Financial Applications of the Analytic Hierarchy Process

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ABSTRACT

The Analytic Hierarchy Process (AHP) is a relatively recent addition to multiple attribute modeling approaches and is attracting increasing attention as an intuitively appealing methodology to model complex ill-structured multiattribute problems. Wind and Saaty (1980) review a variety of marketing applications of the AHP. In similar vein, in this paper, we review the far reaching application potential of the AHP in normative corporate financial decisions. We suggest an analytical framework to integrate the discounted cash flow (DCF) model with strategic and behavioral considerations, thus, attempting to remove the perceived gap between strategic planning and finance theory. Applications are classified into two categories: (i) conventional applications; and (ii) DCF-based applications. The DCF-based applications represent a rich extension to the conventional use of the AHP and the integration framework has wide ranging implications as a methodology for formalizing financial strategy.

INTRODUCTION [1]

Normative finance theory has continued to become more sophisticated over the last two decades and more. At the same time, there is increasing criticism that normative financial theory has led to a great deal of confusion and disillusionment among practitioners. While many reasons can be perhaps identified to explain this phenomenon, we believe two factors have contributed significantly to the perceived gap between finance theory and real world practice: (i) theory's seeming failure to recognize the influence of strategic and behavioral considerations that practitioners perceive to be of value; and (ii) from the perspective of a non-technical financial manager, the complexity of the decision environment presented in normative financial models.

In the present day context, normative finance theory can be dichotomized into two major categories of problems: (i) problems requiring the estimation of a discounted cash flow model, e.g., capital budgeting; and (ii) problems that do not *directly* require the estimation of a discounted cash flow model, e.g., investment quality ratings. The DCF model is the cornerstone of modern financial theory and forms the basis, directly or indirectly, for most decisions falling in these two categories.

In this paper, we review the application potential of the AHP for overcoming the deficiencies noted above in both categories of corporate financial problems. We presume the readers' familiaritywith the AHP and refrain from describing the method here. In Section 3, the use of the AHP for a systematic assessment of investment quality ratings is illustrated as an example of the application potential of the methdology in its conventional form. We then illustrate, in Section 4, the use of a simple and effective framework for integrating the evaluation of qualitative and strategic factors using the AHP with a DCF model, in the context of capital budgeting. We identify other areas of application in financial management including the potential for application of the methodology in positive financial theory. The paper concludes by recognizing the potential for the use of the AHP as a methodology for formalizing normative theories of financial strategy.

THE AHP AND INVESTMENT QUALITY RATINGS

A Sovereign Government Debt Quality Rating Model Based on AHP[2]

The sovereign government rating methodology (SGRM) of the Standard & Poor's Corporation (S&P), a leading rating agency, is a comprehensive two-part procedure for assessing country risk (S&P,1982). The first part attempts to assess direct political risk, mainly focusing on non-economic factors limiting the availability of foreign exchange to a country and the willingness of authorities to meet debt obligations. The second step in the SGRM involves a detailed analysis of the economic characteristics affecting a country's ability to support its current and anticipated level of external debt.

In the SGRM, the degree of political risk is determined based on an analysis of the stability of a country's internal and external relations. Internal relations involve the structure and evolution of a country's governmental system and the state of social conditions within a country. Signals of high political risk resulting from instability in the structure of internal relations include: political events, such as periodic social disorder and riots, military coups and radical ideological shifts; and social conditions, such as rapid population growth, high density and uneven distribution of the population, low per capita income levels, severely skewed distribution of wealth and income, and high unemployment and underemployment. The impact of external relations on the level of political risk is divided into two broad areas. The first involves assessing the economic and political self-interest of a nation in honoring its external obligations. Factors examined include: the degree of economic integration with other Western countries, the extent of participation in international

organizations, and the ideological orientation of the government. The second area involves evaluating a nation's international security. Factors analyzed include the nation's relations with neighboring countries and its geopolitical importance in terms of the balance of power between East and West.

To assess the economic characteristics affecting a country's ability to support its external debt, the SGRM establishes the extent of a country's indebtedness and the sustainability of the government's debt policy. To determine the extent of a country's indebtedness, a comprehensive estimate of total public sector external debt, regardless of maturity, is made. Once the external debt of the public sector is estimated, the burden posed by that debt is measured using basic ratios comparing the debt level with GDP, export earnings and a country's foreign assets. In addition, the level of past and forecast debt services payments is also analyzed. The information on the debt burden is then combined with analyses of a country's international liquidity position and balance of payments flexibility to determine the sustainability of the government's debt policies.

An overall hierarchical representation of the sovereign government rating process, as described above, is presented in Exhibit 1. The hierarchy consists of five levels. The first level represents the overall goal of the rating process. The two major factors, economic and political risk, form the second level of the hierarchy. Economic factors are further decomposed into four criteria groups. Similarly, the political risk factor is broken down into six criteria groups. Each of the criteria groups can be further analyzed through a detailed set of sub-criteria . A complete listing of all the factors, criteria and sub-criteria can be found in (Johnson, et al., 1987).

The hierarchy in Exhibit 1 was evaluated for sovereign governments and applied to New Zealand (NZ). Comparisons were input on the basis of a study of publicly available information on NZ as of April 1987. The results of our evaluation of NZ revealed our perception that NZ's debt should be rated 'A'. Ideally, the weights for a rating category should completely dominate weight profiles for other ratings categories to leave no doubts as to the rating that should be assigned. The results also indicate that with the exception of the 'A' rating, the likelihood of rating NZ's debt as 'AA' is greater than that for the other rating categories. Since the model provides a systematic basis for a dynamic evaluation of sovereign credit ratings, the impact of a change in the assessment of NZ on any of the sub-criteria can be immediately ascertained.

To ascertain the sensitivity of the results to small perturbations in judgements, two limited Monte Carlo simulations and some sensitivity analysis were conducted. In the first simulation , the relative weights for the criteria groups were allowed to randomly vary within a range of $\pm 10\%$, assuming that the weights followed a uniform distribution. In the second simulation , the weights for both the two factor groups and the criteria groups were varied randomly. The results from 100 trials indicate that the perceived 'A' rating is quite robust to minor fluctuations in judgements. The sensitivity of the results to changes in the weights assigned to the two major factor groups was also assessed. The judgements were varied such that the weights for one group changed from 0 to 1.0 and vice-versa. The 'A' rating for NZ remained unchanged, indicating that the results, in this case, are not biased by small differences in judgements.

Implications for Finance Research in Investment Quality Ratings

The AHP-based model illustrated above for investment quality ratings has two major sets of implications. First, there is an important implication for academic research in investment quality ratings. Most academic research in the area has relied on statistical classification models, like the multiple discriminant analysis or recursive partitioning, to identify the objective information embedded in the rating process. These models are, however, dependent on objective information (e.g., financial statements) and cannot be dynamically updated to reflect changes in expectations as the future unfolds until the next set of financial statements becomes available. Thus, they are more useful in isolating, from a universe of attributes, those few attributes that have had a significant influence on the firm's perceived likelihood of default. This view would suggest that the AHP-based model and the classification models can be used to complement each other. The statistical classification model can be used to define the scope of data collection and analysis in the

AHP-based model.

According to the rating agencies [see, e.g., S&P (1982)], their rating process is a combination of qualitative and quantitative analysis. This implies that statistical models, irrespective of the methodology employed, will always yield a non-trivial misclassification rate, if the influence of qualitative analysis is significant. On the other hand, the AHP-based model may allow a more complete modeling of the rating process being a judgemental procedure in nature.

The second major implication is for the rating agencies themselves. In focusing on identification of the objective information used by the rating agencies, academic research has implicitly assumed that the rating process being followed by the agencies is indeed consistent and proper. Attempts to assess the validity of this assumption have been necessarily indirect (see e.g., Ang and Patel, 1975). To our knowledge, research on prescribing a normative framework for the rating process has been conspicuously absent. The AHP-based model represents a potential normative model that the agencies could use to ensure consistency in their rating process.

THE AHP AND THE DCF MODEL[3]

Strategic Capital Budgeting

Beginning with Joel Dean (1951), research on capital budgeting has been extensive. However, the inadequacy of existing normative models for evaluating strategic investment opportunities is being increasingly recognized [see e.g., Logue (1981), Kaplan (1986)]. The major point of criticism seems to be that the discounted cash flow model ignores strategic and qualitative (behavioral) considerations that are often crucial in strategic investment decisions. It is widely recognized that in practical situations where a conflict arises between strategic analysis and financial (DCF) analysis, most often the results of strategic analysis override the results of financial evaluation. The literature is full of reports [e.g., Kester (1984)] where low net present value projects are nurtured "for strategic reasons" and some apparently high net present value projects are passed by because they do not "fit in" with the firm's strategic objectives.

Do the foregoing imply that the DCF model is misspecified? Definitely not, in our opinion. The DCF model is not intrinsically weak. But weaknesses arise in operationalizing the DCF model. More specifically, we believe [as also recognized by Kester (1984) and Myers (1984)] that the problem lies in the estimation of cash flows. As suggested by Myers (1984), the forecasting of cash flows is perhaps the most important element of the DCF model. The theoretical DCF model implies that *all the impacts* of a project need to be measured in cash flow terms for the proper use of the model. However, the influence of many strategic factors cannot be expressed in cash flow terms in any meaningful manner and are typically ignored in the DCF estimation process. This has resulted in the widespread feeling that there is a 'gap' between the DCF model as commonly implemented and corporate strategy. Myers attempts to explain this gap by offering three explanations:

(i) Finance theory and traditional approaches to strategic planning may be kept apart by differences in language and "culture";

(ii) Discounted cash flow analysis may have been misused, and consequently not accepted, in strategic applications; and

(iii) Discounted cash flow analysis may fail in strategic applications, even if it is properly applied.

Myers finds that there are few problems in applying DCF techniques to value safe cash flows, e.g., cash flows from financial lease contracts and "cash cows". DCF is, however, less helpful in

valuing business with substantial growth opportunities or intangible assets and is of no help at all in evaluating pure research and development projects. To bridge this gap, Myers recommends that we, on the financial side:

1. Apply existing finance theory correctly; and
2. Extend the theory to evaluate projects with growth opportunities.

Option pricing is suggested as a mechanism to capture the impact of future growth opportunities and other intangible assets.

Kester (1984) proposes a taxonomy of growth options as a means of integrating strategic planning and conventional capital budgeting and recommends the use of option pricing theory to operationalize the approach. According to the taxonomy, a project's growth opportunities are to be categorized depending on whether they are compound vs. simple, proprietary vs. sharing and deferrable vs. expiring. The growth options concept is intuitively appealing. Unfortunately, operationalizing the growth options framework using the option pricing theory suffers from a major weakness. It requires the direct estimation of the impact of growth options in terms of cash flows. However, this measurement problem is precisely the one that renders the standard DCF procedure inappropriate. Further, the growth options framework proposed by Kester is still narrowly defined and requires that the influence of numerous factors be aggregated and expressed in cash flow terms.

The current practice by businesses appears to be to isolate strategic investments and to evaluate such investments qualitatively outside of the DCF model. Such an informal judgemental approach suffers from a major weakness: inconsistency. Informal judgemental systems have a less than perfect memory. Inconsistency in such systems can span several dimensions. First, a decisionmaker may reach a different conclusion on the same project in different time periods simply because of the inability to retain the specific nature of his/her informal assessment of qualitative strategic attributes. Second, the relative importance attached to specific attributes across projects may not be consistent inducing a bias in comparative selection. Third, if there is more than one decisionmaker evaluating different projects, project decisions may depend on the individual decisionmaker evaluating the project and may be inconsistent.

To illustrate the use of the AHP to integrate strategic considerations and the DCF model in the context of capital budgeting, we consider projects in which some of the impacts can be quantified in cash flow terms and where the strategic impacts cannot be quantified directly in cash flow terms without losing generalities. Consider an illustrative hierarchical representation of the resource allocation process as shown in Exhibit 2. The hierarchy in Exhibit 2 consists of five levels starting with an overall goal level and ending with the 'alternatives' level.

If the resource allocation process only required the evaluation of qualitative factors, decision could be reached on the basis of the strategic global priorities for the alternatives (similar to the investment quality ratings model). However, as assumed earlier, the more common case is one where some of the impacts have been quantified in cash flow terms and the strategic impacts are to be treated qualitatively. In such cases, integration of strategic weights for the alternatives with estimable cash flows can be achieved in a simple expected value format. Consider a single project, where the alternative courses of action are to accept or reject the project. We suggest that the normalized strategic weights for acceptance-rejection from the AHP hierarchy be integrated with the present value of estimable project cash flows to yield a strategic net present value (SNPV) as follows:

$$\text{Strategic Net Present Value (SNPV)} = w_a \, PVCF - w_r \, NINV \qquad (1.0)$$

where, w_a is the strategic weight for acceptance of the project, w_r is the corresponding strategic weight for rejection of the project, PVCF is the present value of estimable project cash flows discounted at an appropriate discount rate, and NINV is the net investment.

As an illustration, consider a project whose present value of estimable cash flows is $10,000 and present value of net investment is $12,000. The NPV is obviously -$2,000. Without considering strategic influences (not quantifiable in cash flow terms), the NPV rule recommends rejection. The corporate manager, however, perceives that the project has strategic impacts that have not been estimated directly in cash flow terms. Assume that the manager evaluates the strategic impacts of the project using an appropriate AHP hierarchy and generates strategic weights of 0.6 and 0.4 for acceptance and rejection, respectively. The project's SNPV with the stated weights is +$1,200. Obviously, the project is acceptable if the NPV rule is used on the project's SNPV. Similarly, of course, an acceptable project using the pure NPV rule may become unacceptable on the basis of its SNPV.

The above framework can be extended in a variety of dimensions. First, in the case of mutually exclusive alternatives, the hierarchy needs to be evaluated for each of the projects and the project with the highest SNPV will be chosen provided that such maximum SNPV is positive. Second, the framework can be extended to compute a strategic internal rate of return (SIRR) and also deal with typical problems like unequal lives and size. Third, the SNPV can be extended to consider the effects of financing decisions within the context of any of the various approaches suggested for the purpose (Chambers, Harris and Pringle, 1982). Fourth, the hierarchies can be constructed on a year to year basis to yield different weights for different years of project life. In such a case, the cash flows will obviously be weighted by the weights for the respective years.

A major extension of the framework is in determining strategic divestment/abandonment decisions. The strategic weights can be dynamically revised as and when the decisionmaker changes his/her perceptions about the relative importance of goals, factor groups and/or criteria. Thus, within this framework, projects may be abandoned even though estimable project cash flows may indicate retention. Conversely, projects may be retained even in cases where project cash flows indicate abandonment.

Other Application Areas

While the integration framework has been illustrated in the context of capital budgeting, the framework has extensive application potential in all areas of financial management. Obviously, most normative financial models rely on the DCF model. The framework is applicable wherever the DCF model is used and the decision process requires the evaluation of strategic and other qualitative factors. A non-exhaustive listing of DCF-based application areas include: (i) financing/capital structure decisions such as choice of financing sources including the choice of issue manager for external issues; (ii) restructuring issues like bond refunding; (iii) corporate credit management decisions including credit granting and determination of credit policy; and (iv) cash management decisions such as selection of banks and choice of short-term investment vehicles.

While we have focused on the application potential of the AHP in normative financial theory, the methodology and the framework-suggested are also potentially applicable in positive financial theories. In particular, the AHP could serve as the bridging mechanism to operationalize some of the recent positive theoretical developments. Two important applications come to mind. First, it may be possible to operationalize the impact of *information*. This may be a crucial breakthrough given the tremendous interest in the role of differential information in financial decisions. Second, and a related application, lies in the possibility of modeling *contracting and agency costs*. This may provide further insight into the issues of moral hazard and stakeholder conflicts.

CONCLUSIONS

While developments in normative finance theory over the last 3 decades have been numerous and multi-faceted, it is interesting to note that the chasm between institutionalists and positivists continues to be strong. A central theme in the suggestions for future research made by financial researchers [see, e.g., Carleton (1978), Pinches (1982), Hempel (1983), Weston (1981)], is the need to consider strategic and behavioral considerations explicitly in normative financial models.

Farrelly (1980) makes a strong argument for investigating a behavioral science approach to financial research. In our opinion, despite Farrelly's persuasive arguments and the suggestions of several leading researchers, research in integrating behavioral and strategic considerations with extant normative financial models has not been forthcoming, largely because of the lack of an analytical framework to accomplish this integration. It is our belief that the AHP-based framework illustrated in this paper is an attractive means of achieving the integration and reducing the perceived "gap" between corporate strategy and normative finance theory.

FOOTNOTES

1. An earlier version of this paper was presented at the *TIMS XXVII Gold Coast*, Australia, July 20-23, 1986. A more detailed version of this paper is available from the authors. We acknowledge the helpful comments of several colleagues both at Northeastern University and the University of Cincinnati and Tom Saaty on an earlier version of this paper. Partial support for Venkat Srinivasan through the *Joseph G. Reisman Research Professorship* is also gratefully acknowledged. All remaining errors are our own.

2. This section has been adopted from Johnson, Srinivasan and Bolster (1987).

3. This section has been adapted from Srinivasan and Kim (1987b).

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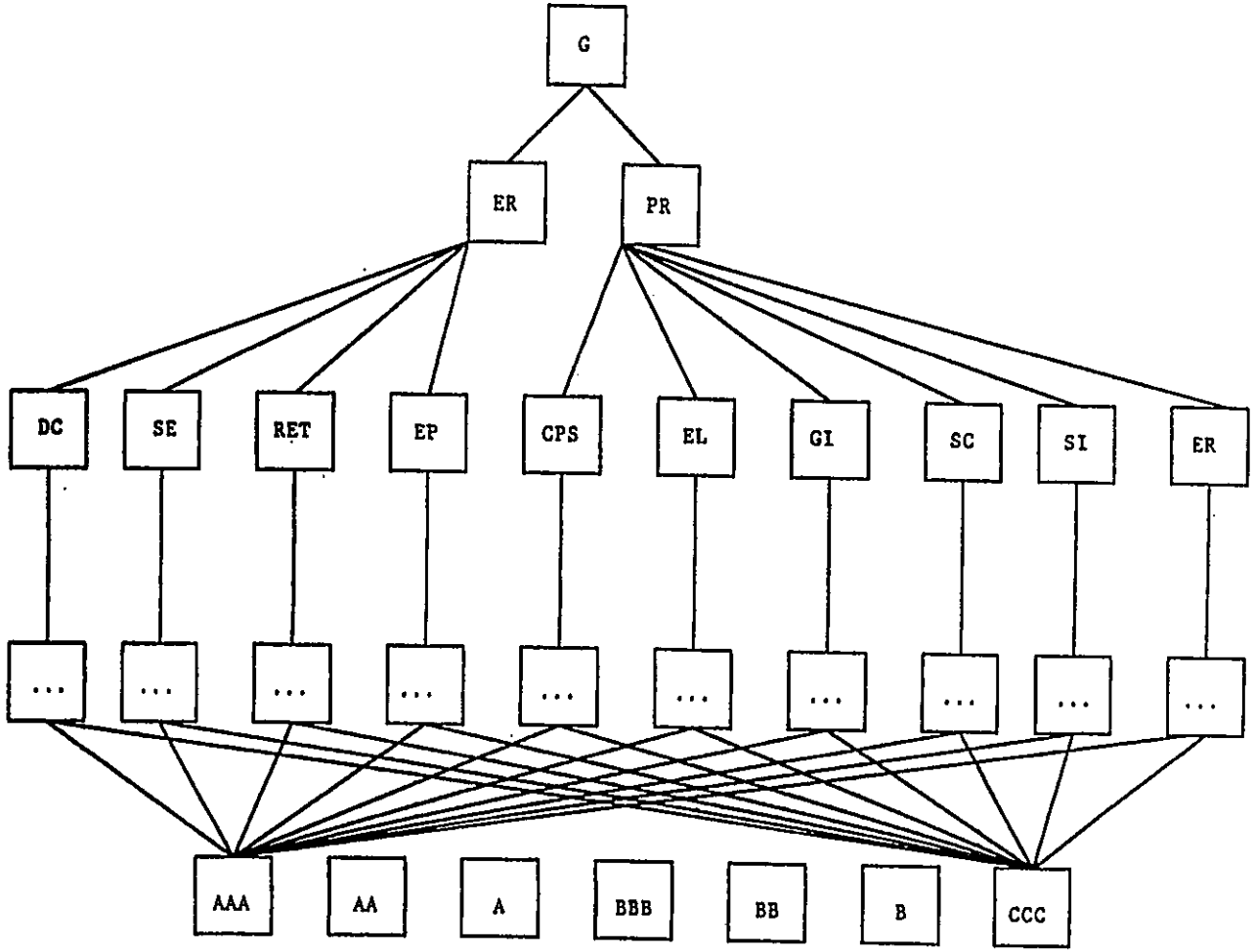
Exhibit 1

Hierarchical Representation of the Sovereign Government Ratings Process



Note: All possible arcs haye not been drawn to retain visual clarity

Exhibit 2
An Illustrative Hierarchical Representation of Strategic Factors in Resource Allocation