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PROJECT VALUATION: PROBLEM AREAS, THEORY AND PRACTICE

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ABSTRACT

This paper examines the current state of theory and practice in the field of corporate project valuation. Scientific papers have explored some problems linked to the traditional discounted cash flow (DCF) model, without finding much of an echo in textbooks. These problems are related to the discount rate, its capacity to track risk and the way it reflects the cost of capital and capital structure. The primacy of the DCF model has been challenged by the real option (RO) approach. Following the pioneering work of Black and Scholes and Merton, researchers have suggested that projects should be viewed as options on real assets and valued as such. This mathematically sophisticated approach is still in infancy as far as real-world application is concerned. Further, due to its "black box" treatment of a firm or project, it seems difficult to reconcile with managers' growing interest in integrated financial management systems articulated around cash flows. A recursive, multiple-rate DCF model, capable of integrating managerial options, might bridge the gap between traditional DCF and the RO approach.

In the field of corporate finance, capital structure theory has always received a fair amount of attention from academics. The same cannot be said about project valuation and performance measurement. For a long period of time, basically the 70's and first half of the 80's, these topics certainly did not inspire many doctoral dissertations or scientific papers, and the field evolved slowly. The situation changed after 1985, when the application of option valuation theory to corporate investment unleashed a flurry of papers. A few years later, interest for performance measurement was revived, this time under the impulse of practitioners rather than academics. The purpose of this paper is to review the issues raised in the field of project valuation. We will also show how managers' interest for performance appraisal may be expected to affect their choice of a valuation method.

The paper is organised as follows. Section 1 is devoted to the discounted cash flow model (DCF) and its problems. Although long unchallenged as the best valuation model, at least in academia, it nevertheless raised a few thorny questions related to the discount rate and the treatment of risk. Section 2 will review the newer "real option" approach (RO). In Section 3, a brief overview of ex post valuation, or performance measurement, will bring us back to the comparison of DCF and RO. Because it is advisable to maintain consistency between project valuation criteria and performance appraisal criteria, we will argue that a revised DCF model, conceptually not that different from an RO model, may offer the most practical solution. Conclusions follow in Section 4.

When reviewing a field of knowledge, one is faced with a choice: either be exhaustive and compile all known contributions in as neutral a fashion as possible, or be selective, quote fewer people and present one's analysis of the issues. We chose selectivity, knowing full well that selection opens the door to personal bias. However, it might make reading more interesting and prompt challenges. To those we have not quoted, we apologise.

1. Problems with the Discounted Cash Flow Model

The traditional DCF approach relies on a single discount rate the value of which should equal the weighted cost of capital. This model is still invariably put forward in financial management textbooks (see Emery, Finnerty and Stowe, 1998, and Damodaran, 1997, for example) despite its demonstrated weaknesses. The issues raised in the financial literature deal mostly with the single rate: should we rather use multiple rates ? should the weighted cost of capital be the average or the marginal cost of capital ? should weights be measured at book or market ? should we weigh at all ? Behind these interrogations lurk the questions of risk tracking and risk-adjusted valuation. Empirical estimation problems also represent an area of concern.

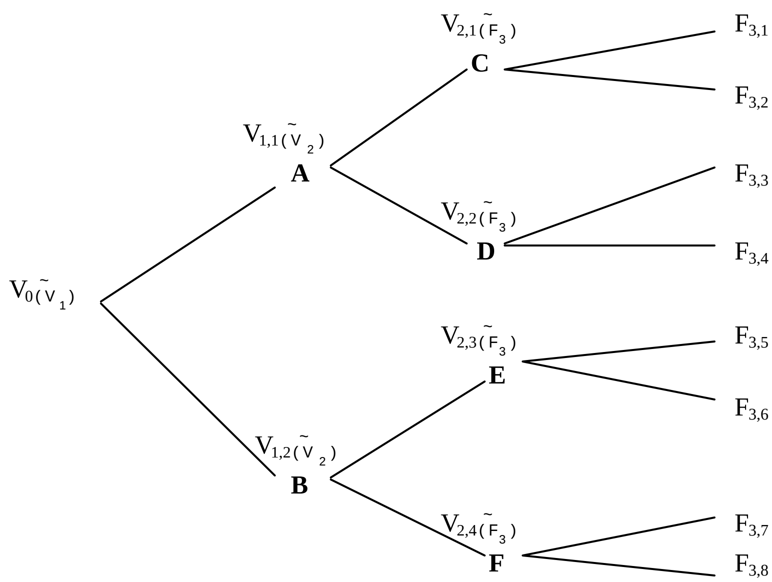
1.1 Single vs multiple discount rates

This issue will take us rather far back in time, but the detour is worth it: it will shed light on one of the arguments recently put forth to drop the DCF model and embrace the RO model, namely the traditional model's inability to track risk appropriately. In 1966, Robichek and Myers questioned the single rate tradition. They showed that discounting a series of expected cash flows at a single rate implies two assumptions.

The first assumption is that the uncertainty attached to a given future cash flow, let us say the nth cash flow, will dissipate at a constant rhythm as time passes and the nth period approaches. In other words, information relevant to the nth cash flow comes in regularly and there are no crucial periods in which more is learned than in any other period. The obverse of "dissipation" being compounding, it can be said that, viewed from time 0, the uncertainty attached to the nth cash flow compounds itself at a constant rate from one period to the next. Since a one period discount rate is meant to correct for the period's contribution to cash flow risk, under these circumstances it is logical to compound n times a single discount rate.

It will be convenient for what follows to illustrate Robichek and Myers' demonstration with a graph. The uncertainty attached to the nth cash flow can be depicted by means of a probability tree, as in Figure 1. In that figure, the realised value of cash flow number 3 depends on a set of intervening events. Each period opens up 2 possibilities per node (or, more generally, x possibilities) for the value of the cash flow to be received at the end of period 3. For the sake of graphical simplicity, let us just state that a given period's contribution to the risk of cash flow 3, as viewed from time 0, is a direct function of the "shape" of the distributions of end-of-that-period values around their means. The standard DCF model implies that the "shape" of the probability distribution of period 1 values viewed from 0, is the same as the "shape" of the distribution of period 2 values viewed from 1 (either from point A or from point B), and the same as the "shape" of the distribution of period 3 realisations viewed from 2 (from either C,D, E or F). This implies that the uncertainty about F_3, such as envisioned from time 0, results from the compounding of identical per-period risks and, conversely, that it will dissipate at a uniform rate as time passes.

FIGURE 1**. A probability tree for the nth cash flow – The case of n=3**



The traditional DCF model is ill-suited for projects characterised by varying degrees of risk resolution across time. Such would be the case of oil exploration projects, for example, or of bio-pharmaceutical R&D projects: exploration/research phases differ markedly, in terms of risk (or probability distribution "shape"), from development and commercial production phases. To be more precise, the exploration phase of an oil project does not lift the same degree of uncertainty about the nth cash flow as the development phase. Therefore, it makes little sense to discount the nth flow at a single compounded rate. Different rates should be used for different "risk-lifting" periods. It might be argued that an appropriate average of multiple rates could be used as a single discount rate. Unfortunately, because of the mathematical properties of compounding/discounting, the "appropriate average" is an extremely complex function of the individual rates, the number and size of cash flows, etc. (see Buse, 1970, for example). It is much less cumbersome to directly use the individual rates.

The traditional model is also ill-suited when the activity can be moth-balled, abandoned, expanded, etc. before reaching its horizon. Dropping (or adding) branches from the tree is sure to modify the "shape" of some periods' probability distributions, invalidating the assumption of equal risk for all periods. It is nevertheless important to be able to include such valuable options in a project's assessment.

The second assumption implicit in the traditional DCF model, is that all cash flows have identical per-period-risk, be they cash flow number 1 or cash flow number 10 or 20. But it is possible that certain cash flows differ markedly from others. For example, cash flows 1 and 2 might be outflows related to planned investments. Their uncertainty may be quite lower than the uncertainty attached to operating net cash flows. The indiscriminate use of the same discount rate will tend to underestimate the true value of investment expenses and overestimate the project's value.

Despite its relevance to both theory and practice, Robichek and Myers' contribution rapidly dropped into oblivion, perhaps because computational means were much more limited at the time than they are now, making the added complexity of multiple discount rates unappealing. Eleven years later, in 1977, Fama would "re-discover" the problem. His angle of attack was quite different since he was concerned with the Capital Asset Pricing Model (CAPM)'s applicability to a multiple-cash-flow valuation problem. He had earlier demonstrated (Fama and McBeth, 1974) that the apparently myopic CAPM is compatible with rational multi-period portfolio optimising behaviour if certain conditions are met. In particular, security returns must be serially independent and independent from the characteristics of the investment opportunity set. In 1977, he showed that expanding the one-period CAPM into a multi-period pricing formula while respecting those underlying assumptions[1] led to a generalised DCF model, the equation of which follows:

$$V_{\emptyset} = \sum_{t=1}^{T} E_0\left(\tilde{F}_t\right) \prod_{\tau=1}^{t} \left[\frac{1}{1 + E(\tilde{R}_{t\tau})} \right] \qquad (1)$$

Inspection of equation (1) makes it plain that the uncertainty attached to a given cash flow does not necessarily dissipate regularly over time and that, as a consequence, discount rates can vary across time for that same flow. The risk attached to all periods except the last one is, to quote Fama, an "expectations reassessment risk", while the last period's risk is a realisation risk. Further, reassessment and realisation risks, and corresponding rates, need not be the same across flows. It is only when imposing additional uniformity constraints on "reassessments" and "realisations" that one obtains the traditional single rate DCF formula. These are exactly Robichek and Myers' conclusions, with the added benefit of an economic equilibrium framework. Multiple discount rates thus seem fully justified on a theoretical level. At the application level, the computing complexity once associated with multiple rates is no longer an issue, thanks to the general availability of user-friendly electronic spreadsheets. The only real problem lies with the choice of each discount rate. However, this estimation problem surfaces even when a single rate is used. It will be addressed in Section 1.5.

Before leaving the topic of single vs multiple discount rates, we must raise a more fundamental issue. It is automatically assumed correct to discount expected cash flows at known (but possibly period-variable) rates. Having demonstrated in 1977 that it is theoretically valid to do so within the CAPM context, Fama proceeded to show, in 1996, that his 1977 results depend on his choice of a multiplicative martingale model to describe the evolution of expected cash flow assessments through time. In other words, as time passes and events unfold, expectations of future cash flows are revised in such a way that $E_t(CF) = E_{t-1}(CF)(1+\varepsilon_t)$. If expectations rather evolve according to an additive martingale model, whereby $E_t(CF) = E_{t-1}(CF) + \varepsilon_t$, then it becomes inappropriate to discount expected values using the simple cross product of non-stochastic period rates. To quote him: “the notion of pricing NCFs [net cash flows] by discounting their expected values with CAPM (or ICAPM) expected 1-period simple returns loses its rigorous justification”. It is of course a matter of empirical evidence to determine which martingale is the most realistic. It is probably not such a pressing concern as to detain people from discounting. However, it is sobering to realise that many sacrosanct “truths” expounded in financial management textbooks are not, after all, so well grounded.

1.2 The weighted cost of capital as a discount rate

Ever since Modigliani and Miller (M&M) (1958,1963), the discount rate has been equated with the cost of capital. The cost of capital is of course a function of both operating and financing risk. Whereas operating risk (discussed in Section 1.1) did not attract much interest, the impact of capital structure did. The questions raised dealt with the weights (book or market) attached to each source of financing cost, and with the legitimacy of a constant cost of capital.

Textbooks routinely advise students to use market value weights when computing the weighted *average* cost of capital (see, for example, Emery et al., p. 487). This is often said to be in keeping with M&M. However, it should be noted that in M&M’s world, the *average* cost of capital is the (weighted) return investors manage to be able to expect on seasoned issues. In other words, given the amount and characteristics of *existing securities*, and given their cash flow anticipations, investors will adjust market prices so as to be able to expect their required rates on each security. The weights associated with these average costs are therefore market value weights. The average cost has not much to do with projects and new financings and much to do with the firm as is, with its results and perspectives such as assessed by the market, and with its financing-in-place. As a point of fact, M&M mention that the average cost of capital should more appropriately be called “yield” because this would “release the term cost of capital for use in discussions of optimal investment policy” (1963, footnote 10). When examining said investment policy, they advocate the use of a weighted *marginal* cost of capital in project valuation. The relevant costs are the costs of the mix of funds planned for the future. A seldom, if ever mentioned “detail” is that the weights are book value weights (M&M, 1963, equation 7), as investors set conditions on the actual amounts they supply, not on an as yet unknown market value. It is not easy to understand just how and when book value weights were discarded in favour of market value weights[2]. One can only surmise that it was a matter of computational convenience: it is (very) relatively easy to infer required rates on existing securities from market data; but it is much more difficult to infer what marginal rates would apply to a given mix of marginal book financing (existing mixes measured in market value terms in general have little to do with original book value mixes). If, for convenience's sake average rather than marginal rates are used, it is a matter of consistency to associate them with market value weights.

However, one might question the wisdom of giving precedence to computational convenience over realism. Using the average market-value weighted cost in lieu of the marginal book-value weighted cost implicitly assumes 1) that the project's operating risk is the same as assets-in-place risk, 2) that the project's cost will be financed by a mix of debt and equity corresponding to current market value weights. Assumption 1 may be unfounded. As to assumption 2, it postulates an irrational financing policy. To see why, let us assume a start-up company which finances its first activity optimally in M&M's sense, that is borrows 99,9% of its cost (assuming no corporate taxes). The company does better than expected and financial markets are on the upswing; as a consequence, the market value of its shares goes up, much more so than the market value of its debt. The market-value capital structure of the company is now much lower than its original, optimal book-value capital structure. The opposite would apply were the company to experience bad times. If projects were to be financed according to current market-value proportions, it would mean that the better past and current performance, the least the company would borrow; the worst current and past performance, the more it would borrow. The last case might be defended on the grounds of the unavailability of internally generated cash, but it is doubtful whether lenders would easily comply. Further, the optimality of such a policy is far from obvious. Nevertheless, it is often hinted in textbooks that it is what businesses should do ! Hence, the recommendation to use market-value weights.

The above discussion refers to initial financing proportions and does not take into account subsequent transactions such as progressive debt retirement. In fact, quite separately from the issue of book versus market-value weights, it has been shown that the use of a single discount rate implies a very peculiar debt management policy. Linke and Kim (1974) and Miles and Ezzell (1980) have demonstrated that it is correct to apply a single weighted cost of capital only if one intends to maintain the debt/equity ratio constant at all times. These authors express the capital structure as percentages of the project's market value. Maintaining constant percentages implies, in Miles and Ezzell's terms, "active rebalancing by the firm" as realised market values change with events and reassessment of anticipations. In clear, it means that if expectations regarding the activity are revised upwards (downwards) and remaining value turns out larger (smaller) than expected, lenders should be called upon to increase (decrease) the size of their loan so that it will always represent the same proportion of total remaining market value ! Debt contracts should thus be "open", that is never include a fixed retirement schedule, make debt callable at will and contractually oblige lenders to put up more money when required to do so. Needless to say that no such contract would ever be written, unless lenders agreed to bear the same uncertainties as shareholders, which begs the question. Expressing initial financing in terms of book-value proportions and maintaining such book values constant would not help. The size of realised operating cash flows would dictate debt and equity refunds[3]: positive cash flows would mean proportional "returns of capital" to both lenders and shareholders, negative cash flows would mean proportional new contributions from each.

Again, the debt contract would have to be open. Again, the assumptions implicit in a single discount rate seem far removed from reality.

Does it matter ? The question is a practical one: does the use of a single weighted cost of capital, when underlying financing assumptions are not met, lead to incorrect investment decisions ? Before answering it, we will examine the very idea of a weighting scheme.

1.3 To weigh or not to weigh ?

By definition, a positive net present value (NPV) is a form of "rent" which belongs to shareholders. It represents the value of what is earned over and above the normal cost of all sources of funds. Lenders do not expect to share in these "excess returns", because of the fixed and limited extent of their contractual rights. Given this, one should expect NPV to be insensitive to the particular formula used, provided the formula is internally consistent. For example, if operating cash flows are discounted, they should be discounted at the weighted cost of capital; if residual flows to shareholders are discounted, they should be discounted at the cost of equity. Nantell and Carlson (1974) even showed that various definitions of "operating cash flows" can be retained and that each definition must be associated with a particular variant of the weighted cost of capital. Taggart (1991) later re-examined the problem, paying particular attention to tax effects and specifically including the residual flows to equity model in his study. He came to similar conclusions. Consistency is the key to accuracy.

Indeed, consistency is both necessary and sufficient when NPV is null, as shown in Mandron (1998, c) and illustrated in case 1 of Table 1. Whatever the approach _ operating cash flows discounted at the weighted cost of capital, or residual flows discounted at the cost of equity _, the result is the same : 0. However, the identity breaks down as soon as NPV is not null. As shown in case 2 of Table 1, results vary with the method retained, although the project is the same and, theoretically, should offer a unique rent to shareholders. The source of the discrepancy lies with the reinvestment assumption implicit in any discounting formula: intermediate cash flows are automatically assumed reinvested at the chosen discount rate. In the traditional DCF model, cash flows are assumed reinvested at the weighted cost of capital. This is tantamount to saying that, whatever their actual sizes, cash flows are shared proportionally by all security holders. In other words, "rents", either positive or negative, are shared by both shareholders and bondholders. This is illustrated in Table 2: when cash flows are broken down into "required flows" and "excess flows" and excess flows are discounted separately at the equity cost of capital, the identity between traditional NPV and Residual NPV (R-NPV) is restored.

Since rent sharing is certainly not the case in capitalist economies, one can conclude that the traditional model does not yield the accurate answer. For accuracy, one should prefer a model which does not assume rent-sharing. R-NPV is one such model.

TABLE 1. NPV (@ WACC) vs R-NPV (@k)

Case 1		**Case 2**	
Assumptions		**Assumptions**	
investment : $1000		investment : $1000	
perpetual before-tax operating cash fl.: $187.69		perpetual before-tax operating cash fl.: $ 350	
perpetual debt: $400		perpetual debt: $400	
corporate tax rate: 35 %		corporate tax rate: 35 %	
cost of equity (k): 16%		cost of equity (k): 16%	
cost of debt: 10 %		cost of debt: 10 %	
NPV @ WACC		**NPV @ WACC**	
WACC =	12.2 %	WACC =	12.2 %
after-tax operating cash flow:	$122.00	after-tax operating cash flow:	$227.50
NPV @ 12.2 %:		NPV @ 12.2 %:	
= - 1000 + (122/.122) =	**$0.00**	= - 1000 + (227.5/.122) =	**$864.75**
R-NPV @ k		**R-NPV @ k**	
after-tax residual cash flow:	$96.00	after-tax residual cash flow:	$201.50
R-NPV @ 16 % :		R-NPV @ 16 % :	
= -600 + (96/.16) =	**$0.00**	= -600 + (201.5/.16) =	**$659.38**

TABLE 2. **Case 2 Revisited: Overriding the Rent-Sharing Assumption**

expected cash-flow from operations :	$227.5
- required cash-flow from operations (@ 12.2 %) :	- $122.0
= periodic rent :	$105.5
NPV (@WACC and k):	
= - 1000 + (122/.122) + (105.5/.16) =	**$659.38**
R-NPV (@ k) from Table 1 :	**$659.38**

1.4 A synthesis and a look at textbooks and practical issues

Here is the picture that emerges from the above review. In theory at least, the formula which best meets real world conditions is the residual net present value formula (R-

NPV), with possibly multiple discount rates representing the cost of equity for varying levels of risk. This formula does not impose unrealistic rent-sharing assumptions, does not artificially constrain operating risk to dissipate at a regular rate and does not assume that capital structure will be constantly re-balanced. Nevertheless, despite the documented weaknesses of the traditional NPV model, it is still the favoured model of textbooks and R-NPV is not often suggested. Why ? We will quote three reasons and discuss their validity.

The first reason, such as put forth by Chambers, Harris and Pringle (1982), is that errors from using the "wrong" formula are immaterial, or not large. They based their conclusion on a numerical study of 4 different hypothetical projects with different lives. Each of the 4 projects was examined under 3 different financing assumptions (constant debt ratio, equal principal repayments, level debt). In each case, 4 variants of NPV or APV (Myers' adjusted present value) were computed, as well as R-NPV. If we choose R-NPV as our benchmark, then, depending on the metric retained and the financing assumptions made, the differences range from 0% to more than 40% of the benchmark. For example, the authors' exhibit 5 shows that for a 5-year project and equal principal repayments, the difference between traditional NPV and R-NPV amounts to 9% of R-NPV. It jumps to 42.2% for a 20-year project. The materiality of differences is a matter of personal appreciation. In Chambers et al.'s particular examples, one might be tempted to dismiss them anyway: the signal given by each formula is almost always the same ("go ahead"), whatever the precise figure obtained. However, the existence of a few contradictory signals (see their project II) prompted us to investigate the matter further. In particular, we felt it necessary to get rid of the level cash flow assumption of Chambers et al. As reported in Mandron (1998, c) a numerical analysis of 24 cases with different cash flow patterns and debt repayment schedules reveals that in more than 70% of the cases studied traditional NPV and R-NPV issue contradictory investment signals. This should be a matter of concern.

A second reason to stick to traditional NPV, despite its unrealistic assumptions, was also offered by Chambers, Harris and Pringle (1982): for short-term projects, formula-induced errors are small relative to forecast errors; so why bother ? According to the authors, it is only for projects of longer duration that "concern over the appropriate model seems in order". We submit that the compounding of avoidable errors (formula induced) and unavoidable ones (forecasting "errors") is hard to defend on rational grounds.

Faced with the above two arguments, most academics fall back to a third reason for not abandoning traditional NPV. They argue that R-NPV is not suited to projects the financing of which is not specific. When projects are financed from a pool of funds, each one should support its "share" of common financing and in there lies the difficulty. To compute the project's share of debt service charges, it is necessary to make assumptions about the planned long term average mix of funds[4], the customary maturity of debt at issue time, the usual debt amortisation schedule, etc.. Only then can residual cash flows be determined and R-NPV computed. Most academics balk at such assumption making, arguing that assumptions cannot be accurate and are highly subjective. Curiously, the practitioners we have worked with are not so reluctant once presented with the implicit choices made by traditional NPV: because high level managers are very sensitive to actual debt service constraints and used to assumption making, R-NPV makes sense to them. They only worry about ease of computation. However, in this age of electronic spreadsheets it is incredibly easy to program debt refunds and discount rates varying with them according to a given formula[5]. Moreover, it should be pointed out that sticking to traditional NPV is no way to avoid assumptions about financing. As emphasised here above, NPV does make stringent, albeit implicit assumptions about capital structure.

The choice therefore seems to lie between implicit, uncontrolled assumptions (NPV) and explicit, analyst-controlled assumptions (R-NPV). To-date, textbooks still favour the first option, somehow neglecting practitioners' concern with debt service capacity. A third, and perhaps more viable option, is to separate investment and financing, and value projects as if they were 100% equity financed. There being no firm theoretical answer about the impact of financing policy on value[6], ignoring the mix of financing when choosing investments may not be dramatic. But it certainly does away with unwarranted financing assumptions and also reflects a reality in large corporations: investment valuation and financing decisions are carried out by different people. This solution is different from Kaplan and Ruback's "Compressed Adjusted Present Value Technique" (1995). In Compressed APV, cash flows from operations (net of capital expenditures) are discounted at the 100% equity financing rate, but cash flows include the debt tax shield associated with an assumed debt ratio. Compressed APV is thus not free from financing assumptions.

1.5 An estimation problem

Whatever the specific formula chosen, any DCF model requires that the cost of equity be estimated. Textbooks invariably recommend the Capital Asset Pricing Model (CAPM) to that effect. The model assumes perfect and costless financial markets and either normal probability distributions or investors' indifference to asymmetry[7]. The key step in obtaining the cost of equity is to run a regression of a given stock' past returns on a market-portfolio proxy's past returns. The regression coefficient, or β coefficient, represents the stock's systematic risk and is used to determine the company's current cost of equity given the market portfolio's expected excess return and the riskless rate of return.

The empirical validity of the CAPM has long been the subject of research. It is not the purpose of this paper to review in detail the evidence published or even give a list of all contributions. Such lists can be found in most textbooks or specialised monographs. We will be content to state that the evidence is not favourable and that many "pricing anomalies" have been found. In a nutshell, whereas systematic risk (β) should be the sole determinant of a stock's average return above the riskless rate, evidence suggests that size and other factors (such as the book-to-market value ratio) are also significant. Recently, one of the fiercest early proponents of the CAPM, Fama himself, went so far as to argue that our criterion and verdict should be reversed: market pricing is not "anomalous", but the CAPM is faulty and "Wanted, Dead or Alive" (Fama and French, 1996) ! Fama and French's empirical investigation, started in 1993, has provoked several reactions (see, for example, "In defense of Beta", by Kothari and Shanken, 1995, and "Reports of Beta's Death are Premature" by Clare, Priestly and Thomas, 1998). However, the argument that Beta partially explains returns is not a vindication of the CAPM, in which Beta is the sole determinant. In Fama and French's own words "because the CAPM is such a simple and attractive tool, we think that many of our colleagues *want* to be confused on this point" (1996, p. 1948).

Although these arguments against the CAPM and "the way it is currently applied, for example, to estimate the cost of capital" are empirically grounded, it is worth mentioning that some authors showed its theoretical weaknesses a long time ago. For example, Levy (1978) demonstrated that when the number of different securities investors can hold is limited, systematic risk cannot be the only risk paid for by the market. The equilibrium pricing equation is much more complex and leaves room to unsystematic risk.

Whatever the reason, theoretical or empirical, the analyst is left in a quandary: how is he, or she to estimate the cost of equity ? An alternative to the CAPM is Ross's APT, or Arbitrage Pricing Theory (1976). This model relates the expected return on an asset to the risk-free rate of interest and a series of other, unspecified common factors. To quote D. Harrington (1987, p. 190): "APT says nothing about either the magnitudes or the signs of the factor coefficients, or what the factors themselves might be". As already mentioned, Fama and French have identified three factors related to the market portfolio, the company's size and its book-to-market-value ratio. However, they are silent on the best way to estimate the expected values of these factors when computing the cost of equity. Nor can we be sure that factor coefficients estimated from past data are stable through time and can be relied on for the future.

In many real world situations, the most sophisticated managers tend to proceed in two or three steps. First they estimate the equity risk premium for the "average market risk" on the basis of the historical average market risk premium. For North America, historical market returns dating back to 1925 are compiled every year by Ibbotson Associates. Ex post risk premia above the riskless rate are also computed; their historical average is deemed representative of the average ex ante risk premium on the market portfolio. The sum of the current riskless rate (usually the rate on a government bond of the appropriate maturity) and of this average risk premium represents the cost of equity for an average corporation. In the second step, managers must adjust this cost of equity upwards or downwards, to reflect the higher or smaller risk of their firm. The adjustment is performed either on the basis of the company's Beta, of some other relevant statistics (for example, net margin volatility, return on assets volatility, etc.), of intuition, or of a combination of all these. In some cases, the company's cost of equity is in turn adjusted, more or less arbitrarily, to reflect the higher/lower risk of the project under study. Academics are usually uncomfortable with this mixture of intuition and past observations. Not so practitioners, who prefer to rely on their experience rather than wait for the ever elusive, perfect formula.

At last, if projects are to be valued assuming 100% equity financing, or a percentage different from the current company-wide ratio, the company's current cost of equity must be un-levered and, if necessary, re-levered. Until more is known about the nature of an optimal capital structure, we suggest that Modigliani and Miller's formula 8 (1958) provides a good starting point to un-lever and re-lever the cost of equity: this formula shows how the cost of equity varies with debt without assuming any cost or advantage to any particular source of financing. In that sense, it is neutral. Their 1963 formula 12-c, by comparison, rests on the idea that there is a tax advantage to corporate debt without any offsetting disadvantages.

2. An Alternative : The Real Option Approach

During the 1970's, option trading soared, in particular on North American stock exchanges. In parallel, research on option valuation was given a strong impulse by Merton (1973) and Black and Scholes (1973). In their paper, the latter had already alluded to a possible extension of option valuation principles to firm valuation. Later, Myers (1977) had the intuition that firms could be seen as portfolios of assets-in-place and options on real assets (or investment opportunities). While this intuition led him to conclusions about capital structure, others developed the analogy in the field of capital budgeting. By the mid 1980's, the field of "real option" valuation was born and its general approach described by Mason and Merton (1985), Kulatilaka and Marcus (1988) and Kulatilaka (1995).

2.1 The RO approach: why ?

Ever since Robichek and Van Horne's 1967 article on abandonment value and capital budgeting, it has been felt that traditional DCF models do not properly account for managerial options. "The classical approach offers no way of allowing for this risk effect [of managerial options] except through some ad hoc adjustment of the discount rate" (Brennan and Schwartz, 1985). We have even emphasised in Section 1.1 that the traditional single rate model implicitly rules out the existence of such options.

Abandonment is not the only valuable flexibility afforded management. Projects can be deferred (McDonald and Siegel, 1986), investment decisions can be made sequentially (Majd and Pindyck, 1987), a project's scale can be altered (Trigeorgis and Mason, 1987), an activity can be interrupted and restarted (Mc Donald and Siegel, 1985), etc.. But, to quote Trigeorgis (1994, p.1) "traditional NPV makes implicit assumptions concerning an "expected scenario" of cash flows and presumes management's passive commitment to a certain "operating strategy"", whereas "management's flexibility to adapt its future actions in response to altered future market conditions expands an investment opportunity's value". Further, some investments which the NPV rule would lead to reject may nevertheless be extremely valuable as "strategic investments". Such might be the case of the construction of a pilot-plant to test and refine a new technology, a new market, etc. Insofar as the pilot-plant opens up future growth opportunities if certain conditions materialise, it may represent a valuable project. This example is representative of the class of managerial options designated as corporate growth options.

The RO valuation method is the latest attempt at recognition that the passage of time, the arrival of information and managerial adaptability can boost a company's upside potential and cut down its losses. Following a brief description of the basic elements of RO valuation, we will examine its practical applicability.

2.2 Valuing real options

The simplest way to present the RO methodology is to compare a real option and a stock option. A stock option gives the right to buy a share of stock for a pre-determined exercise price. A real option gives the right to "buy" a completed project (for example a completed factory) for an exercise price equal to the investment cost. In the case of a stock option, the underlying stock is traded and its price can be observed at all times. Of course the completed factory is not traded (it is not even built, yet) and its market value is unknown. The crucial assumptions needed to extend the stock option pricing methodology to the real option world are thus the following ones: a) there exists a risk-equivalent traded security or a replicating portfolio of traded securities, so that a riskless hedge can be established "‡ la Black and Scholes (1973)"; b) the market value of the completed project, although not observable, can be estimated "by applying appropriate capital budgeting methods to the cash flows from the completed factory" (Majd and Pindyck, 1987, p. 11); c) the market value of the completed project follows a specific diffusion process, let us say a geometric brownian motion (an additive diffusion process is also admissible; see Sick,1989).

Just as the value of a stock option is an implicit function of time to expiry and underlying stock price (O= f(t,S), the value of a real option is an implicit function of time to expiry and of the market value of the completed project (RO=f(t,V)). Black and Scholes used the diffusion equation of dS, together with the implications of the riskless hedge, to compute dO. Their next step was to integrate dO and find the value of O. In the same fashion, RO can be computed based on the process assumed for dV and on the existence of a riskless hedge. Cox and Ross (1976) risk-neutral approach or the binomial or trinomial approach pioneered by Cox, Ross and Rubinstein (1979) can alternatively be applied to yield the same result. All these approaches rely on the same fundamental assumptions regarding the riskless hedge and the possibility to estimate V.

The resulting solution will of course depend on the diffusion process assumed for V (multiplicative or additive), as well as on other characteristics of the project and/or the option: the option may be perpetual or have a finite life, the exercise price (investment cost) may be fixed or stochastic, the completed factory may pay dividends, there may be a time-related reduction in value if the project is postponed, an option to delay may be followed by an option to abandon, to increase scale, etc (compound options).

In some instances, there is an analytic solution, that is an explicit formula. Such is the case for McDonald and Siegel's (1986) perpetual option to wait. The situation they examine is simple in that the value of the completed plant and the cost of investment both follow a geometric Brownian motion and there is no explicit pay-out rate for the completed plant. Although undoubtedly alien to practitioners, the geometric Brownian motion is simple to manipulate for academics with some background in stochastic calculus. Nevertheless, the problem's analytic solution does not look as straightforward as the DCF formula! We show this solution, not for itself but because it will later prove useful as a point of reference in our discussion of the merits/disadvantages of the RO approach:

value of the opportunity to wait: $x = (c^*-1)F_0([V_0/F_0]/c^*)^{\varepsilon}$ (2)

where

$c^* = \varepsilon / (\varepsilon-1)$

$\varepsilon = [\{ (\alpha_v - \alpha_f)/\sigma^2 - ? \}^2 + 2(\mu-\alpha_f)/\sigma^2]^{-1/2} + \{ ? - (\alpha_v-\alpha_f)/\sigma^2 \}$

$\sigma^2 = \sigma_v^2 + \sigma_f^2 - 2\rho_{vf}\sigma_v\sigma_f$

ρ_{vf} is the instantaneous correlation between the rates of increase of V and F

V is the value of the completed project and such that $dV/V = \alpha_v dt + \sigma_v dz_v$

F is the investment cost of the project and such that $dF/F = \alpha_f dt + \sigma_f dz_f$

all α's and σ's are instantaneous parameters.

In most cases, though, there is no closed-form solution to the problem, especially when there are multiple interacting real options. The analyst must then swallow "The bitter pill: numerical techniques" (Trigeorgis, 1994, p. 22). These include numerical integration, Monte Carlo simulation, lattices, etc. All these techniques rely on a large number of iterations and require fairly substantial computer capacity. Trigeorgis (1991) provides a good description of an algorithm designed for the valuation of multi-option investments. Although it is possible to gain insights into what is driving the option's value, numerical techniques remain "a bitter pill" because they are essentially black boxes.

2.3 A critical analysis of the RO method

Needless to say, the great strength of the RO approach is that it squarely faces the role and value of managerial discretion in a dynamic, information-releasing setting. But is the RO method so definitely superior to the traditional DCF model as it is sometimes reported to be ?

As shown here above, the traditional DCF model relies on questionable assumptions. However, so does the RO model. In particular, it is almost always assumed that V, the value of the completed project, follows a geometric Brownian motion. This assumption is mathematically convenient but, as emphasised by Majd and Pindyck (1987, p. 11) not very realistic. They list a whole series of circumstances under which V cannot follow a geometric Brownian motion, for example "when variable costs are positive and managers have the option to shut down temporarily Ö or the option to abandon the project completely" ! In fact, it turns out that, in most cases, V cannot follow such a diffusion process ! And still, the assumption is made and the option value depends on it. It is also often assumed that the completed project will pay dividends in a constant proportion of its market value and that the same proportion also represents the loss of value of the not-yet completed project. These assumptions can hardly be termed realistic.

It is perhaps of more concern to note that V, the current, unobservable market value of the completed project must be estimated "by applying appropriate capital budgeting methods to the cash flows from the completed factory" (Majd and Pindyck, 1987, p.11). In some situations, it has been suggested to replace the completed-project value by the observable market price of a commodity. Such might be the case of an oil-field development project, or a gold mine development project. These projects can be seen as options on the market price of oil or gold (Brennan and Schwartz, 1985). However, in most cases V must be estimated "in the customary fashion".

Thus, the RO solution cannot dispense with cash flow computation and discounting. It follows that all the problems mentioned in Section I may still apply, in particular the single vs multiple rate problem, the rent sharing assumption, etc.! The only novelty, here, is that the analyst should wilfully ignore cash-flow altering options, since the latter will be treated separately, via the diffusion process integration. The analyst trained to make use of modern computing power will certainly envision several economic scenarios. He might assess risk on that basis, and then choose an appropriate discount rate. Further, he might consider that a weighted average of these scenarios represents a better estimate of expected cash flows than a single "most probable scenario". However, if the RO method is to be applied, the analyst should in all cases totally disregard managerial flexibility and all options to modify the situation. In other words, he, or she must be encouraged to practice some sort of "dumb scenario-forecasting". On the other hand, good financial planning relies on good cash flow forecasting for alternative scenarios. Its objective is both to facilitate treasury management and to help devise appropriate courses of action for various turns of events. Thus, the well managed corporation should accept the idea of duplicate work: "dumb" expected cash flow forecasting for valuation purposes, realistic cash flow forecasting for planning purposes. The duplication is both artificial and difficult to rationalise in the eyes of managers.

Shifting our focus from V and cash flows to the option value itself, we can state that, although designed to account for managerial options and evolving economic contexts, the RO model does not in any way help identify specific plausible scenarios, corresponding cash flows and appropriate decisions: all are theoretically taken account of through the choice of a particular statistical process (e.g. a geometric Brownian motion), but none can be separately identified[8]. In that sense, even an analytical formula such as formula (2), is a black box; it may be useful to determine whether the investment is valuable or not, but it is useless for financial planning purposes.

2.4 The present and the future

Because it relies on sophisticated mathematics, the RO valuation methodology has attracted the interest of many researchers. However, it is not part of main stream teaching, except, perhaps, at the PhD level. Most recent textbooks now have a few sections, or even an entire chapter, dedicated to the applications of option pricing theory in corporate finance. But the treatment is usually fairly introductory and much less extensive than the one reserved to traditional DCF. Sometimes, the valuation of real options is not even tackled within the investment valuation part itself (see, for example, Damodaran, 1997). The reason may be that implementation is difficult and illustrative examples necessarily simplistic. Several researchers, whether Faculty members of a University, or research staff members of organisations such as the World Bank, have applied the approach to specific industries, usually the mining, exploration or power industries (see Brennan and Schwartz, Bjerksund and Ekern, 1990, Crousillat and Martzoukos, 1991, among others). However, the simplifications and assumptions made are not always appealing and the computations remain cumbersome. What about application by private corporations ? Our own experience suggests either total ignorance of the approach or lack of interest on the part of managers. A formal scientific investigation of the topic might confirm this casual observation.

In all, the major deterrent, for both students and managers, probably lies in the lack of "business" content of the approach. By this, we mean its black box characteristics. Managers show little interest in a solution the components of which they cannot visualise and identify with (scenarios and cash flows are "hidden", as already explained). Tomorrow's managers, that is the students enrolled in professional programs, also have difficulty navigating from " business reality-oriented" topics, such as financial analysis or working capital management, to very abstract formulas or algorithms.

So, what can we expect for the future ? Trigeorgis wrote: "Clearly, an increased attention to application and implementation issues is the next stage in the evolution of real options" (1993, p. 209). His implicit assumption must have been that the approach can be improved and become appealing to managers and students alike. Only time will confirm or infirm the assumption. But it is interesting, at this juncture, to quote Leslie and Michaels, two consultants from a well known international firm, namely McKinsey, Inc.. In 1997, they authored an article entitled "The Real Power of Real Options" in which it is stated that "the most basic contribution [of real-options thinking] Ö is the attitude it fosters to uncertainty" (p. 22). The term "attitude" is the key. It sums up much of their argument about the importance of thinking strategically and demonstrating "proactive flexibility". Although their article does mention the Black-Scholes option valuation model, it is essentially qualitative. Their message seems to be that adopting an "option philosophy" is what matters most: "[options] will change the way you think" (p. 22).

The next practical question we may ask is the following: if option-thinking is important but the RO valuation approach unwieldy or unsatisfactory, can we nevertheless do better than traditional DCF ? We suggest that it is possible. Before explaining how, we must first detour through the topic of financial performance measurement.

3. An Integrated Approach to Valuation and Financial Performance Measurement

3.1 Financial performance measurement

The beginning of the 1990's has been marked by a renewed interest in the measurement of financial performance. Up to then, ex post performance measurement was mostly the realm of accountants who measured rates of return on equity or on investment, growth in earnings per share, etc.. However, the realisation that accounting measures could be misleading, together with the new emphasis on "creating value for shareholders" led several consultants to develop new metrics. The most renowned of these metrics is probably the proprietary EVA® (for "economic value added") designed by Stern Stewart & Co (S&S). To quote Fortune Magazine, as quoted on the jacket of Stewart's book (1991), "EVA™ is today's hottest financial idea, and getting hotter". As a matter of fact, innumerable conferences, seminars and workshops have been offered, and still are, to managers intrigued by the concept. Rival measures have been put forward, such as The Boston Consulting Group (BCG)'s CFROI (cash flow return on investment). These metrics, although different in their details, present common features.

First, they are purported to be expressed in cash flow terms, as opposed to accounting terms, "because anything else is tea leaf reading" (Stewart, 1991, p. xxi), or because "Cash is king" (Copeland, Koller and Murrin, 1991, p. 73). Second, they stress that a return commensurate with risk must be earned on capital invested and that capital must be recovered for performance to be satisfactory; corresponding benchmarks are thus included in the metrics. The third common feature is the insistence on integration: all facets of financial management should articulate around a common concept, namely "value through cash flow". In other words, project selection criteria, ex post performance measurement and incentive compensation schemes should be consistent with one another to maximise efficiency and prevent conflicts (such as positive NPV projects accompanied by poor accounting returns in the short or medium term and, therefore, a negative impact on bonuses).

It is not the object of this paper to formally present the various metrics nor analyse their strengths and weaknesses. Academics have recently caught up with the practitioner-led movement and analyses can be found in Peterson and Peterson (1996), Dillon and Owers (1997), Mandron (1998, a and b), among others. Rather, we wish to emphasise that managers' growing interest for cash flows and integrated financial management may be indicative of the direction project valuation is going to take.

3.2 Project valuation in an integrated financial management framework

Managers' search for efficiency and consistency in valuation, planning and control is hard to reconcile with the RO approach to valuation. As already explained in Section 2.3, this approach does not rely on realistic cash flow scenario forecasting, nor can it be used to infer potential cash flows. This may explain why the consultants mentioned in 3.1 skirted the RO approach when designing their integrated systems. It would be difficult to ascribe such an "oversight" to lack of familiarity with the latest financial theories: in these well known international consultancy firms, part of the staff is just fresh from University and/or expected to keep abreast of new developments. In this light, it is revealing to note that on the topic of valuation, they invariably refer to the DCF model; either to explain how to use it properly, or to show that their systems are entirely compatible with DCF, albeit reportedly superior (see, for example, Stewart, 1991, p.175 and Chapter 8). Does it mean that "option thinking" must be abandoned in practice and that the DCF model, such as presented in textbooks, must remain the only valuation standard despite its well documented problems ? Certainly not.

DCF can easily be improved upon. A method can be inferred from Fama's 1977 article. To obtain equation (1), such as shown above in Section1.1, he recursively substituted a valuation equation into another one, from horizon date back to time 0. Fama did not proceed to the application stage. However, his article suggests that probability trees can be deployed from time 0 to horizon. They can then be "folded back" by computing value at any point on the tree as a function of subsequent events and remaining value-maximising decisions. For such a tree can incorporate criteria for the optimal exercise of options; it can also accommodate discount rates which vary with the node reached in the tree, that is with the different risk phases (or remaining uncertainty) of the project.

A recursively computed, multiple-rate DCF is conceptually not that different from a lattice-based RO model. A lattice is nothing else than a probability tree. However, whereas the lattice is automatically generated according to some pre-chosen statistical law, the decision tree behind recursively computed DCF is not constrained by any such law. In its case, the analyst's judgement and experience rule. Further, the fact that "branches" are explicitly expressed in cash flow terms makes it easy to dovetail project valuation with treasury planning and compensation management. Some monograph or article authors have illustrated the usefulness of the recursive procedure to incorporate managerial options, although their decision tree approach remained "naive", in their own words, because it relied on a single discount rate chosen without regard to the existence of managerial options (see, for example, Copeland et al., 1991, pp. 348-353, and Trigeorgis and Mason, 1987). However, as demonstrated by Sachdeva and Vanderberg (1993) and Smith and Nau (1995), when care is exercised to choose the appropriate discount rate (or rates), the recursive model is entirely compatible with the RO model.

As we have personally experimented it in real world situations, a recursive, multirate DCF model lends itself very well to the analysis of projects such as exploration projects or bio-pharmaceutical projects. It allows one to focus on key events and managerial decisions, and their consequences. An added benefit is that assigning probabilities to each branch forces the analyst to review his perception of risk. For example, if there is a 5% probability of finding oil in a given area, the exploration phase is not that risky, contrary to popular belief: there is in fact a quasi-certainty of finding nothing and the discount rate for the period should be close to the riskless rate. The "unpleasant", but not very uncertain results will affect value one period earlier, through an extremely low expected end-of-period value. There is no need to again penalise the project through a high discount rate. In fact, a high rate would yield the opposite effect for it would underestimate the value of 100%-sure exploration expenses. Finally, once a problem is expressed in terms of key events and managerial options, it is almost impossible not to notice that some periods dissipate more uncertainty than others and that downside risk can be limited through judicious exercise of options. The need for multiple discount rates becomes obvious.

The above argument is not meant to imply that valuing projects through a recursive, muti-rate DCF model is an easy task. There are many pitfalls to be avoided and choices to be made. First and foremost, the analyst must keep his problem manageable and avoid detailed, but rapidly explosive branching. Fortunately, the rapid pace of technological innovation makes it possible to count on ever increasing computing power, and on the development of flexible templates for specific types of problems in specific industries. Second, the choice of particular discount rates for particular periods of time must, of necessity, rely on intuition as a good theory still seems to be missing (see Section 1.5). However, in an application setting, all models need reinforcement from intuition and experience, the traditional DCF model perhaps more so: in its case, the dose of intuition needed to adjust the single discount rate to take account of varying risk and unspecified options is rather huge. We suggest that explicit thinking and modelling aid intuition.

4. Conclusion

We have examined the two main contenders in the field of project valuation: the DCF model and the newer RO approach. The latter, graced with sophisticated mathematics, is clearly favoured by theoreticians and scientific journals. However, DCF is still the staple of textbooks and the only model managers consider (aside from payback and accounting yardsticks). DCF may well be a "natural" for practitioners just out of habit. It could be argued that the RO model will take over when enough managers have been exposed to it through academic curricula. However, it could as easily be argued that the RO model will not impose itself as the premier valuation model: we have documented a powerful trend towards the integration of valuation, planning, performance measurement and incentive compensation, with cash flow scenarios as the underpinning of integrated systems. The RO approach is clearly at a disadvantage here, as it does not explicitly focus on cash flow scenarios and their levers. This is not to say that the DCF approach is problem-free. We have shown the opposite to be true. We have also shown that its problems may be corrected and that it can even incorporate the "real power of real options", that is "option thinking". Unfortunately, textbooks steadfastly stick to traditional DCF and seldom draw on published research to raise doubts about its basic tenets, such as a single discount rate. Nevertheless, there exists a middle ground between blind adoption and outright rejection in favour of the RO model. This middle ground might be better explored.

Endnotes

1. In a 1996 article published in the Journal of Business, Fama suggested that the positive auto-correlation observed in the market risk premium is a second order problem given that the market premium seems to be mean reverting. In itself, it would not be sufficient to invalidate the practice of discounting with non-stochastic discount rates.
2. Copeland and Weston (1988, p. 446) suggest that the idea was put forth by Modigliani and Miller themselves in their 1963 article. However, they misquote M&M when they state that the latter equated dB/dI (the marginal financing ratio) and B*/V* (the target market-value debt ratio). M&M equated dB/dI and L*, an undefined "target debt ratio". There is no indication whatsoever that they were thinking of a market-value ratio and nowhere is L* equated to B*/V*.
3. More precisely, debt and equity refunds should be computed after subtracting interest and "normal" return on equity from operating cash flows.
4. It would not do to consider the year's financing, as we are really considering an on-going pool of funds for an on-going pool of projects.
5. See, for example, Modigliani and Miller's formulae 8 (1958) and 12.c (1963).
6. Here is a very sketchy summary of the current state of knowledge on this topic: In 1977, Miller showed that the large tax advantages to corporate debt emphasized by Modigliani and Miller (1958, 1963) are in fact wiped out by personal taxes. In 1980, DeAngelo and Masulis argued that the existence of company specific non-debt tax shields causes some tax advantages to revert to the firm, although it is impossible to specify how much ! On the other hand, debt is also associated with agency costs (see Jensen and Meckling, 1976, Myers, 1977) which might offset any tax advantages left, or even surpass them. To complicate things further, because of information asymmetry debt may be an inferior source of financing compared with internal equity, and a superior source of financing when compared with new equity ! (Myers and Majluf, 1984).
7. However, three-moment versions of the CAPM have also been developed. See, for, example, Kraus and Litzenberger (1976)
8. When relying on lattice methods rather than on the solution of a strictly continuous diffusion equation, one could theoretically identify all the paths automatically "drawn up" by the computerized algorithm. However, it would not be practically feasible to do so (too many paths). It would also be meaningless, as the algorithm would produce values for V at different points in time and on different branches, but not cash flows.

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