD		20%	30%	40%
1872-1999	3.24%	5.73%		8.97%	99.05%	90.76%	75.58%
1872-1949	4.01%	4.10%		8.10%	97.20%	95.24%	83.10%
1950-1999	2.05%	8.28%		10.33%	97.75%	74.04%	55.99%
1872-1999	3.24%		3.64%	6.88%	83.13%	98.89%	99.39%
1872-1949	4.01%		3.79%	7.79%	88.48%	99.53%	99.05%
1950-1999	2.05%		3.40%	5.45%	73.21%	96.95%	99.32%

Table 2: Fraction of maximum option value for different discount rates ρ and volatility parameters σ. The expected growth rates of the cash flows, α, is set to zero. r is the real interest rate, RH the realized real return on the S&P, and RD the equity premium estimate by Fama and French (2001) that is based on the dividend growth forecasts. The fraction is computed as $F(C, \gamma)/F(C, \gamma^*)$, i.e., the option value based on a hurdle rate of $\gamma = 12.2\%$, as reported by Poterba and Summers (1995), divided by the maximum option value obtained using the optimal hurdle rate γ^*.