Are Multi-criteria Decision Making Techniques Useful for Solving Corporate Finance Problems? A Bibliometric Analysis

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ABSTRACT

Corporate financial decision making processes (selection of investments and funding sources) are becoming increasingly complex because of the growing number of conflicting criteria that need to be considered. The main aim of this paper is to perform a bibliometric analysis of the international research on the application of multi-criteria decision making (MCDM) techniques to corporate finance issues during the period 1980-2012. A total of 347 publications from the Scopus database have been compiled, classified and analysed. The results obtained confirm: a) an increase in the importance of MCDM in corporate finance; b) the relevance of MCDM techniques in capital budgeting processes (fixed assets investment) and in the assessment of firms' economic and financial performance; c) the techniques based on the multiple attribute utility theory (MAUT) are the most popular in complex decision making situations as they are very simple to implement.

Keywords: corporate finance; multi-criteria decision making; MCDM; bibliometric analysis; review.
JEL classification: G30; C02.
MSC2010: 90B50; 90C29; 91B06.

¿Son adecuadas las técnicas de decisión multicriterio para resolver los problemas financieros corporativos? Un análisis bibliométrico

RESUMEN

Los procesos de decisión de selección de inversiones y de las fuentes de financiación de las empresas se caracterizan por una creciente complejidad, dada la confluencia del cada vez mayor número de criterios a considerar. El objetivo de este trabajo es realizar un análisis bibliométrico de la producción científica internacional que ha abordado la problemática asociada a las finanzas corporativas mediante la implementación del paradigma de Decisión Multicriterio (MCDM) durante el periodo 1980-2012. Un total de 347 publicaciones han sido recopiladas de la base de datos de Scopus, clasificadas y analizadas. De los resultados obtenidos cabe destacar lo siguiente: a) se ha producido un considerable incremento del uso de las técnicas multicriterio en finanzas corporativas; b) las técnicas MCDM se han empleado fundamentalmente en la selección de inversiones productivas, evidenciándose igualmente su utilidad para la evaluación de la situación económico-financiera de las empresas; c) las técnicas basadas en la teoría de la utilidad multiatributo (MAUT) han sido las más empleadas, dada su relativa sencillez operativa.

Palabras clave: finanzas corporativas; teoría de la decisión multicriterio; MCDM; análisis bibliométrico; revisión bibliográfica.
Clasificación JEL: G30; C02.
MSC2010: 90B50; 90C29; 91B06.

1. INTRODUCTION

Finance is a broad field that comprises three areas of study: financial institutions and markets, investments and financial management (Melicher and Norton, 2005). This paper focuses on the latter, which is the activity of the chief financial officers (CFOs) of firms.

Companies face two main types of financial problems: what investments should be made and how to pay for such investments (Brealey *et al.*, 2001), that is, investment and financing decisions. Both issues, together with the assessment of the economic and financial performance of the company, are the main responsibilities of CFOs. Decision making processes in relation to these issues are highly complex due to the need to consider multiple conflicting criteria (mainly goals and targets). This complexity has increased in recent years due to stronger market competitiveness and the need to take into account a growing number of criteria in decision making processes. Thus, besides the traditional objectives of maximising shareholder wealth and minimising business risks, other goals guide business decision making, such as: improving the public image of the company (corporate social responsibility); motivating and encouraging employees (work safety, continuous training and careers) or improving the relative position of the company in the market (market share gain and customer satisfaction and loyalty), among others. *"A firm cannot maximize value if it ignores the interests of its stakeholders"*, according to Jensen (2001), that is, the value maximisation objective cannot be achieved unless complemented by other objectives that unite participants in the organisation. In this context, traditional methods of assessment, valuation and selection of assets (real assets investment) and liabilities (selection of funding sources) are certainly limited, because they only consider the expected return and risk as decisional criteria. Therefore, practitioners are forced to adopt more sophisticated methods that make it possible to include more decision criteria and relax the optimisation assumption.

Simon (1957) argued that the optimisation assumption was not realistic because decision makers face many difficulties in decision making processes, such as incomplete information, limited resources or conflicting interests. Hence, decision makers prefer to find satisficing solutions (achieve 'targets'), rather than optimal solutions (maximise or minimise goals). The ideas of Simon (who was awarded the Nobel Prize in 1978), together with the research by Koopmans (1951), Kuhn and Tucker (1951) and Charnes *et al.* (1955) constitute the beginning of the multi-criteria decision making or, simply, MCDM theory, which was consolidated in the scientific community in the seventies.

In this sense, the MCDM paradigm has developed a range of techniques and methods to sort and choose the best alternative (or a small set of good alternatives) from the feasible set, taking into account multiple criteria (targets or goals), which are usually in conflict. In summary, as noted by Stewart (1992), multi-criteria tools help decision makers to find the most satisfactory alternative as a solution to their decision making, taking into consideration the requirements and limitations imposed by the process.

There are several classifications of multi-criteria techniques (Figueira *et al.*, 2005). In this paper, we have adopted the classification proposed by Pardalos *et al.* (1995), found in other works such as Jacquet-Lagrèze and Siskos (2001), which identifies four main categories: 1) multi-objective programming and goal programming, 2) techniques based on the multi-attribute utility theory (MAUT), 3) the outranking relations approach and 4) preference disaggregation methods.

MCDM techniques help decision makers to solve complex economic problems (Zavadskas and Turskis, 2011) and financial problems (Zopounidis, 1999; Steuer and Na, 2003; Figueira *et al.*, 2005).

Therefore, the MCDM paradigm represents a potentially useful option for solving corporate finance decision problems, because multi-criteria techniques can take into account multiple criteria in the decision making process.

The objective of this paper is to perform a bibliometric analysis of the international literature on the application of multi-criteria decision making techniques to corporate finance issues over the last three decades (1980-2012). Through this analysis, we will establish and differentiate the major trends in this area and we will ascertain how the discipline has evolved over time. This study is likely to be useful for those researchers and practitioners interested in exploring the field as we will detail the corporate financial problems that can be solved satisfactorily with MCDM techniques.

The scientific literature has provided many examples of literature reviews on the use of multi-criteria techniques in different fields of knowledge, such as environmental sciences (Huang *et al.*, 2011), forest science (Diaz-Balteiro and Romero, 2008) or economics (Zavadskas and Turskis, 2011). Moreover, we highlight several reviews of the application of multi-criteria techniques to issues in the generic field of finance (Steuer and Na, 2003; Spronk *et al.*, 2005; Hülle *et al.*, 2011). However, only the paper by Zopounidis (1999) focuses on the specific topic of corporate finance, making it a direct predecessor of this work. The relevance of our paper is nevertheless justified by the need to analyse trends (themes, techniques, etc.) that have emerged in the last decade.

After defining and justifying the aim of this research, we are confident that this paper will answer the following key questions: what kind of corporate finance issues can be satisfactorily solved using MCDM techniques? Also, which techniques are best suited for solving complex corporate finance problems? To this end and following this introduction, Section 2 is devoted to the process of drawing up the database that contains the literature considered for this paper. The third section focuses on study results. The paper ends with concluding remarks in Section 4.

2. MATERIAL AND METHOD

2.1 Method

In order to achieve the objective proposed in this paper, a bibliometric analysis was conducted, defined by Garfield (1977) as the procedure of quantifying available bibliographic information. This analysis is based on the study of some basic indicators, among which we highlight the ratios of production and dispersion. Bibliometric analysis allows the authors to explore the trends and structural patterns of a specific topic through the study of published papers in a particular field (White, 2004). The usefulness of this analysis has been verified in economics (Rubin and Chang, 2003), as well as in management (Charvet *et al.*, 2008). Additionally, papers that conducted bibliometric analyses in the field of finance have also been found (Chun-Hao and Jian-Min, 2012).

Furthermore, in order to measure the relationships between some of the variables studied, we conducted a basic statistical analysis by applying regression techniques and through association analysis (contingency tables). In the latter case, we first analysed the overall association between variables using the chi-square or Fisher's exact test. Then, 2×2 contingency tables were developed in order to examine whether there were significant differences between expected and observed frequencies in each pair of categories.

2.2 Material

The database required in order to conduct the proposed bibliometric analysis was built by collecting all the documents (papers, books and book chapters) indexed by Scopus related to the application of MCDM techniques to corporate finance issues.

Scopus and Web of Science are the two most extensively used scientific databases worldwide (Chadegani *et al.*, 2013). We have chosen Scopus because of its wider coverage: Scopus encompasses information on papers published in about 20,500 peer-reviewed journals and another 788 titles from book series (Scimago Journal and Country Rank, 2012), while the Web of Science contains articles published in about 11,500 peer-reviewed journals (Journal Citation Reports, 2012). Moreover, it is worth commenting that Scopus includes journals/papers with different levels of relevance and quality (Scimago Journal and Country Rank, 2012). In any case, all of them meet a wide range of strict scientific requirements (such as the peer review process for paper selection), guaranteeing that all the papers indexed in this database are of sufficient quality and relevance to be considered in the literature survey performed.

In this way 339 papers plus 8 books (or book chapters) were found. The procedure followed to build the database analysed in this work is justified by objective and pragmatic reasons. First, this selection procedure ensured the quality, scientific rigor and international scope of the papers to be analysed. Second, it was considered relevant due to the possibility of using a comprehensive and easily accessible database (Scopus) to find the papers that met the selection criteria discussed next.

2.3 Period analysed

The time period considered covers three decades, from 1980 to 2012. Although the pioneering works on MCDM techniques appeared in the literature in the seventies, they became more widely used in the eighties with empirical applications in real decisional contexts (Wallenius *et al.*, 2008). This is the reason behind the start date we have chosen for the analysed time period. Thus, it can be stated that the period of time under consideration encompasses practically all of the existing literature on the topic to date.

2.4 Search and classification procedure

The selection of materials (the documents) was performed in two stages. Firstly, we carried out a search in the Scopus database, including a comprehensive set of keywords related to both the field of corporate finance (capital budgeting, working capital, financial planning, financial performance evaluation, etc.) and the field of MCDM (multi-attribute utility theory, multi-objective programming, goal programming, preference disaggregation, etc.). The keywords were combined using the logical operators "OR", indicating that at least one word from each field had to appear in the search output and "AND", in order to obtain the intersection of the keywords of the two knowledge fields. In this first stage 1,417 papers were obtained. In the second stage, we read the Abstracts and eliminated those not related to the field of corporate finance and those papers that did not really use MCDM techniques. Thus, the sample was reduced to 339 papers and 8 books.

Once the scientific paper catalogue was established, a database was built in which each document was an entry. Then, each one was classified according to several variables: year of publication, type of document (paper, book or book chapter), journal title, subject area of the journal, number of authors, geographic area of the authors, specialisation of the departments where they work, type of paper (theoretical or empirical), application area within corporate finance and MCDM technique used. Once

the database was coded, a descriptive statistical analysis was carried out and we determined bibliometric indicators. Subsequently, some basic statistical tests were performed to analyse and discuss the results.

In order to clarify how the variables discussed above were coded, we show the codes used to describe the geographical area of the authors (see Table 1), the specific topic within the field of corporate finance (see Table 2) and the MCDM techniques employed (see Table 3).

TABLE 1
GEOGRAPHICAL AREA OF THE AUTHORS

Europe	1
USA & Canada	2
Rest of America	3
Australia & N. Zealand	4
Asia	5
Africa	6

Source: Own elaboration.

TABLE 2
TOPICS IN CORPORATE FINANCE

1. Capital budgeting	**4. Other topics**
11. Project selection	*41. Financial performance evaluation*
111. Fixed assets	*42. Financial management*
112. Intangibles	421. Financial planning
	422. Financial risk management
2. Capital structure	*43. Accounting*
21. Equity financing	431. Financial accounting
22. Debt financing	432. Management accounting
	44. Mergers and takeovers
3. Working capital	*45. Bankruptcy prediction*
31. Inventory management/control	*46. Credit risk assessment/credit rating*

Source: The classification of the topics in corporate finance comes from Brealey et al. (2001).

TABLE 3
CLASSIFICATION OF MCDM TECHNIQUES

1. Multiobjective and goal programming	**3. Outranking relations approach**
11. Multi-objective programming	*31. ELECTRE Methods*
12. Goal programming	*32. PROMETHEE Methods*
	33. Others
2. Multiattribute utility theory	**4. Preference disaggregation approach**
21. AHP	*41. UTA*
22. ANP	*42. UTADIS*
23. TOPSIS	*43. MHDIS and MINORA*
24. Classic MAUT	*44 .Others*
25. Others	

*Source: The classification of MCDM techniques comes from Pardalos et al. (1995).*

3. RESULTS

This section starts by analysing the evolution of the literature on corporate finance combined with MCDM over the period 1980-2012. Subsequently, the results concerning the authorship of the papers are presented. Finally, we provide a detailed analysis by specific application area in corporate finance and MCDM method used.

3.1 Classification by year of publication

The evolution of research on the application of MCDM techniques to issues and problems in corporate finance displays a clear upward trend over the period 1980-2012. This trend is well illustrated by analysing the number of publications per decade: the eighties were characterised by a low number of papers and books on the subject, more specifically only 27 were published. A considerable increase is observed in the nineties, when 81 documents were published. Scientific production has really boomed since 2001, with a total of 239 papers being identified over this period (2001-2012), a figure that represents 68.8% of the total. This trend can be graphically observed in Figure 1. In fact, the increase in scientific production in this area seems to be polynomial or exponential rather than linear, as revealed by the statistical goodness-of-fit of several regression models estimated (see Table 4).

FIGURE 1
DISTRIBUTION OF PAPERS OVER TIME
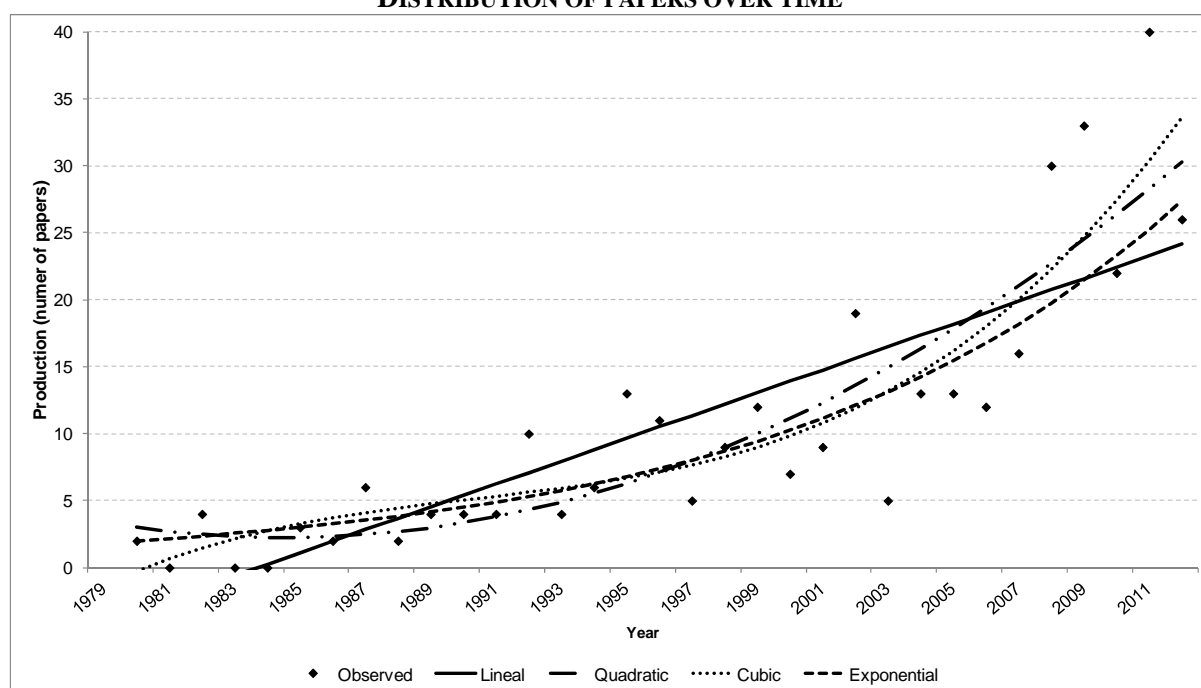
TABLE 4
MODEL SUMMARY AND PARAMETER ESTIMATION

Equation	Model summary					Parameter estimation			
	R^2	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.682	66.544	1	31	.000	-4.009	.853		
Quadratic	.777	52.182	2	30	.000	3.392	-.416	.037	
Cubic	.800	38.707	3	29	.000	-1.385	1.154	-.076	.002
Exponential	.773	95.442	1	28	.000	1.829	0.082		

Source: Own elaboration.

Overall, 347 publications (339 papers and 8 books or book chapters) have analysed the application of MCDM techniques to issues and problems in the field of corporate finance over the last three decades. In relative terms, this number is considered very small in comparison to the total number of corporate finance papers published in the same period in journals indexed by Scopus (approximately 79,303 articles), as our sample only accounts for 0.43% of the total. Therefore, MCDM is a minority approach in financial economics, but at the same time it is emerging as a set of new methods that is becoming increasingly common in this topic, in view of the scientific breakthroughs in recent years.

The 339 papers analysed were published in several journals falling into three subject areas (see Table 5): *Computer Science* (30.7%), *Engineering* (28.6%) and *Operational Research and Management Science* (19.8%). There is a minor presence of papers published in *Business and Economics* journals as they represent only 13.9% of the total. In this regard, five journals figure prominently, publishing a third of all the papers: *Expert Systems with Applications*, the *European Journal of Operational Research*, the *International Journal of Production Economics*, the *International Journal of Production Research* and the *International Journal of Advanced Manufacturing Technology*. The above data leads us to the conclusion that the implementation of multi-criteria techniques in the field of corporate finance has begun to spread in journals focused on quantitative and computational methods. These publications deal with financial topics sporadically and therefore are scarcely read by CFOs. As a result, most financial experts do not realise the real potential of multi-criteria techniques for solving corporate financial problems.

One significant aspect that is worth highlighting is the change in the relative importance of the different subject areas of journals during the three decades analysed (Table 5). Indeed, Fisher's exact test reveals a strong association between the variables subject area of the journal and period (p-value=0.015). Focusing the analysis on each of the cells through the corresponding 2×2 contingency tables (see significance in each cell of the table), we emphasise the decrease in the relative importance of papers published in the subject area of *Operational Research and Management Science* (from 37.0% of the total in the eighties to 18.9% in the first decade of the current century). In contrast, it is worth noting the considerable rise recorded by *Computer Science* journals, from 14.8% in the first period to 40.6% in the 2000s. Statistically significant differences have been found in both subject areas.

TABLE 5
CONTINGENCY TABLE OF SUBJECT AREA OF THE JOURNAL BY PERIOD

Subject area of the journal	Period							
	1980-1990 Frequency		1991-2000 Frequency		2001-2012 Frequency		**Total** Frequency	
	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Computer Science	4	14.8%	19	27.9%	81**	40.6%	**104**	**30.7%**
Engineering	5	18.5%	23	41.9%	69	18.9%	**97**	**28.6%**
O.R. and Management Science	10**	37.0%	19	25.6%	38***	18.9%	**67**	**19.8%**
Business and Economics	7*	25.9%	11	2.3%	29	5.7%	**47**	**13.9%**
Other Subject Areas	1	3.7%	4	2.3%	19	16.0%	**24**	**7.1%**
Total	**27**	**100.0%**	**76**	**100.0%**	**236**	**100.0%**	**339**	**100.0%**

Fisher's exact test=20.613; p-value (sign. Monte Carlo)= 0.015
Analysis of contingency tables 2×2: *** p<0.01; ** p<0.05; * p<0.1.
*Source: The classification of the subject areas of the journals comes from Scopus database.*

3.2 Authorship

The set of publications analysed is characterised by the high proportion of co-authorship (see Figure 2) as two or more authors were involved in more than 83% of cases, with documents being signed by two people the most common (43.2%). Papers written by one author alone account for 16.7% of the total.

In the vast majority of co-authored studies, more specifically in 85.8% (see Figure 3), the type of collaboration has been national, as researchers from institutions, research centres or universities within the same country have worked together. In only 14.2% of cases have authors from centres in different countries cooperated (international collaboration).

FIGURE 2
NUMBER OF AUTHORS
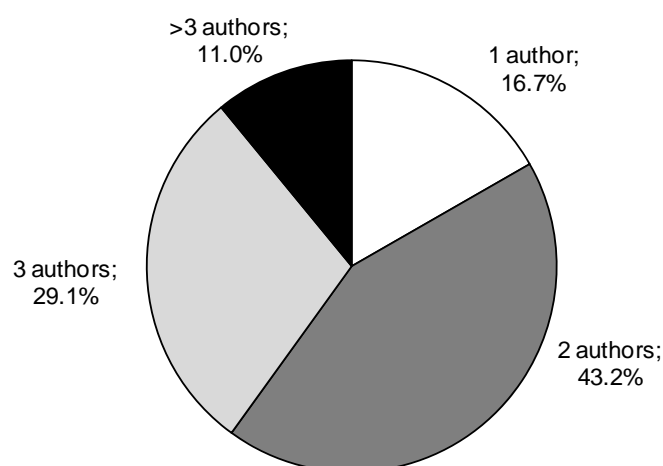
FIGURE 3
TYPE OF COLLABORATION
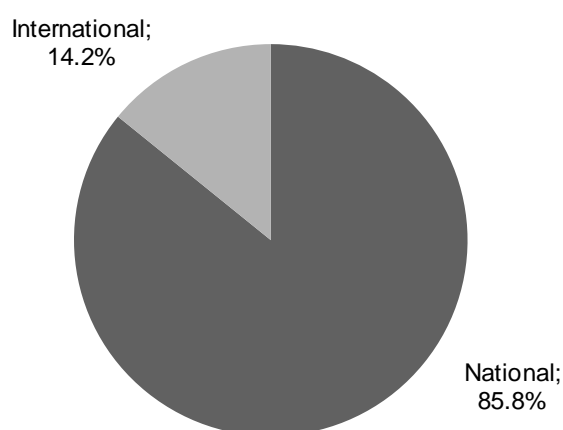
In regard to the affiliation or geographical area of the first authors (see Figure 4), 38.9% of the papers were written by Europeans, mostly from Greece and Turkey, while an Asian presence was also significant (36.3%). Only 18.2% of the papers are signed, first, by American authors, thus underlining the marked imbalance between Europe and Asia compared to North America in the financial literature that has used MCDM techniques, given that traditionally the United States has been the main focus of knowledge generation in financial economics.

FIGURE 4
GEOGRAPHICAL AREA OF THE FIRST AUTHORS
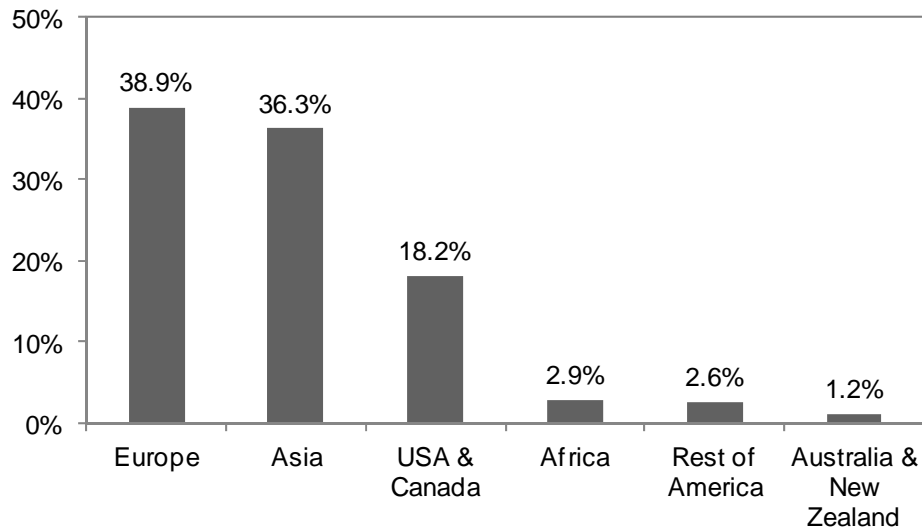
The contingency table that analyses the relationship between the variables origin of the first author and period (see Table 6) shows the increase in the relative importance of some regions such as Europe and Asia: 18.5% and 11.1% in the eighties to 42.7% in both cases in the last decade of the sample. By contrast, the case of North America is peculiar: in the first period, a high percentage of works were published, namely 70.4% of the total, while in the nineties the figure dropped to 32.1% and then to 7.5% in the 2000s. This fact indicates that the MCDM paradigm first began to be applied to corporate finance in North America, but that the main development has occurred later in Europe and Asia.

TABLE 6
CONTINGENCY TABLE OF GEOGRAPHICAL AREA OF THE FIRST AUTHOR AND PERIOD

Geographical area	Period							
	1980-1990		1991-2000		2001-2012		**Total**	
	Frequency		Frequency		Frequency		Frequency	
	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Europe	5**	18.5%	28	34.6%	102**	42.7%	**135**	**38.9%**
USA & Canada	19***	70.4%	26***	32.1%	18***	7.5%	**63**	**18.2%**
Rest of America	0	0.0%	1	1.2%	8	3.3%	**9**	**2.6%**
Australia & N. Zealand	0	0.0%	3	3.7%	1	0.4%	**4**	**1.2%**
Asia	3***	11.1%	21**	25.9%	102***	42.7%	**126**	**36.3%**
Africa	0	0.0%	2	2.5%	8	3.3%	**10**	**2.9%**
Total	**27**	**100.0%**	**81**	**100.0%**	**239**	**100.0%**	**347**	**100.0%**

Fisher's exact test=70.713; p-value (sign. Monte Carlo)=0.000.
Analysis of 2×2 contingency tables: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.
Source: Own elaboration.

We also analysed the type of authors depending on whether they were researchers (working at universities or research institutions) or professionals (if they work in business), concluding that the latter have only been involved in 10.1% of the papers. In over 89.9% of cases, the authors have been scholars, mainly belonging to Engineering (48.9% of the total), Business and Economics (22.2%) and

Management (13.8%) departments. There has only been collaboration between university departments with different orientations in 22.6% of cases. In this regard, we note the fact that while two out of every ten papers have been written by authors belonging to Business and Economics departments, the proportion of papers published in journals that address this subject area is smaller.

3.3 Corporate finance topics

A high percentage of the literature surveyed (80.6%) has been theoretical-empirical, that is, papers that have contributed with novel theories of MCDM techniques to issues in corporate finance and have also applied these advances empirically to real cases. Papers that have only presented theoretical developments account for just 2.1%, while those that were empirical represent 17.3% of the total. In most scientific documents with empirical applications (69.7%), the case study dealt with one company, mainly from the manufacturing (54.5%) or services (17.6%) sectors. These figures suggest that MCDM techniques can be applied in the field of corporate finance and are suitable for implementation by CFOs as support tools for decision making in the real world.

Regarding the specific topics addressed in the studied literature (Figure 5), 64.0% of the total is focused on capital budgeting, mainly on fixed assets valuation. A further 12.4% of the publications are aimed at assessing the financial performance of companies with multicriteria techniques, and 8.4% the management of inventory. Bankruptcy prediction and credit risk assessment are the two most significant topics classified as "others".

FIGURE 5
CLASSIFICATION BY CORPORATE FINANCE TOPIC
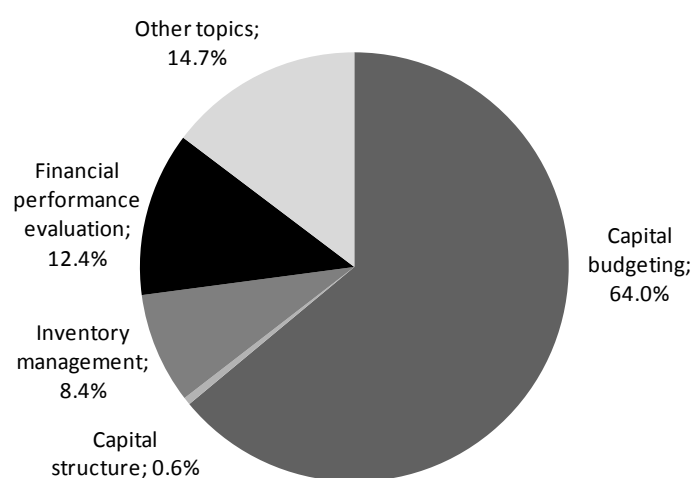
The reason for greater attention being paid to capital budgeting lies in the increased complexity of decision making processes relating to project selection, given the multitude of factors and criteria that affect the evaluation and selection of satisfactory alternatives. This complexity contrasts with the relatively simpler decision making scenario of selecting funding sources, where the cost of capital is, in practice, the only relevant criterion for decision making.

Turning now to analyse the contingency table of specific corporate finance topic and period (see Table 7), the most important observation is that the result of Fisher's exact test strongly supports the likelihood of such a relationship between the two variables. Furthermore, some important aspects should be highlighted: i) evaluation and prioritisation of fixed assets employing MCDM techniques has been the dominant topic over the three periods analysed, although in the eighties it was not as

relevant (29.6% of the total published papers) as in the subsequent decades, when this topic accounted for half; ii) intangibles valuation concern has increased notably over time, to the point where 20.9% of the total documents addressed this topic in the 2000s; iii) interest in inventory management, as well as in financial performance evaluation, has also grown, although to a lesser extent (from 3.7% and 0.0% in the eighties to 9.2% and 12.6% respectively in the first decade of this century); iv) by contrast, it is observed that the attention on financial planning topic has declined since the eighties; v) and finally, although bankruptcy prediction and credit risk assessment present a slight growth over time in absolute terms, it is worth commenting that in relative terms a decrease is observed.

TABLE 7
CONTINGENCY TABLE OF SPECIFIC TOPIC AND PERIOD

Corporate Finance Topic		Period							
		1980-1990		1991-2000		2001-2012		**Total**	
		Frequency		Frequency		Frequency		Frequency	
		Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Capital budgeting	Fixed assets	8*	29.6%	42	51.9%	112	46.9%	**162**	**46.7%**
	Intangibles	4	14.8%	6***	7.4%	50***	20.9%	**60**	**17.3%**
Capital structure	Equity financing	1	3.7%	0	0.0%	1	0.4%	**2**	**0.6%**
	Debt financing	0	0.0%	0	0.0%	0	0.0%	**0**	**0.0%**
Working capital	Inventory management	1	3.7%	6	7.4%	22	9.2%	**29**	**8.4%**
Other topics	Financial perform. evaluat.	0**	0.0%	13	16.0%	30	12.6%	**43**	**12.4%**
	Financial planning	8***	29.6%	2	2.5%	1***	0.4%	**11**	**3.2%**
	Financial risk management	0	0.0%	0	0.0%	2	0.8%	**2**	**0.6%**
	Financial accounting	0	0.0%	0	0.0%	0	0.0%	**0**	**0.0%**
	Management accounting	0	0.0%	1	1.2%	2	0.8%	**3**	**0.9%**
	Mergers and takeovers	0	0.0%	2	2.5%	4	1.7%	**6**	**1.7%**
	Bankruptcy prediction	2	7.4%	6	7.4%	8*	3.3%	**16**	**4.6%**
	Credit risk assessment	3	11.1%	3	3.7%	7*	2.9%	**13**	**3.7%**
Total		**27**	**100.0%**	**81**	**100.0%**	**239**	**100.0%**	**347**	**100.0%**

Fisher's exact test=58.129; p-value (sign. Monte Carlo)=0.000.
Analysis of 2×2 contingency tables: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.
Source: Own elaboration.

Focusing on the most prolific period, 2001-2012, in all geographic regions, the authors have mainly studied the dominant topic: investment in tangible assets (it accounts for about half of all papers in each region) and, to a lesser degree, intangibles valuation (see Table 8). The exception is Asia, where the second most common topic was inventory management (15.7%). In Europe, authors have also shown a special interest in another topic, namely the assessment of the financial performance of companies, with 17.6% of the works published focusing on this issue.

TABLE 8
CONTINGENCY TABLE OF TOPIC AND GEOGRAPHICAL AREA OF THE 1ST AUTHOR IN THE PERIOD 2001-2012

Corporate Finance Topic		Europe		USA & Canada		Asia		Rest of areas		Total	
		Frequency		Frequency		Frequency		Frequency		Frequency	
		Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Capital budgeting	Fixed assets	46	45.1%	9	50.0%	50	49.0%	7	41.2%	**112**	**46.9%**
	Intangibles	25	24.5%	6	33.3%	14**	13.7%	5	29.4%	**50**	**20.9%**
Capital structure	Equity financing	0	0.0%	0	0.0%	1	1.0%	0	0.0%	**1**	**0.4%**
	Debt financing	0	0.0%	0	0.0%	0	0.0%	0	0.0%	**0**	**0.0%**
Working capital	Inventory management	3***	2.9%	2	11.1%	16***	15.7%	1	5.9%	**22**	**9.2%**
Other topics	Financial perform. evaluat.	18**	17.6%	0	0.0%	10	9.8%	2	11.8%	**30**	**12.6%**
	Financial planning	1	1.0%	0	0.0%	0	0.0%	0	0.0%	**1**	**0.4%**
	Financial risk mgmt.	0	0.0%	1	5.6%	1	1.0%	0	0.0%	**2**	**0.8%**
	Financial accounting	0	0.0%	0	0.0%	0	0.0%	0	0.0%	**0**	**0.0%**
	Management accounting	0	0.0%	0	0.0%	0	0.0%	2	11.8%	**2**	**0.8%**
	Mergers and takeovers	2	2.0%	0	0.0%	2	2.0%	0	0.0%	**4**	**1.7%**
	Bankruptcy prediction	2	2.0%	0	0.0%	6*	5.9%	0	0.0%	**8**	**3.3%**
	Credit risk assessment	5	4.9%	0	0.0%	2	2.0%	0	0.0%	**7**	**2.9%**
Total		**102**	**100.0%**	**18**	**100.0%**	**102**	**100.0%**	**17**	**100.0%**	**239**	**100.0%**

Fisher's exact test= 84.236; p-value (sign. Monte Carlo) =0.010.
Analysis of 2×2 contingency tables: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.
Source: Own elaboration.

3.4   Classification by methodology used

Most of the papers, 82.1%, have used a single MCDM technique, while in only 17.9% of cases has the synthesis of two or more techniques in order to combine their strengths and overcome each other's weaknesses been documented. Table 9 shows the multi-criteria tools employed by the authors in the studied documents over the three periods. The result of Fisher's exact test strongly supports the likelihood of such a relationship between the variables MCDM technique and period. The analysis of 2×2 contingency tables highlights the association of each period with goal programming; the first and the third periods with AHP and the second and the third periods with ANP and TOPSIS.

Techniques based on the multi-attribute utility theory have been used in 62.8% of papers, followed, in order of importance, by multi-objective and goal programming, but with a much lower incidence, 19%. In terms of the least used methodology, preference disaggregation was used in only 6.6% of the papers.

Among the entire set of MAUT techniques, it is worth emphasising the use of the analytic hierarchy process (AHP), as it has appeared in 63.8% of the documents that employed MAUT tools. With regard to multi-objective and goal programming, the dominant technique has been goal programming (as used in 72.7% of the documents that focused on these techniques). PROMETHEE (57.5%) is the most common tool among authors working in the field of corporate finance with an outranking relations approach, while in the case of preference disaggregation the uses of UTA (26.1%) and UTADIS (30.4%) are quite similar. The reason AHP is the most popular technique (as noticed in 139 documents out of the total of 347) is due to its simplicity, ease of use, and great flexibility (Ho, 2008).

TABLE 9
CONTINGENCY TABLE OF MCDM TECHNIQUE USED AND PERIOD

MCDM technique	Period								
	1980-1990		1991-2000		2001-2012		Total		
	Frequency		Frequency		Frequency			Frequency	
	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Relat.
MOP and GP	*16*	*59.3%*	*19*	*23.5%*	*31*	*13.0%*	*66*	*100.0%*	*19.0%*
Multi-objective progr.	1		3		14		**18**	**27.3%**	
Goal programming	15***		16*		17**		**48**	**72.7%**	
MAUT	*7*	*25.9%*	*40*	*49.4%*	*171*	*71.5%*	*218*	*100.0%*	*62.8%*
AHP	6*		31		102***		**139**	**63.8%**	
ANP	0		1***		23***		**24**	**11.0%**	
TOPSIS	0		2**		26***		**28**	**12.8%**	
Classic MAUT	1		4		9		**14**	**6.4%**	
Others	0		2		11		**13**	**6.0%**	
Outranking relations approach	*3*	*11.1%*	*10*	*12.3%*	*27*	*11.3%*	*40*	*100.0%*	*11.5%*
ELECTRE	0		4		9		**13**	**32.5%**	
PROMETHEE	2		5		16		**23**	**57.5%**	
Others	1		1		2		**4**	**10.0%**	
Preference disaggregation approach	*1*	*3.7%*	*12*	*14.8%*	*10*	*4.2%*	*23*	*100.0%*	*6.6%*
UTA	1		4**		1**		**6**	**26.1%**	
UTADIS	0		4*		3		**7**	**30.4%**	
MHDIS and MINORA	0		3		1		**4**	**17.4%**	
Others	0		1		5		**6**	**26.1%**	
Total	**27**	**100.0%**	**81**	**100.0%**	**239**	**100.0%**	**347**		**100.0%**

Note: MOP and GP=Multi-objective programming and goal programming.
Fisher's exact test= 116.740; p-value (sign. Monte Carlo) =0.000.
Analysis of 2×2 contingency tables: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.
Source: Own elaboration.

When crossing the corporate finance topic and the methodology used in the last period (Table 10), statistical significant differences appear. Indeed, Fisher's exact test reveals a strong relationship between the two variables (p-value=0.000). One of the most striking aspects of the results presented in this table is the fact that MAUT techniques have been used primarily in decision making processes regarding investments in tangible and intangible fixed assets (52.0% and 24.6% of cases, respectively), supported by a statistically significant difference with respect to the rest of the topics/methods. Moreover, the minimal use of MAUT is quite remarkable in other topics, such as bankruptcy prediction or credit risk assessment, where significant differences can also be observed.

Although multi-objective and goal programming have been extensively used to analyse fixed assets valuation, its relative importance (29.0%) is lower than expected due to the widespread application of this methodology to inventory management issues (35.5%), where we can observe statistically significant differences. Outranking has focused mainly on issues related to fixed assets prioritisation (44.4%), but also on financial performance evaluation (22.2%) and bankruptcy prediction (22.2%). Paired statistical comparisons with Fisher's exact test showed significant differences in the latter.

Unlike the other techniques, the preference disaggregation approach has focused mainly on financial performance evaluation (30.0%) and on credit risk assessment (30.0%), where a significant difference is also seen as determined by its p-value.

An important finding from these results is that, while MAUT, multi-objective and goal programming, and the outranking relations approach focus mainly on capital budgeting decision-making processes (both fixed assets and intangibles), preference disaggregation centres its attention on other corporate finance topics less addressed by other multi-criteria tools.

TABLE 10
CONTINGENCY TABLE OF TOPIC AND TECHNIQUE USED IN THE PERIOD 2001-2012

Corporate Finance Topic		MCDM technique									
		MOP and GP		MAUT		Outranking relations approach		Preference disaggregation approach		Total	
		Frequency		Frequency		Frequency		Frequency		Frequency	
		Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Capital budgeting	Fixed assets	9**	29.0%	89**	52.0%	12	44.4%	2	20.0%	112	46.9%
	Intangibles	7	22.6%	42**	24.6%	1**	3.7%	0	0.0%	50	20.9%
Capital structure	Equity financing	1	3.2%	0	0.0%	0	0.0%	0	0.0%	1	0.4%
	Debt financing	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Working capital	Inventory management	11***	35.5%	11**	6.4%	0	0.0%	0	0.0%	22	9.2%
Other topics	Financial perform. evaluat.	1	3.2%	20	11.7%	6	22.2%	3	30.0%	30	12.6%
	Financial planning	1	3.2%	0	0.0%	0	0.0%	0	0.0%	1	0.4%
	Financial risk mgmt.	0	0.0%	2	1.2%	0	0.0%	0	0.0%	2	0.8%
	Financial accounting	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Management accounting	0	0.0%	2	1.2%	0	0.0%	0	0.0%	2	0.8%
	Mergers and takeovers	1	3.2%	2	1.2%	0	0.0%	1	10.0%	4	1.7%
	Bankruptcy prediction	0	0.0%	1***	0.6%	6***	22.2%	1	10.0%	8	3.3%
	Credit risk assessment	0	0.0%	2*	1.2%	2	7.4%	3***	30.0%	7	2.9%
	Total	31	100.0%	171	100.0%	27	100.0%	10	100.0%	239	100.0%

Fisher's exact test=92.831; p-value (sign. Monte Carlo)=0.000.
Analysis of 2×2 contingency tables: *** p<0.01; ** p<0.05; * p<0.1.
Source: Own elaboration.

Table 11 shows the contingency table of the geographical area of the first author and multi-criteria techniques used in the last period (2001-2012). The most striking thing is that there is no association between the two variables, although some significant statistical differences are observed in 2×2 contingency tables.

In relation to possible differences in the use of different techniques according to the geographic region of the first author, 45.0% of the papers that have used MAUT techniques were written by Asian authors whereas the contribution of Europe has been significantly lower than expected (38.0%). Similarly, Asia (51.6%) and Europe (35.5%) are the main regions for studying multi-objective or goal programming. The outranking relations approach has been mainly applied in Europe (66.7%), while it is worth commenting that practically only Europeans have applied the preference disaggregation approach to corporate finance problems (80.0% with a p-value<0.05).

TABLE 11

TABLE 11
CONTINGENCY TABLE OF GEOGRAPHICAL AREA OF THE 1ST AUTHOR AND MCDM TECHNIQUE IN 2001-2012

Geographical area	MCDM technique								Total	
	MOP and GP		MAUT		Outranking relations approach		Preference disaggregation approach			
	Frequency		Frequency		Frequency		Frequency		Frequency	
	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Europe	11	35.5%	65**	38.0%	18***	66.7%	8**	80.0%	**102**	**42.7%**
USA & Canada	2	6.5%	15	8.8%	1	3.7%	0	0.0%	**18**	**7.5%**
Rest of America	1	3.2%	7	4.1%	0	0.0%	0	0.0%	**8**	**3.3%**
Australia & N. Zealand	0	0.0%	1	0.6%	0	0.0%	0	0.0%	**1**	**0.4%**
Asia	16	51.6%	77	45.0%	7*	25.9%	2	20.0%	**102**	**42.7%**
Africa	1	3.2%	6	3.5%	1	3.7%	0	0.0%	**8**	**3.3%**
Total	**31**	**100.0%**	**171**	**100.0%**	**27**	**100.0%**	**10**	**100.0%**	**239**	**100.0%**

Note: MOP and GP=Multi-objective programming and goal programming.
Fisher's exact test=15.616; p-value (sign. Monte Carlo)= 0.362.
Analysis of 2×2 contingency tables: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.
Source: Own elaboration.

To finalise this section Table 12 is shown, which provides the most recent studies dealing with the use of multi-criteria techniques in corporate finance topics. This set of citations is intended to assist new researchers and practitioners interested in the field.

TABLE 12
SELECTED MORE RECENT PUBLICATIONS FOCUSED ON MCDM APPLIED TO CORPORATE FINANCE

Topic	MCDM technique	Multi-objective programming and goal programming	MAUT	Outranking relations approach	Preference disaggregation approach
Capital budgeting	Fixed assets	San Cristóbal (2011)	Partovi (2006)	García Cebrián and Muñoz Porcar (2009)	Chu and Lai (2005)
	Intangibles	Bhattacharyya *et al.*(2011)	Cebeci (2009)	Tolga (2012)	
Capital structure	Equity financing	Agarwal *et al.* (2012)			
Working capital	Inventory management	Wee *et al.* (2009)	Hadi-Vencheh and Mohamadghasemi (2011)		
Other topics	Financial performance evaluation	Garcia *et al.* (2010)	Ertugrul and Karakasoglu (2009)	Kalogeras *et al.* (2005)	Dimitras *et al.* (2002)
	Financial planning	Martin *et al.* (2011)			
	Financial risk mgmt.		Peng *et al.* (2011)		
	Management accounting		Frezatti *et al.* (2011)		
	Mergers and takeovers	Yücenur and Demirel (2012)	Shyr and Kuo (2008)		Zopounidis and Doumpos (2002)
	Bankruptcy prediction		Park and Han (2002)	Li and Sun (2009)	Pasiouras *et al.* (2009)
	Credit risk assessment		Fan (2012)	Doumpos and Zopounidis (2011)	Doumpos and Pasiouras (2005)

4. CONCLUDING REMARKS

Corporate investment and financing decisions have traditionally been addressed by classical financial theory taking into account a very limited number of criteria (return, cost and risk), considered in an optimisation context. Traditional tools do not allow for the fact that, in most cases, financial managers are faced with very complex decision making processes, characterised by uncertainty (not only financial risk), the influence of different factors (economic, social, environmental) and the existence of an increasing number of conflicting criteria to be taken into consideration. Therefore, these decision makers require sophisticated analytical tools to meet the new demands of decision making processes.

The MCDM paradigm, built on the basis of the ideas of Simon (1957), has developed a set of techniques and tools for evaluating and selecting appropriate and satisfactory alternatives for implementation in complex and dynamic decision making scenarios. In this sense, the main contribution of this paper is the bibliometric analysis of scientific literature that has addressed corporate finance problems and issues through the application of MCDM techniques over the last three decades. The most relevant conclusions are outlined below:

- Although the application of multi-criteria methodologies to corporate finance issues is still a minority line of research, *they are emerging tools in the international scientific literature* and their use will foreseeably become widespread among practitioners. Several reasons justify this assertion. First, the large increase in the number of publications addressing this topic over the period, mainly in the last decade. Second, this trend is expected to continue, in view of the growing complexity of financial decision making processes, which require the incorporation of more suitable appraisal techniques.

- The fact that *the scientific literature considered is located mainly in journals belonging to subject areas not related to finance is a major drawback* in the sense that papers have no visibility for financial researchers or practitioners. Therefore, they face difficulties in learning about new advances and developments in the integration of MCDM techniques in solving problems in their everyday activities.

- The applied nature of multi-criteria techniques in the field of corporate finance, in view of the high percentage of papers that are theoretical-empirical, evidences the *great potential of these techniques as tools to solve real financial problems in companies.*

- The significant *interest shown in using MCDM techniques to appraise investment in productive noncurrent assets is mainly due to the great complexity of that decision making process*, in view of the multiple criteria to be considered in the evaluation of alternatives and in the subsequent decision.

- AHP is the most commonly used technique in solving the problems associated with corporate finance, due to its simplicity, ease of use, and great flexibility.

In short, multi-criteria techniques form a methodological package with great potential for solving corporate finance problems, as they fit properly and more realistically to company investment and financing decision making processes. However, there is still much progress to be made both by researchers and practitioners on the implementation of this methodology in companies before it becomes a reality.

Finally, it is worth mentioning that this paper provides a platform for conducting future theoretical and empirical research within this field, in order to fill the existing knowledge gaps. In this

regard, the application and possible extensions of MAUT techniques (namely AHP and ANP) to specific corporate financial problems, such as capital budgeting issues, could be an interesting line for future research. This could be particularly relevant in terms of analysing, for example, investment alternatives with relatively important non-monetary and intangible impacts (i.e., those that aim to improve the firm's reputation –such as environmental management systems–, or employee knowhow and qualifications –training programs–). In these cases, as classical techniques (NPV or IRR) do not seem capable of dealing with intangible criteria, these multi-criteria tools could be extremely useful for supporting capital budgeting decision-making.

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