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On a realistic paradigm for financial modeling under multiple criteria

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ILMO. SR. DR. D. CONSTANTIN ZOPOUNIDIS

Y contestación del académico de número

EXCMO. SR. DR. D. JOSÉ DANIEL BARQUERO CABRERO

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Sumario

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ON A REALISTIC PARADIGM FOR FINANCIAL MODELING UNDER MULTIPLE CRITERIA

Abstract: Financial modeling has become increasingly important for financial decision making and risk management. Over the years, the sophistication and complexity of financial models has increased, but the recent crisis raised criticism on their effectiveness. From the point of view of financial theory, financial modeling is mainly based on a normative and descriptive approach, which has adopted the wealth maximization principle. The multicriteria decision aid (MCDA) paradigm extends and enhances this framework, emphasizing the multidimensional aspects of financial decisions, which can be represented by quantitative and qualitative factors. MCDA introduces tools and methods that enable the structuring of financial problems, the analysis of trade-offs among multiple objectives, and the evaluation of multiple ways of actions, in a systematic and rigorous manner. This paper discusses the important role that MCDA can play in improving financial models for decision making using examples from the areas of investment appraisal, portfolio selection, and banking management. An up-to-date review of the relevant literature in these two areas is also presented.

Keywords: Financial modeling, Risk management, Multiple criteria decision aid, Decision analysis

UN PARADIGMA REALISTA PARA MODELOS FINANCIEROS EN MULTICRITERIOS

Resumen: Los modelos financieros se han vuelto cada vez más importantes para la decisión financiera y gestión de riesgos. Con los años, se ha incrementado la sofisticación y la complejidad de los modelos financieros, pero la reciente crisis levantó críticas sobre su efectividad. Desde el punto de vista de la teoría financiera, los modelos financieros se basan en un enfoque normativo y descriptivo, que ha adoptado el principio de maximización de la riqueza. El paradigma del análisis de decisiones multicriterio (MCDA) amplía y mejora este marco, haciendo hincapié en los aspectos multidimensionales de las decisiones financieras, que pueden ser representados por factores cuantitativos y cualitativos. MCDA presenta herramientas y métodos que permiten la estructuración de problemas financieros, el análisis de equilibrios entre múltiples objetivos y la evaluación de variadas formas de acciones, de manera sistemática y rigurosa. Este documento analiza el papel importante que MCDA puede desempeñar en la mejora de modelos financieros para la toma de decisiones usando ejemplos de las áreas de valoración de la inversión, la selección de carteras y gestión en banca. También se presenta una revisión actualizada de la literatura relevante en estas áreas.

Palabras clave: Modelos financieros, gestión de riesgos, análisis de decisiones multicriterio

1. INTRODUCTION

The modern financial theory covers areas such as capital budgeting, corporate financing, and investment decisions, focusing on the analysis and description of the effects that financial decisions have on financial markets, the operation of firms, and the wealth of investors. The increasing complexity of these decisions and the volatility in the global financial system highlight the importance of introducing and implementing proper modeling approaches based on analytic techniques.

The modeling approaches used in the context of finance have become considerably sophisticated over the past decades. Markowitz (1959) first introduced analytic quantitative techniques for portfolio selection and risk management, based on optimization and utility theory. Later, the publication of the Black and Scholes option pricing model (Black and Scholes, 1973) set the basis of the modern era of finance, which is characterized by the adoption of a much more analytic-engineering approach based on advanced models for asset valuation and risk management.

The framework introduced by financial theory is necessary for understanding the nature of financial decisions and the operation of financial markets. As far as financial decision making is involved, such a general framework should be combined with the specific features of the decision environment of a particular financial decision problem. Financial modeling introduces this integration. According to Spronk and Hallerbach (1997) “financial modeling is concerned with the development of tools supporting firms, investors, intermediaries, governments, etc. in their financial-economic decision making, including the validation of the premises behind these tools and the measurement of the efficacy of these tools”. Thus, financial modeling introduces a decision support approach to financial decision making, integrating the multiple aspects of financial decisions into operational and practically implementable tools for constructing, analyzing, and selecting proper ways of action.

The multiple aspects of financial decisions become clear by considering the example of the mean-variance analysis on optimal portfolio selection. The

decision-maker's problem is how to form a combination of risky assets such that, for a given level of expected return, risk is minimal. From a decision-theory point of view this is an expected quadratic utility maximization problem. From a probabilistic point of view it is seen as the returns being generated by elliptical distributions. From an operational research point of view it can be seen as a constrained quadratic programming problem. Further, from an econometrics point of view it raises the important problem of predicting expected returns and the conditional covariance matrix. Finally, from a practitioner's perspective, implementation of the implied investment strategy requires further considerations of transaction costs, market impact, etc.

The multi-facet nature of financial decisions, the multiple points of view, and the diversity of the decision factors involved, require the implementation of modeling approaches that accommodate these issues in accordance with the policy and preferences of the actual financial decision makers. Multiple criteria decision aid (MCDA) is well suited in this context. MCDA provides a decision-theoretic paradigm that is suitable for complex, ill-structured problems, involving decision problems under conflicting criteria, goals, and objectives. Clearly, following this approach increases the complexity of financial models and the financial decision process. Nevertheless, the added complexity is compensated by the adoption of a much more realistic and flexible approach, which acts not only as a decision making and analysis tool, but also enhances the understanding of financial decisions, the characteristics of the available options, and the effects of the uncertainties and the risk factors involved. This paper analyzes the relevance of MCDA in the context of financial decisions and financial modeling using examples from three major areas, namely investment analysis, portfolio selection, and banking management.

The rest of the paper is organized as follows. Section 2 provides a brief introductory overview of MCDA. Section 3 discusses the relevance of the multicriteria paradigm in the context of financial decisions and financial modeling with examples from investment appraisal, portfolio selection, and banking management. Finally, section 4 concludes the paper and outlines some future research directions.

2. AN OVERVIEW OF THE MCDA PARADIGM

MCDA has evolved as an independent discipline in the area of operations research, devoted to the development and implementation of decision support tools and methodologies for complex decision problems involving multiple criteria, goals or objectives of conflicting nature.The foundations of the modern MCDA theory have been set through the works of von Neumann and Morgenstern (1944) on expected utility and Koopmans (1951) on efficiency measurement. During the 1960s, Charnes and Cooper (1961) introduced goal programming and Roy (1968) set the foundations of outranking relations. Since then, MCDA has evolved rapidly, scientific associations were formed, and numerous advances have been achieved on the theory and applications of MCDA (Zopounidis and Pardalos, 2010).

The MCDA paradigm is relevant for a wide range of different types of decision problems, including continuous and discrete problems, under uncertainty, fuzziness, and imprecision. Continuous problems, involve situations where the number of alternative ways of action cannot be enumerated, but only be described implicitly through a set of constraints. Resource allocation problems are typical examples of this kind. For instance, in asset allocation the set of feasible portfolios that can be formed using a preselected set of assets cannot be enumerated exhaustively. Instead, the feasible allocations are described by constraints on the proportion of the available capital allocated in each asset. On the other hand, in discrete problems the alternatives under consideration form afinite set. Typical financial examples in this type involve the selection among different investment projects, credit granting decisions, etc. For instance, decisions related to the selection of investment projects involve a well-defined set of projects, each described over a number of selection criteria. Similarly, credit granting involves the evaluation of specific credit applications over a set of criteria related to the creditworthiness of an applicant.

MCDA intervenes in all phases of the decision process, beginning from problem structuring (Beltonand Stewart, 2010; von Winterfeldt and Fasolo, 2009) up to the implementation of the recommended solutions.An outline of the decision aiding process in the context of MCDA is illustrated in Figure 1 following the approach introduced by Roy (1996). The process starts with the problem struc-

turing phase, which involves the identification of the available decision options (alternatives) and the specification of the type of the recommendation (choice, ranking, classification, description). The second stage involves the formulation of a complete and non-redundant set of monotone criteria (consistent family of criteria) and the description of the alternatives on these criteria. The third phase focuses on the collection of preferential information from the decision maker and the aggregation of the criteria in order to form appropriate recommendations. Finally, actions related to the implementation of the solution are undertaken, such as the evaluation of the modeling process and the obtained solutions, their justification, and providing guidance on their implementation.

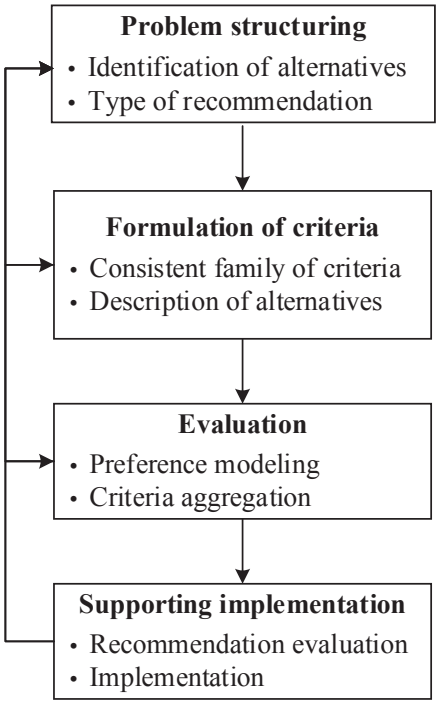

Figure 1: The intervention of multicriteria analysis in the decision aid process

From the methodological point of view, the current MCDA research focuses on four main areas:

- *Multiobjective optimization:* Multiobjective optimization extends the single traditional optimization framework to problems involving multiple objectives and goals. Under situations where these objectives/goals are conflicting, no single solution can be found that optimizes all objectives simultaneously. For instance, in a risk-return asset allocation framework, the maximization of return requires the investor to accept higher levels of risk. Thus, investors seek to identify efficient solutions, i.e., allocations that achieve the maximum level of return of a given level of risk (or the minimum risk for a given level of return). The identification of the set of efficient solutions (Pareto optimal solutions) is accomplished through interactive techniques,which iteratively search the solution space for satisfactory non-dominated solutions taking into consideration the trade-offs among the objectives according to the decision maker's preferences (Miettinen, 1999).

- *Multiattribute utility theory*: Utility theory has played a central role in the field of decision analysis. In a multicriteria context, multiattribute utility theory (MAUT) provides a normative approach for characterizing and analyzing rational decision making (Keeney and Raiffa, 1993; Dyer, 2005). MAUT is mostly involved with the way DMs make choices among a finite set of alternatives, using a functional aggregation model expressed in the form of a utility function of the decision criteria. For instance, under specific criteria independence conditions (for details see Keeney and Raiffa, 1993), an additive utility function can be assumed: $U(\mathbf{x}) = w_1u_1(x_1) + w_2u_2(x_2) + \ldots + w_nu_n(x_n)$, where w_j is the trade-off constant for criterion j and $u_j(x_j)$ is the (non-decreasing) marginal utility function for the same criterion. Such an additive function provides an overall evaluation measure together with its decomposition into partial evaluations (marginal utilities) at the criteria level.

- *Outranking relations*: The founding principles of outranking techniques can be traced to the social choice theory(Arrow and Raynaud,1986) and the introduction of voting systems aggregating the social preferences (e.g., Con-

dorcet rule, Borda count, etc.). An operational framework in the context of decision aiding, was first introduced by Roy(1968) with the ELECTRE methods (ELimination Et Choix Traduisant la REalité). Outranking models are expressed in relational form through which the validity of affirmations such as "alternative **x** is at least as good as (or preferred over) alternative **y**" can be analyzed. Particular features of outranking approaches include their ability to cope with intransitive preferences and non-compensation among the criteria (Roy, 1996). Traditional decision theory usually assumes that transitive models are required for rational decision making. However, intransitive preference due arise in practice, and as argued by Anand (1993) they cannot be simply considered as indicators of irrational behavior. On the other hand, compensatory decision models (e.g., an additive utility function) assume that trade-offs exist between the criteria, such that a low performance in one criterion can be compensated by an improved performance in other dimensions. However, often this is not the case, as there may exist certain trade-offs which are not acceptable. Non-compensatory outranking models enable the modeling of such cases. This is particularly useful for financial decision making, as it can be used to take into account the criticality of particular risk dimensions.

- *Preference disaggregation analysis*: Preference disaggregation analysis (PDA) is involved with the inference of preferential information from decision examples. In the context of PDA, a predefined decision model is inferred with regression-based techniques, through the analysis (disaggregation) of a limited set of representative examples (reference set) involving global judgments made by the decision maker. Jacquet-Lagrèze and Siskos (1982) first defined the PDA framework in the context of decision aiding through the introduction of the UTA method, which is based on an additive utility modeling approach. The method enables the construction of decision models for ranking alternatives (from the best to the worst ones), as consistently as possible with a given set of example alternatives already ranked by the decision maker. Except for utility functions, the PDA framework is also applicable with other decision models, including rule-based models (Grecoetal.,2001), outranking models (Doumposetal.,2009), Choquet integrals (Grabischetal.,2008), and kernel models (Pahikkalaetal.,2010).

The realistic features introduced by MCDA have made a popular tool for supporting decisions in many fields from management and engineering. An overview of the recent developments in several application domains can be found in the books of Figueira et al. (2005) and Zopounidis and Pardalos (2010).

3. FINANCIAL MODELING FROM A PERSPECTIVE WITH MULTIPLE CRITERIA

The finance theory has adopted the principle of wealth maximization as the single objective that drives decision making in the corporate world. Adopting this principle provides financial managers a very clear target that guides the decision making process. Furthermore, it is also easy to monitor and evaluate the results of the decisions taken, usually on the basis of risk-adjusted performance measurement approaches.

However, this approach may be too simplistic to describe the daily operation of the business environment. Bhaskar and McNamee (1983) note that even if a firm does focus on a single objective, this is often may too broadly defined, thus requiring the introduction of multiple proxy goals that can be translated to everyday terms. Steuer and Na (2003) also argue that wealth maximization is not understood in a common way by all stakeholders, as they often have different conceptions of wealth, risk, liquidity, social responsibility, environmental protection, employee welfare, etc. Hallerbach and Spronk (2002) on the other hand, emphasize the role of the imperfections in the decision environment, such as information asymmetries, conflicting interests, and transactions costs, which restrict the available opportunities and require a much richer description. Furthermore, it should be noted that financial decisions are also relevant to nonprofit entities, public organizations, regulators, and policy makers, whose decisions and actions are inevitably driven by a set of complex socio-economic principles.

From a financial modeling perspective, adopting a normative or descriptive approach (Spronk et al., 2005) with a single performance measure is a mathematically convenient approach. For instance:

- Financial planning models are often built assuming a wealth maximization objective with policy and risk constraints. However, transforming goals into constraints alters the nature of the problem, making it difficult for the decision maker to explore in a comprehensive way the trade-offs that may be involved among multiple goals and parameters. Identifying, analyzing, and measuring such trade-offs providesvery useful insights for taking more informed financial decisions.

- In a different context, models analyzing and describing corporate performance are often based on proxies of the overall financial performance of the firms. For instance, there are numerous studies exploring the factors that best describe the stock market returns of a firm, its profitability (usually measured by the return on assets), or its growth (e.g., sales and profit growth). The obtained results are clearly important for the understanding of what drives such success factors (i.e., market performance, profitability, growth etc.).However, the evaluation of corporate financial performance requires the adoption of a holistic approach combining all the relevant factors, including financial criteria (profitability, leverage, liquidity, solvency, managerial performance) and non-financial information which is crucial for the viability of a corporate entity (i.e., organizational structure, market position, competitive advantages, management competence, etc.).

Thus, the "traditional"perspective of financial modeling is indeed useful for understanding the operation of the financial markets, the activities of firms and organizations, and the identification of relevant decision factors. Nevertheless, a realistic financial modeling approach should be directed towards facilitating decision makers in the consideration of all pertinent decision criteria, the analysis of the trade-offs involved, the suggestion of multiple alternatives ways of actions, and their evaluation. Such a comprehensive framework based on multiple criteria may not be straightforward to implement. However, it acts both as a holistic modeling approach for financial decisions, as well as a tool for exploring non-trivial aspects related to the problem, its solutions, and their implementation, thus becoming a learning tool for financial decision makers.

Existing financial models can be useful tools in this enhanced context for financial modeling. For instance, the existing knowledge and state of the art solution algorithms for single objective financial optimization models can set the basis of their extension with multiple objectives. This is clearly evident in the context of multiobjective optimization, which has benefited a lot from the advances in evolutionary methods and metaheuristics initially developed for complex optimization under a single objective. Similarly, parametric and non-parametric estimation techniques (statistical, econometric, data mining, etc.) can be used to obtain estimates on important financial and economic parameters, to construct scenarios based on future projections, to analyze the significance of possible decision factors, as well as to build tests for evaluating the actual usefulness of the results.

The multicriteria paradigm, on the other hand, acts as a complementary approach that enhances normative and descriptive financial models. It adds a prescriptive and constructive perspective in the financial decision making process.A prescriptive approach seeks to discover models suitable for a given decision maker in a specific decision context, whereas in a constructive approach the model is built through a progressive learning process, which seeks to enhance the decision maker's understanding of the problem and ultimately facilitate the construction of a good model (Bouyssou et al., 2006). Implementing a realistic and holistic multicriteria approach in this context facilitates financial decision makers in adopting a structured systematic process in which "all things"are put together: estimates, computational formulations and algorithms, in combination with the trade-offs and judgments of financial decision maker.

The following subsections describe in more detail the multicriteria nature of financial modeling in the context of investment decisions, portfolio selection, and banking management.

3.1 INVESTMENT DECISIONS

Decisions on the choice of investment projects often have a strategic character as they span over a large time period and they require considerable resources.The investment decision process consists of four main stages: perception, formulation, evaluation and choice. The financial theory is mostly involved with the

evaluation and choice stages, through the introduction of investment appraisal criteria such as the net present value, the internal rate of return, and the payback method. Such criteria are aggregated through empirical approaches resulting to a ranking of a set of investment projects on the basis of their attractiveness or to an acceptance/rejection decision in the case of a single project.

However, there are a number of issues with the above process. First, the analysis is restricted to the evaluation of future cash flows on the basis of a predefined discount rate. Secondly, there is no formal framework for analyzing the discrepancies in the results of different investment appraisal criteria. In a realistic setting, the investment analysis is much more involved than a simple discounting of future financial outcomes. Furthermore, the high uncertainties involved with the outcomes of an investment project cannot always be adequately described in probabilistic terms, especially in cases of strategic investments for which similar past instances or historical data are not available.

Instead, a comprehensive investment appraisal process requires the careful consideration of possible options (investment projects), the specification of the goals and objectives of the investments, the identification of their consequences and risks, as well as the formulation of the evaluation results.

The multicriteria paradigm introduces such a holistic view of the investment selection process, supporting all of its stages. Montibeller et al. (2009) analyze the contributions of MCDA in the problem structuring phase, in the context of project portfolio selection. Concerning the stages of evaluation and choice, MCDA offers a methodological framework much more realistic than the one based solely on financial criteria, which a remake assumptions that are often not met in practice. For instance, Götze et al. (2008) note that investment appraisal based on the net present value, assumes among others that: (1) a single performance measure is adequate, (2) the economic life of the investment is known, (3) the investment appraisal process is separated from other relevant decisions regarding the financing of the project and its operation, (4) the cash flows are known.

In fact, the financial outcomes of the project and the associated risks depend on a number of factors, which are often difficult to quantify. For instance one can

mention the strategic benefits of the investment, its relation to the organization strategy of the firm, technical aspects of the investment, operational risk factors related to the implementation of the investment, regulatory and legalissues,etc. Recently new trends have also emerged with regard to socially responsible investments, thus adding ethical, social, and environmental criteria in the analysis.

The multidimensional nature of the investment appraisal process is further highlighted by the multiple objectives that managers seek to achieve through the implementation of an investment project. Bhaskar and McNamee(1983) presented empirical results from large companies from the United Kingdom, showing that 96% of the companies consider more than one objective during the investment selection process (with the most common number of objectives being eight). In most cases, profitability was found to be given top priority, followed by company growth, risk, liquidity, flexibility, etc.

In a venture capital investment context, empirical survey studies, such as those of Dixon (1991), Hall and Hofer (1993), Macmillan et al. (1985), and Muzyka et al. (1996), have presented extensive empirical results from survey studies conducted among US, UK, and European venture capital firms, in order to identify the criteria that they consider in their investment process. The results demonstrate that such investment decisions are driven by a diverse set of qualitative and quantitative factors, involving among others:[1]

- the qualities and experience of the management team of the firms,
- the experience and personality of the entrepreneurs,
- product-market criteria,
- the financial characteristics of the investments,
- the lending guidelines followed by the venture capital firms, etc.

The aggregation of such a diverse set of decision criteria in an ad-hoc manner, without a solid, structured, and sound framework underlying the characteristics of the evaluation process can easily flawed and unexpected results. For in-

1. According to Kollmann and Kuckertz (2010) the literature in this area has suggested well up to 400 criteria.

stance, Keeney (2002) analyzes 12 common mistakes in making value trade-offs, which are also relevant in other evaluation contexts. Among the most generally applicable ones, we can mention the following:

- not understanding the decision context,
- not having measures for consequences (i.e., criteria),
- using inadequate measures,
- not knowing what the measures represent,
- replacing fundamental objectives with alternative proxies,
- focusing on calculating "correct"trade-offs,
- using screening criteria impose value judgments
- failure to use consistency checks.

The MCDA paradigm provides investors and managers with a systematic approach to handle such issues, thus enabling the consideration of the investment appraisal process in a realistic and flexible multicriteria context. Among others, MCDA techniques which are applicable in investment appraisal are involved with issues such as:

1. Facilitating the managers in specifying a solid and transparent structure of the investment selection process.
2. Analyzing the trade-offs among the investment selection criteria and measuring their relative importance.
3. Aggregating multiple appraisal measures of diverse nature (qualitative, quantitative, deterministic, stochastic, fuzzy, etc.) into global investment selection indices.
4. Exploring the uncertainties involved in the selection process, through systematic sensitivity and robustness analyses.

Table 1 reports some recent studies using MCDA approaches for investment appraisal in different contexts.

Table 1: Some recent studies on investment appraisal under multiple criteria

Studies	Decision context
Angelou and Economides (2009)	Information & communication technologies
Chan et al. (2005)	Army modernization
Cundricet al. (2008)	Transport
Han et al. (2004)	International project portfolios
Jiménez and Pascual(2008)	Cash flow modeling
Kunsch(2008)	Capital budgeting under fuzziness & uncertainty
Machariset al. (2009)	Transport
Papadopoulos and Karagiannidis(2008)	Energy systems
Rousosand Lee (2012)	Shipping
Sayers et al. (2003)	Transport
van Haarenand Fthenakis(2011)	Wind farm site selection
Vučinaet al. (2010)	Product design

3.2 PORTFOLIO MANAGEMENT

Harry Markowitz set the basis of the modern portfolio theory (Markowitz, 1959) through the introduction of the mean-variance (MV) model for asset allocation. The MV model is essentially based on a bi-objective approach where the expected return and risk of a portfolio are statistically estimated from historical data. In his 1959 book, Markowitz briefly discussed some extensions involving other risk measures (e.g., semi-variance, mean absolute deviation, expected loss) and highlighted the importance of combining statistical estimates with the expert judgment of portfolio analysts.

In that regard, Markowitz acknowledged that the portfolio management process is not only involved with performing statistical estimations and solving an optimization problem. Portfolio analysts and investors perform multiple analyses to identify trends in the market and the general economy, to select promising investment opportunities among a large number of assets, to perform risk-return

estimates, as well as to construct portfolios and dynamic trading strategies.In this context, Figure 2 presents an overview of the portfolio management process.

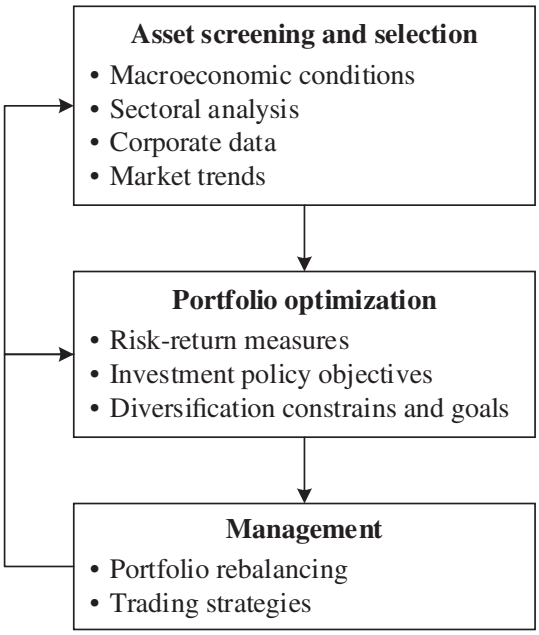

Figure 2: Outline of a three-phase portfolio management process

Return and risk are the two core concepts in the context of portfolio management. Despite the apparent difficulties in predicting it, return is easy to conceptualize as the percentage change in asset prices over time. Risk on the other hand, is much more challenging, as it can take various forms (with different sources, e.g., systematic vs. non-systematic risk), decision makers have different perceptions of risk and risk attitudes, and risk management practices are constantly updated to accommodate the dynamic nature of the financial environment and the requirements of the regulatory framework.

In a recent study, Fabozzi et al. (2007) provide an overview of the current practices and trends inquantitative portfolio management, which highlights a number of different risk measures currently used in practice, such as variance,

downside risk measures, value at risk, conditional value at risk, extreme value theory. This observation led the authors to emphasize the need to "merge the different risk views into a coherent risk assessment". During the past two decades there has been growing debate in the academic community as well as among professionals on the use of proper (coherent) measures of financial risks (see for instance Szegö, 2005).

The introduction of integrated approaches combining multiple points of view towards a comprehensive portfolio selection framework, naturally leads to a multicriteria approach. To this end, significant research has been devoted to the formulation of multi-objective formulations combining the MV framework with-new risk-related measures. Some examples include the consideration of the skewness and kurtosis of returns (Jondeau and Rockinger, 2006; Kerstenset al., 2011; Yu and Lee, 2011), value at risk and conditional value at risk (Mansiniet al., 2007; Romanetal.,2012), and mean absolute deviation (Ogryczak, 2000). The synthesis of multiple risk measures enables the analysts and the investor to take into account different aspects of the risk management process and ameliorates the assumptions imposed by focusing on a single measure of risk.

Other important portfolio selection criteria which are commonly used in practice include transaction costs, liquidity considerations, dividends, the number of assets in the portfolio and other goals used to ensure a sufficient diversification of the investment. While such factors are often considered as constraints in the portfolio selection process, their consideration as separate objectives provides the analysts and the investor a holistic view of their relation with the risk and the return of the investment and the trade-offs involved. Steuer et al. (2008) provide a comprehensive overview of the relevance of such factors in a portfolio selection setting, their modeling process, and their impact on the final results.

However, as explained earlier the portfolio management process is not only involved with criteria related to the construction of asset allocation strategies. Traders and investors also seek to select appropriate assets which can be included in a portfolio. Asset screening and selection improves the potentials of risk diversification (especially when assets from different classes are considered) and reduces the complexity of the portfolio construction and management process, by focusing only

on assets with certain characteristics which are deemed as important by the investor. Investors and portfolio analysts select assets on the basis of a number of fundamental and technical analysis criteria. These are related to the financial characteristics of firms (profitability, solvency, and managerial performance ratios), stock market ratios (e.g., market to book value, price/earnings, earnings per share, dividends/earnings, etc.), information on the general economic and business outlook, as well as estimates of the short and long term trends of the markets. The multicriteria approach enables the consideration of such factors, in an integrated framework that combines asset screening with portfolio construction. Such a modeling framework was first explored by Hurson and Zopounidis (1997) who used outranking and PDA methods to evaluate a number of firms and classify them into performance groups, and then employed multiobjective optimization technique for the synthesis of a portfolio comprised of firms with strong performance. This framework has recently been extended with other MCDA methods and implementations into decision support systems. Some recent studies, employing this approach, including implementations in decision support systems and empirical results can be found in several works, such as Sevastjanov and Dymova (2009), Xidonasetal.(2012).

Finally, trading is also an important part in active portfolio management. With the all the recent major advances in telecommunications and computer science, together the widespread use of electronic trading platforms, institutional investors (banks, funds, and investment companies) are actively pursuing algorithmic trading. Algorithmic trading is focused on automated buy/sell decisions taken by a machine. Thus, the traditional decision-theoretic aiding approach of MCDA may not seem to apply in this context. Nevertheless, recent studies provide evidence indicating that the performance of algorithmic trading systems can be improved if the systems are optimized under multiple objectives involving risk-return performance measures (Briza and Naval, 2011), technical trading indicators (Lohpetchand Corne, 2011) and multiple model fitting criteria (Ghandar et al., 2012), in combination with advanced techniques from the areas of artificial intelligence such as metaheuristics, evolutionary methods, and fuzzy systems.

Summarizing the above discussion, a list of indicative decision criteria used in each phase of the portfolio management process can be compiled as shown in Table 2.

Table 2: Decision criteria for portfolio management

Portfolio construction	
Risk-return measures	*Investment policy objectives*
Return	Transaction costs
Variance, skewness, kurtosis	Dividends
Systematic risk	Liquidity
Mean absolute deviation	Number of assets in the portfolio
Downside risk measures	Diversification over specific asset classes
Value at risk	
Conditional value at risk	
Omega ratio	
Maximum drawdown	
Asset selection	

- *Corporate data*
    - o Corporate financial performance ratios: Profitability, solvency, liquidity, leverage, managerial performance
    - o Stock market ratios: Market to book value, price/earnings, earnings per share, dividends/earnings
    - o Social responsibility indicators, business ethics, corporate governance
- *Trends in the macroeconomic environment, sectoral analysis*
- *Technical indicators of market trends*

Moving averages, price and volume-based indicators, oscillators

It should also be noted that the above multicriteria framework for portfolio management is also relevant in other similar contexts, such as the design and implementation of passive investment strategies based on index replication (Li, 2011), as well as mutual fund investments (Babalos et al., 2012; Davies et al., 2009;Pendaraki et al., 2005; Perez-Gladish et al., 2007; Tamiz et al., 2013).

3.3 BANKING

Banks are at the heart of the worldwide financial system, acting as intermediaries by providing credit to firms and individuals using deposits and their investment activities. Of course, over the years the role of banks has undergone significant changes and their importance has increased. Nowadays, banks have extended their range of traditional commercial activities, through the introduction of specialized deposit, financing and investment products, providing new services to their customers, and expanding their operations in the global financial markets. Clearly, this context creates a wide range of new opportunities. At the same time, however, it also creates a plethora of challenges, as it has been clearly demonstrated by the recent credit crisis that began from the USA and later transmitted to Europe in the form of a banking and sovereign debt crisis.

As a consequence of the diverse nature of a bank's operation, the area of banking management is involved with a wide range of issues related to all types of financial risks faced by banks, their investment and financing activities, the efficiency of their operation, as well as the regulatory and supervisory framework that governs their full range of operations. The latter has been a focal point for policy makers over the past two decades. The regulatory framework of Basel II, which is currently active, has been designed to improve the risk management practices in financial institutions and ensure the stability of the global financial system. Among others, Basel II emphasizes the procedures and practices that should be adopted for assessing and managing financial risks including credit risk, market risk, and operational risk, whereas the upcoming revision of Basel III is expected to bring a more refined approach with new risk dimensions (e.g., liquidity risk). Even through it is now apparent that the existing regulatory framework failed to prevent the crisis, the adoption of common rules in a global context can be indeed positive for financial stability.

Obviously the implementation of successful policies at all levels of a bank's operation should lead to improved overall performance and reduced exposure to excessive risks. The evaluation of the performance and viability of banks have received much interest among researchers, bank managers, and regulators. Such evaluations are performed considering all the factors that describe the activities,

operations, and risks of a bank. The most popular evaluation framework is based on the consideration of multiple performance and risk attributes categorized in six major dimensions:

1. capital adequacy,
2. assets quality,
3. management competence,
4. earnings generating ability,
5. liquidity, and sensitivity to market risks.

The evaluation context consisting of these dimensions is known as CAMELS (capital, assets, management, earnings, liquidity, sensitivity to market risks). Sahajwala and Van den Bergh (2000) present a comprehensive overview of the practices followed by supervisory authorities in G10 countries with respect to the adoption of risk assessment and early warning systems used for evaluating and monitoring the performance of banks. The overview indicates that central banks often use more than one systems based on CAMELS and other similar frameworks, usually following a peer review approach combining financial and qualitative data.

Implementing MCDA techniques in this context provides a systematic approach to the evaluation of bank performance. An example or a comprehensive multicriteria approach for bank performance evaluation, currently in use by the Bank of Greece, was presented by Doumpos and Zopounidis (2010). The multicriteria methodology was implemented in a decision support system providing access to different levels of bank analysts (senior and junior analysts) with capabilities to perform comprehensive analysis of the risk and performance of banks in Greece. The system was developed on the basis of the principles of a CAMELS framework for supervisory risk analysis, combining more than 30 quantitative and qualitative criteria. The system provides analysts with flexibility on the definition of the evaluation criteria (i.e., addition, deletion, or modification of the criteria), which is an important feature given the dynamic changes in the banking and economic environment. Additionally, the system provides a variety of options for the specification of the relative importance of the criteria, the type of the evaluation process and the aggregation of the criteria on the basis of a multicriteria outrank-

ing method. Extensive sensitivity analysis results are also provided, thus supporting the analysts in performing a comprehensive evaluation with respect to input data and the evaluation parameters. Graphical and tabular reporting tools are also available, allowing the analysts to monitor the results over time, to perform comparisons among banks, and identify their strengths and weaknesses of the whole banking sector and each separate bank.

Other studies using MCDA approaches have considered criteria related to the regulatory and supervisory framework using PDA techniques classifying banks and banking sectors into predefined performance rating categories (Ganisetal., 2010; Ioannidisetal., 2010), as well as considering specific banking risk dimensions such as operational risk (Bayrakdaroğlu and Yalçin, 2013). The evaluation of banking institutions has also been explored in a ranking context using goal programming formulations inspired by efficiency analysis techniques (Jablonsky, 2012).

Of course, banking management is not restricted to bank performance evaluation. Other important areas with applications of multicriteria techniques include:

- Credit risk rating: García et al. (2012), Doumpos and Zopounidis (2011), Papageorgiou et al. (2008).
- Asset liability management: Dash and Kajiji(2002), Kosmidou and Zopounidis (2004), Tektas et al. (2005).
- Loan portfolio optimization: Guoand Zhou (2005)
- Bank branches network management: Ferreira et al. (2012), Jablonsky (2012)
- Evaluation of electronic banking services: Hu and Liao (2011), Rigopoulos and Anagnostopoulos (2010)
- Customer relationship management: Grigoroudisetal. (2013)

4. **CONCLUSIONS AND FUTURE DIRECTIONS**

Despite their increasing level of sophistication, financial models have received much criticism during the recent crisis. Similarly to models in other sci-

ences, financial models are nothing more than mathematical representations of financial phenomena, based on assumptions, hypotheses, and simplifications that facilitate the model building and solution process. In a highly volatile global environment, building accurate models becomes a very challenging task. Relaxing the set of assumptions and simplifications leads to more realistic but also more challenging models.

The multicriteria paradigm in financial modeling introduces a decision-theoretic approach, based on the simple finding that decisions are taken by actual decision makers instead of models. In this context, the decision maker is supported in all stages of the decision process and particular emphasis is given on incorporating in the analysis all relevant decision criteria (qualitative and quantitative). The introduction of multiple criteria contributes in reducing model risk, facilitates the learning process of financial decision makers, and ultimately leads to more informed decisions. The techniques and methodologies available in the field of MCDA introduce a systematic approach in addressing the conflicts a rising from the consideration of multiple points of view, criteria, and objectives.

However, despite the promising results already achieved, there is a number of exciting future research directions with significant implications in practice. Among others one could mention:

1. Strengthening the connections and synergies with the latest developments in financial risk management, behavioral finance, and financial economics, using updated data, research findings, and exploring new application areas, in the view of the effects of the ongoing crisis.
2. Introduction of systematic ex ante and ex post validation procedures for multicriteria models under financial performance measures in accordance with the requirements imposed by the regulatory environment.
3. Implementation into decision support systems, taking advantage of new technologies from the fields of information systems (e.g., web-based technologies, distributing computing, agent systems, etc.).
4. Introduction of computational improvements that will allow existing models and algorithms to scale up to massive financial data, in a real-time decision support context.

5. Integration of other emerging areas in operations research and computational intelligence (e.g., data mining, evolutionary algorithms, fuzzy systems and other soft computing technologies), thus further strengthening the applicability of the multicriteria paradigm in financial domains of high complexity, non-linearity, and uncertainty.

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Discurso de contestación por el Académico de Número

EXCMO. SR. DR. D. JOSÉ DANIEL BARQUERO CABRERO

EXCMO. SR. DR. D. JOSÉ DANIEL BARQUERO CABRERO

Excelentísimo Señor Presidente,
Excelentísimos Señores Académicos,
Excelentísimas e Ilustrísimas Autoridades,
Señoras y Señores:

Tengo el honor de contestar en nombre de esta Real Corporación al excelente discurso del Profesor Dr. CONSTANTIN ZOPOUNIDIS, autoridad mundialmente conocida en el campo de la investigación, y es una honra para este Real Academia, tener en su seno a esta personalidad científica que con sus trabajos está contribuyendo a realzar un campo tan trascendental, pero actualmente tan criticado y puesto en entredicho, como lo es el mundo de las finanzas.

Constantin Zopounidis se licencia en administración y dirección de empresas en la Universidad de Macedonia, en Tesalónica, esa ciudad tan unida a España por la comunidad sefardí, que durante varios siglos constituyó el grupo de población más numeroso en Tesalónica, hasta que fue brutalmente aniquilado por el nacionalsocialismo. Estudia después en la universidad de París Dauphine, donde adquiere el título de doctor en la misma materia, y actualmente es profesor de ingeniería científica y de investigación de operaciones en la Universidad de Creta. Es además, profesor asociado en el Grupo Audencia, Escuela de Dirección de Empresas de Nantes, considerada, según el Financial Times y The Economist, como una de las más prestigiosas universidades en su ramo, especialmente por sus cursos de educación a distancia y por la alta formación de sus alumnos.

Aunque el Prof. Zopounidis tiene su centro de actividades en Creta, esa preciosa isla mediterránea a donde Zeus se llevó a Europa después de raptarla disfrazado de toro, sin embargo, por su actividad docente y por sus publicaciones, está presente en toda Europa y en otras muchas partes del mundo.

El Dr. Zopounidis es el editor jefe de las siguientes publicaciones científicas: Operational Research, un diario internacional del Grupo Springer, Berlín, del International Journal of Multicriteria Decisión Making (Grupo Inderscience), del International Journal of Financial Engineering and Risk Management (Grupo Inderscience), del Journal of Computation Optimization in Economics and

Finance (Nova Publishers, New York) y del International Journal of Corparate Finance and Accounting (IGI Global, Pennsylvania). Es también editor asociado del New Mathematics and Natural Computation (World Scientific, Singapur), de Optimization Letters (Springer, Berlín), del International Journal of Banking, Accounting and Finance (Grupo Inderscience), del International Journal of Data Analysis Techniques and Strategies (Grupo Inderscience) y del European Journal of Operational Research (Elsevier, Ámsterdam) Y desde 2012 dirige, como presidente electo, la Financial Engineering and Banking Society

El campo de investigación del Dr. Zopounidis abarca la ingeniería financiera, la gestión del riesgo financiero y la toma de decisiones multicriterio. Ha publicado más de 300 artículos en periódicos del más elevado nivel científico e internacional y también numerosas obras sobre ingeniería financiera e investigación de operaciones.

En reconocimiento a su labor científica y de investigación el Dr. Zopounidis ha sido galardonado, entre otras condecoraciones, con la medalla de oro y el Diploma de Ciencias Sociales y Humanas de MOISIL INTERNATIONAL Foundation, en el año 2000 obtuvo el premio al mejor trabajo de investigación interdisciplinar por el Decision Sciences Institute por razón de sus investigaciones sobre los sistemas de apoyo a las decisiones inteligentes con multicriterios, en 2009 fue el ganador del premio otorgado por The Emerald Literati Network al artículo más recomendado, en 2010 obtuvo el premio Best Review del European Journal Research y en 2012 el premio de ESCP Europe, París, por su larga contribución a la investigación en el campo de la ingeniería financiera y de toma de decisiones.

En el excelente discurso del Profesor Zopounidis sobre “un paradigma realista para la creación de un modelo financiero adoptado mediante una decisión multicriterio” nos ha mostrado el camino científico no sólo para tomar decisiones en el campo de las finanzas, sino también para cualquier decisión de cierta importancia en nuestra vida, tanto particular como profesional.

El análisis de decisiones multicriterio (MCDA) es un término amplio que incluye toda una serie de conceptos, métodos y técnicas que persiguen ayudar a los individuos o grupos a tomar decisiones y que implican no sólo diferentes

puntos de vista en conflicto, sino también múltiples agentes interesados. Desde mediados del siglo XX se ha venido desarrollando una intensa investigación en este campo, cuyo objetivo ha sido ayudar a los gerentes y líderes a tomar decisiones complejas que precisan de gran cantidad de información.

Respecto al campo de las finanzas, los procesos decisionales de selección de inversiones y de las fuentes de financiación de las empresas se caracterizan por una creciente complejidad y por el número de criterios cada vez mayor que se deben tener en cuenta.

La teoría del modelo financiero abarca diversas áreas: la de presupuestos, la de financiación de las empresas y las inversiones.

Las decisiones financieras de la empresa hasta ahora se han tomado generalmente desde una óptica de optimización. A largo plazo, la empresa toma sus decisiones intentando conseguir una asignación óptima de sus bienes y una estructura óptima de su capital. A corto plazo, la empresa decide en cuanto a la gestión de su fondo de operaciones buscando la optimización de los stocks, de la caja y de los créditos. Esta problemática de la optimización tiene su origen en la década de 1960 y se basa en unos modelos monocriterio de decisión. En una segunda fase se empezaron a analizar los problemas de las decisiones financieras desde una óptica multicriterio. El análisis multicriterio permite una aproximación más global, más realista, además de que salta del marco restrictivo de la optimización y tiene en cuenta otros aspectos. De esta forma, se crea un modelo para representar matemáticamente las relaciones entre las variables de un problema y poder hacer proyecciones. Un modelo financiero debe poder calcular el valor de ciertas variables dependientes cuando se le suministra el valor de determinados datos fijos e independientes: Es decir, debe poder responder a la cuestión "¿qué sucedería si yo cambiara el valor de uno o de vario datos fijos e independientes? ¿Cuál sería el impacto de este cambio sobre el valor de las variables dependientes de mi modelo financiero?

La elección de un proyecto de inversión significa una decisión muy importante, ya se trate de una empresa pública o privada, de una empresa pequeña o de una grande. Por su duración, por su importe, por su carácter irreversible, toda

decisión de inversión es considerada como una decisión capital y estratégica. Por esta razón, las decisiones de inversión se deben someter debidamente a un modelo.

El proceso de decisión está constituido, por regla general, por cuatro etapas importantes: percepción, formulación, evaluación y elección. **La primera etapa consiste en definir el problema. Si no hubiera problema, evidentemente no había necesidad de tomar ninguna decisión. En la segunda etapa, después de definir el problema, se trata de estudiar las alternativas posibles al problema. En la tercera se analizan y se evalúan las alternativas, teniendo en cuenta las ventajas y los inconvenientes de cada una de las opciones y descartando las opciones que resultan imposibles o no responden a las necesidades. Y por último, en la cuarta etapa nos inclinamos por la decisión que nos parece más adecuada.**

Hasta ahora la teoría financiera ha intervenido únicamente en las dos últimas etapas, es decir en la evaluación y en la elección. Cuando se trataba de clasificar varios proyectos de inversión, la teoría financiera nos los clasificaba por orden desde el mejor al peor. Y cuando se trataba de un solo proyecto, nos proponía la aceptación o el rechazo. Aunque se haya avanzado mucho en cuanto a las herramientas de que se dispone actualmente, sin embargo, existen aún problemas respecto a la evaluación y a la selección de los proyectos de inversión. La teoría financiera tradicional es limitada, pues se reduce únicamente a las etapas de evaluación y de selección, y, además, no es realista pues se funda únicamente en criterios financieros.

Por el contrario, el análisis multicriterio, contribuye de manera original al proceso de decisión financiera. En primer lugar, el análisis multicriterio interviene en las cuatro etapas del proceso de inversión: percepción, formulación, evaluación y elección. Además, en lo que respecta a las etapas de evaluación y de elección, el análisis multicriterio ofrece un cuadro metodológico mucho más realista que la teoría financiera, ya que introduce en el estudio de los proyectos de inversión aspectos tanto cuantitativos como cualitativos, tales como la urgencia del proyecto, la coherencia de los objetivos del proyecto con los objetivos de la política general de la empresa, y los aspectos sociales y medioambientales. El análisis multicriterio contribuye, por tanto, a resaltar los mejores proyectos de acuerdo con la

problemática elegida, a resolver la cuestión de manera satisfactoria, indicando su importancia relativa en el proceso de toma de decisiones, y a dar a conocer las preferencias y el sistema de valores de los inversores.

En resumen, el análisis de decisiones multicriterio resulta una herramienta utilísima en el momento de tomar decisiones importantes, en proyectos de tipo financiero, pues nos permite estudiar el proyecto no sólo desde la óptica de la optimización, sino desde múltiples puntos de vista. Durante el desarrollo de un proyecto de inversión, por ejemplo, hay que adoptar decisiones que son críticas para el futuro desarrollo del mismo. Además, los encargados de tomar decisiones asumen grandes responsabilidades, teniéndose que apoyar la mayoría de las veces en expertos que los asesoren. En otras ocasiones, los intereses de los diferentes agentes son totalmente contrapuestos, y hay que conjugarlos para lograr una solución.

En tal contexto, estas técnicas pueden servir de apoyo. Permiten abordar problemas complejos analizando los diferentes aspectos, dimensiones o puntos de vista del problema. Los expertos o las partes interesadas pueden aportar sus puntos de vista y sus valoraciones. Esto suele conducir a adoptar decisiones de consenso, que son mejor aceptadas por las partes afectadas. Además, por medio de estas técnicas se puede generar una gran cantidad de información y analizarla con profundidad.

Los métodos multicriterio van a tener un futuro prometedor en campo de las finanzas, ya que ofrecen un marco altamente metodológico y realista de los problemas de decisión y presentan muchas ventajas con respecto a los métodos anteriores: estructuración de los problemas complejos de evaluación, utilización conjunta de criterios cuantitativos (ratios financieros) y cualitativos en el proceso de evaluación, transparencia en la evaluación y mejora del “arte financiero” gracias a unos métodos científicos muy sofisticados.

Al Profesor Zopounidis, que es pionero en el estudio y la aplicación de este método, le preguntaría si este sistema de decisiones multicriterio, que tan buenos resultados puede dar en el campo de la economía y de las finanzas y que, al tratar de tomar decisiones, tiene en cuenta las opiniones y los intereses contrapuestos,

¿no podría ser un método muy adecuado para las grandes decisiones de consenso que está necesitando, tanto en el campo económico como en el campo político, nuestro país y también la Unión Europea?. ¿No se podría aplicar este método científico a la toma de decisiones en el mundo de lo social y de lo político?

Quiero finalizar mi intervención agradeciendo al Profesor Zopounidis la deferencia que ha tenido en compartir sus ideas con nosotros, felicitándole no solo por lo que hoy nos ha expuesto, sino por toda su labor investigadora.

Si el nombre de Europa está relacionado con su isla de Creta, quizá sería necesario un nuevo rapto de este proyecto que se llama Unión Europea, para que la idea de democracia, que nació en su país, Grecia, traiga a Europa un poco más hacia el Sur y que el Sur se acerque también un poco más hacia Europa.

Muchas gracias a todos.