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La valoración de inversiones corporativas desde la perspectiva del capital intelectual: una aproximación multicriterio

María Dolores Guerrero Baena

Córdoba, abril de 2014

TITULO: *La valoración de inversiones corporativas desde la perspectiva del capital intelectual: una aproximación multicriterio*

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La valoración de inversiones corporativas desde la perspectiva del capital intelectual: una aproximación multicriterio

Memoria de tesis doctoral presentada por

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Tesis Doctoral con Mención Internacional

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La autora de este trabajo ha sido beneficiaria de un incentivo para la *Formación de Personal Docente e Investigador Predoctoral en áreas de conocimiento consideradas deficitarias,* concedido por la Consejería de Innovación, Ciencia y Empresa de la Junta de Andalucía durante el periodo 2010-2014.

TÍTULO DE LA TESIS: La valoración de inversiones corporativas desde la perspectiva del capital intelectual: una aproximación multicriterio

DOCTORANDA: María Dolores Guerrero Baena

INFORME RAZONADO DE LOS DIRECTORES DE LA TESIS

La presente tesis doctoral propone un nuevo método de valoración de inversiones corporativas que considera, además de los clásicos criterios financieros, criterios intangibles o de capital intelectual. Esta proposición metodológica es implementada en dos casos de estudio de la industria agroalimentaria andaluza al objeto de corroborar su validez y eficacia. Los objetivos y las conclusiones alcanzadas en esta tesis contribuyen de manera significativa al avance del conocimiento en finanzas corporativas y, concretamente, en la valoración de inversiones no financieras.

Para la realización de esta tesis doctoral, la autora ha sido beneficiaria del incentivo de *Formación de Personal Docente e Investigador Predoctoral en áreas de conocimiento consideradas deficitarias* de la Consejería de Innovación, Ciencia y Empresa de la Junta de Andalucía, durante el periodo 2010-2014.

De la presente tesis se ha derivado la siguiente publicación científica:

- La valoración de inversiones productivas: Una aproximación metodológica basada en la creación de valor financiero e intelectual, *Intangible Capital*, 2013, Vol. 9, No. 4, pp. 1145-1169.

Asimismo, los resultados se han presentado en forma de comunicaciones científicas en los siguientes congresos nacionales e internacionales:

- Decomposing value creation when assessing investments: a multi-criteria approach, *22nd International Conference on Multiple Criteria Decision Making 'MCDM for Tomorrow's World'*, Universidad de Málaga, 17-21 de junio de 2013.
- La valoración de inversiones productivas en la empresa: una propuesta metodológica basada en la creación de valor, *XVII Congreso AECA 'Ética y Emprendimiento: valores para un nuevo desarrollo'*, Universidad de Navarra, 25-27 de septiembre de 2013.

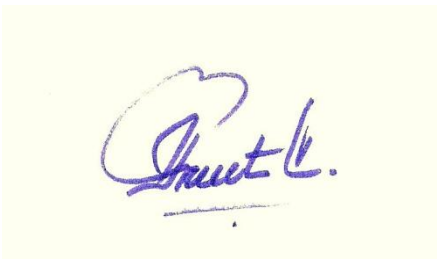
- La evaluación de proyectos de inversión productiva en la empresa: Una propuesta metodológica basada en la creación de valor, *III Congreso Científico de Investigadores en Formación de la Universidad de Córdoba,* 9-10 de abril de 2013.
- Las decisiones financieras corporativas y el paradigma multicriterio: estado de la cuestión, *XV Encuentro AECA 'Nuevos caminos para Europa: El papel de las empresas y los gobiernos'*, Ofir-Esposende (Portugal), 20 y 21 de septiembre de 2012.
- Las decisiones financieras corporativas y el paradigma multicriterio: estado de la cuestión, *XXVI Congreso Internacional de Economía Aplicada –ASEPELT– 'El efecto de la crisis y el futuro de la sociedad del bienestar'*, Madrid, 4-7 de julio de 2012.
- El estado del arte del uso de técnicas de decisión multicriterio en finanzas corporativas, *II Congreso Científico de Investigadores en Formación de la Universidad de Córdoba,* 8-9 de mayo de 2012.

La autora de la presente tesis doctoral ha realizado una estancia de investigación en *Keele University* (Reino Unido) de 3 meses de duración y ha completado su formación investigadora con el curso *EURO PhD School on Multicriteria Decision Making with Mathematical Programming*, de 3 créditos ECTS, en la Universidad Complutense de Madrid.

Por todo ello, se autoriza la presentación de esta tesis doctoral.

Córdoba, 28 de abril de 2014

Firma de los directores



Fdo.: Prof. Dr. José A. Gómez-Limón Fdo.: Prof. Dr. J. Vicente Fruet Cardozo

‘El entusiasmo que produce el descubrimiento de los hallazgos que han hecho otros y que nos llegan a través del estudio desemboca en la curiosidad creciente por conocer más. La deslumbrante revelación del conocimiento es el punto de partida para cualquier actividad intelectual. El mundo de los libros, la pasión por la lectura, suponen un estímulo decisivo que acelera la constante evolución, el creciente interés por lo desconocido, el cauce para dar forma y sentido no sólo a la función intelectual sino también a la sensibilidad y a la capacidad de acercamiento solidario hacia el resto de los seres humanos’.

Josefina Aldecoa

A mi familia, mi luz, mi vida.

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RESUMEN

El aumento de la complejidad en la definición y posterior adopción de estrategias corporativas, especialmente las relativas a las decisiones de inversión, es uno de los elementos más significativos derivados del escenario económico internacional en el que operan en la actualidad las empresas. Una serie de factores concretos explican esta circunstancia, tales como la intensificación de los problemas de agencia, el carácter multidimensional del factor riesgo, o la naturaleza intangible de buena parte de los beneficios que generan las inversiones de carácter estratégico adoptadas en el marco de la denominada *economía del conocimiento*. Todos estos factores de complejidad están condicionando la correcta y eficiente asignación de recursos en la empresa y los procesos de decisión que la modelan. Las técnicas financieras clásicas, que abordan la resolución de dichos procesos desde la perspectiva de la optimización de los atributos rentabilidad y riesgo, son en la actualidad criticadas por no considerar determinados beneficios intangibles que se derivan de los proyectos de inversión.

El objetivo general de esta tesis doctoral es desarrollar un nuevo enfoque teórico de valoración de inversiones no financieras fundamentado en el constructo ampliamente aceptado de *creación de valor de mercado* entendido desde una perspectiva integral y completa. Este enfoque implica una redefinición del término creación de valor, incorporando a la generación de valor financiero la creación de valor no financiero o de capital intelectual, a la vista del decisivo protagonismo de los intangibles como fuente de valor y de ventaja competitiva sostenible.

El enfoque teórico de valoración propuesto se articula a través de dos métodos de análisis multicriterio: el proceso analítico jerárquico y el proceso analítico en red. Ambos permiten integrar en el estudio tanto los criterios que inciden en la creación de valor financiero, como aquellos que contribuyen a la creación de valor no financiero o de capital intelectual. Esta integración permite que los dos modelos de valoración que aquí se proponen cuantifiquen el valor total que genera cada alternativa de inversión, con el fin de ayudar a los directivos en sus procesos de decisión corporativos.

La metodología propuesta se implementa en dos casos de estudio de la industria agroalimentaria andaluza. El primero consiste en la valoración de tres alternativas de sistemas de gestión de la calidad en el sector cárnico y, en el segundo caso, se evalúan las posibles alternativas de sistemas de gestión ambiental en la industria almazarera.

Los resultados de la implementación empírica, además de validar los modelos, han evidenciado la conveniencia de considerar los impactos de las inversiones sobre los activos intangibles de la empresa, pues estos determinan en el mundo real la selección de la alternativa de inversión óptima. Los dos métodos de valoración propuestos implican la formalización del proceso de valoración de inversiones no financieras que actualmente siguen los directivos en las empresas.

ABSTRACT

Increasing complexity in terms of defining and subsequently adopting corporate strategies, especially those relating to investment decisions, is one of the most significant issues emerging from the international economic environment in which businesses operate today. A number of specific factors play a part in this situation, such as the intensification of agency problems , the multidimensional nature of the risk factor, or the intangible nature of many of the benefits generated by strategic investments within the so-called 'knowledge economy'. All these factors of complexity affect the appropriate and efficient allocation of company resources and the decision-making processes that determine them. Classical financial techniques that seek to address these processes from the perspective of optimizing risk and return attributes are now criticized because this kind of analysis ignore several key intangible issues also involved in investment projects.

The overall objective of this thesis is to develop a new theoretical approach to evaluating nonfinancial investments, based on the widely-accepted concept of 'creating market value', understood from a holistic, comprehensive perspective. This approach requires a redefinition of the term 'value creation' to incorporate the creation of nonfinancial value or intellectual capital alongside the concept of financial value creation. This reflects the decisive role of intangible benefits as a source of value and sustainable competitive advantage.

The proposed theoretical valuation approach is applied via two multicriteria methods: the analytic hierarchy process and the analytic network process. These allow the inclusion in the analysis of both the criteria that influence the creation of financial value as well as those that contribute to the creation of nonfinancial value or intellectual capital. This integration allows the two proposed valuation models to quantify the total value generated by each investment alternative in order to assist decision-makers in corporate decision processes.

The proposed methodology is implemented in two case studies of the Andalusian food industry. The first concerns the evaluation of three alternative systems of quality management in the meat sector, and the second case evaluates possible alternatives for environmental management systems in the olive oil industry.

The results of the empirical implementation, as well as validating the models, demonstrate the merits of considering the impact of investments on an organization's intangible assets, as these influence the selection of the optimal investment alternative in the real world. The two proposed methods of assessment involve formalizing the current process of evaluating nonfinancial investments carried out by a company's decision makers.

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Capítulo 1

Introducción

1.1 ANTECEDENTES DE LA INVESTIGACIÓN

El proceso de globalización comercial y financiera, acelerado notablemente desde la última década del siglo XX, está produciendo una importante reconfiguración del escenario económico internacional en el que operan las empresas (Parker, 2005). Factores como la libre circulación de capitales, bienes y servicios, con la consiguiente intensificación de la presión competitiva; el actual sistema financiero –cada vez más regulado desde instancias internacionales–; la aceleración del cambio tecnológico en la actual *economía del conocimiento* (Nonaka y Takeuchi, 1995; Nonaka et al., 2000) o las dinámicas demandas de los consumidores –asociadas a la elevada variabilidad de sus gustos y preferencias–, están perfilando una nueva realidad e incidiendo en el aumento de la *incertidumbre e inestabilidad* de las empresas en los mercados.

En este contexto, no es de extrañar que se haya acentuado la complejidad en la definición e implementación de estrategias corporativas encaminadas, por un lado, a conseguir la adaptación de las organizaciones a las nuevas directrices

del mercado y, por otro lado, a avanzar en competitividad y eficiencia con el fin de conseguir ventajas competitivas sostenibles. En la actualidad, el diseño y operatividad de tales estrategias se fundamentan, principalmente, en el desarrollo de los propios recursos internos y capacidades clave de las organizaciones (Barney y Clark, 2007), más que en la búsqueda de rentabilidades en factores del entorno, en consonancia con *la teoría de los recursos y capacidades* (Barney, 1991; Peteraf, 1993).

Especialmente compleja es, además, la definición de las estrategias funcionales relativas a las *decisiones de inversión y financiación corporativas*. Son variadas las razones que lo explican:

i. La intensificación de los *problemas relacionados con la teoría de la agencia* (Jensen y Meckling, 1976; Shapiro, 2005; Dalton et al., 2007) derivados del conflicto de intereses y de los distintos objetivos de propietarios –que desean la maximización del valor de la empresa a largo plazo– y directivos[1], de quienes se dice que adolecen de la denominada *miopía directiva*, por su preferencia por la maximización del beneficio a corto plazo. Estos problemas y sus asociados *costes de agencia* están aumentando como consecuencia de la progresiva separación entre propiedad y control, y están incidiendo en la correcta y eficiente asignación de recursos en la empresa (Cuervo, 2004).

ii. La incidencia de *múltiples y diversos factores de riesgo*, además del financiero, como pueden ser el riesgo político o regulatorio, el riesgo medioambiental, el riesgo reputacional o el riesgo de obsolescencia tecnológica, y su necesaria inclusión en los procesos de decisión corporativos (Reuvid, 2010).

iii. La incertidumbre acerca de la ocurrencia de los eventos asociados a la *teoría del cisne negro* (Taleb, 2007). Esta corriente postula que, determinados acontecimientos con escasa probabilidad de ocurrencia, tales como los conflictos políticos o naturales –metafóricamente serían

[1] Aunque se han identificado en la literatura tres orígenes de los problemas de agencia –los que se producen entre directivos y accionistas, los derivados de la relación entre acreedores y accionistas y los que tienen lugar entre los accionistas mayoritarios y los minoritarios–, sólo nos referimos aquí a los primeros por considerar que son los que influyen, en mayor medida, en la toma de decisiones financieras en la empresa.

los *cisnes negros*– pueden tener un impacto significativo y no previsto en los procesos decisionales.

iv. La *limitación de los recursos financieros* disponibles, agravada desde el inicio de la actual crisis económica, y que está afectando de manera particular a la efectividad de los proyectos de inversión en las pequeñas y medianas empresas (Ferrando, 2012).

v. La tendencia, cada vez mayor, a adoptar *nuevas tecnologías y procesos de I+D* apoyados, en gran medida, en recursos y activos intangibles o de conocimiento (Brealey et al., 2011). Dada su naturaleza estratégica –se caracterizan por proyectarse en un horizonte temporal de largo o muy largo plazo y por tener efectos e impactos no monetarios— son difíciles de valorar y, por lo tanto, la toma de decisiones relativa a su adopción e implementación requiere de un mayor esfuerzo que si se tratara de activos fijos comunes.

vi. La nueva concepción de empresa en el actual enfoque pluralista de la *teoría de los stakeholders* (Freeman, 1984; Donaldson y Preston, 1995; Post et al., 2002), que postula que la empresa ha de crear riqueza para todos sus partícipes o grupos de interés[2], y no sólo para sus accionistas. Además de la maximización de la rentabilidad y la minimización del riesgo, la organización debe satisfacer, en mayor o menor medida, las demandas de los demás *stakeholders*, como empleados, acreedores, consumidores, proveedores u organizaciones sociales. Demandas que, en la práctica, se traducen en la concreción de objetivos corporativos (Sundin et al., 2010): mejorar la satisfacción y la motivación del capital humano, incorporar la variable medioambiental en la estrategia empresarial, fomentar la transparencia en la información y en la comunicación externas o el impulso en general, en todas sus dimensiones, de la responsabilidad social corporativa (RSC).

La teoría financiera clásica aborda la resolución de los procesos de decisión financieros –de inversión y financiación– desde la perspectiva de la optimización, bien maximizando una función de rentabilidad como único objetivo o, bien, optimizando funciones objetivo bi-atributo. En este segundo

[2] Freeman (1984) define *stakeholder* o grupo de interés de una empresa como 'cualquier grupo que puede afectar o ser afectado por la actuación llevada a cabo por la organización a la hora de alcanzar sus objetivos'.

caso, se consideran tanto la rentabilidad –objetivo a maximizar– como el riesgo –objetivo a minimizar– en el proceso de toma de decisiones, tratando de encontrar soluciones eficientes en el correspondiente espacio bidimensional rentabilidad-riesgo. Se destacan los modelos de valoración de activos de los flujos de fondos descontados (valor actual neto, tasa interna de rentabilidad, etc.) y los de selección de carteras de Markowitz (1952). Pero esta perspectiva clásica de optimización uni y bi-objetivo se revela reducida y limitada en la resolución de los complejos procesos de decisión financieros actuales y así lo han manifestado diversos autores (Hallerbach y Spronk, 2002; Zopounidis y Doumpos, 2002; Steuer y Na, 2003). Sus procedimientos y metodologías no permiten considerar la verdadera multiplicidad de objetivos –derivados de los distintos intereses de directivos y propietarios o los que se plantean si se consideran las demandas de los *stakeholders*–; ni introducir en el análisis la incidencia de los diversos factores de riesgo, además del financiero, que pueden afectar a la buena marcha de los proyectos; y, menos aún, evaluar tecnologías y procesos de carácter estratégico, ya que las técnicas de valoración clásicas no permiten la introducción de criterios intangibles o no financieros (Abdel-Kader y Dugdale, 2001). Todas estas circunstancias limitan los análisis basados únicamente en los flujos monetarios derivados del proyecto de inversión, aunque su aplicación sigue siendo ampliamente generalizada.

Paralelamente al aumento del dinamismo del entorno competitivo y de la complejidad de los procesos financieros de las empresas se ha ido desarrollando, desde la década de los setenta, la *teoría de decisión multicriterio* (multicriteria decision making o, por sus siglas en inglés, MCDM), con base en las ideas iniciales de la *teoría de la racionalidad limitada* y de la *teoría de la satisfacción* de Simon (1957). El axioma básico de este paradigma es que, efectivamente, los centros decisores reales –empresas, gobiernos, consumidores, etc.– toman sus decisiones en base a varios criterios y no en base a uno sólo (Romero, 1993). Desde este axioma básico, el paradigma multicriterio ofrece un extenso y variado conjunto de modelos de decisión, como la *programación multiobjetivo*, la *teoría de la utilidad multiatributo* o los *métodos de sobreclasificación*. Estos modelos configuran un enfoque más realista, permitiendo la consideración de múltiples criterios –de carácter tanto cuantitativo como intangible o cualitativo– en los problemas de decisión. Es, precisamente, el interés por examinar la potencialidad y el atractivo de esta metodología en la resolución de los complejos procesos de decisión financieros lo que marca la

definición del objetivo preliminar de esta investigación, tal y como a continuación se detalla.

1.2 OBJETIVOS DE LA INVESTIGACIÓN

Los objetivos que se pretenden alcanzar en esta tesis doctoral se han diseñado de manera *sistemática* y *estructurada*, siguiendo una secuencia descendente, quedando organizados en torno a las siguientes categorías: *objetivo preliminar*, *objetivo general* y *objetivos específicos u operativos*. Esto significa que el objetivo preliminar, una vez alcanzado, ha permitido orientar la definición del objetivo general y, éste, a su vez, ha posibilitado enfocar la concreción de los objetivos específicos u operativos.

El *objetivo preliminar* de esta tesis consiste en analizar de manera crítica la *investigación científica internacional centrada en el estudio del desarrollo y/o aplicación de las metodologías multicriterio, como alternativas a las técnicas financieras clásicas, en los procesos de decisión de las finanzas corporativas.* Este primer objetivo de revisión de la literatura se aborda desde una *perspectiva bibliométrica*, esto es, realizando un estudio cuantitativo de la producción científica mediante el análisis de un conjunto de indicadores y apoyado en un análisis estadístico. De esta manera, se exploran las tendencias y los patrones estructurales de la disciplina a nivel general, examinándose los siguientes ítems a nivel particular: i) la evolución temporal de las publicaciones científicas en la materia; ii) los problemas de decisión de las finanzas corporativas que se han abordado adecuadamente desde el paradigma multicriterio; iii) las técnicas multicriterio concretas que se han empleado para resolver los problemas anteriores; iv) las principales revistas que publican los trabajos, así como las áreas temáticas a las cuales pertenecen[3]; v) los principales polos geográficos de investigación, atendiendo al origen de los autores.

Como se ha apuntado al comienzo de este epígrafe, el diseño de los objetivos se ha realizado siguiendo una secuencia descendente. En este sentido, la consecución del objetivo preliminar es de suma importancia, ya que las

[3] Aunque pueda parecer este un asunto baladí, conocer las áreas temáticas de las revistas donde se publican los trabajos puede guiarnos a comprender el grado de visibilidad, conocimiento y de aceptación de esta metodología por parte de los profesionales y consultores de empresas.

conclusiones derivadas de su logro marcan la pauta de direccionalidad en la definición del resto de objetivos y, más directamente, del objetivo general.

Así, el *objetivo general* consiste en desarrollar un *nuevo enfoque teórico de valoración de inversiones no financieras,* basado en el concepto ampliamente aceptado de *creación de valor de mercado,* entendiéndolo desde una perspectiva integral y completa, esto es, considerando tanto la creación de *valor financiero* como la creación de *valor no financiero o de capital intelectual*. La concreción de este objetivo se justifica, en primer lugar, en el interés por examinar los factores explicativos de la extensa implementación de la metodología multicriterio en la evaluación y selección de inversiones no financieras y de naturaleza estratégica, como medio para considerar criterios de carácter cualitativo. Y, en segundo lugar, en el intento por ofrecer un enfoque teórico financiero de valoración en el que apoyar lo anterior, dado que esos criterios cualitativos son, en muchas ocasiones, fuente de creación de valor corporativo.

El enfoque teórico propuesto de valoración de inversiones no financieras y de naturaleza estratégica, que constituye el objetivo general de esta tesis, se inscribe en la línea de la teoría de la creación de valor o de la gestión basada en la creación de valor (Hawawini y Viallet, 2010). Esta contribución teórica se instrumentará a través de dos técnicas multicriterio con una fuerte potencialidad de aplicación práctica y, ampliamente conocidas en disciplinas como la investigación operativa: el proceso analítico jerárquico –AHP– y el proceso analítico en red –ANP–. Asimismo, es necesario comentar que este objetivo general no es únicamente de carácter metodológico sino que, por el contrario, pretende igualmente contrastar empíricamente las técnicas de análisis desarrolladas, implementándolas de manera piloto en un conjunto de empresas de la industria agroalimentaria andaluza, al objeto de testar su eficacia y validez.

De esta manera, siguiendo con la estructuración de objetivos antes apuntada, se introducen los siguientes *objetivos específicos u operativos*:

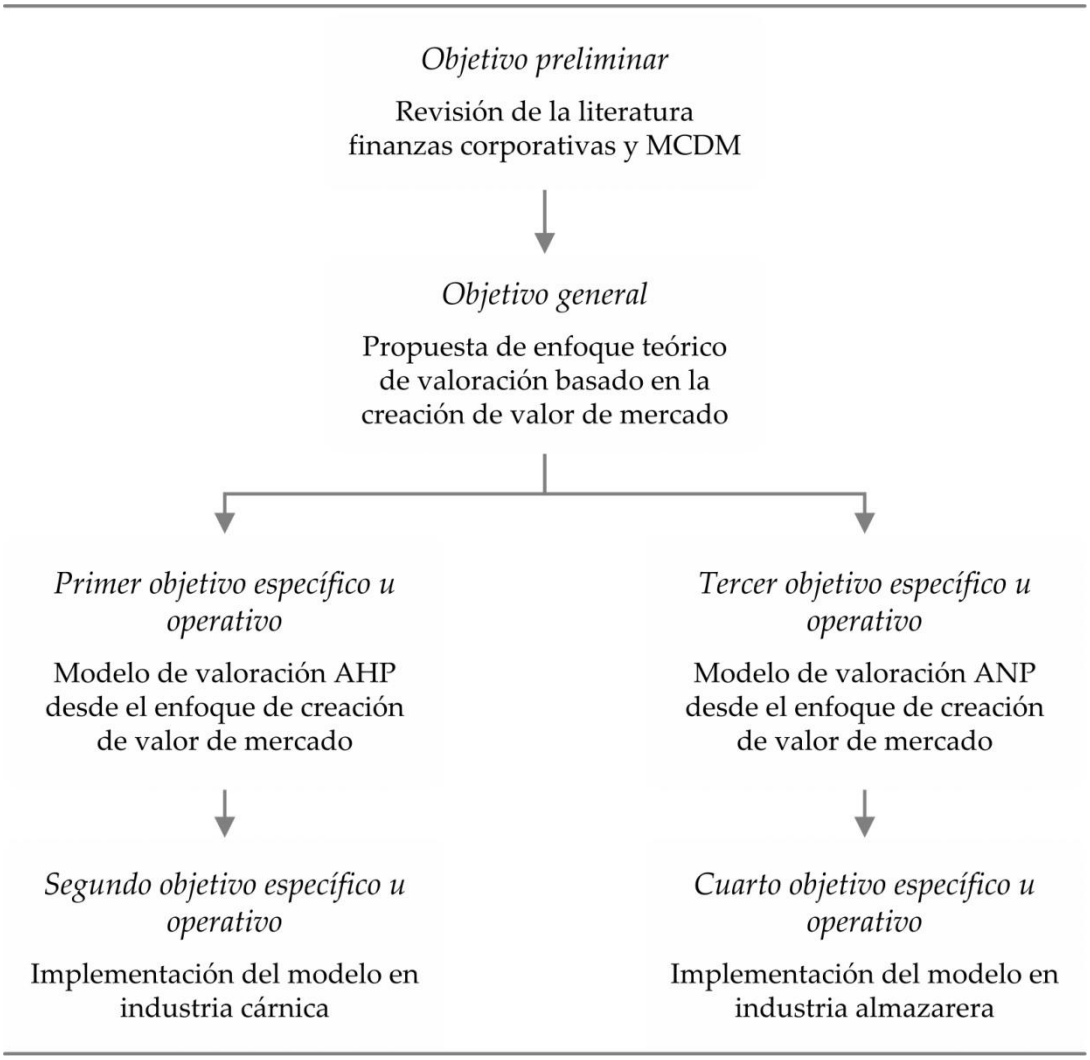
- *Primer objetivo específico u operativo:* desarrollar un *primer modelo de valoración de inversiones* a partir del enfoque teórico de *creación de valor de mercado* basado en la técnica multicriterio del *proceso analítico jerárquico* (*AHP*). Este modelo permitirá determinar el valor total generado con el proyecto de inversión, tanto el componente de valor financiero como el

componente de valor no financiero o de capital intelectual, cuantificándose ambos a través de un conjunto de criterios y subcriterios.

- *Segundo objetivo específico u operativo:* implementar el anterior modelo de valoración, al objeto de validarlo empíricamente, en un *grupo de empresas del sector industrial cárnico* interesadas en evaluar y priorizar varias alternativas de inversión para sus sistemas de control de la calidad.
- *Tercer objetivo específico u operativo*: desarrollar un *segundo modelo de valoración* desde el enfoque teórico propuesto de *creación de valor,* al igual que en el caso anterior. La particularidad de este modelo es que integrará los criterios que conforman los componentes de valor financiero y de capital intelectual desde una *perspectiva dinámica*, esto es, teniendo en cuenta las relaciones intrínsecas entre los distintos elementos, utilizando para ello la técnica multicriterio del *proceso analítico en red* (ANP).
- *Cuarto objetivo específico u operativo*: implementar el segundo modelo de valoración, al objeto de validarlo, en la evaluación y selección de las alternativas de sistemas de gestión ambiental (SGA) en un conjunto de almazaras olivareras de las provincias de Córdoba y Jaén.

La Figura 1.1 recoge de manera gráfica la definición y estructuración de los objetivos propuestos para la realización de esta tesis doctoral.

Figura 1.1 Estructura y diseño de los objetivos



Fuente: Elaboración propia.

1.3 ESTRUCTURA DE LA TESIS

Para alcanzar los objetivos planteados en esta investigación, se ha estructurado la tesis en seis capítulos. Tras este *primer capítulo* de *introducción*, el *Capítulo 2* presenta el *marco teórico* que da sustento a la investigación, mientras que en el *Capítulo 3* se aborda la *revisión de la literatura* concerniente al desarrollo y/o aplicación de herramientas multicriterio en la resolución de los procesos de decisión de las finanzas corporativas.

El *Capítulo 4* desarrolla el primer *modelo propuesto para la valoración de inversiones no financieras*, basado en la técnica multicriterio del *proceso analítico jerárquico*, y fundamentado en la idea de la estimación del *valor total de mercado* generado con cada proyecto de inversión, así como su implementación práctica a un caso de

estudio consistente en la selección óptima del sistema de control de la calidad en un conjunto de empresas del sector cárnico.

En el *Capítulo 5* se presenta el segundo *modelo propuesto de valoración de inversiones no financieras*, basado en la técnica multicriterio del *proceso analítico en red*, y fundamentado, al igual que en el primer modelo, en el enfoque de la creación total de valor de mercado. Asimismo, se valida este segundo modelo de valoración mediante su aplicación a un conjunto de almazaras andaluzas al objeto de seleccionar la mejor alternativa para sus sistemas de gestión ambiental.

Finalmente, el *Capítulo 6* presenta las *conclusiones* alcanzadas por la investigación, las limitaciones encontradas y las *futuras líneas de investigación* que se pueden derivar de este trabajo.

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Capítulo 2

Marco teórico

El presente capítulo sintetiza la posición de las diferentes corrientes teóricas que dan sustento a la investigación, enfatizando el estudio en la teoría de la decisión multicriterio y en el capital intelectual de las empresas, por ser los paradigmas de mayor protagonismo de esta tesis.

En un primer bloque, se analiza el origen de la *decisión multicriterio*, se aportan definiciones de los conceptos más empleados y se aborda una revisión de todos los métodos de ayuda a la decisión multicriterio desarrollados hasta el momento.

Las *técnicas clásicas de valoración* de proyectos de inversión, si bien son ampliamente conocidas, se exponen brevemente en un segundo apartado.

A continuación, se presentan las distintas acepciones del término *capital intelectual* y su estructura dimensional más aceptada, la que lo divide en capital humano, capital estructural y capital relacional. Asimismo, se describen las etapas en la investigación científica de este paradigma y algunos de los modelos de medición del capital intelectual más conocidos.

Para finalizar, se hace una breve reseña de la *industria agroalimentaria* en España, incidiendo en los aspectos de la calidad y la gestión ambiental, por ser los dos temas abordados en esta tesis.

2.1 LA TEORÍA DE DECISIÓN MULTICRITERIO

2.1.1 Referencias históricas de la teoría de decisión multicriterio

Las ideas de Simon (1955, 1957) constituyen la base de las primeras discusiones teóricas sobre decisión multicriterio, al cuestionar algunos planteamientos básicos de la Economía, aceptados hasta entonces sin objeción, e insistir en la necesidad de modelar de manera más realista el modo de proceder de los decisores. Este autor, Premio Nobel de Economía en 1978, postuló que la hipótesis económica de la *optimización* no es realista, ya que las empresas y resto de agentes económicos no actúan guiadas por la maximización de una determinada función de beneficio o de utilidad de un solo objetivo. Por el contrario, Simon plantea que la toma de decisiones se basa en la consideración de *distintos criterios al mismo tiempo*, unos del tipo 'cuanto más, mejor' y, otros del tipo 'cuanto menos, mejor'. No obstante, este autor sostiene que la pretensión de las empresas, y de los agentes económicos en general, es satisfacer sus necesidades, esto es, conseguir un *nivel de satisfacción* –metas en el argot del paradigma multicriterio– en cada uno de estos criterios, en lugar de optimizarlos –maximizarlos o minimizarlos–. Este comportamiento basado en una lógica satisfaciente –en vez de optimizadora– está justificado por el contexto en que se mueven los agentes, caracterizado por una información incompleta y sesgada de la realidad, que únicamente les permite alcanzar una *racionalidad limitada*.

Por su parte, Von Neumann y Morgenstern (1944) plantean un nuevo paradigma relativo al *concepto de utilidad* proponiendo una aproximación metodológica para resolver racionalmente problemas de decisión donde intervienen diferentes criterios en conflicto. Con este propósito axiomatizaron la *teoría de la utilidad esperada*, sentando así las bases de la *teoría de la utilidad multiatributo*.

Los trabajos de Koopmans (1951), Kuhn y Tucker (1951) y Charnes et al. (1955) contribuyen, asimismo, al inicio del pensamiento multicriterio mediante sus

aportes matemáticos: Koopmans (1951) desarrolla el concepto de *vector eficiente o no dominado;* Kuhn y Tucker (1951) analizan las condiciones que garantizan la existencia de *soluciones eficientes* en un problema multiobjetivo; y el trabajo de Charnes et al. (1955) presenta los aspectos esenciales de la *programación por metas*, avanzando posteriormente en ella en Charnes y Cooper (1961).

Friedman (1962) define los *problemas económicos* como aquéllos en los que subyace la existencia de criterios múltiples, en contraposición a los *problemas tecnológicos*, establecidos en base a un solo criterio. Considera que existe un *problema económico* siempre que los recursos sean escasos y los fines o alternativas sean variadas; y, por el contrario, si los recursos son escasos, pero sólo hay un fin, la forma de utilizar los recursos es un *problema tecnológico* y no económico, ya que no intervienen juicios de valor en la solución, solamente el conocimiento y el manejo de las técnicas de medición. En ese sentido, también para Zeleny (1982), los problemas tecnológicos sólo implican problemas de medición, pero no de decisión.

El concepto de solución de la teoría de la decisión multicriterio se fundamenta en el concepto de *óptimo de Pareto*, enunciado por Wilfredo Pareto en 1896. Según este principio, se considera que una o varias soluciones son eficientes –o Pareto óptimas– si son soluciones factibles, esto es, cumplen el conjunto de restricciones, tales que no existe otra solución factible que proporcione una mejora en un atributo sin producir un empeoramiento en, al menos, otro de los atributos. Ningún atributo puede mejorar sino es a costa de que otro empeore; así se deriva el concepto de *tasa de intercambio* o *trade-off*, ampliamente extendido en la literatura económica. El conjunto eficiente de soluciones, también denominado frontera de Pareto, recoge todas las *alternativas no dominadas*. De aquí, se deriva el concepto de *alternativa dominada o no eficiente* como aquella alternativa para la que existe otra con todos los atributos mejores. Todos los enfoques multicriterio tienen como fin encontrar soluciones eficientes o Pareto óptimas.

En las décadas de los sesenta y setenta surgen los primeros modelos multicriterio, destacando la *programación por metas –goal programming–* inicialmente introducida por Charnes et al. (1955) y posteriormente desarrollada por Ijiri (1965), Lee (1972) e Ignizio (1976); y el método *ELECTRE* (Roy, 1968), fundamentado en las llamadas *relaciones de superación.*

Desde mediados de la década de los setenta, comienzan a asentarse dos escuelas de pensamiento multicriterio:

- La *escuela americana*, con autores como Saaty, Keeney, Raiffa, Yoon, Zionts o Zeleny. Sus primeras discusiones sobre la toma de decisiones multicriterio se centraron en la posibilidad de agregar las preferencias del decisor por cada uno de los criterios en una única función de las anteriores, surgiendo así la *teoría de la utilidad multiatributo* (Keeney y Raiffa, 1976). Posteriormente, en base a las funciones de utilidad, se desarrollarían modelos como el *proceso analítico jerárquico –AHP–* o el método *SMART –simple multiattribute rating technique–*.
- La *escuela europea*, donde destacan autores como Brans, Jacques-Lagrèze, Roy, Roubens, Vansnick o Vincke, ha explorado particularmente las técnicas multicriterio para la elección de alternativas dentro de un conjunto discreto sobre la base de las relaciones de superación y las preferencias del decisor. Ha propuesto los métodos denominados de *sobreclasificación ELECTRE –élimination et choix traduisant la réalité–*, la familia de métodos *PROMETHEE –préférence ranking organisation méthode for enrichment évaluations–*, y *MACBETH –the measuring by a categorical based evaluation technique–*.

Al margen de estas dos escuelas, destacan algunos investigadores europeos como Wallenius o Spronk y asiáticos –Takeda, Seo o Tabucanon, entre otros–.

Desde mediados de los ochenta se produce un fuerte desarrollo de los métodos multicriterio, tanto discretos como continuos, a lo que contribuye la introducción de la informática para resolver muchos de los problemas multicriterio operativamente complejos.

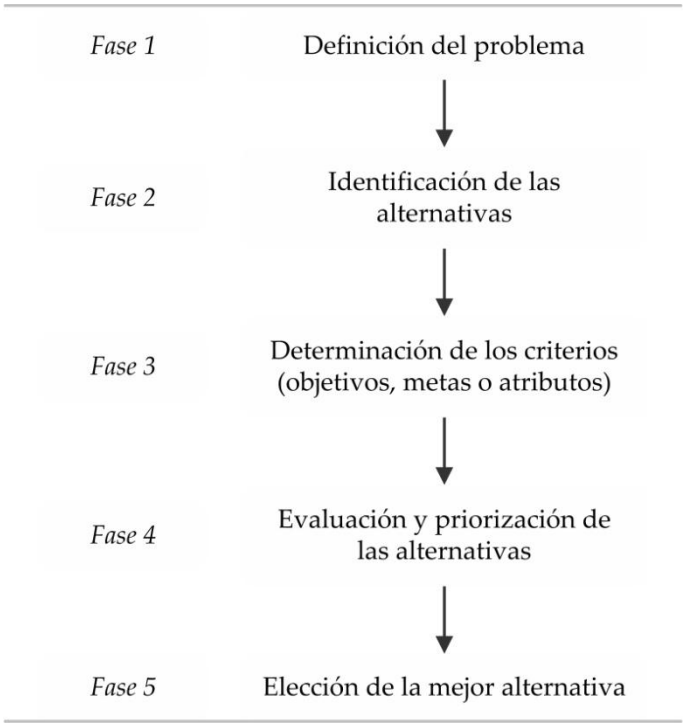
2.1.2 ¿Qué es la decisión multicriterio?

Los individuos toman decisiones cada día, ya sea en su ámbito personal o profesional; decidir implica tomar una *'determinación o resolución sobre una cosa dudosa'*[4]. Por tanto, un problema general de decisión consiste en elegir 'lo mejor' de entre todo 'lo posible', de lo que surgen dos preguntas: ¿qué es 'lo posible'? y

[4] Definición de la Real Academia Española.

¿qué es 'lo mejor'? Las fases que normalmente se siguen en un proceso de decisión son básicamente las que aparecen en la siguiente figura.

Figura 2.1 Proceso de toma de decisiones



Fuente: Elaboración propia.

Las tres primeras fases del proceso, esto es, la definición del problema, la identificación de las alternativas y la determinación de los criterios de decisión son las etapas menos complejas. La posterior evaluación de las alternativas implica, en general, el establecimiento de relaciones matemáticas en las que se describen los objetivos y las restricciones del problema, empleándose para ello alguna herramienta o técnica matemática, aunque no se puede ignorar el hecho de que, en ocasiones, la evaluación de las alternativas se aborda de forma cualitativa a través de la intuición o de la experiencia.

Si el problema de decisión se caracteriza por considerar un solo criterio, se dice que el problema es *monocriterio*, mientras que si intervienen varios criterios decisionales, estaríamos ante problemas *multicriterio*.

Así, el paradigma de la decisión multicriterio o teoría de la decisión multicriterio es definido como el conjunto de conceptos, métodos y técnicas que persiguen ayudar a los individuos o grupos a tomar decisiones que implican diferentes criterios o puntos de vista en conflicto y/o múltiples agentes interesados (Belton y Stewart, 2002).

Por su parte, Romero y Rehman (2003) definen la teoría de la decisión multicriterio como el conjunto de métodos matemáticos y de técnicas computacionales que, con un propósito explicativo, normativo o prescriptivo, tienen por objetivo evaluar un conjunto finito de alternativas –caso discreto– o un conjunto infinito de alternativas –caso continuo– considerando un número finito de criterios.

2.1.3 Conceptos básicos en decisión multicriterio

Decisor o unidad decisora

Individuo o conjunto de individuos que tienen la responsabilidad de tomar la decisión.

Criterios: objetivos, atributos y metas

Los criterios de decisión $C = \{C_1, C_2, \dots, C_n\}$ donde $C_j (j = 1, \dots, n)$ constituyen los parámetros que se utilizan para recoger las preferencias del decisor. Según Romero (1993), el término *criterio* se utiliza como un término general que engloba los tres conceptos siguientes:

- *Atributo*: término que se refiere a los valores relacionados con una realidad objetiva, es decir, las características que definen a las alternativas, y pueden medirse independientemente de los deseos del decisor. Cada uno de los atributos que interviene en el proceso de decisión se suele expresar como una función matemática $f(x)$ de las variables de decisión. Atributos serían, por ejemplo, el beneficio o el impacto ambiental.
- *Objetivo*: representa la dirección de mejora de un atributo, en sentido de maximización –cuanto más del atributo, mejor–, o en sentido de minimización –cuanto menos del atributo, mejor–. En el ejemplo anterior, se tendrían los objetivos de maximizar el beneficio y minimizar el impacto ambiental.
- *Meta*: valor que cuantifica un nivel de logro aceptable que un atributo debe esforzarse por alcanzar. Por ejemplo, una meta puede ser alcanzar, al menos, 1 millón de euros de beneficios en un año.

Pesos

Los pesos o ponderaciones son las medidas de la importancia relativa que los decisores asignan para cada criterio. Los pesos de los criterios se recogen en el

denominado *vector de pesos* $w = \{w_1, w_2, \dots, w_n\}$ siendo n el número de criterios. Existen diferentes métodos de asignación de pesos, siendo los más conocidos el método de asignación directa y el método del autovector o *eigenvector*.

Tasa de intercambio o trade-off entre criterios

La tasa de intercambio entre dos criterios significa la cantidad de logro de un criterio que debe sacrificarse para conseguir, a cambio, un incremento en otro criterio. Constituye la medida del coste de oportunidad de un criterio en términos de otro que se esté considerando.

Solución eficiente o Pareto óptima

Una solución o conjunto de soluciones es eficiente o Pareto óptima cuando no existe otra solución factible que proporcione una mejora en un atributo sin producir un empeoramiento en, al menos, otro de los atributos.

2.1.4 Métodos de decisión multicriterio

Se distinguen dos tipos de técnicas multicriterio en función del número de alternativas a considerar: i) t*écnicas multicriterio continuas*, que tratan de resolver problemas con un número infinito de alternativas posibles, destacando la programación multiobjetivo y la programación por metas; ii) t*écnicas multicriterio discretas*, orientadas a la resolución de aquellos problemas que consideran un número finito e, incluso, no muy elevado de alternativas, siendo los principales métodos la utilidad multiatributo o MAUT, las relaciones de sobreclasificación y el análisis jerárquico o AHP.

Además de la tipología general anterior existen otras clasificaciones (Figueira et al., 2005). En este trabajo, se ha adoptado la propuesta por Pardalos et al. (1995) que identifica cuatro categorías de técnicas multicriterio: 1) programación multiobjetivo y programación por metas; 2) técnicas basadas en la teoría de la utilidad multiatributo; 3) enfoque de las relaciones de sobreclasificación; y 4) métodos de desagregación de preferencias.

2.1.4.1 Programación multiobjetivo y programación por metas

Programación multiobjetivo –multiobjective programming–

La programación multiobjetivo, como extensión de la programación matemática tradicional, constituye un enfoque multicriterio de gran potencialidad cuando el contexto decisional está definido por un conjunto de objetivos a optimizar –en sentido de maximización o de minimización– que deben de satisfacer un determinado conjunto de restricciones (Romero, 1993).

Como la optimización simultánea de todos los objetivos es habitualmente imposible, la programación multiobjetivo establece el conjunto de soluciones eficientes o no dominadas en el sentido de Pareto. La formulación general del problema es como sigue:

$$Eff\ f(x) = [f_1\ (x), f_2\ (x), \dots, f_n\ (x)] \qquad [2.1]$$

sujeto a:

$$X\ \in F$$

donde:

Eff significa la búsqueda de soluciones eficientes o Pareto óptimas

$f_1\ , f_2\ , \dots , f_n$ = expresión matemática del atributo n

X = vector de variables de decisión

F = conjunto de restricciones que definen el conjunto de soluciones posibles

El propósito de la programación multiobjetivo consiste en encontrar el conjunto de *soluciones eficientes* de entre todo el conjunto de soluciones posibles. Este conjunto de soluciones eficientes está formado por todas aquellas soluciones no dominadas por ninguna otra. Tal tarea se aborda utilizando una información estrictamente técnica y matemática, sin incorporar al análisis ninguna información sobre las preferencias del decisor.

Para la obtención del conjunto eficiente, es necesario el cálculo previo de la *matriz de pagos –payoff matrix–*, que representa el grado de conflicto que hay entre los objetivos que se estén considerando. En cada fila de la matriz, aparece el valor óptimo de un objetivo sin considerar el resto –resolviendo el problema

independientemente– y los valores que resultarían para los demás objetivos con esa solución. Los valores de la diagonal principal de la matriz reciben el nombre de *punto ideal*, es decir, la solución en la que todos los objetivos alcanzan su valor óptimo. El peor elemento de cada columna de la matriz se denomina *punto anti-ideal*.

En Goicoechea et al. (1982) se expone una descripción detallada de la programación multiobjetivo, así como en Miettinen (1999).

Una variante de la programación multiobjetivo es la *programación compromiso* (Zeleny, 1973). Su fundamento básico consiste en considerar el punto ideal como punto de referencia para el centro decisor, de modo que el comportamiento más racional será elegir aquel punto eficiente que se encuentre más próximo al punto ideal. Para medir la proximidad de las soluciones eficientes al punto ideal se utiliza la medida de la *distancia generalizada*.

Programación por metas –goal programming–

Existen criterios del tipo 'cuanto más, mejor' o 'cuanto menos, mejor' en los cuales no es posible obtener un óptimo en su aplicación concreta, por tanto en estos casos lo que se pretende es alcanzar una meta que se fija como satisfaciente. Esta es la idea básica de la programación por metas, fundamentada en el supuesto de racionalidad limitada de Simon (1957) e inicialmente propuesta por Charnes y Cooper (1961).

La programación por metas implica asumir que el centro decisor, en lugar de maximizar o minimizar una determinada función objetivo, intenta que unos *niveles de aspiración* fijados de antemano se aproximen lo más posible a una serie de *metas*. Esta asunción es consecuencia de la complejidad de muchos de los problemas de decisión que impide el logro de 'la mejor' alternativa.

El procedimiento de resolución de un problema mediante la programación por metas pasa por las siguientes fases: i) fijación de los atributos relevantes para el problema; ii) determinación del nivel de aspiración correspondiente a cada atributo; iii) introducción de las variables de desviación negativa y positiva, con el fin de relacionar cada atributo con cada nivel de aspiración; y iv) minimización de dichas variables de desviación, al objeto de encontrar la alternativa satisfaciente. Según el proceso de minimización adoptado se origina una de las posibles variantes de la programación por metas (Romero, 2001):

programación por metas ponderadas, programación por metas lexicográficas, programación por metas MINIMAX o programación multimetas. A continuación se expresa el modelo general de la programación por metas ponderadas –variante más utilizada–.

$$Min \sum_{i=1}^{q} (a_i n_i + b_i p_i) \qquad [2.2]$$

sujeto a:

$$f_i(x) + n_i - p_i = t_i \;\; i \in \{1, \dots, q\}$$

$$x \in F$$

$$n, p \geq 0$$

donde:

F = región factible

$f_i(x)$ = función del objetivo i

t_i = valor de la meta para el objetivo i

n_i, p_i = variables de desviación negativa y positiva

a_i, b_i = pesos de importancia relativa

2.1.4.2 Teoría de la utilidad multiatributo –multiattribute utility theory, MAUT–

MAUT se fundamenta en la idea de la existencia de una función de utilidad asociada a cada uno de los atributos que se consideran en el problema de decisión. El objetivo es conseguir una medida de la utilidad total de cada una de las alternativas mediante la composición de las n funciones de utilidad correspondientes a los n atributos (Keeney y Raiffa, 1976; Winterfeldt y Edwards, 1986; Yoon y Hwang, 1995).

La función de utilidad $U(x)$ de una alternativa x es de naturaleza no lineal, de tal modo que:

$$U(a_j) \succ U(a_k) \leftrightarrow a_j \succ a_k \quad (a_j \text{ es preferida a } a_k)$$

$$U(a_j) = U(a_k) \leftrightarrow a_j \sim a_k \quad (a_j \text{ es indiferente a } a_k)$$

En primer lugar, el decisor tiene que encontrar la función de utilidad $U(f_i(a))$ y, después, maximizarla:

$$\max U\big(f_i(a)\big)$$

Las formas más comunes de la función de utilidad son la *aditiva* o la *multiplicativa*. La forma aditiva sólo es posible bajo la condición de *independencia de preferencias*: se dice que el par de atributos a_1 y a_2 es preferencialmente independiente del atributo a_3 si el trade-off o tasa de intercambio entre a_1 y a_2 no se ve afectada por el nivel alcanzado por a_3. La expresión matemática de la función de utilidad aditiva es la siguiente:

$$U(a_i) = w_1u_1(a_1) + \ \ldots + w_nu_n(a_n) = \sum_{i=1}^{n} w_iu_i(a_i) \qquad [2.3]$$

Y la de la función de utilidad multiplicativa es como sigue:

$$U(a_i) = \prod_{i=1}^{n}[1 + w_iU_i(a_i)] \qquad [2.4]$$

donde:

$u_i(a_i)$ define la utilidad de la alternativa ith para el criterio a_i

w_1, w_2, w_n representan los pesos de los criterios

El proceso analítico jerárquico (AHP) es un caso particular de la teoría de la utilidad multiatributo, propuesto por Saaty (1980). AHP estructura el problema de decisión construyendo una jerarquía con varios niveles. Se fundamenta en la idea de trasladar las preferencias del decisor –sus juicios de valor– a una escala de razón que refleja las prioridades relativas de los elementos del problema –criterios, subcriterios y alternativas–. En el Capítulo 4 se describe más detalladamente esta técnica de decisión.

El método del proceso analítico en red o ANP (Saaty, 1996; 2001) es una generalización de AHP. Representa el problema de decisión como una red de elementos agrupados en componentes o clusters considerando las posibles interdependencias entre los elementos. Es una técnica más adecuada para resolver problemas de decisión muy complejos. En el Capítulo 5 se expone esta técnica en profundidad.

2.1.4.3 *Enfoque de relaciones de sobreclasificación –outranking relations approach–*

Las técnicas basadas en el *enfoque de las relaciones de sobreclasificación* persiguen reducir el tamaño del conjunto de soluciones eficientes dividiéndolo en dos grupos de alternativas: aquellas que son más favorables al decisor y las que son menos favorables.

Se dice que la alternativa E_i *sobreclasifica –outranks–* a otra alternativa E_j cuando para los atributos considerados, la alternativa E_i es al menos tan buena como la alternativa E_j. La sobreclasificación se establece en base a dos conceptos: concordancia y discordancia. La *concordancia* cuantifica hasta qué punto para un elevado número de atributos E_i es preferida a E_j; la *discordancia* cuantifica hasta qué punto no existe ningún atributo para el que E_j es mucho mejor que E_i.

En este grupo de técnicas destacan ELECTRE *–élimination et choix traduisant la réalité–* y PROMETHEE *–préférence ranking organisation méthode for enrichment évaluations–*.

El método ELECTRE (Roy, 1971) constituye una herramienta muy sencilla para realizar una preselección de grupos amplios de alternativas mediante la formación de un grafo para cada atributo. Cada uno de los vértices del grafo representa una alternativa no dominada o eficiente y los arcos se definen de acuerdo a la relación de preferencia observada en cada atributo. A partir de este grafo, se crea un subgrafo formado por las alternativas más favorables, eliminando del análisis las menos favorables. Las relaciones de sobreclasificación se apoyan en el cálculo de los índices de concordancia y de discordancia. La técnica inicial ha evolucionado de tal manera que han surgido algunas variantes: ELECTRE I, ELECTRE II, ELECTRE III, ELECTRE TRI.

En el método PROMETHEE (Brans et al., 1986) se trata de establecer, mediante la evaluación en función del conjunto de criterios, una ordenación jerarquizada en el conjunto de alternativas. La principal idea que subyace es el enriquecimiento de la estructura de preferencias, esto es, el enriquecimiento de la relación de dominio existente entre las distintas alternativas.

Una descripción detallada de estos métodos se puede consultar en Bana e Costa (1990), Vincke (1992) o Roy y Bouyssou (1993).

2.1.4.4 Enfoque de la desagregación de preferencias

La filosofía de este enfoque se basa en inferir modelos de preferencias en base a los juicios de valor reales del decisor usando funciones de utilidad a través de técnicas de regresión (Jacquet-Lagrèze and Siskos, 2001). Los métodos UTA y UTADIS son los más conocidos.

2.2 LA VALORACIÓN DE PROYECTOS DE INVERSIÓN

El análisis de los proyectos de inversión tiene como objetivo encontrar aquel que *maximice el valor de la empresa en el mercado* de entre un conjunto más o menos amplio de alternativas (Ross et al., 2007).

Tradicionalmente las empresas no han utilizado ninguna técnica específica para evaluar y seleccionar sus proyectos de inversión (Moore y Baker, 1969), sino que este proceso se realizaba de manera subjetiva y cualitativa, basándose en la intuición. Es a mediados del siglo pasado cuando los gestores comenzaron a tomar sus decisiones basándose en modelos matemáticos sencillos (Baker y Freeland, 1975), principalmente de análisis de costes o de beneficios.

Los métodos que más se utilizan en la actualidad, según Graham y Harvey (2001) son los siguientes: la *tasa interna de rentabilidad* y el *valor actual neto*, técnicas que consideran el valor del dinero en el tiempo; y la *tasa de rendimiento requerida* y el *plazo de recuperación*, más sencillas que las anteriores pues no tienen en cuenta el valor del dinero en el tiempo. Estos métodos y algunos más se repasan brevemente en este apartado.

2.2.1 Valor actual neto (VAN)

Es una técnica de las consideradas dinámicas, esto es, tiene en cuenta el valor del dinero en el tiempo. Se define como el valor actualizado de la corriente de los flujos de caja que el proyecto de inversión se prevé genere a lo largo de su vida útil. Si el $VAN > 0$, la realización de la inversión resulta atractiva[5], pues significa que en el año 0 la suma de todos los flujos de caja actualizados supera

[5] Si bien este criterio resulta válido tanto para las empresas del sector privado como del sector público, en la práctica estas últimas emplean otros parámetros de decisión diferentes, como el empleo generado con el proyecto de inversión.

la cuantía del desembolso inicial. En otras palabras, la inversión crea más valor para la empresa.

La formulación matemática de esta técnica de valoración es la siguiente:

$$VAN = -A + \sum_{i=1}^{n} \frac{Q_i}{(1+r)^i} \qquad [2.5]$$

donde:

A = desembolso inicial
Q_i = flujo de caja en el año i
r = tipo de descuento

2.2.2 Tasa interna de rentabilidad (TIR)

La TIR es una medida de la rentabilidad relativa de un proyecto de inversión. Es la tasa de descuento para la cual un proyecto de inversión tiene un VAN igual a cero. De la siguiente ecuación se despejaría r y esa sería la TIR.

$$-A + \frac{Q_1}{(1+r)} + \frac{Q_2}{(1+r)^2} + \cdots + \frac{Q_n}{(1+r)^n} = 0 \qquad [2.6]$$

donde:

A = desembolso inicial
Q_i = flujo de caja en el año i
r = tipo de descuento que sería la TIR

Según este criterio, la inversión resultará atractiva –crea valor para la empresa– siempre que el valor de la TIR sea mayor que la tasa de descuento más apropiada para descontar dicha inversión, en la medida que esto implica necesariamente un VAN de la inversión positivo.

Esta técnica adolece de una debilidad a considerar: en algunos proyectos de inversión no existe una sola TIR sino varias, tantas como cambios de signo tenga el flujo de efectivo. En estas situaciones, no sería congruente emplear esta técnica de decisión.

2.2.3 Plazo de recuperación de la inversión simple o *payback*

Se define como el tiempo en el que se tarda en recuperar el desembolso inicial de una inversión. Además del inconveniente de ser un método estático –no tiene en cuenta el valor del dinero en el tiempo–, no considera todos los flujos de caja del proyecto, sino sólo aquellos que se encuadren dentro del plazo de recuperación. Atendiendo a esta técnica, se preferirán los proyectos de inversión con un plazo de recuperación inferior, independientemente de los beneficios que genere la inversión a largo plazo.

2.2.4 Plazo de recuperación descontado

Técnica similar al plazo de recuperación de la inversión simple o *payback* pero, en este caso, sí se considera el vencimiento de los flujos de caja de la inversión, empleando como tasa de actualización el coste de oportunidad del capital.

2.2.5 Otros métodos

2.2.5.1 Índice de rentabilidad (IR)

Esta técnica consiste en dividir el valor actual de los flujos de caja por el desembolso inicial de la inversión. La formulación es la siguiente:

$$IR = \frac{1}{A}\left(\frac{Q_1}{(1+r)} + \frac{Q_2}{(1+r)^2} + \cdots + \frac{Q_n}{(1+r)^n}\right) = \frac{VA}{A} \qquad [2.7]$$

donde:

A = desembolso inicial
Q_i = flujo de caja en el año i
r = tipo de descuento
VA = valor actual de los flujos de caja

Si $IR > 1$, significa que el valor actualizado de los flujos de caja es superior al desembolso inicial, indicando que la inversión es atractiva. Así, se preferirán los proyectos con un índice de rentabilidad o IR superior.

2.2.5.2 *Ratio beneficio-coste (BCR)*

Con esta técnica se compara el valor actual de los ingresos del proyecto frente al valor actual de los costes. Aunque su nombre es ratio beneficio-coste, en realidad se comparan los ingresos y los gastos.

$$BCR_i = \frac{VAI_i}{VAC_i} \qquad [2.8]$$

donde:

VAI = valor actual de los ingresos
VAC = valor actual de los costes

Si este ratio es superior a 1, esto indica que el valor actual de los ingresos es superior al valor actual de los costes, con el cual el proyecto generará valor a la empresa.

Como complemento a las técnicas anteriores, el análisis de sensibilidad estudia cuál es el valor del VAN, de la TIR, o de cualquier otra técnica al variar cada una de las variables del proyecto, dejando constantes las demás. Este análisis permite conocer qué variables son las más importantes en su influencia en el valor esperado de la inversión.

2.3 EL CAPITAL INTELECTUAL DE LA EMPRESA

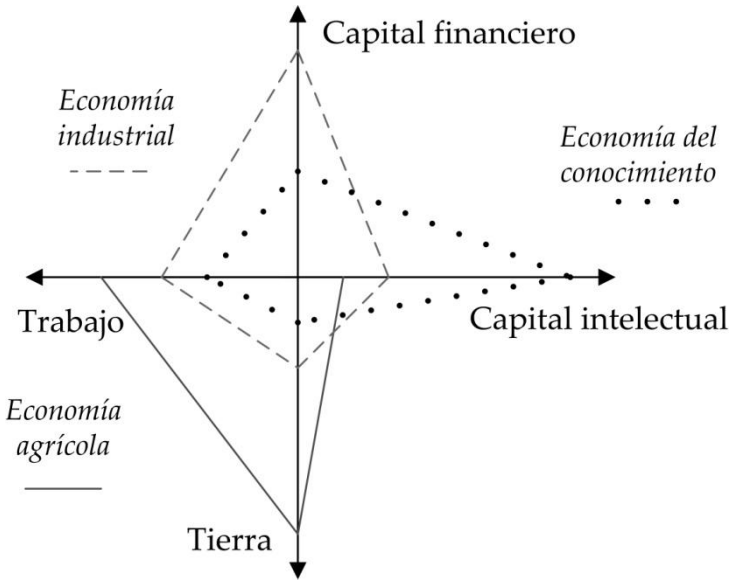
2.3.1 Concepto de capital intelectual

El campo de estudio del *capital intelectual* conforma una disciplina relativamente joven, pero intensa (Castilla Polo, 2007; Serenko et al., 2010). Aunque aún no existe consenso en la literatura acerca de la definición del término, en la mayoría de las aproximaciones conceptuales se relaciona el capital intelectual, implícita o explícitamente, con la *teoría de recursos y capacidades* de la empresa (Kristandl y Bontis, 2007), haciendo hincapié en el *conocimiento* como el principal recurso estratégico de las organizaciones.

Barney (1991) y Barney y Clark (2007) fundamentan la creación de ventajas competitivas en la empresa en el desarrollo de los propios recursos –tangibles o intangibles– y de las propias capacidades de la organización. Esta es la idea

básica de la *teoría de recursos y capacidades* que, además considera que, para que puedan crear valor, los recursos y las capacidades han de ser escasos, valiosos, difícilmente imitables por la competencia y limitadamente sustituibles. Según este enfoque, las empresas más rentables son aquellas que poseen recursos o capacidades superiores al resto de los competidores. El *conocimiento* constituye la base a partir de la cual se explica la existencia de una ventaja competitiva sostenible (Lev, 2001), convirtiéndose así en un recurso crucial de carácter estratégico. Mientras que en la economía agrícola el recurso principal era la tierra y en la economía industrial fue el capital financiero, el conocimiento se ha convertido en la actualidad en el recurso estratégico por excelencia (Bueno et al., 2008), como se observa en la Figura 2.2.

Figura 2.2 Factores productivos críticos en cada era económica



Fuente: Elaboración propia a partir de Gorey y Dobat (1996).

El conocimiento se localiza principalmente en los recursos humanos de la organización, pero también en otros elementos, como los valores corporativos, la cultura, las rutinas y los procesos de trabajo o el gobierno corporativo. De hecho, Reed et al. (2006) definen el capital intelectual como el conocimiento creado y almacenado en la empresa a través de sus tres componentes: tecnología y procesos, personal y relaciones sociales.

El término capital intelectual fue inicialmente empleado por John Kenneth Galbraith en 1969 (Feiwel, 1975; Bontis, 1998), quien afirmó que el capital intelectual era más que el intelecto como puro intelecto, que incorporaba una

acción intelectual, describiéndose como un proceso de creación de valor y como un activo.

Desde la década de los noventa, ha sido muy prolija la investigación en capital intelectual y han sido muchas las definiciones del término que se han aportado. Por ejemplo, Sveiby (1997a) y Edvinsson y Malone (1997) denominan capital intelectual a la diferencia entre el valor de mercado y el valor contable de una compañía, definición apoyada por autores como Cañibano et al. (2000). Así, el capital intelectual está compuesto por todas las inversiones en intangibles que no se contabilizan y, por tanto, no se reflejan en los balances de las empresas, esto es, en su valor contable. Así, los estados financieros no proporcionan información sobre el conjunto completo de activos, de ahí que la diferencia entre el valor de mercado y el valor contable de las compañías esté continuamente aumentando.

Para Stewart (1997), el capital intelectual es la suma de todo lo que cada uno sabe en la empresa y proporciona a esta una ventaja competitiva en el mercado: el conocimiento, la información o la experiencia de empleados y directivos. Además, apunta que es difícil de identificar y muy complicado mantenerlo, pero una vez que es identificado, es fácil explotarlo y conseguir ventajas competitivas a partir del mismo. Edvinsson y Malone (2003) utilizan una metáfora para explicar el concepto de capital intelectual: 'Si nos imaginamos una empresa como un árbol, entonces lo que se describe en las cuentas anuales es el tronco, las ramas y las hojas. El inversor inteligente estudia este árbol en busca de fruta madura para cosechar. Pero suponer que ese es todo el árbol porque representa todo lo que salta a la vista es obviamente un error. La mitad, o quizá más, está bajo tierra, en el sistema de raíces. Y si bien el aroma de la fruta y el color de las hojas dan testimonio de la salud del árbol en ese momento, entender lo que está ocurriendo en las raíces es una manera mucho más eficaz de calcular cuál será el estado de salud del árbol en los próximos años'.

No hay duda en la discusión científica de que los activos intangibles conforman la principal fuente de creación de ventaja competitiva sostenible de la empresa y de generación de valor en la llamada *economía del conocimiento* (Lev, 2001), y constituyen el denominado *balance invisible* (Sveiby, 1997a), paralelo al balance contable de las compañías.

En esa línea, más recientemente se ha definido el capital intelectual como el conjunto de recursos estratégicos organizativos escasos que permiten a la empresa crear valor sostenible, que generan beneficios potenciales futuros y que no pueden ser apropiados por otros, ya que no son fácilmente imitables o sustituibles (Kristandl y Bontis, 2007). Por su parte, Delgado-Verde et al. (2013) lo definen como el conjunto de diferentes categorías de conocimiento –ya sea a nivel individual, organizacional o inter-organizacional– poseídos por una empresa y que son susceptibles de proporcionar una ventaja competitiva. Además, numerosos estudios han corroborado una relación positiva y directa entre capital intelectual y desempeño financiero (Chen et al., 2004; Phusavat et al., 2011), lo que confirma la hipótesis de que el capital intelectual es un determinante clave en la creación de valor empresarial.

Para algunos autores, los términos *activos intangibles* y *capital intelectual* son sinónimos (Brooking, 1996; Lev, 2001; Andriessen, 2004a). Otros autores prefieren tratar como equivalentes los conceptos *intangibles* y *capital intelectual* (Cañibano et al., 2000), diferenciándolos firmemente del elemento *activos intangibles* de la contabilidad financiera y definido en las normas internacionales IAS 38 e IFRS 3. Por otro lado, Roos et al. (1998) consideran que los activos intangibles son sólo una parte del capital intelectual. Para nuestro propósito, los tres términos van a ser considerados sinónimos, pero subrayando la diferencia con los *activos intangibles* en el sentido de la contabilidad financiera, como recursos inmateriales susceptibles de contabilización, como las patentes o las aplicaciones informáticas.

2.3.2 Etapas en la investigación científica del capital intelectual

Se han identificado tres etapas en la evolución de la investigación en capital intelectual (Guthrie et al., 2012). En una *primera fase*, desde finales de la década de los ochenta y durante los noventa, se desarrolló el marco teórico, relativo a la definición de conceptos principalmente, en el que se asentaría el nuevo paradigma (Petty y Guthrie, 2000). Se advertía, además, de la influencia del capital intelectual en el desarrollo y en el mantenimiento de ventajas competitivas en la empresa y, por lo tanto, se consideraba necesario visibilizarlo mediante su medición e información externa. En esta etapa, es característico el impulso de la disciplina desde el ámbito empresarial: por ejemplo, Karl-Erik Sveiby descubrió la denominada *organización basada en el conocimiento* (Sveiby, 1997a) mientras trabajaba en un grupo editorial, comprendiendo que era

necesario considerar los intangibles que muchas empresas como la suya poseían; o Leif Edvinsson, conocido desde su trabajo en la aseguradora Skandia (Edvinsson, 1997).

En una *segunda etapa*, desde finales de los noventa y durante los primeros años de la década de los dos mil, se concretaron diferentes modelos de medición de intangibles en la empresa (Andriessen, 2004b), llevándose a cabo un profundo trabajo acerca de la identificación de los elementos específicos integrantes del capital intelectual. En esta etapa fue necesario desarrollar herramientas adecuadas para identificar, medir, informar y gestionar los recursos estratégicos basados en conocimiento (Petty y Guthrie, 2000). Entre los modelos de medición de intangibles más conocidos destacan el *Skandia Navigator* (Edvinsson, 1997) o el *Intangible Assets Monitor* (Sveiby, 1997b).

Numerosas investigaciones empíricas que analizaban el impacto del capital intelectual en la *performance* financiera y en la creación de valor de las compañías surgieron durante esta segunda etapa. Así, trabajos como los de Riahi-Belkaoui (2003), Chen et al. (2004) o Chen et al. (2005) constataron una fuerte relación positiva entre el capital intangible y el desempeño financiero en varios grupos de empresas. Sin embargo, aunque otros autores revelaron una relación negativa entre ambas variables (Firer y Williams, 2003), la mayor evidencia empírica de los primeros ha permitido confirmar la hipótesis manifestada en la primera etapa de investigación acerca de que el capital intelectual es un determinante clave en la creación de valor empresarial. A este debate habría que unir el trabajo de Youndt et al. (2004), que demostró que las empresas intensivas en capital intelectual son más competitivas y tienen más éxito en los mercados.

Una nueva línea de investigación apareció también en esta segunda etapa de investigación, centrada en el estudio del carácter dinámico del capital intelectual dentro del proceso de creación de valor de la empresa (Marr et al., 2004). Así, según este nuevo enfoque, los intangibles no son activos estáticos, sino que entre ellos se producen sinergias, de tal manera que el reforzamiento de unos puede incrementar el stock de otros. En este sentido, Hussi y Ahonen (2002) argumentan que ningún activo intangible es por sí solo suficiente para mejorar el desempeño de la organización, sino que el establecimiento de sinergias entre los mismos genera flujos que impulsan los procesos de creación de valor.

Mientras que en la segunda etapa los esfuerzos se centraron mayoritariamente en la medición del capital intelectual a través de su influencia en el desempeño financiero de las empresas, en la *tercera fase* del programa de investigación sobre la materia actualmente en desarrollo se trata de investigar, desde una perspectiva más crítica, la gestión del capital intangible y su implicación en la administración y dirección corporativas (Dumay y Garanina, 2013). En este sentido debe aclararse que el ejercicio de identificación y medición del capital intelectual no resulta un fin en sí mismo, sino más bien un requisito imprescindible para actuar coherentemente desde la gestión de los activos que aportan valor a las organizaciones (Bueno et al., 2008).

2.3.3 Dimensiones del capital intelectual

La mayor parte de la literatura (Stewart, 1997; Bontis, 1998; Roos et al., 1998; Youndt et al., 2004; Cabrita y Bontis, 2008) coincide en la siguiente triple categorización de capital intelectual: *capital humano*, *capital estructural* y *capital relacional*.

2.3.3.1 Capital humano

El *capital humano* se define como el conjunto de conocimientos, habilidades y capacidades que reside en los individuos (Subramaniam y Youndt, 2005) o, simplemente, como el conocimiento tácito de los empleados (Chang et al., 2008), que no pertenece a la organización. El capital humano incluye las competencias de empleados y directivos, la experiencia, el conocimiento, la actitud, el compromiso y las habilidades (Hsu y Fang, 2009). Para Martín-de-Castro et al. (2011), el capital humano hace referencia al conocimiento tácito o explícito de los empleados, así como a su habilidad para generar más conocimiento, e incluye valores, actitudes, aptitudes y *knowhow*. Cabrita y Bontis (2008) consideran que el capital humano es la *principal dimensión del capital intelectual*, sobre la que se asienta la posibilidad de desarrollar ventajas competitivas sostenibles.

Se identifican tres grandes componentes dentro del capital humano: i) los *conocimientos*, que incluye la educación formal, la formación o el entrenamiento específico, la experiencia y el desarrollo personal; ii) las *habilidades*, que engloba el conocimiento individualizado, la capacidad de trabajar en equipo, la comunicación y el liderazgo; iii) el *comportamiento*, que abarca el compromiso de

los empleados y el sentimiento de pertenencia, la motivación, la satisfacción, la flexibilidad y la creatividad (Martín-de-Castro et al., 2011).

Los recursos humanos contribuyen a la creación de valor en la empresa y, por esta razón, Edvinsson y Sullivan (1996) argumentaron que el capital humano es un *activo* de la organización cuyo valor se deriva de la competencia, de las actitudes y de la inteligencia de los empleados (Roos et al., 1998). Es muy probable que una empresa con empleados cualificados se posicione mejor en el mercado que sus competidores (Cañibano et al., 2000) influyendo positivamente sobre los resultados empresariales e impactando en la ventaja competitiva.

2.3.3.2 Capital estructural

El *capital estructural* es el conocimiento institucionalizado y codificado de la organización (Hall, 1992), incluido en las bases de datos, en los manuales de procedimientos, en las estrategias y rutinas organizativas. Es el conocimiento que permanece en la empresa cuando los empleados se marchan a casa (Stewart, 1997). El capital estructural es el *esqueleto* y el *adhesivo* de la organización, porque incluye las herramientas y la arquitectura necesarias para retener, almacenar, reforzar y transferir el conocimiento a lo largo de todas las actividades de la organización (Cabrita y Bontis, 2008). Compañías con fuerte capital estructural crean condiciones favorables para potenciar el capital humano y el capital relacional (Wu et al., 2008).

Algunos autores (Chen et al., 2004; Sánchez-Cañizares et al., 2007; Hsu y Fang, 2009) distinguen dentro del capital estructural el capital tecnológico y el capital organizativo, el primero vinculado con el esfuerzo en I+D o el uso de la dotación tecnológica y el segundo con el ámbito estructural de los diseños, procesos y cultura (Bueno et al., 2008). Así, el *capital tecnológico* incluye la tecnología organizacional o la forma en que se realizan los procesos, las rutinas, los procedimientos, las metodologías, los sistemas y las bases de datos; y el *capital organizativo* hace referencia a la forma de distribución de las responsabilidades de la organización, la toma de decisiones, la comunicación dentro de la empresa, la estrategia, la cultura y la capacidad de innovación, entre otros. La esencia del capital estructural es el conocimiento derivado de la práctica organizacional, conteniendo elementos clave para conseguir eficiencia productiva, la optimización de los tiempos de transacción o la mejora en el manejo de la información (Bontis, 1998).

Existe igualmente una relación positiva entre capital estructural y creación de valor (Marr et al., 2004; Díez et al., 2010), en la medida en que aquel contribuye a generar ventajas competitivas en la empresa, impactando así en el desempeño corporativo y en la creación de valor.

2.3.3.3 Capital relacional

El *capital relacional* se refiere al conocimiento derivado de las relaciones que la empresa mantiene con sus *stakeholders*, tanto internos –accionistas, directivos,…– como externos –clientes o proveedores– (Bontis, 1999; Chang et al., 2008). Esta dimensión del capital intelectual se justifica en el hecho de que las organizaciones no pueden considerarse como sistemas aislados, sino que muchas de sus ventajas competitivas futuras dependen de la capacidad de la organización para capturar conocimiento externo (Cohen y Levinthal, 1990). El capital relacional es la dimensión del capital intelectual de naturaleza más compleja y heterogénea, debido a los diferentes tipos de activos intangibles que posee (Martín-de-Castro et al., 2011). Por su parte, Bontis (1999) y Johnson (1999) señalan que el capital relacional impacta positivamente en la ventaja competitiva de la empresa.

Algunos autores (Bueno y CIC, 2003; Sánchez-Cañizares et al., 2007) dividen el capital relacional en *capital de negocio* y *capital social*. El primero hace referencia a los flujos de información y conocimiento de carácter externo, derivados de las relaciones con los clientes, con los proveedores, con los aliados y con los competidores. El *capital relacional social* encuadra el marco de relaciones fuera del ámbito del negocio –compromiso y acción social, reputación e imagen corporativa, prestigio o conservación del medio ambiente–.

2.3.4 Modelos de medición del capital intelectual

Bajo la premisa de que el capital intelectual es un importante inductor del valor y del desempeño en las organizaciones (Roos et al., 2006), han sido muchos los intentos de elaboración de modelos de medición de intangibles. Entre los más conocidos destacan el *monitor de activos intangibles* de Sveiby (Sveiby, 1997b), el *technology broker* de Brooking (1996) y el *navegador de Skandia* (Edvinsson y Malone, 1997). Sin ánimo de ser exhaustivos, ya que no es el principal tema de esta tesis, se presentan a continuación brevemente estos modelos.

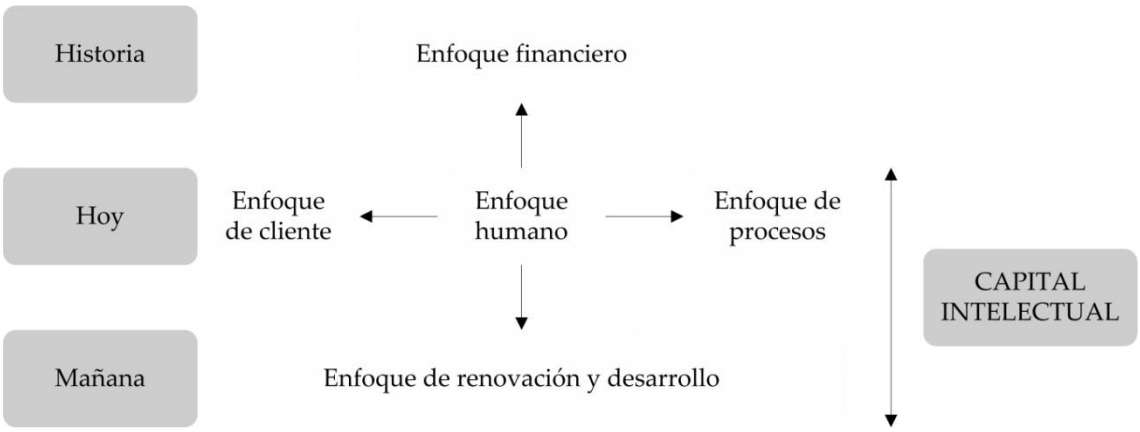
2.3.4.1 Navegador de Skandia

En 1995, el grupo de organizaciones financieras Skandia, con sede en Suecia, publicó el primer informe de capital intelectual como suplemento al informe financiero (Edvinsson, 1997), en un intento de conocer el verdadero valor de la organización.

El modelo de Skandia se fundamenta en la idea de que la generación de valor de una empresa está en su capacidad de crear valor sostenible a través de una estrategia basada en cinco enfoques: financiero, de cliente, de procesos, de renovación y desarrollo y humano, este último común a los anteriores.

Combinando estos cinco enfoques se desarrolla un nuevo modelo de presentar informes que Skandia denominó el *navegador*, tal y como se representa en la siguiente figura.

Figura 2.3 Navegador de Skandia

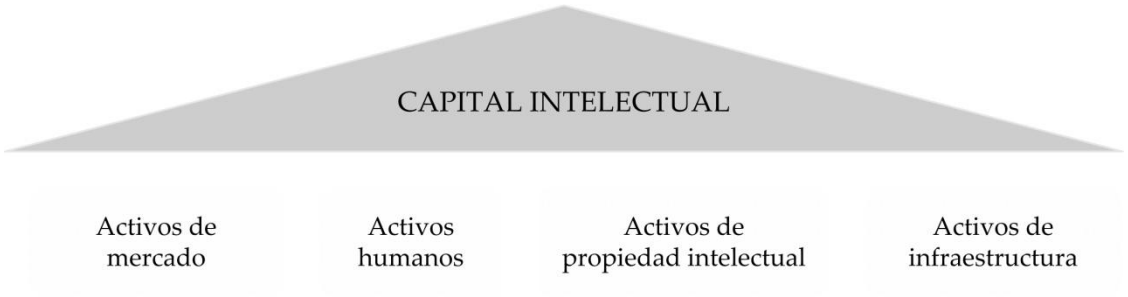


Fuente: Edvinsson (1997).

2.3.4.2 Technology Broker

El modelo de gestión del capital intelectual planteado por Annie Brooking en 1996 (Brooking, 1996) clasifica los componentes del capital intelectual en cuatro categorías: activos de mercado, activos humanos, activos de propiedad individual y activos de infraestructura. Este modelo se caracteriza porque, para valorar monetariamente los activos intangibles, primero se debe realizar una auditoría de capital intelectual basada en un conjunto de preguntas de naturaleza cualitativa. Una vez realizada esta auditoría se procede a valorar económicamente los activos inmateriales conforme a los enfoques de costes, de mercado y de ingresos.

Figura 2.4 Technology broker

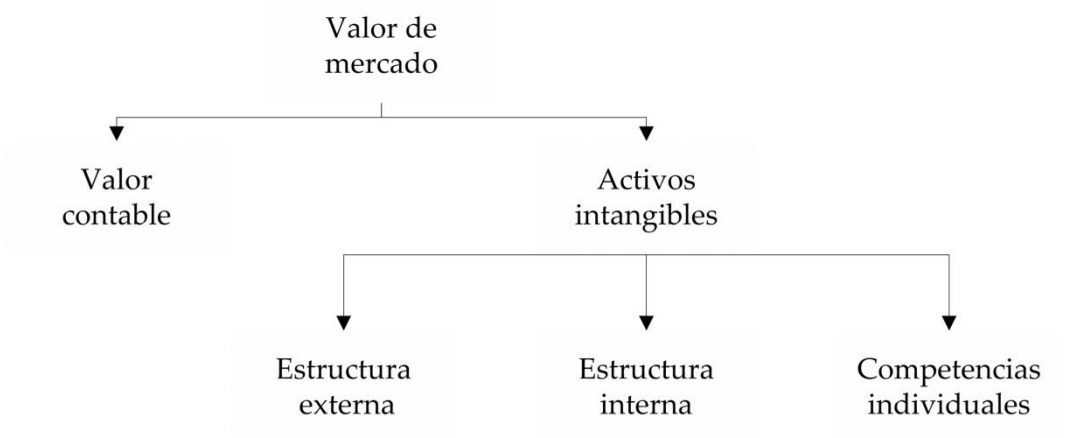


Fuente: Brooking (1996).

2.3.4.3 Monitor de activos intangibles

El *monitor de activos intangibles* (Sveiby, 1997b) clasifica los activos intangibles en tres grandes bloques: estructura externa, estructura interna y competencias individuales, generándose una serie de indicadores para la medición y gestión de los intangibles (Figura 2.5). Para su creador, Sveiby, el principal activo intangible reside en el bloque de las competencias individuales.

Figura 2.5 Monitor de activos intangibles



Fuente: Sveiby (1997b).

Este modelo mide la evolución de los tres bloques de intangibles mediante *indicadores de crecimiento e innovación*, *indicadores de eficiencia* e *indicadores de estabilidad* (Figura 2.6). Los indicadores de crecimiento e innovación tratan de reflejar el potencial futuro de la empresa; los de eficiencia reflejan la productividad de los activos intangibles y los de estabilidad evalúan el grado de permanencia en la empresa de estos activos.

Figura 2.6 Balance invisible de Sveiby

	Balance invisible		
	Capital invisible		Compromisos
	Estructura interna	Estructura externa	Competencias individuales
Indicadores de crecimiento e innovación			
Indicadores de eficiencia			
Indicadores de estabilidad			

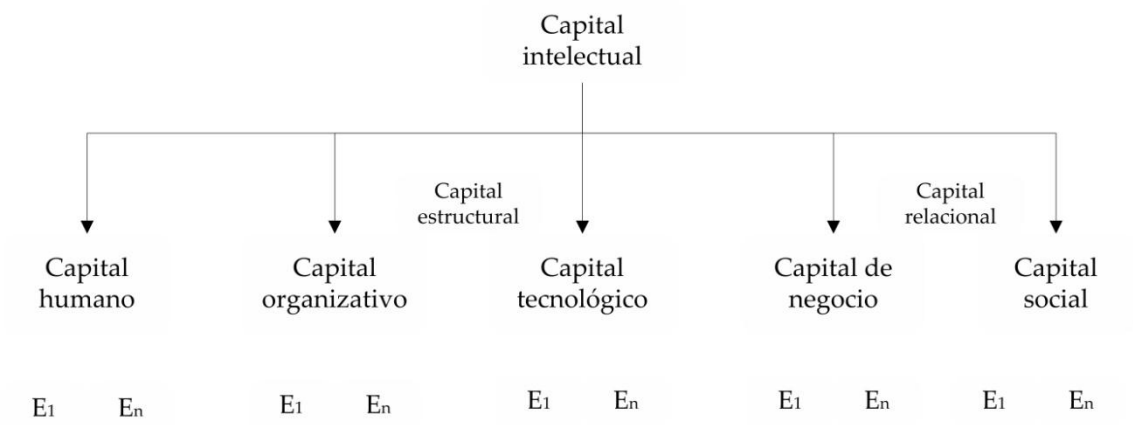
Fuente: Sveiby (1997b).

2.3.4.4 Modelo Intellectus

El Modelo Intellectus (Bueno y CIC, 2003) se ha construido bajo la premisa de cinco capitales –humano, organizativo, tecnológico, de negocio y social– que interactúan en la dinámica de configuración del potencial organizativo (Bueno et al., 2008), siguiendo la pauta básica generalmente aceptada de las dimensiones del capital intelectual. Con este modelo, se obtiene una panorámica o stock temporal de los activos intangibles que posee la organización, información que se considera muy útil para la toma de decisiones. Es un modelo que se considera en línea con la estrategia de la empresa y se caracteriza por ser abierto –contempla la interacción con terceros–, dinámico, flexible en la implantación y sistémico.

El modelo, como se observa en la Figura 2.7, se estructura en bloques –los cinco componentes del capital intelectual–, elementos –recursos y activos intangibles que integran cada componente– e indicadores.

Figura 2.7 Modelo Intellectus



Fuente: Bueno y CIC (2003).

2.4 CALIDAD Y GESTIÓN AMBIENTAL EN EL SECTOR AGROALIMENTARIO

La industria agroalimentaria tiene en España un innegable carácter estratégico, tanto como componente del sistema económico –por su aportación a las cuentas económicas industriales nacionales– como por su papel integrador del territorio –principalmente por la generación de empleos rurales– (García Sanz, 2003; Jordana, 2009).

El sector agroalimentario contribuye al total de la cifra de negocios de la industria nacional con un 13,3% y con el 15,3% del total de personas ocupadas, según datos del Instituto Nacional de Estadística (INE) para el año 2012[6]. Además, se destaca su fuerte carácter anticíclico, ya que su aportación relativa a las cifras globales industriales no ha hecho sino aumentar desde el año 2008. Así, en ese año la contribución relativa a la cifra de negocios fue del 11,5% y al total de personas ocupadas del 12,6%. Y, aunque en términos absolutos el número de personas ocupadas ha disminuido de 316.730 personas, en 2008, a 294.616, en 2012, la cifra de negocios ha aumentado un 4,5% en dicho periodo 2008-2012: de 72,7 mil millones de euros a 76,0 mil millones de euros.

Se destaca también el importante papel de la industria agroalimentaria en la balanza comercial española. Así, con un ratio de cobertura de 121,3% en 2012, ha presentado un importe total de superávit de 6.142 millones de euros[7]. Si se comparan estos datos con los registrados en 2008 –ratio de cobertura de 102,7% y superávit de 733 millones de euros–, el carácter dinámico y la fortaleza de este sector quedan constatados.

Sin embargo, la atomización del sector, la concentración de la demanda en grandes grupos de distribución comercial, el entorno cada vez más competitivo que caracteriza al mercado de la alimentación, o el hecho de que los consumidores son cada vez más exigentes en sus demandas, configuran las características principales del sector agroalimentario español (Fernández, 2000; Mamaqi et al., 2009). Además, como consecuencia de las últimas crisis alimentarias, el consumidor está cada vez más preocupado por la seguridad y calidad de los alimentos que adquiere, lo cual origina nuevas demandas para la industria (van der Valk y Wynstra, 2005).

[6] INE 2012 de la Encuesta Industrial de Empresas.

[7] Ministerio de Economía y Competitividad.

La creciente preocupación social por el medioambiente exige la reducción de la contaminación generada por todos los sectores productivos, incluido el agroalimentario. Esta circunstancia se traduce en el creciente interés de los consumidores por la producción sostenible de alimentos (Maloni y Brown, 2006). En este sentido, los recursos que permiten a la industria agroalimentaria conseguir ventajas competitivas y diferenciarse de la competencia se basan fundamentalmente en la innovación de proceso o de producto (Traill y Meulenberg, 2002), en la mejora de la calidad (Ménard y Valceschini, 2005), en la participación en cadenas de valor sostenibles (Maloni y Brown, 2006) o en la adopción de sistemas de gestión ambientales (Boudouropoulos y Arvanitoyannis, 2000).

Según Potter y Hotchkiss (1998) la calidad de los alimentos es la medida de la excelencia de un producto e incluye aspectos como sabor, apariencia y contenido nutricional y comprende todas aquellas características que tienen importancia para determinar su aceptabilidad por los consumidores. La mejora de la calidad alimentaria no viene exclusivamente de la mano de la legislación, sino que se exige una mejora efectiva en el control sobre la producción de alimentos en todas sus etapas. En este sentido, la tecnología NIRS –*near infrared spectroscopy system*– supone una importante innovación de proceso que influye sobre la mejora de la calidad y, en menor medida, sobre el comportamiento medioambiental de la industria (Pérez-Marín et al., 2009). La determinación de los parámetros químicos de la carne con métodos clásicos basados en la extracción de muestras y en análisis en laboratorio es lenta y genera residuos contaminantes porque emplea productos químicos. Así, en el sector cárnico la adopción de la tecnología NIRS es cada vez más común (Prieto et al., 2009), como método no sólo para mejorar la calidad del producto, sino también para fortalecer la imagen de responsabilidad medioambiental.

La literatura científica ha constatado que las estrategias medioambientales proactivas generan capacidades organizativas y ventajas competitivas en las empresas (Hart, 1995; Aragón-Correa y Sharma, 2003). Aunque existe poca evidencia empírica en el sector agroalimentario, los trabajos de Martín-Tapia et al. (2010) y de Gómez et al. (2013) encuentran que la adopción de una estrategia medioambiental proactiva tiene beneficios para la empresa agraria relacionados con la internacionalización. Además, se considera que la reputación y la imagen corporativas en la industria agroalimentaria están íntimamente unidas a la

percepción y a la preocupación medioambiental de los consumidores (Grolleau et al., 2007).

La adopción de un sistema de gestión ambiental –ya sea certificado, como ISO 14001 o EMAS, o no certificado– genera importantes beneficios a la industria agroalimentaria, no sólo en términos de minimización de impacto ambiental, sino también de mejora de la imagen corporativa o de reducción de costes por la mejora de la eficiencia (Massoud et al., 2010).

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Capítulo 3

Corporate financial decisions and multicriteria decision making: a survey of the state of the art

ABSTRACT

Corporate financial decision making processes –selection of investments and funding sources– are becoming increasingly complex because of the influence of the growing number of conflicting criteria that need to be considered. The main aim of this chapter is to analyse the international research on the application of multiple criteria decision making (MCDM) techniques to issues and problems in corporate finance during the period 1980-2012. A total of 347 publications 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 the economic and financial performance of firms; c) the techniques based on the multiple attribute utility theory (MAUT) are the most popular among chief financial officers in complex decision making situations, because they are very simple.

3.1 INTRODUCTION

Finance is a broad field that comprises of three areas of study: financial institutions and markets, investments and financial management (Melicher and Norton, 2005). This chapter 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 organization. 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, CFOs 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 multicriteria 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 (a summary of MCDM techniques has been presented in Chapter 2). In short, as noted by Stewart (1992), multicriteria 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 multicriteria techniques (Figueira et al., 2005). In this thesis, as noted in Chapter 2, 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 multicriteria techniques can take into account multiple criteria in the decision making process.

The objective of this chapter is to *analyse the international research on the application of multiple criteria decision making techniques to issues in corporate finance over the last three decades (1980-2012).* Through this analysis, I will establish and differentiate the major trends in this area. This study could be very useful for CFOs, because I 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 multicriteria 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, several

reviews of the application of multicriteria techniques to issues and problems in the generic field of finance are highlighted (Zopounidis and Doumpos, 2002a; Steuer and Na, 2003; Spronk et al., 2005; Hülle et al., 2011; Zopounidis and Doumpos, 2013). 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 this chapter 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 chapter, we are confident that it will answer the following key questions: *what kind of problems and issues in corporate finance can be solved properly using MCDM techniques?* And, *what are the techniques that CFOs should know to solve corporate finance problems?* To this end and following this introduction, Section 3.2 is devoted to the process of drawing up the database that contains the literature considered for this review chapter. The third section focuses on study results. The chapter ends with concluding remarks in Section 3.4.

3.2 MATERIAL AND METHOD

3.2.1 Method

In order to achieve the objective proposed in this chapter, 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 I 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 publications 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 (Schibrowsky et al., 2007; Charvet et al., 2008). And papers that have conducted bibliometric analyses in the field of finance have also been found (Chung and Cox, 1990; 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, 2x2 contingency tables were developed in order to examine whether there were significant differences between expected and observed frequencies in each pair of categories.

3.2.2 Material

The database required to conduct the bibliometric analysis proposed was built by collecting all the documents –papers, books and book chapters– indexed by Scopus (http://www.scopus.com/home.url) related to the application of MCDM techniques to corporate finance issues. Furthermore, this database was also fed with complementary papers published in other relevant journals such as the *Journal of Multi-Criteria Decision Analysis* or the *International Journal of Multicriteria Decision Making* that have not been indexed by Scopus. In this way 339 papers plus 8 books –or book chapters– were found[8]. The procedure followed to build the database analysed in this work is justified by objective and pragmatic reasons. First, this selection criterion ensured the quality, scientific rigor and international scope of the papers to be analysed. Secondly, the selection criterion 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. In this regard, it should be noted that we have not considered professional articles, as it has been assumed that the most relevant contributions in this area of knowledge have been published as scientific papers in journals with a certain degree of impact.

3.2.3 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.

[8] The complete list of papers included in the analysed database is presented in Annex 1.

3.2.4 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 I 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, I show the codes used to describe the geographical area of the authors (see Table 3.1), the specific topic within the field of corporate finance (see Table 3.2) and the MCDM techniques employed (see Table 3.3).

Table 3.1 Geographical area of the authors

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

Source: Own elaboration.

Table 3.2 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: Own elaboration.

Table 3.3 Classification of MCDM techniques

1. Multiobjective and goal programming	*3. Outranking relations approach*	
11. Multiobjective programming	*31. ELECTRE methods*	
111. Classic	311. ELECTRE	314. ELECTRE III
112. 'Fuzzy'	312. ELECTRE I	315. ELECTRE TRI
113. Compromise programming	313. ELECTRE II	316. Fuzzy ELECTRE
12. Goal programming	*32. PROMETHEE methods*	
121. Classic	321. PROMETHEE	324. PROMETHEE III
122. Interactive	322. PROMETHEE I	325. Fuzzy PROMETHEE
123. 0-1 Goal programming	323. PROMETHEE II	
124. Fuzzy goal programming	*33. OTHERS*	
2. Multiattribute utility theory	*4. Preference disaggregation approach*	
21. AHP	*41. UTA*	
211. AHP		
212. Fuzzy AHP	*42. UTADIS*	
213. ANP	421. UTADIS	
214. Fuzzy ANP	422. UTADIS I	
22. TOPSIS	423. UTADIS II	
221. TOPSIS	424. UTADIS III	
222. Fuzzy TOPSIS		
23. MAUT	43. OTHERS	
231. Classic MAUT	431. MHDIS	
232. Fuzzy MAUT	432. MINORA	
24. OTHERS	433. Others	

Source: Own elaboration.

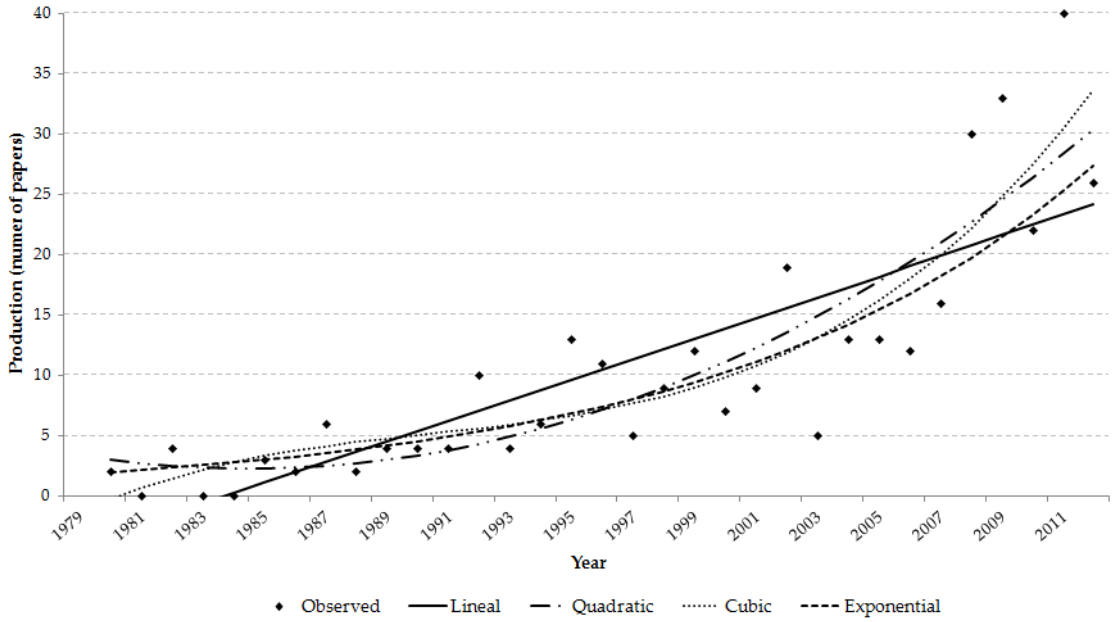
3.3 RESULTS

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, I provide a detailed analysis by specific application area in corporate finance and MCDM method used.

3.3.1 Classification by year of publication

The evolution of research on the application of MCDM techniques to issues and problems in corporate finance displays *a clearly 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 3.1. 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 3.4).

Figure 3.1 Distribution of papers over time



Source: Own elaboration.

Table 3.4 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 3.5): *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 multicriteria 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 multicriteria techniques to solve 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 3.5). 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 2x2 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 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 3.5 Contingency table of subject area of the journal by period

Subject area of the journal	*Period*							
	1980-1990		*1991-2000*		*2001-2012*		*Total*	
	Frequency		Frequency		Frequency		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%***

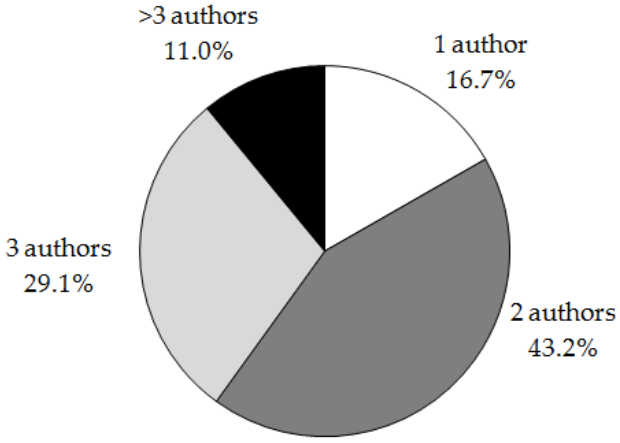
Source: Own elaboration.
Fisher's exact test=20.613; p-value (sign. Monte Carlo)= 0.015
*Analysis of contingency tables 2×2: *** p<0.01; ** p<0.05; * p<0.1.*

3.3.2 Authorship

The set of publications analysed is characterised by the high proportion of co-authorship (see Figure 3.2) 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.

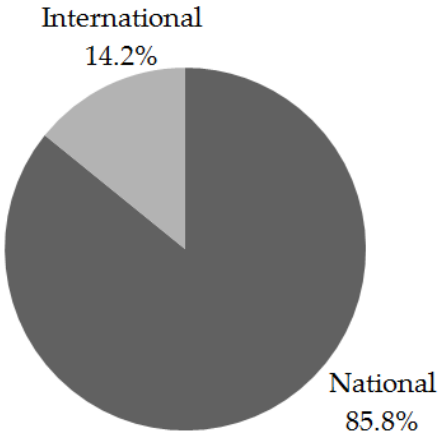
In the vast majority of co-authored studies, more specifically in 85.8% (see Figure 3.3), the type of collaboration has been national, as researchers from institutions, research centres or universities within the same country have worked together. In only 14.2% of cases have authors from centres in different countries cooperated (international collaboration).

Figure 3.2 Number of authors



Source: Own elaboration.

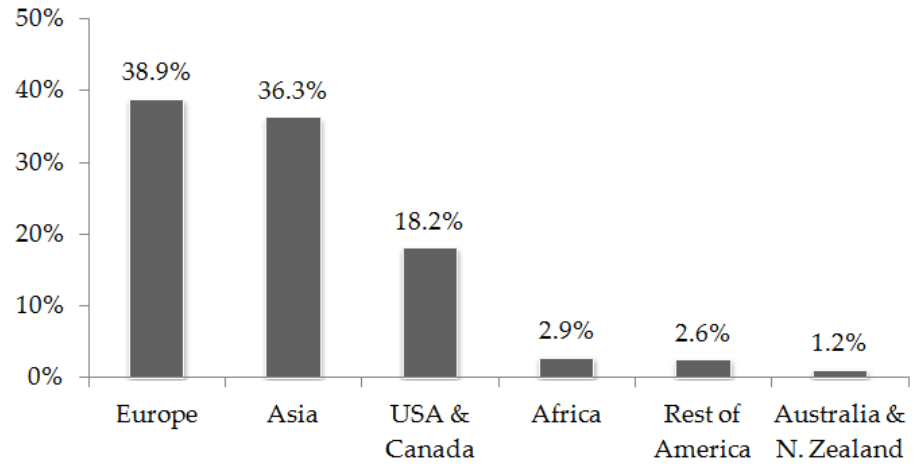
Figure 3.3 Type of collaboration



Source: Own elaboration.

In regard to the affiliation or geographical area of the first authors (see Figure 3.4), 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 3.4 Geographical area of the first authors



Source: Own elaboration.

The contingency table that analyses the relationship between the variables origin of the first author and period (see Table 3.6) 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 3.6 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%***

Source: Own elaboration.
Fisher's exact test=70.713; p-value (sign. Monte Carlo)=0.000.
*Analysis of 2x2 contingency tables: *** p<0.01; ** p<0.05; * p<0.1.*

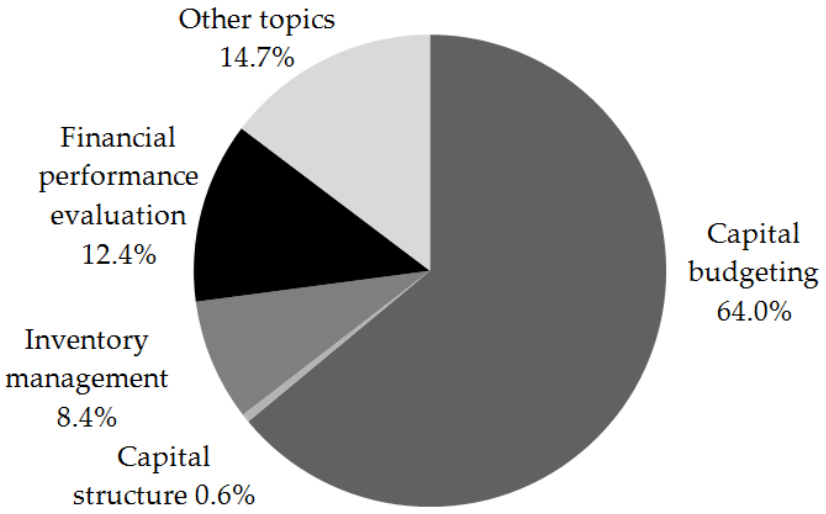
I also analysed the type of authors depending on whether they were researchers –working at universities or research institutions– or professionals –if they do business–, concluding that the latter have only been involved in 10.1% of the papers. In over 89.9% of cases, the authors have been scholars, 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, I 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.

3.3.3 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 3.5), 64.0% of the total is focused on capital budgeting, mainly on fixed assets valuation. More specifically, the main research orientation within this field has been focused on efforts to integrate and quantify non-monetary or intangible criteria in evaluating strategic and long-term investments. 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 3.5 Classification by corporate finance topic



Source: Own elaboration.

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 the 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 3.7), 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 prioritization 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 a half; ii) intangibles valuation concern has increased notably over time, to the point at which 20.9% of the total documents addressed this topic in the 2000s; iii) interest on inventory management, as well as on financial performance evaluation, has also grown, although to a lesser extent (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, bankruptcy prediction and credit risk assessment, although in absolute terms present a slight growth over time, it is worth commenting that in relative terms a decrease is observed.

Table 3.7 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 perf. evaluation	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%***

Source: Own elaboration.
Fisher's exact test=58.129; p-value (sign. Monte Carlo)=0.000.
*Analysis of 2x2 contingency tables: *** p<0.01; ** p<0.05; * p<0.1.*

In all geographic regions, the authors have mainly studied the dominant topic: investment in tangible assets and, to a lesser degree, intangibles valuation (see Table 3.8). In Europe, authors have also shown a special interest in another topic, namely the assessment of the financial performance of companies, with 19.3% of the works published being focused on this issue. Meanwhile, authors in the USA and Canada have been particularly interested in financial planning topics, where 9.5% of the literature has dealt with this issue. Finally, inventory management (15.1%) has been also addressed, particularly by Asian authors.

Table 3.8 Contingency table of topic and geographical area of the first author

Corporate Finance topic	*Geographical area*									
	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	55*	40.7%	30	47.6%	66	52.4%	11	47.8%	162	46.7%
Intangibles	27	20.0%	12	19.0%	16*	12.7%	5	21.7%	60	17.3%
Capital structure										
Equity financing	0	0.0%	1	1.6%	1	0.8%	0	0.0%	2	0.6%
Debt financing	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Working capital										
Inventory management	4***	3.0%	5	7.9%	19***	15.1%	1	4.3%	29	8.4%
Other topics										
Financial perform. eval.	26***	19.3%	1***	1.6%	12	9.5%	4	17.4%	43	12.4%
Financial planning	4	3.0%	6***	9.5%	1	0.8%	0	0.0%	11	3.2%
Financial risk mgmt.	0	0.0%	1	1.6%	1	0.8%	0	0.0%	2	0.6%
Financial accounting	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Management accounting	0	0.0%	1	1.6%	0	0.0%	2	8.7%	3	0.9%
Mergers and takeovers	3	2.2%	1	1.6%	2	1.6%	0	0.0%	6	1.7%
Bankruptcy prediction	9	6.7%	1	1.6%	6	4.8%	0	0.0%	16	4.6%
Credit risk assessment	7	5.2%	4	6.3%	2	1.6%	0	0.0%	13	3.7%
Total	***135***	***100.0%***	***63***	***100.0%***	***126***	***100.0%***	***23***	***100.0%***	***347***	***100.0%***

Source: Own elaboration.
Fisher's exact test= 82.713; p-value (sign. Monte Carlo) =0.000.
*Analysis of 2x2 contingency tables: *** p<0.01; ** p<0.05; * p<0.1.*

3.3.4 Classification by methodology used

Most of the papers, 82.1%, have used a single MCDM technique, while in only 17.9% of cases the synthesis of two or more techniques in order to combine their strengths and overcome each other's weaknesses have been documented.

Table 3.9 shows the multicriteria tools employed by the authors in the studied documents. We highlight those based on the multi-attribute utility theory, as they 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.

Table 3.9 MCDM techniques used

MCDM technique	*Frequency*		
	Abs.	*Relat.*	
Multi-objective and goal programming	66	100.0%	19.0%
Multi-objective programming	18	27.3%	
Goal programming	48	72.7%	
MAUT	218	100.0%	62.8%
AHP	139	63.8%	
ANP	24	11.0%	
TOPSIS	28	12.8%	
Classic MAUT	14	6.4%	
Others	13	6.0%	
Outranking relations approach	40	100.0%	11.5%
ELECTRE	13	32.5%	
PROMETHEE	23	57.5%	
Others	4	10.0%	
Preference disaggregation approach	23	100.0%	6.6%
UTA	6	26.1%	
UTADIS	7	30.4%	
MHDIS and MINORA	4	17.4%	
Others	6	26.1%	
Total	***347***		***100.0%***

Source: Own elaboration.

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 have 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–. While 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).

When crossing the corporate finance topic and the methodology used (Table 3.10), 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 (54.1% and 22.5% of cases, respectively), supported by a statistically significant difference with respect to the rest of topics/methods. Moreover, the low attention to MAUT is quite remarkable in other topics, such as financial planning or bankruptcy prediction, where significant differences can also be observed.

Although multi-objective and goal programming has been extensively used to analyse fixed assets valuation, its relative importance (36.4%) is lower that expected due to the widespread application of this methodology to other issues, such as inventory management (24.2%) or financial planning (16.7%). In fact, in these two topics we can observe statistically significant differences.

Outranking has focused mainly on issues related to fixed assets prioritization (42.5%) and financial performance evaluation (25.0%), but this approach has also been notably employed in bankruptcy prediction (17.5%). Paired statistical comparisons with Fisher exact test showed significant differences in the latter two topics.

Unlike the other techniques, the preference disaggregation approach has focused mainly on financial performance evaluation (30.4%) and on bankruptcy prediction (30.4%), where significant differences are also seen as determined by their respective p-values.

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 the rest of multicriteria tools.

Table 3.10 Contingency table of topic and technique used

Corporate Finance topic	*MCDM technique*									
	MO and GP		*MAUT*		*Outranking*		*Prefer. Disag.*		*Total*	
	Frequency		Frequency		Frequency		Frequency		Frequency	
	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Capital budgeting										
Fixed assets	24*	36.4%	118***	54.1%	17	42.5%	3***	13.0%	162	46.7%
Intangibles	9	13.6%	49***	22.5%	1***	2.5%	1	4.3%	60	17.3%
Capital structure										
Equity financing	1	1.5%	1	0.5%	0	0.0%	0	0.0%	2	0.6%
Debt financing	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Working capital										
Inventory management	16***	24.2%	13**	6.0%	0**	0.0%	0	0.0%	29	8.4%
Other topics										
Financial perform. evaluat.	2**	3.0%	24	11.0%	10**	25.0%	7***	30.4%	43	12.4%
Financial planning	11***	16.7%	0***	0.0%	0	0.0%	0	0.0%	11	3.2%
Financial risk mgmt.	0	0.0%	2	0.9%	0	0.0%	0	0.0%	2	0.6%
Financial accounting	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Management accounting	0	0.0%	3	1.4%	0	0.0%	0	0.0%	3	0.9%
Mergers and takeovers	2	3.0%	3	1.4%	0	0.0%	1	4.3%	6	1.7%
Bankruptcy prediction	1	1.5%	1***	0.5%	7***	17.5%	7***	30.4%	16	4.6%
Credit risk assessment	0	0.0%	4**	1.8%	5**	12.5%	4***	17.4%	13	3.7%
Total	***66***	***100.0%***	***218***	***100.0%***	***40***	***100.0%***	***23***	***100.0%***	***347***	***100.0%***

Source: Own elaboration.
MO and GP = Multi-objective and Goal programming
Fisher's exact test=153.042; p-value (sign. Monte Carlo)=0.000.
*Analysis of 2x2 contingency tables: *** p<0.01; ** p<0.05; * p<0.1.*

In relation to possible differences in the use of different techniques according to the geographic region of the first author (see Table 3.11), 43.1% of the papers that have used MAUT techniques were written by Asian authors, the contribution of Europe, the USA & Canada being significantly lower than expected (32.6% and 16.5%, respectively). By contrast, 33.3% of multiobjective or goal programming documents were signed by North Americans (with a statistical significant difference), followed by European and Asians authors (25.8% and 34.8%, respectively), whom have used these MCDM techniques less than expected. The outranking relations approach has been mainly applied in Europe (65.0%), while it is significant that this methodology has been rarely implemented by Asian or North American authors (17.5% and 0.0%, respectively). In all these cases, Fisher exact tests show significant differences.

Finally, it is worth commenting that practically only Europeans have applied the preference disaggregation approach to corporate finance problems (91.3% with a p-value<0.01).

Table 3.11 Contingency table of geographical area of the first author and MCDM technique

Geographical area	MCDM technique									
	MO and GP		MAUT		Outranking		Prefer. disag.		Total	
	Frequency		Frequency		Frequency		Frequency		Frequency	
	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.	Abs.	Relat.
Europe	17**	25.8%	71***	32.6%	26***	65.0%	21***	91.3%	135	38.9%
USA & Canada	22***	33.3%	36	16.5%	5	12.5%	0**	0.0%	63	18.2%
Rest of America	1	1.5%	8	3.7%	0	0.0%	0	0.0%	9	2.6%
Australia & N. Zealand	0	0.0%	3	1.4%	1	2.5%	0	0.0%	4	1.2%
Asia	23	34.8%	94***	43.1%	7***	17.5%	2***	8.7%	126	36.3%
Africa	3	4.5%	6	2.8%	1	2.5%	0	0.0%	10	2.9%
Total	***66***	***100.0%***	***218***	***100.0%***	***40***	***100.0%***	***23***	***100.0%***	***347***	***100.0%***

Source: Own elaboration.
MO and GP = Multi-objective and Goal programming
Fisher's exact test=53.585; p-value (sign. Monte Carlo)= 0.000.
*Analysis of 2x2 contingency tables: *** p<0.01; ** p<0.05; * p<0.1.*

To finalize this section Table 3.12 is shown, which provides some relevant and widely quoted studies dealing with the use of multicriteria techniques in corporate finance topics. With this set of citations, it is intended that novel researchers and practitioners interested in the field will be assisted.

Table 3.12 Selected publications focused on MCDM applied to corporate finance

		MO and GP	MAUT	Outranking	Prefer. Disag.
Capital budgeting	Fixed assets	Mukherjee and Bera (1995); Karsak and Kuzgunkaya (2002); San Cristóbal (2011); Wei and Chang (2011)	Alidi (1996); Braglia et al. (2001); Chu (2002); Burnaz and Topcu (2006); Partovi (2006); Rao et al. (2012)	Halouani et al. (2009); Shakhsi-Niaei et al. (2011); Yilmaz and Dagdeviren (2011)	Chen (2001); Chu and Lai (2005)
	Intangibles	Lee and Kim (2001); Karsak and Özogul (2009); Bhattacharyya et al. (2011)	Liberatore (1987); Henig and Katz (1996); Ayag and Ozdemir (2007); Cebeci (2009)	Tolga (2012)	Jacquet-Lagrèze (1995)
Capital structure	Equity financing	Agarwal et al. (2012)	Meziani and Rezvani (1988)		
Working capital	Inventory management	Agrell (1995); Roy and Maiti (1998); Tsou (2008); Wee et al. (2009)	Flores et al. (1992); Partovi and Hopton (1994); Hadi-Vencheh and Mohamadghasemi (2011)		
Other topics	Financial performance evaluation	Kalu (1994); Garcia et al. (2010)	Diakoulaki et al. (1992); Deng et al. (2000); Ertugrul and Karakasoglu (2009); Yalcin et al. (2012)	Babic and Plazibat (1998); Pardalos et al. (1997); Baourakis et al. (2002); Kalogeras et al. (2005)	Voulgaris et al. (2000); Zopounidis and Doumpos (2001); Dimitras et al. (2002)
	Financial planning	Kvanli (1980); Goedhart and Spronk (1995a); Goedhart and Spronk (1995b); Martin et al. (2011)			
	Financial risk mgmt.		Dia and Zeghal (2008); Peng et al. (2011)		
	Management accounting		Schniederjans and Garvin (1997); Frezatti et al. (2011); Kalantari et al. (2012)		
	Mergers and takeovers	Schniederjans and Hoffman (1992); Yücenur and Demirel (2012)	Ossadnik (1996); Shyr and Kuo (2008); Lee et al. (2011)		Zopounidis and Doumpos (2002b)
	Bankruptcy prediction	Gupta, et al. (1990)	Park and Han (2002)	Dimitras et al. (1995); Doumpos and Zopounidis (2002); Li and Sun (2009)	Zopounidis and Doumpos (1998); Pasiouras et al. (2009)
	Credit risk assessment		Srinivasan and Ruparel (1990); Fan (2012)	Zollinger (1982); Doumpos and Zopounidis (2011); Vukovic et al. (2012)	Doumpos et al. (2002); Doumpos and Pasiouras (2005)

Source: Own elaboration.

3.4 CONCLUDING REMARKS

Corporate investment and financing decisions have traditionally been addressed by classical financial theory considering a very limited number of criteria –return, cost, and risk–, considered in an optimisation context. Traditional tools are unaware 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 chapter is the *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 multicriteria 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 CFOs. Therefore, they face difficulties to learn about new advances and developments in the integration of MCDM techniques in solving problems in their everyday activities.

- The applied nature of multicriteria techniques in the field of corporate finance, in view of the high percentage of papers that are theoretical-empirical, evidence 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, multicriteria 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 professionals on the implementation of this methodology in companies to become a reality.

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Capítulo 4

Decomposing value creation when assessing investments: a multicriteria approach based on AHP

ABSTRACT

This chapter aims to develop a novel capital budgeting method to improve the quality of the appraisal process for productive investments by decomposing the total value that is created by the new assets into two components: financial value and nonfinancial capital value, the latter stemming from the intellectual capital of the firm. We propose a methodology based on the multicriteria technique called the *analytic hierarchy process*. Within the model, four main criteria –financial capital, human capital, structural capital, and relational capital–, several subcriteria and the investment alternatives are defined. In order to determine the total value of each alternative, chief executive officer (CEO) preferences are required using a pairwise comparison-based questionnaire. A case study on the agrifood sector illustrates the model empirically. This illustrative application evidences the need to consider the impact of productive investments on firms' intangible assets, as this impact actually affects the choice of optimal investment alternative in the real world. Using the theoretical model proposed, CEOs can appraise productive investments by incorporating nonfinancial capital value creation into the analysis.

4.1 INTRODUCTION

The corporate capital budgeting process is one of the most challenging tasks facing firms' management (Baker and English, 2011), as it concerns investment decisions which involve allocating scarce funds over time to achieve a firm's objectives. In order to support decision-making in investment appraisal processes, traditional financial techniques based on net present value (NPV) and the internal rate of return (IRR) have been widely employed by corporate decision-makers (Brounen et al., 2004). However, many authors have identified various problems and shortcomings derived from their application. Some of these criticisms question the realism of the firm's value maximization assumption when analyzing investment alternatives. In this sense Steuer and Na (2003) affirm that modern corporations do not pursue the single objective of shareholder wealth maximization assumed by traditional techniques, instead taking into account a full array of objectives concerning the different stakeholders of the firm –shareholders, managers, employees, and customers–, according to the *stakeholders' theory* (Freeman, 1984; Donaldson and Preston, 1995). More recently, Koontz and Weihrich (2007) and Götze et al. (2008), following the seminal work by Freeman (1984), maintain that decision-makers in organizations wish to pursue several competing goals rather than a single one as traditional methods assume[9]. Another source of criticism is related to the inability of traditional appraisal techniques to recognize the real value generated by an investment, simply because they ignore important qualitative variables, hardly measurable in monetary terms, that also add value to the firm (Firouzabadi et al., 2008; Kreng et al., 2011). This paper focuses on the latter source of criticism of traditional corporate finance theory. Thus, assuming that the main objective when appraising investments in for-profit firms is *market value creation* (Dayananda et al., 2002; Ross et al., 2007), we aim to –partially– solve the inability of conventional appraisal methods to recognize the real value of new productive assets by developing a novel approach to assessing investments.

[9] This circumstance is particularly relevant in nonprofit organizations (i.e., public administrations, NGOs, etc.), where other criteria such as employment generation, equity or gender issues can be taken into account. However, for most of for-profit firms, the assumption of firm's value maximization can be still considered as the most important criterion when making investment decisions (Brigham and Ehrhardt, 2008).

Capital budgeting decisions have a major effect on the total or market value of the firm (Dayananda et al., 2002), affecting its two components, financial value and nonfinancial capital value, the latter created by the intellectual capital of the firm, a concept that can be defined as all nonmonetary and nonphysical resources controlled by the firm that contribute to the organization's value creation (Roos et al., 2006). However, the effects of investments on the second component of the firm's value have, largely, not been considered by traditional financial appraisal techniques for two main reasons: first, because of the difficulty of monetarily quantifying the increase in cash flows from investing in intellectual capital –how much–; and second, because of the uncertainty about the point in time where these cash flows will take place –when–. Therefore, new capital budgeting methodologies capable of decomposing the total value generated by investments into these two components of a firm's value, financial and nonfinancial capital value, are welcome.

This paper intends to develop a novel approach to improve the quality of the investment appraisal process in for-profit firms by decomposing the overall value that is created by new assets into its two components, financial and intellectual value. In order to do so, this paper proposes a methodology based on the analytic hierarchy process (AHP), which permits a more accurate assessment of the value creation of the different project investment alternatives, determining for this purpose the relative importance of each criterion –financial and intellectual value– and subcriterion involved in these decision-making processes. The method proposed is empirically illustrated by a case study of the agrifood sector.

The remainder of the chapter is structured as follows. Section 4.2 briefly discusses a firm's total value and its two main components, financial and intellectual value, and describes the AHP technique. Furthermore, this section provides an analytical framework to quantify and decompose the real value of an investment project. In Section 4.3, the methodological approach proposed is implemented in a real case study, focusing on investment decisions in the meat industry regarding the food quality control system to be implemented. Finally, Section 4.4 presents the conclusions and suggested lines for further research.

4.2 INVESTMENT DECISION-MAKING AND VALUE CREATION

4.2.1 Firm total value: financial and nonfinancial capital value

The total economic value of a firm, or simply the market value, is the result of adding up its financial capital –book value– and nonfinancial capital, also called intellectual capital (Roos et al., 1998; Johnson, 1999). Hence, a company's economic value is not merely the sum of the value of its tangible assets, but also the value of its intangible assets (Curado et al., 2011), most of the latter being hidden or invisible for accounting and not reported in any financial statement. The knowledge of high-quality production processes or employees' talent and knowhow are good examples of the latter. In fact, intangible resources controlled by the firm have been identified as major contributors to the generation of persistent profits (Villalonga, 2004) and, thus, to increasing market value (Cañibano et al., 2000; Sullivan, 2000; Edvinsson, 2013), the management of these invisible assets being a key element of business strategy. Both financial and nonfinancial indicators should be jointly used to provide a complete measurement of company success and shareholder value (Sveiby, 1997).

The first component of a firm's total value –*financial capital*– has been *extensively studied* by classical finance theory. Both business valuation methods –balance sheet-based methods or income statement-based techniques– and capital budgeting methods such as the discounted cash flow techniques –net present value, internal rate of return, or the discounted payback period– have been proposed for this purpose. The latter of these techniques represents indicators of financial value creation by new investment projects.

The net present value is one of the most frequently used capital budgeting techniques (Graham and Harvey, 2001; Brounen et al., 2004). This method evaluates an investment project by discounting its future cash flows to their present values and subtracting the amount of the initial outlay from their sum. If the NPV is greater than 0, the project will create value for the firm. Two elements must be known to apply this technique: the net cash flow that the investment will generate over its life, that is, cash inflows minus cash outflows, and the discount rate that should reflect the degree of risk inherent in the project under consideration.

In contrast, *nonfinancial or intellectual capital* (IC) is a more recent concept grounded on the *resource-based view (RBV) of firm theory* (Kristandl and Bontis, 2007) which has been discussed in the literature over the last two decades. In fact, researchers are still to fully agree on a definition of this term. Some of the most widely accepted definitions focus on the intangible aspect of the assets composing this kind of capital: *'the sum of the hidden assets of the company not fully captured on the balance sheet'* (Roos and Roos, 1997) or *'the total stocks of all intangible assets and capabilities'* (Edvinsson and Malone, 1997). Stewart (1997) provides a complementary view when stating that IC is *'the sum of everything everybody in a company knows that gives it a competitive edge'*, that is, the full array of knowledge, information, intellectual property and experience useful in generating profits –wealth creation–. Other definitions of intellectual capital also focus on its ability to provide value and utility for the company (Bontis, 1999; Sullivan, 2000; Roos et al., 2006).

There is no doubt that IC is an important source of sustainable competitive advantage for the firm (Itami, 1987; Roos and Roos, 1997) because invisible assets are difficult for competitors to imitate. Intangibles are important in the management process, as they have become a crucial resource for the firm, mainly due to their impact on innovation processes (Sánchez et al., 2000). Villalonga (2004) found that intangibles play an effective role in sustaining a firm's competitive advantage, measured through the persistence of firm-specific profits. Finally, it is worth mentioning that a strong relationship between intellectual capital and business performance has already been found in several empirical papers (Chen et al., 2004; Phusavat et al., 2011), confirming the hypothesis that intellectual capital is a key element for value creation within the firm.

Although there is no unique classification of the components of IC, a considerable number of papers in the literature (Stewart, 1997; Bontis, 1998; Roos et al., 1998; Youndt et al., 2004) have divided it into the following three categories: *human capital*, *structural capital* and *relational capital* (see Figure 4.1).

Human capital may be defined as the collective capabilities of employees (Edvinsson and Sullivan, 1996): expertise, skills, intelligence and general knowhow of all of the firm´s employees. In the late sixties, Likert (1967) postulated that human resources contribute to value creation in the company and, following this theory, Edvinsson and Sullivan (1996) argued that human

capital is a resource because it generates value for the company. This value stems from competence, attitude and the intellectual agility of employees (Roos et al., 1998). A firm with more capable employees is likely to earn higher profits than its competitors (Cañibano et al., 2000), thus positively affecting the firm's outcomes (Huselid, 1995; Hitt et al., 2001) and also impacting on its competitive advantages (Johnson, 1999; Grigoroudis et al., 2013). The scientific literature provides different attributes that can be measured relative to human capital: knowhow, capability, satisfaction, entrepreneurial spirit, leadership, attitude, creativity, etc. Among all these components of human capital, employees' knowhow, entrepreneurial spirit and employees' satisfaction are the most highlighted (Becker et al., 2001).

Structural capital is defined as the organizational ability of the firm to utilize human intellect and innovation to create wealth (Johnson, 1999), representing institutionalized knowledge and codified experience stored in databases, routines, manuals, structures and the like (Hall, 1992). This type of knowledge 'doesn't go home at night' (Stewart, 1997), unlike human capital, and provides coherence and guidance for the whole organization (Edvinsson and Malone, 1997). The essence of structural capital is the knowledge embedded within the routines of an organization, containing the key elements for productive efficiency, optimization of transaction times, procedural innovativeness and adequate access to information (Bontis, 1998). There is also a positive relationship between structural capital and value creation (Marr et al., 2004; Díez et al., 2010). Chen et al. (2004) break this category of IC down into company culture, organizational structure, organizational learning, operational processes and information systems. The same authors also find that the *product quality level* is an important structural capital indicator, because it has a direct effect on customer satisfaction and therefore upon customer loyalty. Also, numerous authors (Chang et al., 2008; Wu et al., 2008) have pointed to organizational routine knowledge as another important indicator of structural capital.

Lastly, *relational capital* refers to all resources that are linked to the external relationships of the firm, those connecting it to both other economic agents related to the business –shareholders, customers, suppliers, allies, unions, etc.–, and also social or civil agents, such as non-governmental organizations (NGO) or public institutions (Martín-de-Castro et al., 2011). Johnson (1999) and Bontis (1999) point out that companies' relational capital has a positive effect on their

competitive advantage, customer relations, supplier relations and environmental consciousness being considered its most important components (Lev, 2004). Regarding the first element, a positive association exists between customer satisfaction and market value (Anderson et al., 2004), because higher customer satisfaction increases the loyalty of existing customers, reduces price elasticity and enhances the firm´s reputation. Better supplier-firm interaction may also enhance the reputation of the firm (Johnson, 1999). Many authors (Claver et al., 2007; López-Gamero et al., 2011) have considered environmental consciousness, that is, the total perception of an organization regarding topics such as environmental protection, environmental policy or environmental management (Ahmed et al., 1998), as an important component of *relational capital*. Furthermore, numerous references in the literature identify a positive relationship between environmental management and firm performance (Naffziger et al., 2003; Montabon et al., 2007). Porter and van der Linde (1995) argued that companies which engage in corporate environmental management and green innovation can actively improve their corporate image, charge relatively high prices for green products, sell the knowhow and services of environmental protection, develop new markets and eventually obtain competitive advantages.

4.2.2 The analytic hierarchy process

The AHP method (Saaty, 1980) is a structured but flexible technique to support multicriteria decision making, suitable when both qualitative and quantitative aspects need to be considered in the problem. This section provides a brief overview of the AHP technique. For a more detailed explanation of the method, both from a theoretical and a practical point of view, readers can consult Saaty (1980) and Saaty and Vargas (2000).

The implementation of AHP involves *four phases*. In the first step, *a complex decision problem is structured as a tree-based hierarchy*, with at least three levels: the final 'target' at the highest level of the structure, decision 'criteria' at an intermediate level and 'alternatives' forming the base of the structure. When criteria are abstract or complex, the intermediate level can be split into a series of sequentially organized 'subcriteria' levels.

The second step is the *measurement and data collection*, which involves assigning pairwise comparisons –judgments– by the decision maker to all elements –

criteria/subcriteria/alternatives– hanging from every node in the hierarchy following Saaty's fundamental scale (see Table 4.1). The comparative judgments start from target node, comparing all criteria included in the second level of the hierarchy and finish with the (sub)criteria nodes, comparing the alternatives considered in the lowest level. For each node, the hanging elements are pairwise compared according to the decision maker's opinions on their importance regarding the (sub)criteria considered in the higher level. A questionnaire is designed and used to collect these comparison judgments.

Table 4.1 The nine-point scale for pairwise comparison in the AHP

Importance intensity	*Definition*
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2, 4, 6, 8	Intermediate values

Source: Own elaboration.

The judgments provided allow positive matrices to be built for each node with the following structure (Saaty's matrixes):

$$A = \left(a_{ij}\right)_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & a_{ij} & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad [4.1]$$

where a_{ij} represents the relative importance of the element i with respect to the element j (both at the same level of the hierarchy). This matrix has two fundamental properties: (i) all the elements in its main diagonal area take a value of one; and (ii) all other elements maintain that pairwise comparisons are reciprocal (if $a_{ij} = x$, then $a_{ji} = 1/x$). Given that the second property, one needs to make only $n(n-1)/2$ of the comparisons to fill in the matrix of judgments. Furthermore, if the pairwise comparison matrix A satisfies that $a_{ih} \times a_{hj} = a_{ij}$ for all i, j, and h, then A is said to be perfectly consistent, meaning that the numerical ratings a_{ij} satisfy $a_{ij} = w_i/w_j$, with w_i and w_j being the weights of the elements i and j, respectively. In this case, weights for every element can be obtained by normalizing any of the rows or columns of A.

However, decision makers rarely provide perfect consistent judgments in reality –especially for high-order matrices– for a number of reasons –lack of information or an unclear opinion, lack of concentration, etc.–. In these cases, the literature proposes different approaches to estimate the weight vector $\left(W = (w_1, \dots, w_i, \dots w_n)\right)$ for each matrix, that is, the vector of the relative priorities of the elements that hang from a common node –local priorities–. Saaty (1980, 2003) proposed two alternatives: the row geometric mean and the main eigenvector. Other alternatives also suggested include models based on regression analysis or goal programming (Srdjevic, 2005). Although there is no agreement in the literature regarding any alternative outperforming another (Fichtner, 1986), we have chosen the row geometric mean. Following this method the vector of priority weights is obtained by solving the following characteristic equation:

$$AW = \lambda_{max} W \qquad [4.2]$$

where λ_{max} is the maximum eigenvalue of A.

AHP allows some small inconsistency in decision maker's judgments, but obtaining reliable weights requires that this inconsistency remains below certain limits; otherwise, the weight vector W derived from the eigenvector –or any other– method could not be considered trustworthy. In order to check this requirement, a specific measure of inconsistency for each Saaty's matrix A needs to be calculated. If the pairwise comparisons provided by the decision maker are completely consistent, the maximum eigenvalue (λ_{max}) of matrix A is equal to the number of elements considered (n). Then, the amount resulting from the difference $\lambda_{max} - n$ is a measure of the degree of inconsistency within the matrix A. This is why Saaty (1980) defined the consistency index (CI) as:

$$CI = (\lambda_{max} - n)/(n - 1) \qquad [4.3]$$

Denote the consistency index for a randomly generated $n \times n$ matrix as RI. From CI and RI indexes, Saaty (1980) defined the consistency ratio (CR) as:

$$CR = CI/RI \quad [4.4]$$

If the CR is smaller than 0.1, then the matrix A can be considered as *having an acceptable consistency*, and the resulting weights are deemed as reliable. If the CR is greater than 0.1, the subjective judgments need to be revised.

If we wish to compare the relative importance assigned to the different (sub)criteria proposed in the hierarchy, it is necessary to obtain the corresponding global priorities (w_i^*) for all the (sub)criteria on the same level of the hierarchy, that add up to one. Thus, w_i^* is an indicator of the importance of (sub)criterion i across the whole set of (sub)criteria considered on this level with respect to the global goal. These global priorities are obtained from the second level down by the *hierarchical composition principle*, multiplying each local priority by the priority of the parent node in the level immediately above –the second level elements are each multiplied by unity, the weight of the single top level goal–.

The quantification of local and global priorities and the measurement of the consistency constitute the third stage of the AHP, *prioritization*.

And finally, in the fourth stage, *synthesis*, the composite priority of each alternative with respect to the decision goal on the top of the hierarchy is generated by the adding of weights to the common nodes at the bottom level[10]. This is why the AHP has been traditionally associated with an additive value function (Kamenetzky, 1982) as follows:

$$V_i = \sum_{j=1}^{m} v_{ij} w_j \quad [4.5]$$

where V_i $(i = 1, \dots, n)$ are the overall values of decision alternatives; v_{ij} $(j = 1, \dots, n)$ are the values of decision alternatives with respect to (sub)criteria j, and w_j $(j = 1, \dots, m)$ are the weights of decision (sub)criteria.

[10] Other aggregation procedures to obtain composite priorities of alternatives have been proposed, including both additive and multiplicative shaped formulations (Stam and Duarte Silva, 2003).

4.2.3 Proposal for quantifying total value generated by productive investments

Since AHP is perfectly suited to capital budgeting decision-making, this technique has been widely used in the literature to support investment selection in multicriteria frameworks (Vaidya and Kumar, 2006). However, no research has addressed investment appraisal considering both the financial and intellectual value derived from the capital budgeting decision. Furthermore, researchers have paid little attention to the management of intellectual capital with multicriteria techniques. The only exceptions are a few papers focusing on the selection of indicators to measure intellectual capital (Han and Han, 2004; Bozbura et al., 2007) and on the relationships linking knowledge assets with company's performance in a new product development problem (Carlucci and Schiuma, 2007).

Being aware that value creation in the firm does not only stem from financial capital, as traditional valuation methods assume, but also from nonfinancial capital, it is necessary to incorporate the latter into capital budgeting appraisal processes. We therefore propose an analytical approach based on the AHP technique that quantifies the total market value created by productive asset investments.

The hierarchical structure of the proposed approach has four levels (see Figure 4.1): the final target of the decision problem –market value creation by investments–, criteria –the components of financial capital and intellectual capital–, subcriteria –indicators of the different components of a firm's capital– and alternatives –investment alternatives–.

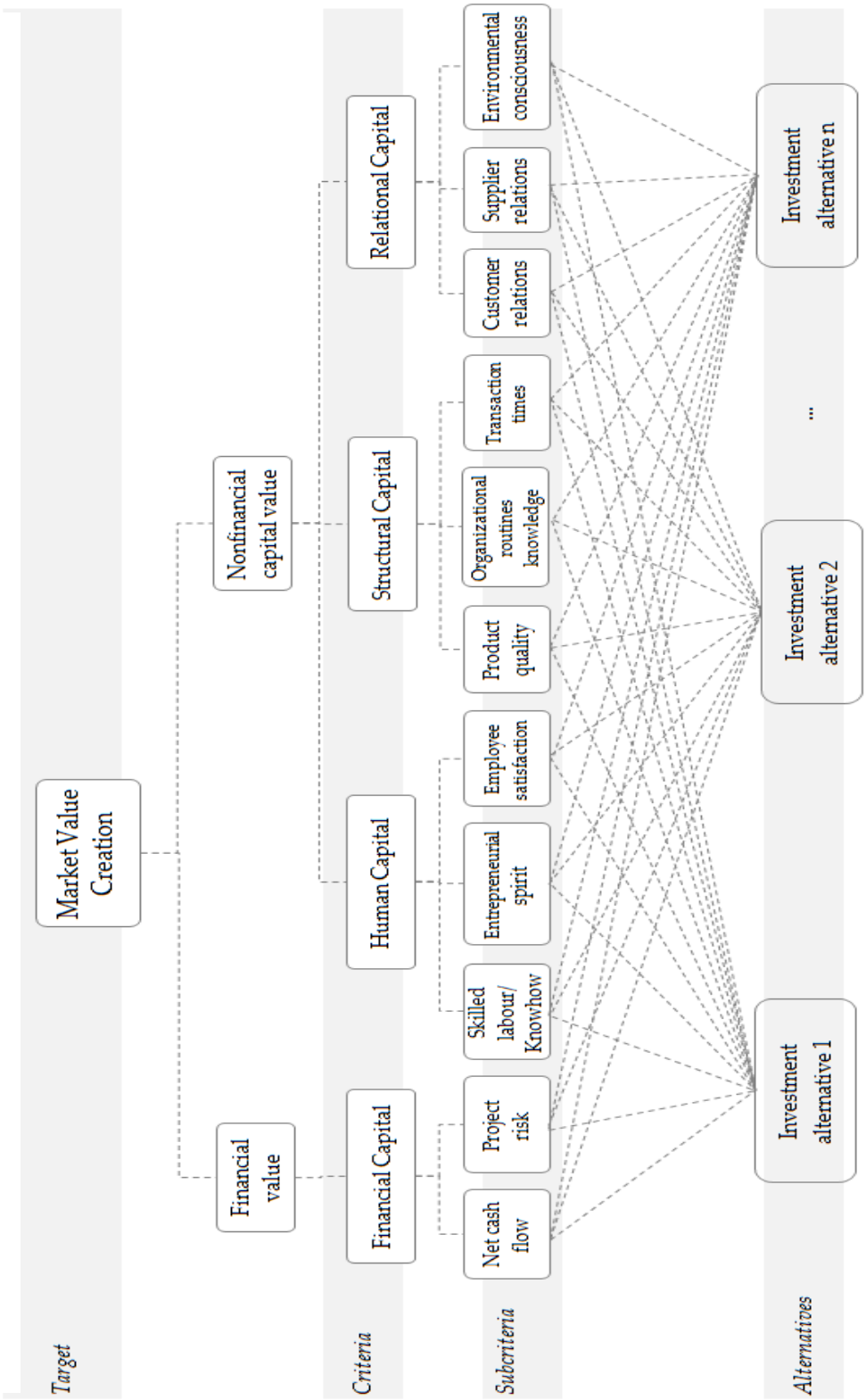


Figure 4.1 Decomposition of market value creation in assessing productive investments

Source: Own elaboration.

This hierarchy has been developed based on the literature review carried out regarding this field of knowledge. Moreover, this structure has been found suitable for investment appraisal in for-profit firms in a real setting by a group of academic experts in the fields of corporate finance and management science and by several widely experienced managers. In any case it is worth mentioning that the experts consulted agreed that the structure shown in Figure 4.1 must be considered only as a general yet flexible hierarchy, which would need specific fine-tuning before its implementation in case studies. Thus, this model needs to be adaptively modified in accordance with each investment appraisal process in order to consider the specific features of the assets to be incorporated and the influence of the investment options on the different components of a firm's value. This is particularly relevant when defining the concrete set of indicators of the intellectual capital subcriteria, an issue that is directly influenced by the nature of the investment and the features –size, structure, market orientation, etc.– of the firm.

Finally, it is also worth noting that the experts consulted commented that the measurement of the values of investment alternatives with respect to nonfinancial criteria (v_{ij} in expression [4.5]) would be the main difficulty for the implementation of this proposal in the real world, taking into account that most of these criteria have an intangible nature –i.e., there is no measurement scale for them–. However, all experts agreed that using the AHP to quantify these intangible criteria as proposed by Saaty et al. (2003) is an accurate enough solution in order to make this proposal operative; see, for example, Sundarraj (2006). In our case, this measurement process involves calculating the weights derived from paired comparisons of the investment alternatives considered with respect to their efficiency in attaining each of the nonfinancial criteria. These weights are a measure of the value v_{ij} along a ratio scale within a range [0-1]. For homogeneity reasons, the same method of measurement has been used for financial criteria, valuing investment alternatives for these criteria also within a range [0-1].

4.3 AN ILLUSTRATIVE CASE STUDY

4.3.1 Model tuning

In order to demonstrate the applicability of the proposed model, this section presents a real decision-making problem focused on the selection of an investment project in the food industry. The problem consists of assessing and prioritizing the following three alternative systems for meat-product quality control:

(1) *Establishing a firm´s own traditional laboratory*, where samples of products are analyzed to control their quality.

(2) *Acquiring a near infrared spectroscopy (NIRS) system*, a fast and non-destructive analytical technique based on the absorption of electromagnetic spectrum of the products suitable to control all quality parameters. These features are resulting in the application of the system being increasingly widespread in the food industry in general and meat manufacturing in particular (Pérez-Marín et al., 2009).

(3) *Outsourcing analysis* and quality control services to an external laboratory.

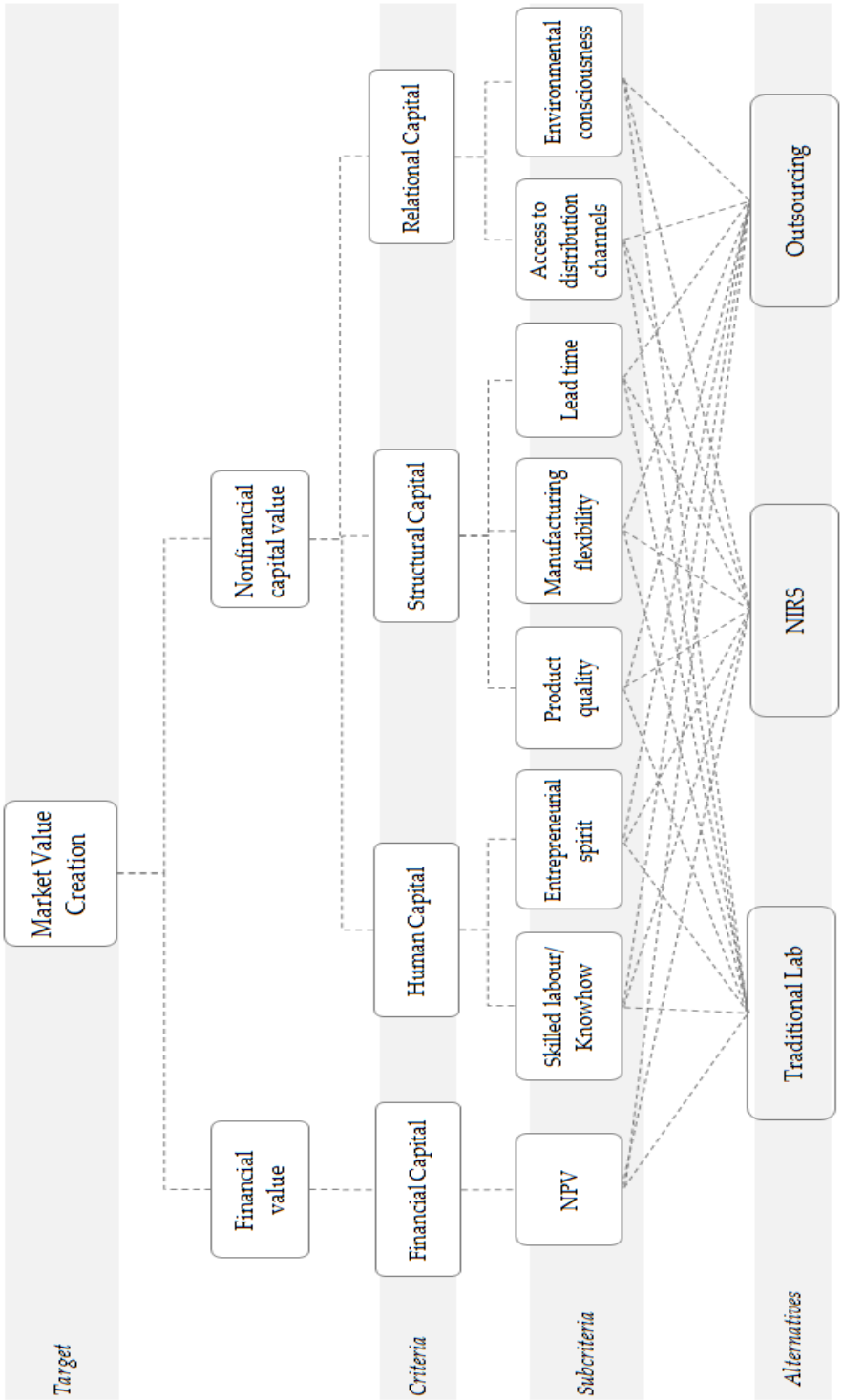
Valuation of these three alternatives is a complex task, as food quality control systems have strategic implications for the firm as a whole, impacting on both tangible and intangible capital (Irudayaraj and Reh, 2008). For this reason, the model proposed in the previous section is suitable to be applied to this case study.

Based on the *value creation model proposed* (Figure 4.1), I fine-tuned the hierarchy to be used in this case study. In order to do so, the author first performed an extensive review of the literature to catalogue indicators of value creation in the food industry regarding each of the subcriteria considered in the general model. Later, a group of academic experts –four with expertise in *finance* and *management* and the other two from the *food technology* field– discussed the catalogue developed, choosing the most relevant subcriteria to be taken into account in order to analyze value creation by the investments in quality control in the meat industry. In this way eight subcriteria were finally chosen, as displayed in the adapted hierarchy shown in Figure 4.2. Lastly, it is worth

mentioning that the five firms' managers (CEO) involved in the empirical application (see next section) also validated the subcriteria chosen and the whole hierarchy proposed, prior to completing the questionnaire developed for the implementation of the methodology[11].

[11] The AHP questionnaire can be consulted in Annex 2.

Figure 4.2 Hierarchical structure used to value an investment in food quality assessment



Source: Own elaboration.

4.3.2 Data collection

Five Spanish meat firms with a minimum annual turnover of 1.5 million Euros each were selected for the empirical application of the proposed methodology (referred to as A, B, C, D, and E to protect their identity). This size restriction is justified by the technical and financial impossibility of undertaking the investment projects required by the two first alternatives.

Table 4.2 shows the main characteristics of the five firms. On the one hand, it is worth noting that A and D are family businesses with annual turnovers of less than €2 million, total assets of 5.3 and 1.9 million, respectively, and that neither has more than ten employees. On the other hand, the rest of the firms are larger corporations displaying higher annual turnovers, ranging from €6.4 million in the case of B to €15.8 million for E, as well as higher total asset figures, amounting to €31.2 million in the case of B. Furthermore, the number of employees ranges from 31 in B to 53 in C.

Table 4.2 Financial-economic description of the firms

	FIRM				
	A	B	C	D	E
Net revenue (M€)	1.9	6.4	14.8	1.6	15.8
Total assets (M€)	5.3	31.2	16.6	1.9	14.1
Employees	8	31	53	10	46

Source: Own elaboration.

After selecting the five firms, I contacted their CEOs for an interview at their workplaces during which they completed the questionnaire provided in order to obtain the evaluations. Thus, each CEO was asked to make pairwise comparisons to obtain the weights of the criteria and subcriteria considered in the analysis. Furthermore, these managers also provided the pairwise comparisons required to quantify the contribution of each investment alternative with respect to each subcriterion.

4.3.3 Results[12]

First, to determine the consistency of CEO's in assessing pairwise comparisons, the CR was calculated for each judgment matrix. Since CR was in all cases smaller than the threshold value of 0.1, judgments and the derived weights were considered consistent and valid for the empirical analysis.

Table 4.3 summarizes the relative importance assigned to financial and nonfinancial capital values for each firm. As can be observed, the family-run firms (A and D) assigned greater relevance to nonfinancial capital value, 75% in both cases; while for large industrial corporations (B, C, and E) financial value is substantially more important, at around 80%. This duality is justified, firstly because family firms prefer to improve their competitiveness and therefore their total value, through long term strategies (D´Allura and Minichilli, 2012) focused primarily on intangible issues (Habbershon et al., 2003). Thus, their value creation strategies are mainly based on increasing their nonfinancial capital value. Secondly, the differing importance assigned to financial and nonfinancial capital values by firms can be explained by the *agency theory* (Jensen and Meckling, 1976) and, more specifically, by *managerial myopia*: managers of large corporations may pursue their own interests by investing in projects with cash-flows closer in time, but less profitable in the long term; or by rejecting highly profitable projects because they have smaller cash flows in the short term (Byrd et al., 1998). However, in family businesses, where ownership and management are not separate, this problem has very little impact; hence, they prefer to sacrifice short-term profitability to generate long-term value, prioritizing attributes associated with nonfinancial capital. By contrast, in larger firms where there is total separation between shareholders and managers, this agency problem does occur, the short-term view taking priority and more relevance being assigned to the attributes associated with financial value (NPV).

[12] Detailed results can be consulted in Annex 3.

Table 4.3 Weights assigned to the criteria and subcriteria by each firm

	FIRM				
	A	B	C	D	E
Financial value	**25.0**	**75.0**	**83.3**	**25.0**	**87.5**
Financial Capital	*25.0*	*75.0*	*83.3*	*25.0*	*87.5*
NPV	25.0	75.0	83.3	25.0	87.5
Nonfinancial capital value	**75.0**	**25.0**	**16.7**	**75.0**	**12.5**
Human Capital	*32.1*	*10.7*	*11.6*	*25.0*	*3.5*
Skilled labor/knowhow	24.1	1.8	1.5	3.1	0.9
Entrepreneurial spirit	8.0	8.9	10.1	21.9	2.6
Structural Capital	*10.7*	*10.7*	*2.2*	*25.0*	*7.3*
Product quality	6.8	6.3	1.7	19.2	1.6
Manufacturing flexibility	3.3	3.0	0.2	1.9	5.2
Lead time	0.7	1.5	0.2	4.0	0.5
Relational Capital	*32.2*	*3.6*	*2.9*	*25.0*	*1.7*
Access to distribution channels	28.1	3.0	2.5	21.9	1.5
Environmental consciousness	4.0	0.6	0.4	3.1	0.2

Source: Own elaboration.

Table 4.3 also shows the weights of the criteria and subcriteria in each firm. In reference to nonfinancial capital value, there is no common pattern regarding the weights assigned to the different components. As regards the two family firms, which assigned a preferential weight to this component of total value, it is worth noting that A gives a strong and similar weight to the criteria related to *human capital* and *relational capital* (32% each), while D gives equal importance (25%) to each of the three nonfinancial capital value criteria. In any case, it is worth pointing out that *human capital* is highly relevant in both firms because it is an essential element of the success of smaller companies (Coleman, 2007). Also, access to distribution channels, as a subcriterion of *relational capital*, was perceived as highly significant by the two family firms: 28.1% in A and 21.9% in D. This fact can be explained by the strategic importance of commercial relations in small firms positioned in market segments of high quality and high added value products, which require narrow and specific marketing channels.

Referring to larger industrial firms, it should be emphasized that B assigns the most importance (25%) to nonfinancial capital value, primarily to *human capital* and *structural capital*, with 10.7% each. In C, much of its nonfinancial capital value is generated by *human capital* and, in particular, through the entrepreneurial spirit of employees (10.1% out of a total of 16.7% of the

nonfinancial capital value). In contrast, in the case of the firm that gives the least weight to this second component of value (E), *structural capital* is the most important criterion, *manufacturing flexibility* figuring prominently with 5.2%, which reflects the need of this firm to adjust their production portfolio quickly to meet variable customer demands.

One common feature of four out of the five firms –all except E– is that *product quality* is the key subcriterion within *structural capital* (reaching up to 19.2% in D), which reflects that the focus on quality is the main differentiation and value generation strategy of most of the firms in this food sector.

These results corroborate the evidence obtained in Youndt et al. (2004), which confirmed the existence of *multiple intellectual capital profiles* in a wide group of firms. According to these authors, *business strategy* determines orientation towards different types of intellectual capital.

After obtaining the weights of the criteria and subcriteria from the CEOs, expression [4.5] can be used to compare the total value generated by each investment alternative in every firm, providing the results shown in Table 4.4. Furthermore, in order to validate the proposed model, these results are compared to the alternatives to meat quality control actually chosen by the five firms analyzed.

As can be seen, NIRS is the alternative that, to a greater extent, creates the most value in four of the five firms (A, B, C, and E), considerably ahead of the other two alternatives in larger firms. For example in E, the NIRS system records a value of 0.75, compared to 0.17 in the case of traditional lab and 0.08 for outsourcing. However, only two (B and E) of the four firms have already implemented this technology. In any case, it is worth mentioning that the CEOs at A and C indicated in their interviews that the decision to invest in NIRS had actually been taken, but effective implementation of the system would ultimately depend on the restrictions on access to credit arising from the current financial crisis. In fact, these two firms are involved in two research projects for the development and future implementation of NIRS in their production processes.

Regarding firm D, the smallest of the five, outsourcing is the alternative that generates the most value and this is the option the firm actually chose for meat quality control.

Table 4.4 Market value creation of each alternative

Firm	Traditional Lab	Near Infrared Spectroscopy	Outsourcing	Quality control system currently implemented
A	0.27	**0.50**	0.23	Outsourcing*
B	0.26	**0.51**	0.23	NIRS
C	0.09	**0.73**	0.18	Outsourcing*
D	0.32	0.28	**0.40**	Outsourcing
E	0.17	**0.75**	0.08	NIRS

Source: Own elaboration.
** The decision to invest in NIRS system has already been taken but it still has not been effective.*

The practical interest of the theoretical model this paper proposes is thus confirmed when comparing the results obtained by our model and the actual investment decisions taken in each firm. This fact leads to the conclusion that *the proposed model is a formalization of the process actually followed by financial decision makers to capital budgeting*. In this formalized process, all value creation criteria, both financial and nonfinancial, are integrated in a transparent and instrumentalized way. However, further empirical evidence is required to definitively confirm this proposition. Nevertheless, these results clearly evidence that the CEOs of the firms surveyed certainly consider nonfinancial capital value creation components in their analysis for capital budgeting decision-making, in addition to traditional financial criteria (financial value measured by NPV or IRR).

4.4 CONCLUSIONS AND FUTURE RESEARCH

This chapter has developed a *novel methodology for capital budgeting* in for-profit firms, bearing in mind that this is a complex task due to the non-monetary and intangible impacts involved in productive assets investment, which have traditionally been ignored by classical financial techniques. Thus, it has been assumed that investment appraisal in for-profit firms should take into account not only financial value creation, that is, the contribution of new assets to the cash-flows of the firm –as NPV and IRR do–, but also the creation of nonfinancial capital value derived from the increase in corporate intellectual capital.

Given the intangible nature of nonfinancial capital value, as well as its three components –*human capital*, *structural capital* and *relational capital*–, an AHP-

based model has been formulated to quantify and assess both the criteria and subcriteria related to financial value creation and the intangibles related to nonfinancial capital value. In this way, we have tried to –partially– avoid the problem of estimating how much cash flows will increase associated with the intellectual capital generation due to productive investments, and the problem of fixing when it does occur.

The proposed investment appraisal model has been applied to a real case study in order to assess several quality control investment alternatives in the meat industry. The empirical application of our model to this case study has demonstrated its *feasibility* and *effectiveness* in a real setting and also evidenced the need to consider the impacts of productive investments on a firm's intangible assets, as *these impacts actually affect the selection of optimal investment alternatives in the food industry*.

Furthermore, it is also worth indicating that the model proposed could be applied to any investment decision, albeit following adaptation to each particular case study in order to initially establish the specific intangibles –components or subcriteria related to *human capital*, *structural capital* and *relational capital*– that the investment alternatives under consideration may have an impact on.

Based on the *empirical application*, we also reached the *following conclusions*:

- There is a *clear duality between family firms and industrial corporations* regarding the relative importance assigned to the generation of financial and nonfinancial capital value. Although this situation appears in regard to the firms analyzed in our case study, we believe it can be extrapolated to the whole industry due to *managerial myopia* affecting larger companies, where there is a clear separation between shareholders and managers, leading to much higher relative importance being given to financial value creation.
- Taking into account the paragraph above, it is suggested that the capital budgeting model proposed here is *particularly suited to explaining investment decisions in family firms*. In any case, considering that even the larger companies in our case study assign a non-negligible weight to nonfinancial capital value –figures above 10%–, there is justification to apply this approach to any firm.

- There is *no common pattern in the sample considered that explains the distribution of intellectual capital components*. Why firms focus on one type of intellectual capital or another is determined by organizations' own strategies. Therefore, it is necessary for financial decision-makers to link the investment project valuation process to the business strategy followed in order to give more weight to attributes related to it. This diversity of business strategies –disparity in the contribution of financial capital and intangible capital to firms' total value– can be seen in an integrative way through the methodology proposed here.
- The prioritization of investment project alternatives in the case study has been satisfactorily corroborated by actual decision-making, thereby validating the proposed model both theoretically and empirically.

Nevertheless, it is worth pointing out that *the conclusions above are still tentative*, since they cannot be definitively confirmed based only on a pilot study with an empirical application reduced to five companies. Therefore, further empirical investigation is needed to validate these findings. In this sense, it is suggested that the approach proposed here be implemented to larger samples of firms in different economic sectors and for different types of investments. Only by testing the adaptation of this approach to different contexts in this way, will the validity of the methodology proposed and the main conclusions achieved be corroborated (or not).

In any case, this paper is expected to provide *a contribution to the current literature by providing a new capital budgeting methodology for for-profit firms*, entailing the consideration of nonfinancial value creation criteria into the investment valuation process. This novel approach aims to achieve more effective decision-making in order to select the investment alternatives that maximize total value creation or firms' market value.

Finally, it is worth mentioning that as an interesting line for future research, one might try to extend the proposed model to determine the intangible value of firms in monetary terms. This should be especially interesting for purposes of mergers and acquisitions or when the companies are preparing to float on the stock market and estimations of the intangible value of firms are needed.

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Capítulo 5

An ANP-based framework for environmental management system selection: an intellectual capital approach

ABSTRACT

The adoption of environmental management systems have expanded among those firms looking to minimize their environmental impacts. In view of the fact that companies have to select the optimal management system from a set of possible alternatives, this paper presents a novel decision-making approach based on the multicriteria method of *analytic network process*, in order to evaluate and prioritize the implementation of environmental management systems alternatives in for-profit firms. Since several relevant intangible benefits are derived from the adoption of this kind of systems –such as enhancing employees' knowledge, skills, and corporate reputation–, the method integrates and quantifies both financial and non-financial –intellectual capital– value creation criteria in order to identify the alternative that maximizes a firm's total market value. The proposed approach is empirically tested in a group of proactive environmental firms in the Spanish olive oil industry, and the results confirm the reliability of the proposed model. Furthermore, the empirical applications reveal that a great importance is placed on the intangible elements in all olive oil industries when assessing environmental management systems. These results suggest the appropriateness

of considering, in the decision making process, the intellectual capital value emerging from these kinds of management systems. We conclude that the proposed method formalizes the evaluation process actually followed by companies, as they are certainly considering, although in an intuitive way, non-financial capital value creation elements.

5.1 INTRODUCTION

Firms have traditionally responded reactively to the ecological environment, doing only the minimum required by law and investing in end-of-pipe pollution control measures (Delgado-Ceballos et al., 2012). Firms following this strategy perceived that a good environmental performance was negatively associated with a good financial performance. Therefore, issues regarding the ecological environment were viewed as business costs and possible detractions from the objective of maximizing shareholder value (Sharma and Vredenburg, 1998). In the mid nineties, Porter and van der Linde (1995) offered a new approach to analyze this topic by proposing that environmental regulation can lead to win-win situations in which environmental performance as well as the private benefits of firms can both be improved. Since then, most studies have linked *the firm's investment in environmental practices to competitiveness and to a good financial performance* (Link and Naveh, 2006; Lopez-Gamero et al., 2010).

Due to this new approach and, as a consequence of the growing pressures that firms are facing nowadays, the adoption of environmental management systems (EMSs) as frameworks for integrating corporate environmental protection policies, programs, and practices have expanded among both domestic and multinational companies around the world (Morrow and Rondinelli, 2002; Simon et al., 2012). EMSs tend to be based on international standards of reference; the most popular systems are the ISO 14001 and the Eco-Management and Audit Scheme (EMAS) created within the European Union. The latest available data from ISO by 2012 reveal that the number of ISO 14001 certificates awarded exceeded 285,000 around the world: China, Japan, Italy, Spain and United Kingdom are the top five countries for number of certificates (ISO, 2012). According to the data from the European Commission (2013), by the end of 2012 more than 8,500 sites and 4,400 organizations had registered under EMAS guidelines. It is also worth pointing out that other companies are adopting major components of international standards for environmental

management without formally certifying them, thus avoiding the cost of certification by a third-party auditor (Morrow and Rondinelli, 2002).

EMSs positively impact on the two key pillars of for-profit firms' value creation: financial capital flows, i.e. improving the efficiency in resource-use and reducing costs (Gavronski et al., 2008), which improves the *financial* or *book value* of the firm; and the intangible capital, i.e. improving the company's reputation and image, increasing employee motivation, or getting a better internal organization and documentation (Psomas et al., 2011; Martín-Peña et al., 2014), which raises the *intellectual capital value* of the firm. These two impacts are reflected by a firm's higher market value, thus justifying the EMS investment costs. However, no studies have examined the evaluation of corporate environmental management systems. The reason behind this gap is because whereas the costs and financial benefits –financial capital flows– related with EMSs are immediate and measurable, some major benefits associated with these investments are intangible (Steger, 2000). These latter benefits are those provided by the improved firm's *intellectual capital*, which is difficult to measure because these benefits are hardly quantified in monetary terms, unlike financial capital flows. Identifying and measuring these kinds of benefits represent critical aspects of the decision-making process in selecting the best EMS alternative, yet the intangibility of intellectual capital has made it quite challenging to analyze and justify the investment in EMSs. The traditional capital budgeting methodologies –discounted cash flow techniques, such as net present value, internal rate of return, or payback methods– are difficult to use in justifying this type of investment, as these techniques only consider the direct monetary effects –financial capital flows– of investments and overlook the indirect ones affecting the firm's intangibles (Götze et al., 2008; Liang and Li, 2008; Kreng et al., 2011). Thus, new appraisal methods are required to evaluate investments with substantial intangible outcomes, such as environmental management systems.

The main objective of this chapter is *to provide for-profit firms with a decision-making approach for the selection of the 'best' EMS alternative*, that is, the one that maximizes a firm's market value. For this purpose, not only direct and financial benefits are included in the analysis, but also intangible and non-financial benefits associated with the adoption of each environmental management system. The proposed approach is based on the multicriteria technique of the analytic network process (ANP) and categorizes EMS selection criteria into two

main sets: *financial value* and *intellectual capital value*. The latter set is divided into three dimensions: human, structural, and relational capital values. This ANP model allows the quantification of both the financial and non-financial (intellectual capital-related) value creation by EMSs, enabling the selection of the alternative that maximizes value creation. This new methodological approach is furthermore empirically tested in a real setting; we implement this approach as an illustrative case study for the selection of the best EMS alternative in firms within the Spanish olive oil industry.

The remainder of this chapter is arranged as follows: Section 5.2 presents the theoretical framework underlying this study, where we briefly discuss corporate environmental management systems and the fundamental basis of value creation in firms. Section 5.3 introduces the proposed decision model to evaluate and prioritize a set of EMS alternatives. The empirical case study within the olive oil industry will be illustrated in Section 5.4 in order to test the applicability of the proposed decision framework. Finally, in Section 5.5 the conclusions are presented, and the original contributions made by this research are identified.

5.2 LITERATURE REVIEW

5.2.1 Environmental management systems

EMSs are *strategic management approaches* that define how an organization addresses its impacts on the natural environment (Darnall et al., 2008). EMSs consist of a collection of internal policies, assessments, plans and implementation actions affecting the entire organization (Coglianese and Nash, 2001). EMSs are increasingly being recognized as systematic and comprehensive mechanisms for improving not only environmental performance but also business performance (Curkovic et al., 2000).

Not all EMSs are designed and implemented similarly, mainly because EMSs must be put into action in different organizational settings, and facilities may adhere to different types of EMS standards (Coglianese and Nash, 2001). One of the main distinctions among EMSs is whether or not they are certified by an independent third-party auditor. The two most frequently used guidelines for EMS design and certification are the standard *ISO 14001*, proposed by the

International Organization for Standardization, and the European standard *EMAS*. The main difference between these two options is the requirement of a public statement reporting the organization's environmental performance in the case of the latter option. By contrast, organizations may also adopt *non-certified EMSs*, avoiding certification costs and having more flexibility in the degree to which environmental management is integrated throughout the organization (Darnall and Edwards, 2006).

Two main theoretical approaches are found in the literature regarding the sources of motivation leading companies to implement different environmental self-regulation initiatives in their organizations (Heras-Saizarbitoria et al., 2011a). From one perspective, *external pressures* are identified as the main motivation to adopt EMSs. In this sense, certified EMSs serve as a signaling device, informing regulators, buyers, and consumers that they are managing their environmental impacts efficiently (Johnstone and Labonne, 2009). The alternative approach, supported by the *resource-based view theory*, explains the sources of motivation from an *internal perspective* (Hart, 1995; Sharma and Vredenburg, 1998); proactive environmental management leads to the development of firm-specific capabilities, which are expected to give companies a sustainable competitive advantage.

A substantial amount of evidence has been collected regarding the positive effects of EMSs on the firm's overall *environmental performance* (King et al., 2005; Arimura et al., 2008; Iraldo et al., 2009). EMSs can reduce the probability of unintentional non-compliance with regulations and may help managers identify and implement the most cost-effective means to meet their environmental objectives (Johnstone and Labonne, 2009).

Regarding the impact of EMSs on *economic performance*, a few early authors questioned the optimism of environmental advocates and demonstrated the negative relationship between both kinds of performance (Cordeiro and Sarkis, 1997). However, the most recent literature has clearly identified a positive relationship between both variables (Hart and Ahuja, 1996; Klassen and McLaughlin, 1996; Judge and Douglas, 1998; Al-Tuwaijri et al., 2004; Aragón-Correa et al., 2008). In fact, companies which engage corporate environmental management and green innovation actively can not only reduce production waste and increase productivity but also: a) improve corporate public image and enhance communication with their stakeholders, b) charge relatively higher

prices for greener products and services, c) sell the knowhow of environmental protection, d) develop new markets –i.e., international ones–, e) improve compliance with the many and complicated environmental regulations and hence reduce the risk of future liabilities, and f) increase employees' motivation (Porter and van der Linde, 1995; Shrivastava, 1995; Petroni, 2001; Steger, 2000; Gavronski et al., 2008). As will be explained in the next section, all of these aspects increase the *intellectual capital* of the firms, allowing them to achieve sustainable competitive advantages that also involve value creation –an increased market value–.

Due to the reasons provided above, EMSs are particularly interesting for those firms needing increased public legitimacy (Prakash, 2001). Therefore, companies in pollution-intensive industries or with bad reputations of complying with environmental laws are more likely to adopt them.

5.2.2 Value creation in firms: financial and intellectual capital value

The market value of a firm is the result of adding its financial capital, represented by the book value, and non-financial or intangible capital, also called intellectual capital (Roos et al. 1998; Johnson, 1999). Examples of the latter are certain hidden and intangible resources such as reputation of the firm, employee knowhow, and customer satisfaction. The increasing gap between a firm's market and book value –i.e., the intellectual capital– has driven researchers to explore this invisible value omitted from financial statements (Chen et al., 2005). Furthermore, in today's ever-competitive markets, both academics and practitioners identify intellectual capital (IC) resources as the key to obtaining and maintaining competitive advantages (Lev and Zambon, 2003). Nevertheless, estimating value from IC is a much more complicated and risky process than extracting value from financial capital (Augier and Teece, 2005), since IC components are difficult to identify and measure because of their intangible features. Thus, following classical capital budgeting approaches, the impacts of the investments on intellectual capital value are usually not taken into account. Two main reasons are behind this shortcoming: first, the difficulty of monetarily quantifying the indirect increase of cash flows derived from the raising of intellectual capital; and second, the uncertainty about the point in time where these cash flows will take place.

IC has been identified as a key resource driving organizational performance and value creation for the firm (Nahapiet and Ghoshal, 1998). It is defined as all nonmonetary and nonphysical resources that are fully or partly controlled by the organization and that contribute to the organization's value creation (Roos et al., 2006) as a needed complement to financial capital. IC represents knowledge-related intangible assets having a positive impact on competitiveness, business performance, and market value, making it a crucial indicator for future financial performance (Hand and Lev, 2003; Lev and Daum, 2004).

It is generally acknowledged that IC is the combination of the following three main dimensions: human, structural, and relational capital. *Human capital* is the individual-level knowledge encompassing employees' competence, commitment, motivation and loyalty (Chen et al., 2005), which is valuable when it is firm-specific and resides in the environment where it was originally developed (Hitt et al., 2001). A firm with more capable employees is likely to earn higher profits than its competitors, thus positively affecting the firm's outcomes and also impacting on its competitive advantage (Huselid, 1995; Hitt et al., 2001). *Structural capital* is defined as the organizational ability of the firm to utilize human intelligence and innovation to create wealth (Johnson, 1999), representing institutionalized knowledge and codified experience stored in databases, routines, manuals, structures and the like (Hall, 1992). It is the skeleton and the glue of an organization because it provides the tools and architecture for retaining, packaging and moving knowledge along the value chain (Cabrita and Bontis, 2008). There is also a positive relationship between structural capital and value creation (Marr et al., 2004; Díez et al., 2010). Lastly, *relational capital* represents the portion of a company's market value that is attributable to its portfolios of business relationships (Roos et al., 1998). These portfolios comprise relations with customers and suppliers as well as with relevant stakeholders such as lobby groups or government agencies.

In approaching IC, two main perspectives seem to dominate: the first perspective is *static*, the other, *dynamic* (Marr et al., 2004). The *static perspective* focuses on the properties of the three IC components, identifying their size through financial and nonfinancial indicators in company reports. The *dynamic perspective*, instead, seeks to investigate the interactions among IC components and the linkages between IC and financial performance (Marr et al., 2004; Cuganesan and Dumay, 2009). Efficient management of organizational assets is

impossible without understanding the interrelationships and interdependencies of IC assets (Marr et al., 2004). Therefore, recasting extant models and frameworks to better represent IC-in-action is imperative, given that the majority of organizations are engaged in IC dialogue in relation to long-term value creation aspirations (Roslender and Fincham, 2004).

5.3 METHODOLOGY

This section is divided into two sub-items. First, the multicriteria decision making method of analytic network process is explained; and second, the proposed ANP-based model for EMS selection is presented.

5.3.1 The analytic network process

The ANP is a multicriteria decision-making tool that extends the widely used AHP –analytic hierarchy process–. The main purpose of both techniques is to select the best alternative from a given set of alternatives by considering the judgments on pairwise comparisons from decision-makers. AHP has been applied to a large variety of decision-making problems (Vaidya and Kumar, 2006), such as for supplier selection (Kannan et al., 2013) or for project selection issue (Wei et al., 2005; Çimren et al., 2007; Jiang et al., 2011). However, the implementation of ANP is much sparser in the literature due to the recent development of this technique. In fact, only a few case studies can be found as applications of ANP regarding capital budgeting decisions (Liang and Li, 2008).

The AHP decomposes a problem into several levels of elements –criteria and subcriteria–, forming a hierarchy (Saaty, 1980), as it has been seen in Chapter 4. Each of these elements is assumed to be independent, thus considering a unidirectional hierarchical relationship among decision levels. The criteria and subcriteria considered in the analysis can be related with both the tangible and intangible aspects of the decision-making problems. However, many decision-making problems cannot be structured hierarchically as they are with AHP, because they involve linkages and interdependences among the elements considered. This situation occurs when considering financial capital and the different dimensions of IC as decision criteria for capital budgeting, because of the *dynamic view* of intellectual capital. This perspective assumes linkages and interdependencies between human, structural, relational and financial capital.

In these cases, ANP is a useful instrument, as this technique goes beyond linear relationships and captures interdependencies among the decision criteria and among the alternatives, with respect to each criterion. Instead of a hierarchy, ANP is based on a network that replaces single-direction relationships with multiple dependences and feedback (Saaty, 1996).

Briefly, the ANP technique is implemented following these steps:

Step 1. *Developing the decision model structure*. Elements or nodes –decision criteria, subcriteria, and the alternatives– are identified and grouped into clusters. Relations between all of them are shown in a network structure, where it is possible to determine interactions and feedback within clusters –inner dependencies, represented by looped arcs– and between clusters –outer dependencies, represented by arcs with directions–.

Step 2. *Conducting pairwise comparisons on the elements through a questionnaire*. Decision-makers are asked to compare between pairs of elements at each cluster with respect to their importance towards their control factor using Saaty's 1-9 scale (see Table 5.1). The way of conducting pairwise comparisons and obtaining priority vectors is the same as in the AHP. A score of 1 indicates equal importance of the two elements, whereas a score of 9 indicates overwhelming dominance of the element under consideration over the comparison element.

Table 5.1 Saaty's 1-9 scale for ANP

Intensity of importance	Definition
1	Equal importance/influence of one over another
3	Moderate importance/influence of one over another
5	Strong importance/influence of one over another
7	Very strong importance/influence of one over another
9	Extreme or absolute importance/influence of one over another
2, 4, 6, 8	Intermediate values between the two adjacent judgments

Source: Saaty (1980).

Then, a local priority vector for each pairwise comparison matrix can be derived using the *eigenvector method*, as an estimate of relative

importance associated with the elements being compared. Moreover, the consistency of judgments is checked.

Step 3. *Forming the unweighted supermatrix*. For this purpose the resulting relative importance weights –eigenvectors– in pairwise comparison matrices are placed within the unweighted supermatrix.

Step 4. *Conducting pairwise comparisons on the clusters*. Clusters are also compared pairwisely with respect to their impacts on each control cluster following the same procedure as Step 2. The priorities form the cluster matrix.

Step 5. *Constructing the* w*eighted supermatrix*. The unweighted supermatrix is multiplied by the priority weights from the clusters, yielding the weighted supermatrix, which is stochastic.

Step 6. *Constructing the limit supermatrix*. Raising the weighted supermatrix to limiting powers, to $2k + 1$, where k is an arbitrarily large number, until the importance weights converge and remain stable. In this new matrix, called the limit supermatrix, all the columns are the same.

Step 7. *Selecting the best alternative*. The final priorities of elements in the network are in the corresponding columns in the limit supermatrix. The alternative with the largest overall priority should be the one selected.

Further detailed information about the theory and the praxis of ANP can be found in Saaty (1996).

Due to of the explanations already given, the main motivations for adopting ANP as a procedure to find the best EMS for the firm are: a) both tangible and intangible factors could be considered in the appraisal process, making it possible to quantify the effects of the EMS not only on the firm's financial value –monetary or tangible criterion–, but also on the firm's intellectual capital value –intangible criterion–; b) complex decision models with feedback and interdependence among their criteria –in our case between human capital, structural capital, relational capital, and financial capital– can be solved with this technique; and c) ANP is an intuitive approach that decision-makers can easily understand and implement even without any special skill or training.

Despite the above advantages of ANP, several disadvantages are also worth mentioning. First, determining the relative importance of the criteria requires a

very time-intensive discussion process for decision-makers. Second, ANP demands many more pairwise comparisons and more calculations as compared to the AHP process. In any case, the latter disadvantage has been overcome by using Superdecisions software (http://www.superdecisions.com) to alleviate the mathematical burden.

5.3.2 An integrated model for EMS selection

In this section, we attempt to present the structure of a generalized decision-making model for EMS selection (Step 1 mentioned in Section 5.3.1). Four clusters, in addition to the alternatives' cluster, have been formed corresponding to the four sources of value creation in for-profit firms: *financial capital value*, *human capital value*, *structural capital value*, and *relational capital value*. Within each cluster, several subcriteria have been identified on the basis of literature review and a series of discussions with a panel of academicians and food industry experts. Although this set of subcriteria has been determined as the most prevalent and meaningful for EMS prioritization and selection, it is worth pointing out that these elements could be adapted or extended to support decision-making in other different situations or organizations.

Financial capital value cluster (FC) includes the following two elements: i) total cost, both start-up and operating costs (FC1) and ii) revenues derived from higher sales and efficiency enhancement (FC2) (Hillary, 2004). Cost (FC1) will vary depending on a number of quantitative and qualitative characteristics of the firm (Halkos and Evangelinos, 2002), such as its size or the complexity of its operations. In addition, organizations that have previously adopted similar standards, such as ISO 9001, are more likely to incur lower costs because of learning by doing (King and Lenox, 2001). On the other hand, firms adopting proactive environmental strategies –EMS implementation– may get a double benefit (FC2). First, they may have premium pricing and increased sales because of enhanced market legitimacy (Heras-Saizarbitoria et al., 2011b) or through the access to new 'environmentally friendly' segments of the market. Second, revenues may increase because of an improved productive efficiency, related to lower water or energy consumption, or the reduced need for raw materials, all of which are accomplished by adopting an EMS.

Human capital value cluster (HC) also integrates two subcriteria. The first one is employees' knowledge and skills (HC1), since successful EMS development

mandates employees receive thorough environmental training (Daily and Huang, 2001). These training programs are conducted to reinforce the knowledge and skills of employees, facilitating their involvement in the EMS implementation process and minimizing their 'natural' resistance to changes. The second component of HC is employees' commitment and motivation (HC2) (Morrow and Rondinelli, 2002), because EMS has the potential to enhance awareness of environmental issues among employees, which may result in improved employee morale and motivation (Petroni, 2001).

Structural capital value cluster (SC) comprises only one element, internal organization and documentation (SC1). Morrow and Rondinelli (2002) found, in a survey conducted among German companies with certified environmental management systems, that one of the most highlighted benefits was a better internal organization and documentation in the firm. The first mainly refers to a clearer division of roles, tasks and responsibilities, while documentation is related to more comprehensive record keeping, which leads to improved documentation control.

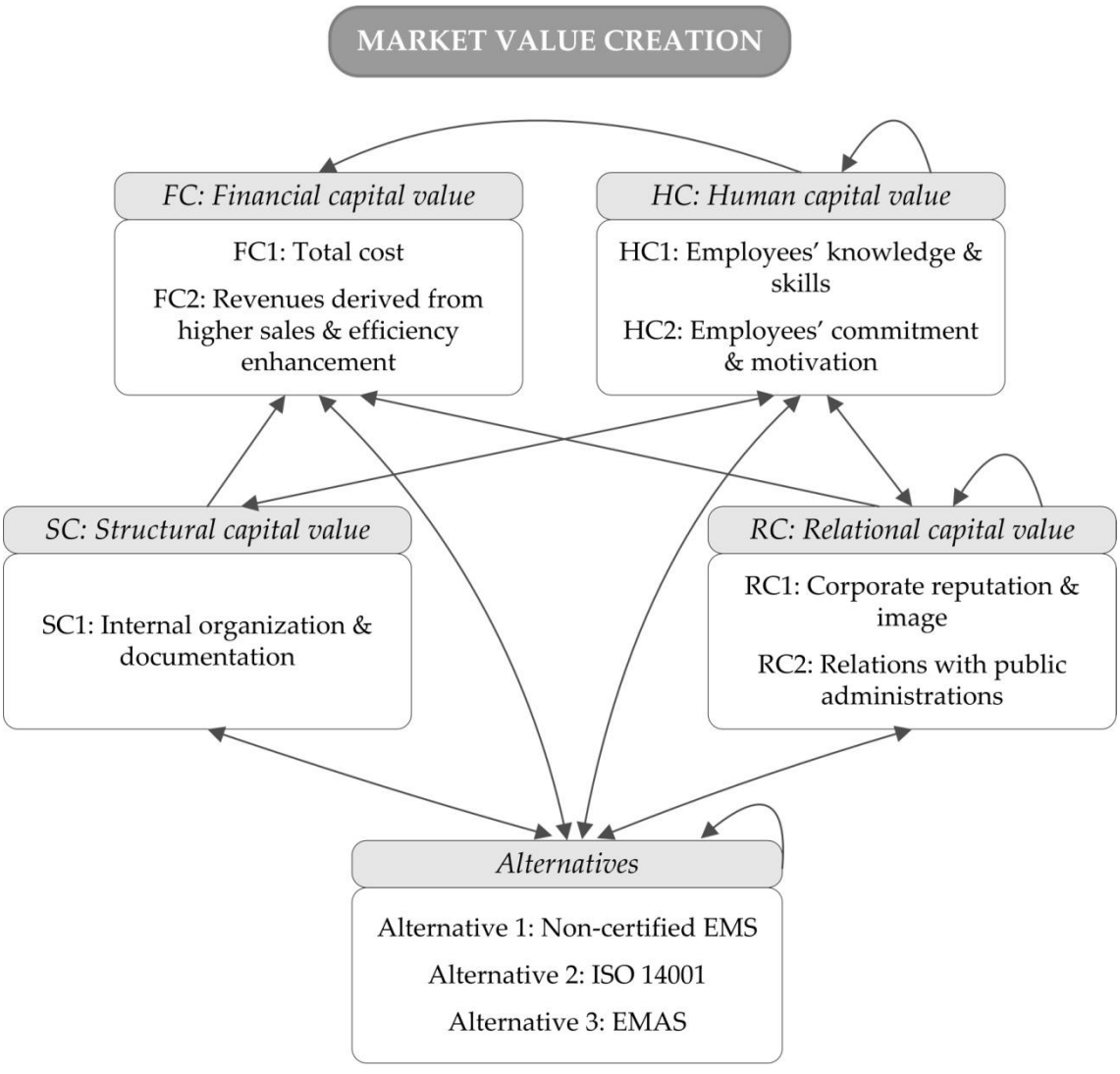
Finally, *relational capital value cluster* (RC) contains two subcriteria. The first one is the corporate reputation and image (RC1), defined as the perception the relevant stakeholders –such as owners, society and community, customers, employees, and non-governmental organizations– have of the firm (Carroll and Buchholtz, 2009). This corporate reputation is enhanced because of the 'environmental-friendly organization' image (Zutshi and Sohal, 2004) provided by EMSs. The second component is RC2, the relations with public administrations, which could be facilitated as a result of the adoption of a certified or non-certified EMS.

The cluster of *alternatives* includes the most well-known and used environmental management systems: ISO 14001 and EMAS, besides the non-certified EMS. The latter alternative resembles the ISO 14001 system in all of its technical requirements, while avoiding the certification cost.

In order to determine inner and outer dependencies, first we conducted an extensive literature review to explore causal relationships between IC and financial capital clusters. Prior research, however, has given little guidance on how the different value clusters interact with each other (Moustaghfir, 2009). In any case, there is some evidence that the three dimensions of IC have an influence on a firm's financial value (Chen et al., 2005), while HC may have

some degree of interdependence with SC and with RC (Johnson, 1999; Chen et al., 2004). Furthermore, each value cluster is interdependent with the alternatives cluster because the adoption of an EMS impacts on the four value clusters and, in the same way, the selection of the best EMS depends on the total market value achieved by each. These relationships were discussed with the panel of academicians and food industry experts, who supported the network but also suggested the insertion of inner dependences on HC and RC value clusters, as well as on the alternatives cluster. A graphical summary of the ANP model is presented in Figure 5.1.

Figure 5.1 An overview of the proposed ANP-based model for EMS selection



Source: Own elaboration.

5.4 ILLUSTRATIVE APPLICATION

In this section, several case studies in the Spanish olive oil production industry –i.e. oil extraction mills– are presented to test the applicability and efficacy of the proposed ANP-based approach. This sector has been chosen for the empirical analysis for several reasons. Firstly, the olive oil industry is a pollution-intensive one, given the huge quantity of waste generated that may have a great impact on land and water ecosystems (Roig et al., 2006). Therefore, firms in this sector are more likely to adopt EMSs because stakeholder pressure is higher. Secondly, in olive oil mills there is an important set of intangible assets (Castilla and Cámara, 2003) to account for in capital budgeting processes. Thirdly, recent management trends in this sector advocate for producing not only a high quality oil with a greater degree of food safety and traceability, but also incorporating attributes of environmental quality (Sanz and Macías, 2005), as a strategy allowing food industries to remain competitive in international markets through enhancing environmental reputation, which is a major asset in agrifood industries and very sensitive to environmental concerns (Grolleau et al., 2007). Indeed, the evolution of the number of ISO 14001 certifications in the food industry confirm that assumption: from 834 certificates in the year 2000 to 5,884 in 2012 worldwide (ISO, 2012).

5.4.1 Profile of the analyzed firms

Eight olive oil mills with a proactive environmental management orientation –i.e., firms that have voluntarily implemented any practices or initiatives aimed at improving environmental performance– located in Southern Spain were chosen. For confidentiality reasons, the real names of these companies are not reported. Instead letters are used to refer to them.

This sample of mill industries was obtained from the records of the *Spanish Association of Olive Municipalities*, which helped us to identify an initial set of environmental leaders within the sector. The final selection of the industries to be analyzed was obtained based on the firms' willingness to participate in the research.

In each mill industry selected, the objective was to evaluate the three EMSs alternatives –ISO 14001, EMAS, and non-certified EMS– following the methodological approach explained above, in order to *determine the best one in*

terms of market value creation. We also checked if it corresponded to the alternative actually adopted by each company.

Table 5.2 shows the main features of the eight firms. As can be observed, the vast majority of mills are agrarian cooperatives (coop), while only two are private with a legal form of limited liability company (LLC). In fact, in Spain, olive oil cooperatives account for more than 70% of all the olive oil produced, in addition to a minority segment of private mills (Sanz and Macías, 2005). Regarding the dimension of the firms, four mills are small (A, B, C and H), with annual net revenues ranging from €6.0 million to €13.6 million and an average workforce between 15 and 31 employees; two mills are medium-sized (E and F, with €40.2m and €55.4m, respectively); one mill is considered a microbusiness, with net revenues less than €1.0m and an average workforce of only 3 employees; also, one is a big firm (€96.0m of net revenues).

Table 5.2 Profile of the firms under study

	FIRMS							
	A	B	C	D	E	F	G	H
Legal form	Coop	Coop	Coop	LLC	Coop	Coop	LLC	Coop
Net revenues (M€)	6.1	6.0	13.6	0.8	40.2	55.4	96.0	10.5
Average workforce	15	15	19	3	58	193	128	31
Classification	Small	Small	Small	Micro	Medium	Medium	Big	Small

Source: Own elaboration.

5.4.2 Application of the ANP model

We considered chief executive officers (CEOs) to be the most appropriate decision-makers in disclosing judgments and opinions; they have a global vision of the firm they run and an important influence on its managerial strategies. So they were contacted individually in order to schedule a meeting in their office. Then, CEOs were asked to respond to a questionnaire containing 58 questions[13] (Steps 2 and 4 of the ANP method). These questions were pair-comparisons between every pair of elements at each cluster, and also between clusters, with respect to their importance towards the control factor, using Saaty's 1-9 point scale (see Table 5.1). To illustrate, Table 5.3 shows one of these questions as an example.

[13] The complete questionnaire can be consulted in Annex 4.

Table 5.3 Example of the questions and answers (in bold) used for elements comparison

Node comparison with respect to 'Total cost'									
Which alternative do you consider more important in minimizing total implementation cost?									
Non-certified EMS							*ISO 14001*		
X									
To what extent?	1	2	3	4	5	6	7	8	9
				X					

Source: Own elaboration.

The entire computing process was completed using *Superdecisions* software. The unweighted, weighted, and limit matrices were built for each case study based on each CEO's judgments. For the sake of brevity, we only present the global weights of all the elements[14], both subcriteria and alternatives, in each firm, obtained from the limit matrices. The results are displayed in Table 5.4, where the first seven rows reflect the weights of the subcriteria and the last three the overall priorities of the alternatives.

Two subcriteria related with non-financial values, *employee's knowledge and skills* (HC1) and *internal organization and documentation* (SC1), have been given the highest rating in all mills, except in G, where *relational capital* (RC) criteria are the most important ones in determining market value creation. These results confirm the hypothesis initially assumed that capital budgeting for EMS selection –just as any other investment impacting on firms' IC– needs to consider the non-accountable variations of intangible assets –intellectual capital–. Regarding HC1 criterion, the CEOs considered that adopting an EMS presents an opportunity to successfully enhance employees' knowledge and skills, in a sector characterized by a low level of qualification. Both the implementation of ISO 14001 and EMAS require training programs for the employees (Daily and Huang, 2001), leading to a significant non-financial –intellectual capital related– value creation. The SC1 subcriterion, *internal organization and documentation control* of the firm, is also improved through EMS implementation by clarifying definition of policies, objectives and procedures, as well as the assignment of roles and responsibilities required by the adoption of this kind of management system. These features also lead to an increase in the firm's market value due to IC enhancement.

[14] Detailed results can be consulted in Annex 5.

On the other hand, *total cost* (FC1) is the least significant criterion in five of the eight mills (A-E), not exceeding 0.01 in each of them, and not being particularly high in the rest of the companies. Moreover, *revenues derived from higher sales and efficiency enhancement* (FC2) is also relatively low weighted in most of the industries analyzed. This fact confirms that financial capital flows related with EMS implementation have only a minor impact on the firm's market value. However, it is worth pointing out that this circumstance can be largely explained because all facilities analyzed, except one, as depicted in Table 5.5, are certified with ISO 9001. Thus, these firms already have a wide experience with quality management systems, assuming they are going to incur lower additional costs due to EMS implementation. This is due to learning by doing and scale economies (King and Lenox, 2001; Grolleau et al., 2007). For the same reason, these firms also consider that the increased profit due to efficiency enhancement associated with EMS would probably be negligible.

In the sense, the company F stands out from the others as it assigns a significant priority level (0.083) to the FC1 subcriterion. This high weight attained in this subcriterion is explained by this firm's several economic activities beyond olive oil production; furthermore, the implementation of any new management systems would involve higher costs. This fact directly affects the prioritization of the alternatives; for this mill, the *non-certified EMS* alternative has a very high weight (0.225), ranking first. This suggests that one of the major barriers to certifying EMS may be the cost of both implementation and certification.

Regarding the prioritization of the EMS alternatives, the ISO 14001 scores the highest in five of the analyzed firms (A, B, C, E, and H), while the EMAS only in one of those, G, the largest one. To the contrary, the non-certified EMS results as the best alternative for the cases of D and F. The reasons why these firms prefer the non-certified EMS are different in each case. According to the information provided by their CEOs and the analysis of results obtained, decision maker in mill D does not perceive certification to have any value added in enhancing the firm's competitiveness. Meanwhile, in the case of F, the certification cost is the major barrier for the implementation of certificated EMSs, as has been already explained.

Table 5.4 Elements prioritization results from the limit matrices (the highest ranked alternatives are marked in bold)

Subcriteria / Alternatives	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F	Firm G	Firm H
FC1	0.007	0.004	0.007	0.010	0.007	0.083	0.031	0.070
FC2	0.046	0.026	0.033	0.052	0.053	0.017	0.093	0.023
HC1	0.223	0.279	0.209	0.282	0.181	0.125	0.062	0.264
HC2	0.068	0.042	0.089	0.012	0.080	0.086	0.064	0.032
RC1	0.099	0.076	0.091	0.121	0.114	0.039	0.093	0.042
RC2	0.011	0.007	0.033	0.012	0.010	0.050	0.143	0.042
SC1	0.211	0.288	0.209	0.289	0.188	0.205	0.064	0.225
Non cert. EMS	0.066	0.045	0.046	**0.080**	0.055	**0.225**	0.077	0.074
ISO 14001	**0.184**	**0.126**	**0.188**	0.073	**0.168**	0.083	0.156	**0.118**
EMAS	0.085	0.106	0.095	0.069	0.144	0.087	**0.216**	0.109

Source: Own elaboration.

Finally, the proposed theoretical model is validated by comparing the most prioritized alternatives with the EMSs currently adopted by each firm (see Table 5.5). As can be observed, in each of the firms analyzed, except in the last one, the best EMS alternative according to the ANP model implemented corresponds to the system currently adopted by the firms. This fact may lead to the conclusion that the proposed model is primarily a formalization of the capital budgeting process actually followed by firms' decision makers. As the results suggest, CEOs are certainly considering non-financial capital value creation elements in their decision-making processes, although they do it in an intuitive and informal way. In this sense, the proposed assessment procedure has the advantage of considering all value creation criteria, both financial and non-financial ones, which are integrated in a transparent and instrumentalized way.

Table 5.5 Comparison of ANP model results with the EMS currently adopted

Firm	Best EMS according to the ANP results	EMS currently adopted	Other certifications
A	ISO 14001	ISO 14001	ISO 9001
B	ISO 14001	ISO 14001	ISO 9001, ISO 22000
C	ISO 14001	ISO 14001	ISO 9001
D	Non-certified EMS	Non-certified EMS	-
E	ISO 14001	ISO 14001	ISO 9001
F	Non-certified EMS	Non-certified EMS	ISO 9001, OHSAS 18001
G	EMAS	EMAS	ISO 9001, OHSAS 18001, ISO 22000
H	ISO 14001	Non-certified EMS	ISO 9001

Source: Own elaboration.

5.5 CONCLUSIONS

The main objective of this paper was to present a novel decision-making approach, based on the multicriteria method of *analytic network process*, to evaluate and effectively identify the best EMS alternative in for-profit firms, the one that maximizes the firm's market value. *Financial* and *non-financial* –intellectual capital– value creation criteria were included in the analysis and the approach was empirically tested in a group of proactive environmental firms within the Spanish olive oil industry.

To our knowledge, this study contributes to the existing literature, since thus far the literature has lacked the justification approaches of this kind of corporate investment. This is mainly because of the intangible and non-financial nature of the benefits involved. In a systematic and formalized way, the proposed evaluation method combines for-profit firms' four sources of value creation: financial capital value, and the three dimensions of intellectual capital value –human, structural and relational–, in order to prioritize the set of EMS alternatives according to the market value generated by each of them.

Evidence derived from empirical applications seems to indicate that the proposed approach is robust and reliable. In the vast majority of firms, the best EMS alternative, according to our model, corresponds to the system currently adopted by each firm. This leads to the conclusion that the proposed method formalizes the evaluation and prioritization process actually followed by CEOs in firms, as they are certainly considering, although in an informal way, non-

financial capital value creation elements in their decision-making processes. Furthermore, a major finding derived from the empirical applications is the appropriateness of considering and quantifying the intellectual capital value emerging from the EMS adoption, taking into account that intellectual capital-related elements were given the highest rating in all industry mills, unlike the financial capital ones.

The proposed method is flexible enough to be adapted or extended to evaluate other kinds of investment projects, mainly those with significant intangible benefits. In any case, the use of the proposed approach must be handled with care, paying particular attention to its most critical steps. For instance, designing the value creation network structure needs to be accurate, well defined, and agreed upon with decision-makers in order to include all the elements and their possible interactions influencing investment alternatives prioritization.

While we believe the model developed in this paper is a valuable capital budgeting method, there are potential interesting areas for future research aiming at a more accurate and useful implementation. One of the most significant enhancements would be the introduction of the group decision-making approach –as usually happens in real situations– in order to overcome the limitation of having only one decision-maker in the evaluation process. This approach would allow the aggregation of different individual opinions –for example, from executive and functional managers as well as from external specialists or experts– to obtain a single collective preference to rank the set of EMS alternatives.

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Capítulo 6

Conclusiones y futuras líneas de investigación
Conclusions and future research lines

El objetivo de este último capítulo es sintetizar las conclusiones derivadas de la presente investigación, así como exponer las principales limitaciones del trabajo realizado. Las futuras líneas de investigación, originadas en las ideas surgidas durante la realización de esta tesis doctoral, también se recogen al final de este capítulo.

CONCLUSIONES

Conclusiones derivadas del objetivo preliminar

De la consecución del objetivo preliminar, esto es, del análisis de la producción científica internacional centrada en el estudio del desarrollo y/o aplicación de la metodología multicriterio, como alternativa a las técnicas financieras clásicas, en los procesos de decisión de las finanzas corporativas, se derivan una serie de conclusiones, que se exponen a continuación.

En primer lugar, si bien el paradigma multicriterio ha sido hasta el momento poco utilizado en la resolución de los problemas financieros corporativos, se pone de manifiesto el *extraordinario crecimiento de los estudios científicos en la materia durante la primera década del siglo XXI.* Crecimiento que, gráficamente, se

ajusta a una línea de tendencia de carácter exponencial. Esto implica que, aunque este enfoque metodológico sea aún minoritario en economía financiera, en los últimos años se han estado produciendo importantes avances que están posicionándolo en un lugar cada vez más destacado en la resolución de los procesos de decisión financieros corporativos. Y ello porque el aumento de la complejidad operativa de tales procesos está obligando a buscar técnicas alternativas a las clásicas herramientas financieras con las que poder considerar, de una manera más integral, las diferentes circunstancias (multiplicidad de criterios –objetivos, metas y atributos) que rodean a estos problemas decisionales.

Sin embargo, y en segundo lugar, el considerable aumento de la investigación en finanzas corporativas empleando técnicas multicriterio se ha materializado en publicaciones en *revistas correspondientes a áreas temáticas alejadas de la disciplina financiera*, como son ciencias de la computación, ingeniería e investigación operativa. Este hecho nos lleva a deducir algunas importantes conclusiones:

- El grado de visibilidad de los avances de la metodología multicriterio como herramienta para resolver problemas financieros es, hasta la fecha, muy bajo para quienes trabajan en el campo de las finanzas corporativas, ya sea como investigadores o como profesionales. Esto nos conduce a sugerir que su grado de aceptación entre este grupo también es poco significativo y, por tanto, son necesarias aún más contribuciones científicas al respecto, tanto teóricas como metodológicas, que destaquen la potencialidad de estas técnicas para resolver los complejos procesos financieros. En este sentido, se indica que el traslado efectivo al ámbito financiero de las técnicas analíticas multicriterio posibilitaría novedosos desarrollos de la teoría financiera y de su aplicación empírica para la resolución de complejos problemas reales que, hasta el momento, se abordan de manera no formalizada, dadas las carencias de modelos decisionales que las respalden.
- La escasez de publicaciones que emplean técnicas multicriterio en revistas financieras puede ser interpretado, en términos de Kuhn, como la negación por parte del paradigma predominante de aquellos logros científicos que pudieran derivar en una crisis del mismo, ya que tales logros pondrían de manifiesto anomalías de dicho paradigma que no pueden explicarse mediante la ciencia normal en el que este se apoya.

> Este supuesto se basa en el hecho de que mientras dos de cada diez autores pertenecen a departamentos de finanzas o economía, sin embargo, el número de publicaciones en revistas de ese ámbito es mucho menor.

En tercer lugar, la *naturaleza fundamentalmente empírica de las técnicas multicriterio* se refleja en el alto porcentaje de investigaciones que no sólo presentan avances metodológicos, sino que también los aplican a la resolución de problemas reales, lo que pone de manifiesto la potencialidad de estas técnicas para ser utilizadas por los profesionales y consultores de empresas. Sin embargo, tal y como se señala en la literatura, existe una brecha importante entre la teoría y la práctica en el campo multicriterio –entendido en su globalidad–, *brecha que se agrava al conjugar multicriterio con finanzas corporativas*. Esta circunstancia no nos debe extrañar ya que, por ejemplo, estudios recientes acerca de cuáles son las técnicas de valoración de inversiones que emplean los directores financieros en la actualidad destacan la predominancia casi absoluta de los criterios clásicos –valor actual neto, tasa interna de rendimiento y plazo de recuperación– sobre otros modelos más sofisticados como el análisis de sensibilidad estocástico, el análisis del riesgo o las opciones reales, entre otros. Así, es de prever que la incorporación de las técnicas multicriterio como herramientas eficaces de resolución de los problemas decisionales financieros por parte de los profesionales y consultores no se producirá hasta que estos conozcan la potencialidad de las mismas y existan herramientas –software– para su aplicación operativa a los procesos financieros corporativos.

En cuarto lugar, la *complejidad creciente de los procesos de evaluación de proyectos de inversión*, como consecuencia de varios factores –la necesidad de considerar distintos objetivos usualmente en conflicto derivados de los problemas de agencia o de la inclusión de las demandas de los *stakeholders* en la gestión corporativa, unido al carácter intangible de buena parte de los criterios de valoración de las inversiones estratégicas, o las distintas dimensiones del criterio riesgo– está impulsando la *búsqueda de nuevas herramientas metodológicas.* Y ello con el fin de poder considerar criterios adicionales a los tradicionales de rentabilidad y riesgo, al objeto de dotar a las decisiones de inversión de una verdadera multidimensionalidad. En ese proceso de búsqueda, ha sido mayoritaria la orientación hacia la integración y cuantificación de criterios no monetarios o intangibles en la valoración de inversiones estratégicas, para lo cual la técnica AHP es la que parece ajustarse de manera más conveniente a la

resolución de esta problemática, a la vista de su extensa implementación para resolver ese tipo de cuestiones. Un conjunto de razones, adicionales a la capacidad de incluir criterios no monetarios o intangibles en el análisis, lo explican: es una técnica simple en su desarrollo y no requiere de una especialización previa excesiva; se adapta a decisiones tanto individuales como en grupo, lo que la capacita para encontrar soluciones consensuadas; permite introducir las preferencias o juicios de valor del decisor; y posibilita la transformación de un problema multidimensional o multicriterio en uno de carácter unidimensional mostrando la priorización de cada una de las alternativas u opciones de decisión y de cada uno de los criterios y, en su caso, subcriterios considerados en el análisis.

En síntesis, el aumento de la complejidad de los procesos financieros corporativos relativos a las decisiones de inversión ha determinado que comiencen a explorarse las ventajas de la aplicación de las técnicas multicriterio a la resolución de este tipo de problemas aunque, hasta el momento, las experiencias realizadas se han basado en el empleo de las técnicas multicriterio más simples –como el AHP–. Se ha tratado de manera mayoritaria la inclusión en los procesos de valoración de inversiones del factor de complejidad relativo al conjunto de criterios intangibles o de carácter no monetario que inciden en las decisiones de inversión. Se preve, a la vista de los estudios más recientes, que esta tendencia de introducción paulatina de técnicas multicriterio en la operativa ordinaria de las decisiones financieras va a continuar. Se intuye que especialmente serán aquellas orientadas a la incorporación de los distintos criterios que presentan los diferentes grupos de interés implicados en estos procesos decisionales –gestores, propietarios, clientes, proveedores, administraciones públicas, etc.–, al objeto de superar así la primera de las críticas al paradigma clásico comentada en el Capítulo 3.

Conclusiones derivadas del objetivo general

El objetivo general de esta tesis ha consistido en desarrollar un *nuevo enfoque teórico de valoración de inversiones no financieras,* desde la perspectiva ampliamente aceptada de la creación de valor, pero entendiéndola en un sentido integral, esto es, considerando tanto la creación de valor financiero como la creación de valor no financiero o de capital intelectual.

La definición de este objetivo ha estado motivada por varios factores. En primer lugar, los resultados del objetivo preliminar confirmaron que las técnicas multicriterio se han empleado mayoritariamente en la valoración de aquellas *inversiones de carácter estratégico* en las que es necesario considerar ciertos criterios no monetarios o de carácter intangible, y no sólo criterios tangibles o financieros. En segundo lugar, la dificultad de las técnicas de valoración financieras clásicas para reconocer el *valor real generado con la inversión*, que ha sido una de las críticas que más debate ha suscitado en la literatura científica, especialmente en relación con determinados proyectos de inversión que influyen principalmente sobre el valor no financiero de la empresa –por ejemplo, aquellos que promueven la mejora de la imagen corporativa o la motivación y el *knowhow* de los empleados–. Y, en tercer lugar, se ha considerado la imperiosa necesidad de incluir el *capital no financiero o capital intelectual* en los procesos de decisión corporativos con el fin de, no sólo visibilizarlo, sino también de proceder a su medición, ya que en la actualidad se ha convertido en una de las principales fuentes de ventaja competitiva sostenible de las organizaciones.

Por todo lo anterior, se decidió seguir la línea de investigación mayoritaria de valoración de inversiones estratégicas con técnicas multicriterio al objeto de proponer un nuevo enfoque teórico de evaluación y priorización de este tipo de inversiones. Con este nuevo enfoque, no se trata simplemente de considerar criterios intangibles en el análisis con el objetivo de seleccionar la *mejor alternativa* –como se ha venido haciendo hasta el momento–, sino de cuantificar de manera específica la creación de valor financiero y no financiero –derivada de aquellos elementos intangibles que tienen un impacto en el capital intelectual de la compañía– de cada alternativa de inversión, con el fin de seleccionar la *alternativa que maximice la creación de valor total*.

Se confirma que el objetivo general se ha alcanzado plenamente, tal y como se desprende de los resultados de los capítulos 4 y 5. El nuevo enfoque teórico de valoración ha permitido cuantificar y valorar de manera integrada tanto los criterios y subcriterios asociados a la generación de valor financiero, como los de naturaleza intangible relacionados con el valor del capital intelectual o no financiero. Así, se considera que esta propuesta teórica contribuye al avance del conocimiento en la línea de la valoración de inversiones no financieras, y solventa en buena medida uno de los problemas fundamentales del análisis de inversiones, como es la integración de todo un conjunto de criterios que afectan

a las decisiones de inversión y que, a priori, son difícilmente cuantificables por ser de naturaleza no monetaria y por impactar en el capital intelectual corporativo. Además, este nuevo enfoque teórico posibilita el acercamiento de la teoría financiera de la creación de valor a la teoría de los stakeholders, en el sentido de que dos componentes del capital intelectual, el capital humano y el capital relacional, consideran explícitamente los intereses de los empleados y de los grupos de interés externos, respectivamente.

Conclusiones derivadas de los objetivos específicos u operativos

Conclusiones derivadas de los dos primeros objetivos específicos u operativos

Al objeto de poder implementar en la práctica el enfoque teórico de valoración derivado del objetivo general, se ha desarrollado, en primer lugar, una metodología de valoración de inversiones basada en la técnica multicriterio del proceso analítico jerárquico o AHP –primer objetivo específico u operativo–. La elección de esta herramienta ha venido determinada, fundamentalmente, por tres razones principales: en primer lugar, por su idoneidad para introducir en el análisis criterios decisionales tanto de carácter cuantitativo como cualitativo; en segundo lugar, por su extenso uso en la priorización y selección de inversiones en contextos multicriterio, de lo que se infiere su continua validación; y, en tercer lugar, por tratarse de una técnica simple en su desarrollo, que no requiere de una especialización específica para su uso, con lo cual es factible pensar que su uso podría extenderse entre los directores financieros y consultores de empresas.

Este primer objetivo específico u operativo se ha alcanzado en el Capítulo 3, donde se ha desarrollado un *modelo AHP para la cuantificación integral de la creación de valor generada por diferentes alternativas de inversión*. Para ello, se ha dispuesto una estructura jerárquica compuesta de cuatro niveles: en el más alto nivel, el objetivo principal del problema de decisión, la *creación de valor de mercado*; a continuación, los cuatro criterios que constituyen las fuentes de valor en la organización, esto es, el *capital financiero*, el *capital humano*, el *capital estructural* y el *capital relacional*; los subcriterios concretos de cada componente del valor en el siguiente nivel; y las alternativas u opciones de inversión en la base de la jerarquía. Se ha considerado que el primer y el segundo nivel son de

carácter genérico y universal para todos los procesos de valoración, mientras que los dos últimos niveles han de adaptarse a cada caso de estudio concreto.

En el mismo Capítulo 3, se ha desarrollado el segundo objetivo específico u operativo, que ha consistido en la implementación del modelo AHP de valoración, al objeto de validarlo empíricamente, a un grupo de cinco empresas andaluzas del sector industrial cárnico interesadas en evaluar y priorizar tres alternativas de inversión para sus sistemas de control de la calidad: i) la implantación de un laboratorio propio tradicional en la propia instalación; ii) la adquisición de un sistema NIRS –*near infrared spectroscopy system*–; y iii) la externalización del servicio de análisis y control de la calidad a un laboratorio externo. Dado que los sistemas analíticos de control de la calidad agroalimentaria tienen implicaciones estratégicas en la empresa en su conjunto, generando impactos tanto tangibles como intangibles, se ha considerado que este es un caso de estudio apropiado y pertinente para implementar la metodología de valoración antes comentada.

La implementación empírica de este primer modelo, además de demostrar la *aplicabilidad* y *sencillez operativa* de la metodología desarrollada, ha evidenciado la conveniencia de considerar los *impactos de tales alternativas de inversión sobre los activos intangibles de la empresa*, pues estos condicionan en el mundo real la selección de la alternativa de inversión óptima.

Además, de este primer caso de estudio se destacan las siguientes conclusiones:

- Existe una evidente *dualidad* entre pequeñas y grandes empresas en relación a la importancia relativa asignada a cada uno de los dos grandes componentes de la creación de valor: capital financiero y capital intelectual. Mientras que las empresas más pequeñas le asignan una elevada ponderación al valor del capital intelectual, las más grandes conceden mayor peso al valor del capital financiero. Esto podría ser como consecuencia de la visión cortoplacista de los directivos, la denominada 'miopía directiva', que afecta a las empresas de mayor dimensión con clara diferenciación entre propietarios y directivos.
- Aunque el modelo de valoración propuesto resulte especialmente conveniente en las pequeñas empresas, debido al elevado peso asignado al capital no financiero, en el caso de las empresas de mayor tamaño no es despreciable este valor, pues es superior al 10% del valor total creado

por la inversión, lo que justifica la utilidad universal del método propuesto.

- El propio *enfoque estratégico de la organización* es el que determina la focalización en una o varias de las dimensiones del capital intelectual, de ahí que no exista un patrón común de comportamiento que explique la distribución de los pesos en los distintos criterios del capital no financiero. Por ello, se considera de suma importancia que el decisor financiero enlace el proceso de valoración del proyecto de inversión con la propia estrategia corporativa, al objeto de asignar mayor peso a los atributos más vinculados a esta.

Los resultados de la priorización de las tres alternativas de inversión en el caso de estudio han sido plenamente corroborados con los resultados de la toma de decisiones reales adoptadas por las empresas analizadas, validando así el modelo propuesto tanto teórica como empíricamente.

La conclusión global que se desprende de la consideración conjunta del objetivo general y de los dos primeros objetivos específicos u operativos, señala que la metodología propuesta supone la *formalización del proceso de valoración de inversiones llevado a cabo por los gestores financieros en la realidad*. Efectivamente, los decisores reales son conscientes de la influencia de determinadas inversiones en algunos de los elementos intangibles de la compañía y de su papel como inductores o generadores de valor no financiero. Pero la inclusión de estos criterios intangibles en los procedimientos de valoración de inversiones se ha venido abordando únicamente desde la intuición, sin utilizar método formalizado alguno. Así, el modelo AHP propuesto permite valorar de una manera clara y transparente cada una de las alternativas de inversión estimando la *creación de valor total* de cada una de ellas, tanto la relativa al valor financiero como la concerniente al valor no financiero.

La conformación del caso de estudio de este primer modelo de valoración, que se ha aplicado a un número reducido de empresas, podría entenderse como la *principal limitación* de este bloque de la investigación. Sin embargo, debe aclararse que el propósito del segundo objetivo específico u operativo no ha sido el de disponer de una muestra representativa del sector cárnico, ni tampoco la de realizar una validación definitiva del modelo de valoración de inversiones propuesto, sino tan sólo ilustrar la aplicabilidad del mismo al

mundo real y evidenciar su utilidad potencial como herramienta de apoyo a la toma de decisiones para los gestores empresariales.

Conclusiones derivadas del tercer y cuarto objetivos específicos u operativos

El tercer objetivo específico u operativo –alcanzado en el Capítulo 5– ha consistido en desarrollar un segundo modelo de valoración, igualmente desde el enfoque teórico de creación de valor del objetivo general, fundamentado en la técnica multicriterio del proceso analítico en red o ANP. La particularidad de este segundo modelo de valoración es que se inserta en la reciente línea de investigación relativa al estudio de la generación de valor del capital intelectual desde una *perspectiva dinámica*, esto es, considerando las relaciones e interdependencias intrínsecas que tienen lugar entre los distintos inductores del valor en las organizaciones. Este enfoque considera que los elementos de cada uno de los cuatro componentes o fuentes de valor no son estáticos, sino que interactúan entre sí, siendo necesario gestionar los flujos que se derivan de los mismos. La opción de introducir esta nueva perspectiva del capital intelectual en el proceso de valoración de inversiones desde el enfoque teórico propuesto, se sopesó tras alcanzar los dos primeros objetivos específicos, entendiendo que era necesario contemplar esta nueva perspectiva para añadir más realismo y exactitud al proceso de evaluación.

El proceso analítico en red o ANP es la técnica más adecuada para conseguir un efectivo tratamiento de las interacciones que se producen entre los distintos elementos inductores del valor corporativo. Esta técnica multicriterio permite plantear el modelo como una red de elementos con relaciones causa-efecto o de tipo bidireccional. Así, en este segundo modelo de valoración, a través de ANP se asigna un valor total a cada una de las alternativas u opciones de inversión, no en base únicamente a la influencia directa de cada una de las alternativas sobre cada elemento generador de valor, sino también en base a las influencias entre los distintos elementos de los cuatro componentes del valor. En este sentido, se señala que ANP es la técnica más apropiada para aquellas situaciones de decisión más complejas que, obviamente, al igual que AHP, también puede incluir en el análisis criterios tangibles e intangibles.

El tercer objetivo específico u operativo está íntimamente ligado al cuarto. Se orienta hacia la implementación del modelo de valoración basado en ANP al caso concreto de la valoración de los sistemas de gestión ambiental en la

empresa. Esta decisión estuvo motivada por el *gap* de conocimiento existente en lo relativo a la valoración y justificación de este tipo de inversiones. Además, tanto la literatura científica como las reuniones mantenidas con el grupo de expertos que soportó esta parte del trabajo corroboraron que los beneficios de estos sistemas son mayoritariamente de carácter intangible, por lo que las técnicas de valoración clásicas no resultan adecuadas y, por tanto, era necesario encontrar una metodología que abordara la cuantificación del vasto conjunto de beneficios intangibles que aportan los sistemas de gestión ambiental a la organización.

La aplicación empírica del modelo, correspondiente al cuarto objetivo específico u operativo, se diseñó en un grupo de ocho almazaras de las provincias de Córdoba y Jaén, al objeto de evaluar y priorizar los tres sistemas más comunes de gestión ambiental (ISO 14001, EMAS, y SGA no certificado), y comparar los resultados alcanzados con la alternativa realmente elegida por la organización.

Los resultados de la implementación empírica han confirmado la validez y robustez del modelo propuesto, pues en la gran mayoría de almazaras –todas excepto en una– el sistema que crea más valor atendiendo a los resultados del análisis es el que, en la actualidad, ha adoptado la organización. Además, en todos los casos se ha asignado un peso muy superior a los criterios intangibles o de capital intelectual con respecto a los dos criterios financieros considerados, hecho que corrobora lo apuntado anteriormente acerca del grueso conjunto de beneficios intangibles que aportan estos sistemas de gestión.

Del caso de estudio se deduce, por tanto, que el método propuesto constituye una formalización y materialización del proceso de valoración de inversiones no financieras que actualmente siguen los gestores en las empresas. En este sentido, se afirma que el grado de formalización es mayor que en el caso del primer modelo, en la medida que contempla de manera complementaria las interacciones existentes entre los criterios inductores de valor –perspectiva dinámica–. En todo caso, este segundo enfoque de valoración de inversiones también cubre, aunque sea de manera parcial, una laguna de conocimiento en cuanto a las técnicas de análisis existentes para la selección de inversiones no financieras de carácter estratégico. Efectivamente, tanto la literatura como los expertos académicos y los gestores de las empresas consultados han revelado que, hasta el momento, la toma de decisiones relativa a la adopción de tales inversiones no se basa en el empleo de ninguna técnica concreta de valoración.

La práctica más común se limita a calcular el coste total de la inversión, estudiar si constituye un gasto asumible por la empresa, y observar si los competidores más directos han implementado o están en vías de implementación de alguno de los sistemas.

Para concluir se señala que, aunque este segundo modelo ANP se haya orientado a la valoración de los sistemas de gestión ambiental, es lo suficientemente flexible para ser adaptado a cualquier otro tipo de inversión, justificándose en mayor medida su uso en aquellos proyectos de carácter estratégico que se prevea impacten en el valor no financiero corporativo.

Asimismo, es necesario comentar algunas de las limitaciones o inconvenientes encontrados en este segundo modelo de valoración: en primer lugar, el fundamento metodológico de ANP no es tan sencillo como AHP, requiriendo el decisor de una mayor preparación previa a su uso; en segundo lugar, el diseño de la red de criterios y subcriterios se concibe como un proceso de discusión y consenso entre distintos expertos de manera que no se ignore ninguna de las posibles relaciones entre los elementos; y, en tercer lugar, la implementación del método, basado en un cuestionario mucho más extenso que en el caso de AHP, podría resultar tedioso en los casos con estructuras en red más complejas.

Algunas consideraciones finales

No parece razonable que los *elementos intangibles*, que constituyen hoy una de las principales *fuentes de valor y de competitividad sostenible* de las empresas, no sean tenidos en cuenta en los procesos de gestión y de decisión corporativos. Este planteamiento resulta especialmente relevante en la valoración de los proyectos de inversión que se acometen en las organizaciones, en la medida en que estos impactan, en mayor o menor medida, en determinados elementos intangibles –como en el capital humano o en la imagen corporativa–, aumentando el stock de capital intelectual y generando valor para la organización. En esta investigación se han visto dos claros ejemplos de ello: los *sistemas de control de la calidad* y los *sistemas de gestión ambiental*.

Lo anterior ha constituido la principal motivación de esta tesis doctoral y ha sido la idea que ha guiado nuestro esfuerzo y dedicación. Se han desarrollado dos modelos de valoración con una serie de características, como son la sencillez operativa, la flexibilidad para ser adaptados a cualquier proceso

decisional de inversión, o la capacidad de inclusión de tantos criterios y, en su caso, subcriterios como sea necesario, que los convierten en técnicas atractivas y eficaces de valoración. Con este trabajo, se ha pretendido contribuir a la investigación científica en la materia, intentando animar a la reflexión, al estudio y al avance en este campo.

FUTURAS LÍNEAS DE INVESTIGACIÓN

A continuación se exponen algunas posibles líneas futuras de investigación derivadas de la presente tesis doctoral:

- Planteamiento de *nuevos casos de estudio* en otros sectores productivos distintos de la industria agroalimentaria o, bien, la orientación hacia otro tipo de inversiones, al objeto de conseguir evidencias más fundamentadas que refuercen –o pongan en duda– la validez de la hipótesis de partida y corroboren –o no– las conclusiones aquí presentadas.
- Orientación de los modelos propuestos a la *toma de decisiones en grupo* y no en base, únicamente, a los juicios de valor de un solo decisor –director financiero o director general–, como se ha realizado en esta investigación. La confluencia de distintos puntos de vista de un variado grupo de gestores –miembros del consejo de dirección y/o consejo de administración– o expertos externos conocedores de la propia organización podría enriquecer el proceso de valoración.
- Avance en el estudio de la *fundamentación teórica de la creación de valor en las organizaciones*, planteando nuevas hipótesis relativas a la generación de valor no financiero, como por ejemplo: la posible inclusión de nuevos componentes en el capital intelectual o la redimensión de los mismos –capital humano y capital relacional podrían converger hacia el constructo *capital social*–; la adecuación de considerar los denominados *pasivos intangibles* como detractores del valor generado por los activos intangibles y que podrían surgir como consecuencia de la adopción de determinadas decisiones corporativas; o la profundización en el estudio de la diferencia observada entre valor de mercado y valor contable en un intento por encontrar otros factores de peso que expliquen esta diferencia.

- Tratamiento de la *incertidumbre o de la vaguedad en la valoración de los criterios* inherente a los procesos de decisión mediante la teoría *fuzzy* aplicada a los dos modelos de valoración propuestos.

The objective of the final chapter is to summarize the conclusions of this thesis and present the main limitations of the work. The future lines of research, which stem from some of the ideas that emerged during the course of this thesis, are proposed at the end of the chapter.

CONCLUSIONS

Conclusions from the preliminary objective

The preliminary objective of this thesis was to *analyze the international scientific literature* focused on developing and/or applying the multicriteria decision-making approach to corporate finance topics, as an alternative to the classical financial techniques. We aimed to identify the major trends in the field. A set of conclusions arising from this analysis is presented below.

First, *the multicriteria techniques have so far not been widely-used in solving corporate financial problems.* However, an extraordinary growth of research during the first decade of the twenty-first century is evidenced, which graphically fits an exponential trend line. Therefore, although this methodological approach is still relatively unusual in financial economics, *major advances in recent years* have led to it occupying an increasingly prominent role in solving corporate financial processes. The growing prominence of this approach is due to the increased complexity of these processes, which necessitates the search for alternative techniques to traditional financial tools. These alternative techniques allow us to consider, in a more comprehensive way, the different circumstances (multiple criteria, objectives, goals and attributes) surrounding these problems.

Second, on the other hand, the implementation of multicriteria techniques in the field of corporate finance has begun to spread in *computer science, engineering and operational research journals*: subject areas far removed from the financial discipline. This leads us to draw some important conclusions:

- The degree of visibility of multicriteria methods as tools to solve financial problems is very low for those working in the field of corporate finance, either as researchers or as professionals. Therefore, we suggest that its degree of acceptance is also insignificant among financial experts. Hence more scientific contributions are needed, both theoretical and methodological, highlighting the potential of these techniques to solve

complex financial problems. The financial sector's acceptance of the multicriteria paradigm would enable innovative developments in financial theory that would solve real, complex problems currently being addressed in a non-formalized way, given the absence of models to apply.

- The comparatively low number of papers in financial journals can be interpreted, as per Kuhn, as the authors of the dominant financial paradigm denying the scientific progress which could damage the current paradigm by highlighting its faults and drawbacks. This assumption is based on the fact that while two of the ten authors are in finance or economics departments, the number of journal publications on that topic is much smaller.

Third, the *empirical nature of the multicriteria techniques* is reflected in the high percentage of papers presenting methodological developments and applying them to solving real problems. Thus, the potential use of these techniques by practitioners is clear. However, as noted in the literature, there is a significant gap between theory and practice in the multicriteria field, which is further widened if we apply MCDM to corporate finance issues. This should not be surprising since, for example, recent studies as to which investment appraisal techniques financial managers use today highlight the almost total dominance of the classical criteria—net present value, internal rate of return, and payback method—in more sophisticated models such as stochastic sensitivity analysis, real options or simulation models. Therefore, it is expected that practitioners will not adopt multicriteria techniques as tools for solving financial decision-making problems until they realize their potential. The availability of specific software would encourage the adoption of such techniques.

Fourth, *capital budgeting processes are becoming increasingly complex* as a result of several factors, such as the need to consider various, often conflicting, objectives (those related to agency problems or to the consideration of stakeholders' interests in corporate management), the intangible benefits of the strategic investments, or the multiple dimensions of risk criterion. This complexity is driving the search for methodological tools that can take into account additional criteria to the traditional return and risk, in order to provide truly multidimensional investment decisions. In this search process, the main research orientation has been focused on efforts to integrate and quantify non-monetary or intangible criteria in evaluating strategic investments, to which

end AHP seems to be the best fit, in view of the fact that it has already been widely used to address such issues. There are a number of reasons for this, in addition to the ability to include non-monetary or intangible criteria in the analysis: it is a simple technique and does not require excessive prior specialization; it supports both individual and group decision-making and allows consensual solutions; the preferences or judgments of decision-makers are considered; and it transforms a multidimensional problem into a unidimensional one by prioritizing the decision alternatives, criteria, and subcriteria.

In short, the increasing *complexity* of corporate financial processes related to *investment decisions* has led to the study of how *MCDM* could apply to such problems. So far, however, experiences have been based on the use of the simplest multicriteria techniques, such as AHP. The inclusion of the complexity factor related to the set of intangible or non-monetary criteria affecting investment decisions has largely been addressed. We believe, in view of the most recent studies, that this trend of gradually introducing multicriteria techniques in corporate financial processes will continue, especially those that aim to take into account the different objectives of stakeholders such as managers, owners, employees, suppliers, public administrations and so on. This serves to counter the first criticism of the classic paradigm discussed in Chapter 3.

Conclusions from the overall objective

The overall objective of this thesis was to develop *a new theoretical approach to capital budgeting* taking into account the generally accepted value creation logic. However, we take a comprehensive view of this logic, that is, we consider both the financial and non-financial or intellectual capital value creation.

The definition of the overall objective was motivated by *several factors*. First, preliminary results confirmed that the multicriteria techniques have mainly been used to evaluate strategic investments which require consideration of non-monetary or intangible criteria and not just tangible or financial ones. Second, the limitations of using classical financial valuation techniques to understand the real value generated by an investment has been one of the most important criticisms raised in the scientific literature. This is particularly true in terms of investment projects that principally affect the firm's non-financial value, for

example, those that promote an improved corporate image or the knowhow and motivation of employees. Third, we strongly believe it is necessary to include the non-financial or intellectual capital value in corporate decision processes in order to make it visible and measure it, because intellectual capital has become a major source of sustainable competitive advantage in organizations.

In light of the above, we decided to follow the main research line, *using multicriteria techniques to evaluate strategic investment projects*. However, we proposed a new theoretical approach to evaluate and prioritize these kinds of investments. With this new approach, we do not simply try to consider intangible criteria in the analysis in order to select the best alternative, as has been done so far. This approach allows us to specifically quantify both financial and non-financial value creation of each investment project in order to identify the one that maximizes a firm's total market value. The non-financial value is derived from those intangible elements that have an impact on the firm's intellectual capital.

The results of Chapters 4 and 5 confirm that the overall objective has been fully achieved. The proposed theoretical valuation approach allows us to quantify both the criteria and subcriteria related to financial value creation, as well as the criteria and subcriteria of an intangible nature related to non-financial or intellectual capital value creation. Thus, we believe that this theoretical proposal contributes to the sum of knowledge in this field because it largely solves one of the most prominent problems in capital budgeting practice: integrating a set of criteria that affect investment decisions but which, a priori, are difficult to quantify in terms of their impact on the intellectual capital of the firm due to their intangible or non-monetary nature. In addition, this proposal brings value creation financial theory closer to the stakeholder theory, in the sense that two components of intellectual capital, human capital and relational capital, explicitly consider the interests of the employees and the external stakeholders, respectively.

Conclusions from the specific or operational objectives

Conclusions from the two first specific or operational objectives

In order to implement in practice the proposed theoretical valuation approach from the overall objective, we first developed a *capital budgeting method based on the multicriteria technique of analytic hierarchy process or AHP*. This corresponds to the first specific or operational objective. We chose AHP for three main reasons: first, it allows us to consider both quantitative and qualitative criteria in the decision-making process; second, because of its widespread use in the assessment and prioritization of project investments in multicriteria environments, its worth has already been demonstrated; and third, it is a simple technique that does not require prior specific specialization so we believe it could be widely used by CFOs and business consultants.

This first specific or operational objective was achieved in Chapter 4, where we developed an AHP-based model for quantifying the total value creation generated by different investment alternatives. A hierarchical structure composed of four levels was created. At the highest level was the main objective of the decision problem; *market value creation*. This was followed by the four criteria that are the sources of value creation in the organizations: *financial capital, human capital, structural capital* and *relational capital*. The next level contained the specific subcriteria of each component from the previous level. At the base of the hierarchy was the set of investment alternatives. The first and second levels are generic and universal for all valuation processes, while the last two levels have to be adapted to each specific case study.

The second specific or operational objective has also been carried out in Chapter 4. This objective involved implementing the AHP-based model in order to empirically validate it in a group of five Andalusian meat industry firms interested in prioritizing the following three *quality control system alternatives*: i) establishing a firm´s own traditional laboratory; ii) acquiring a near infrared spectroscopy system (NIRS); iii) outsourcing analysis and quality control services to an external laboratory. The AHP-based model was suitable for this case study because food quality control systems have strategic implications for the firm as a whole, influencing both tangible and intangible capital.

The empirical application of the AHP-based model to this case study has demonstrated its feasibility and effectiveness in a real setting and has also demonstrated the need to consider the impacts of productive investments on a firm's intangible assets, as these impacts affect the selection of optimal investment alternatives in the food industry. Furthermore, we also reached the following conclusions:

- There is a clear duality between family firms and industrial corporations regarding the relative importance assigned to the generation of financial and nonfinancial capital value. We believe this situation can be extrapolated from the firms analyzed in our case study to the whole industry. It stems from *managerial myopia* affecting larger companies, where there is a clear separation between shareholders and managers, leading to much higher relative importance being given to financial value creation.
- It is suggested that the capital budgeting model proposed here is particularly suitable for explaining investment decisions in family firms. In any case, considering that even the larger companies assign a non-negligible weight to nonfinancial capital value (figures above 10%), *the application of this approach to any firm* can be justified.
- There is *no common pattern* in the sample considered that explains the distribution of intellectual capital components. Why firms focus on one type of intellectual capital or another is determined by an organization's own strategies. Therefore, it is necessary for financial decision-makers to link the investment project valuation process to the business strategy followed in order to give more weight to related attributes.

The prioritization of investment project alternatives in the case study has been satisfactorily corroborated by actual decision-making, thereby validating the proposed model both theoretically and empirically.

The general conclusion that emerges from the joint consideration of the overall objective and the first two specific or operational objectives is that the proposed method formalizes the capital budgeting process held by financial decision-makers. Indeed, decision-makers are aware of the influence of certain investments on some of the intangible elements of the company and their role as non-financial value creation drivers. However, until now the inclusion of these intangible criteria in project evaluation procedures has only been

addressed intuitively, without using any formalized method. Thus, the proposed AHP-based model allows assessment of each of the investment alternatives by estimating the total value creation, both the financial value and the non-financial value, in an integrative and transparent way.

The case study of the first valuation model has been applied to a small number of firms, which could be seen as the main limitation of this research block. However, the purpose of the second specific or operational objective has not been to provide a representative sample of the meat sector, nor to make a final validation of the proposed model. Rather, the aim has been to illustrate the applicability of the model in the real world and to demonstrate its usefulness as a tool to support decision-making for business managers.

Conclusions from the third and fourth specific or operational objectives

The third specific objective, discussed in Chapter 5, was to develop *a second valuation model*, also from the theoretical approach of *value creation*, based on the multicriteria technique of *analytic network process or ANP*. This model is situated in the recent line of research focused on the value creation of intellectual capital from a *dynamic perspective*, that is, considering the intrinsic relations and interdependencies that occur between the different value drivers in organizations. According to this model, elements of each of the four value components are not static but interactive, so it is necessary to manage flows arising from synergies between these components. We introduced this new intellectual capital perspective to the process of assessing investments in order to make it more realistic and accurate.

The analytic network process or ANP is the most suitable technique for the effective treatment of the interactions between the different elements of corporate value drivers. This technique allows us to propose the model as a network of elements with cause-effect relationships or bidirectional type. Thus, in this second valuation model, we can calculate the total value of each of the investment alternatives based not only on the alternatives' direct influence on each value element, but also on considering the influences between the different elements of the four components of value. ANP is the most appropriate technique for complex decision-making and, as with AHP, tangible and intangible criteria can also be included in the analysis.

The fourth objective is the implementation of the proposed ANP-based approach in a case study about a *firm's environmental management systems assessment*. This decision was motivated by the existing knowledge gap regarding the evaluation and justification of such investments. Furthermore, both the scientific literature review and the expert group's opinions corroborated the fact that the benefits of these systems are largely intangible, so classical valuation techniques are not suitable. Therefore, we considered it necessary to find a method that addresses the quantification of all the intangible benefits to the organization stemming from the environmental management systems.

The empirical application of the model regarding the fourth specific or operational objective was designed in a group of *eight mills* in the provinces of Cordoba and Jaen. The aim was to assess and prioritize the three most common environmental management systems (ISO 14001, EMAS and non-certified EMS) and to compare the results obtained to the alternative actually chosen by the organization.

The results of the empirical application have confirmed the *validity* and *robustness* of the proposed model, since in the vast majority of mills—all except one—the system that creates more value is the one the organization has adopted. Furthermore, in all cases, intangible or intellectual capital criteria have been assigned a much higher weight with respect to the two financial criteria considered. This confirms what we stated previously regarding the essential set of intangible benefits that environmental management systems provide.

The proposed method is a *formalization of the capital budgeting process* actually followed by decision-makers in companies. The degree of formalization is greater than in the AHP-based model because of the inclusion of the interactions between the value drivers, that is, it takes a dynamic perspective on intellectual capital. This second capital budgeting approach also covers, albeit partially, a gap in knowledge regarding existing techniques for selecting strategic investments. Indeed, both the literature review and the experts (academic and practitioners) revealed that currently, making decisions on adopting such investments is not based on the use of any particular valuation technique. The most common practice is limited to calculating the total cost of the project investment, considering whether it is an acceptable expense for the company, and observing whether the most direct competitors have

implemented or are in the process of implementing any of the environmental management systems.

In conclusion, it can be seen that although the ANP-based model has been used to assess environmental management systems, it is flexible enough to be adapted to any other type of investment. Its use is justified more in terms of strategic projects that are expected to impact the nonfinancial corporate value.

It is necessary to discuss some of the limitations or drawbacks of this second valuation model: first, the methodological basis of ANP is not as simple as AHP; therefore, the decision-maker requires more prior specialization. Second, the design of the network of criteria and sub-criteria is conceived as a process of discussion and consensus among different experts so that none of the possible interactions between elements is ignored. Third, implementing the method based on a much more extensive questionnaire than in the case of AHP can be tedious in cases with more complex network structures.

Some final considerations

It seems unreasonable that the intangible elements, which these days constitute one of the main sources of a firm's value creation and sustainable competitiveness, are not taken into account in the process of corporate decision-making. This is particularly relevant when assessing investment projects within organizations, since they affect certain intangible elements, such as human capital or corporate image, to a greater or lesser extent, thus increasing the stock of intellectual capital and generating value for the organization. In this research, we have seen two clear examples: quality control systems and environmental management systems.

The ideas in the previous paragraph have been the main motivation of this thesis. We have presented two valuation models with an array of features, such as operative simplicity, flexibility to adapt to any kind of investment decision-making process, or the ability to include many criteria and, where appropriate, subcriteria as needed. All of these features make these models attractive and effective assessment techniques. This thesis aims to contribute to scientific research in the field and tries to encourage discussion, study and further additions to the sum of knowledge in this area.

FUTURE LINES OF RESEARCH

Some possible future research lines arising from this PhD thesis are outlined below:

- Presenting *new case studies* in productive sectors other than the food industry or even in relation to other kinds of investments. This would yield more evidence that either strengthens or questions the validity of the hypothesis and may corroborate, or not, the conclusions presented here.
- Orienting the two models proposed to *group decision-making*, and not solely to the value judgments of a single financial decision-maker, as has been done in this research. The confluence of different perspectives of a diverse group of managers or external experts could enrich the assessment process.
- Advancing the study of *organizations' theoretical foundations of value creation*, raising new hypotheses concerning the generation of non-financial value. New intellectual capital components could be included or resized (human capital and relational capital may converge towards social capital construct). We could also consider the intangible liabilities that arise as a result of adopting certain corporate decisions as detracting from the value generated by the intangible assets. Additionally, we could analyse in depth the difference between market value and book value in an attempt to find other important factors explaining that difference.
- Tackling *uncertainty or vagueness* in the assessment of criteria in decision-making processes by applying the fuzzy theory to the two models proposed here.

Anexos

Annex 1.

Complete list of papers included in the database for the survey

1. Abdi M, Fathi MR, Faghih A, Tavakoli S. 2011. Performance evaluation of metal ore mining firms in Tehran Stock Exchange using of VIKOR and AHP methodology. *European Journal of Scientific Research* 63:110–121.

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4. Aghajani Bazzazi A, Osanloo M, Karimi B. 2011. Deriving preference order of open pit mines equipment through MADM methods: Application of modified VIKOR method. *Expert Systems with Applications* 38:2550–2556.

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Anexo 2.
Cuestionario empleado para la implementación del modelo AHP en las empresas del caso de estudio

Primera parte. Comparación entre cada par de alternativas con respecto a cada uno de los subcriterios.

Cuestiones 1, 2 y 3. En su opinión, ¿cuál es las siguientes pares de alternativas considera que le reportaría a su empresa un *valor actual neto mayor*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 4, 5 y 6. En su opinión, ¿cuál de las siguientes pares de alternativas considera que influiría más en la mejora de la *cualificación y el knowhow de sus empleados*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 7, 8 y 9. En su opinión, ¿cuál de las siguientes pares de alternativas considera que fomentaría más el *espíritu emprendedor de sus trabajadores*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 10, 11 y 12. En su opinión, ¿cuál de las siguientes pares de alternativas considera que influiría más en la *mejora de la calidad de su producto*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 13, 14 y 15. En su opinión, ¿cuál de las siguientes pares de alternativas considera que influiría más en la *mejora de la flexibilidad productiva*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 16, 17 y 18. En su opinión, ¿cuál de las siguientes pares de alternativas cree que influiría más en el acortamiento del *periodo medio de producción*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 19, 20 y 21. En su opinión, ¿cuál de las siguientes pares de alternativas cree que influiría más en la mejora del *acceso a los canales de distribución*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Cuestiones 12, 23 y 24. En su opinión, ¿cuál de las siguientes pares de alternativas cree que influiría más en la *mejora de la imagen por una mayor preocupación medioambiental corporativa*? ¿y en qué grado?

Laboratorio tradicional										NIR
	9	7	5	3	1	3	5	7	9	

Laboratorio tradicional										Externalización
	9	7	5	3	1	3	5	7	9	

NIR										Externalización
	9	7	5	3	1	3	5	7	9	

Segunda parte. Comparación entre cada par de subcriterios con respecto a su influencia en el criterio del que depende.

Cuestión 1. En su opinión, ¿qué subcriterio de los dos siguientes considera que contribuye más a mejorar el *capital humano* de su empresa? ¿y en qué grado?

Cualificación trabajadores/ knowhow										Espíritu emprendedor
	9	7	5	3	1	3	5	7	9	

Cuestiones 2, 3 y 4. En su opinión, ¿cuál de los siguientes pares de subcriterios considera que contribuye más a mejorar el *capital estructural* de su empresa? y ¿en qué grado?

Calidad del producto										Flexibilidad productiva
	9	7	5	3	1	3	5	7	9	

Calidad del producto										Tiempo medio de fabricación
	9	7	5	3	1	3	5	7	9	

Flexibilidad productiva										Tiempo medio de fabricación
	9	7	5	3	1	3	5	7	9	

Cuestión 5. En su opinión, ¿qué subcriterio de los dos siguientes considera que contribuye más a mejorar el *capital relacional* de su empresa? ¿y en qué grado?

Acceso a canales de distribución										Preocupación medioambiental
	9	7	5	3	1	3	5	7	9	

Tercera parte. Comparación entre cada par de criterios con respecto a su influencia en el nivel superior correspondiente.

Cuestiones 1, 2 y 3. En su opinión, ¿cuál de los siguientes pares de criterios considera que contribuye más a crear *valor no financiero* en su empresa? y ¿en qué grado?

Capital humano	9	7	5	3	1	3	5	7	9	Capital estructural

Capital humano	9	7	5	3	1	3	5	7	9	Capital relacional

Capital estructural	9	7	5	3	1	3	5	7	9	Capital relacional

Cuarta parte. Comparación de los dos componentes de la creación de valor de mercado.

Cuestión 1. En su opinión, ¿qué considera que contribuye más a la *creación de valor de mercado* en su empresa, el valor financiero o el valor no financiero? ¿y en qué grado?

Valor financiero	9	7	5	3	1	3	5	7	9	Valor no financiero

Annex 3.

AHP-based model detailed results

FIRM A

1. Alternatives pairwise comparison with respect to each subcriterion

1.1. NPV

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,20	0,14	0,31	0,07
NIRS	5,00	1,00	0,33	1,19	0,28
Outs.	7,00	3,00	1,00	2,76	0,65

1.2. Skilled labour/knowhow

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	7,00	9,00	3,98	0,79
NIRS	0,14	1,00	3,00	0,75	0,15
Outs.	0,11	0,33	1,00	0,33	0,07

1.3. Entrepreneurial spirit

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	3,00	3,98	0,15
NIRS	7,00	1,00	9,00	0,75	0,79
Outs.	0,33	0,11	1,00	0,33	0,07

1.4. Product quality

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,11	1,00	0,48	0,09
NIRS	9,00	1,00	9,00	4,33	0,82
Outs.	1,00	0,11	1,00	0,48	0,09

1.5. Manufacturing flexibility

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	3,00	0,75	0,15
NIRS	7,00	1,00	9,00	3,98	0,79
Outs.	0,33	0,11	1,00	0,33	0,07

1.6. Lead time

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,33
NIRS	1,00	1,00	1,00	1,00	0,33
Outs.	1,00	1,00	1,00	1,00	0,33

1.7. Access to distribution channels

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	1,00	0,52	0,11
NIRS	7,00	1,00	7,00	3,66	0,78
Outs.	1,00	0,14	1,00	0,52	0,11

1.8. Environmental consciousness

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,11	1,00	0,48	0,09
NIRS	9,00	1,00	9,00	4,33	0,82
Outs.	1,00	0,11	1,00	0,48	0,09

2. Subcriteria pairwise comparison with respect to the corresponding criterion

2.1. Human capital

HC1: Skilled labour/knowhow
HC2: Entrepreneurial spirit

	HC1	*HC2*	*Geometric mean*	*Local weights*
HC1	1,00	3,00	1,73	0,75
HC2	0,33	1,00	0,58	0,25

2.2. Structural capital

SC1: Product quality
SC2: Manufacturing flexibility
SC3: Lead time

	SC1	*SC2*	*SC3*	*Geometric mean*	*Local weights*
SC1	1,00	3,00	7,00	2,76	0,63
SC2	0,33	1,00	7,00	1,33	0,30
SC3	0,14	0,14	1,00	0,27	0,06

2.3. Relational capital

RC1: Access to distribution channels
RC2: Environmental consciousness

	RC1	*RC2*	*Geometric mean*	*Local weights*
RC1	1,00	7,00	2,65	0,88
RC2	0,14	1,00	0,38	0,13

3. Criteria pairwise comparison

HC: Human capital
SC: Sctructural capital
RC: Relational capital

	HC	*SC*	*RC*	*Geometric mean*	*Local weights*
HC	1,00	3,00	1,00	1,44	0,43
SC	0,33	1,00	0,33	0,48	0,14
RC	1,00	3,00	1,00	1,44	0,43

4. Financial and nonfinancial value pairwise comparison

FC: Financial capital
NFC: Non financial capital

	FC	*NFC*	*Geometric mean*	*Global weights*
FC	1,00	0,33	0,58	0,25
NFC	3,00	1,00	1,73	0,75

5. Subcriteria global weights

	NPV	HC1	HC2	SC1	SC2	SC3	RC1	RC2
Lab	0,072	0,785	0,149	0,091	0,149	0,333	0,111	0,091
NIRS	0,279	0,149	0,785	0,818	0,785	0,333	0,778	0,818
Outs.	0,649	0,066	0,066	0,091	0,066	0,333	0,111	0,091
Global weights	*25,00%*	*24,11%*	*8,04%*	*6,78%*	*3,26%*	*0,67%*	*28,13%*	*4,02%*

6. Value creation of each alternative. Additive function

Lab	0,018	0,189	0,012	0,006	0,005	0,002	0,031	0,004	*0,267*
NIRS	0,070	0,036	0,063	0,055	0,026	0,002	0,219	0,033	*0,504*
Outs.	0,162	0,016	0,005	0,006	0,002	0,002	0,031	0,004	*0,229*

FIRM B

1. Alternatives pairwise comparison with respect to each subcriterion

1.1. NPV

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,32
NIRS	1,00	1,00	3,00	1,44	0,46
Outs.	1,00	0,33	1,00	0,69	0,22

1.2. Skilled labour/knowhow

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,33	0,36	0,08
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	3,00	0,14	1,00	0,75	0,16

1.3. Entrepreneurial spirit

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,33	0,36	0,08
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	3,00	0,14	1,00	0,75	0,16

1.4. Product quality

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,33	0,36	0,09
NIRS	7,00	1,00	3,00	2,76	0,67
Outs.	3,00	0,33	1,00	1,00	0,24

1.5. Manufacturing flexibility

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,33	0,33	0,48	0,14
NIRS	3,00	1,00	0,33	1,00	0,28
Outs.	3,00	3,00	1,00	2,08	0,58

1.6. Lead time

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,33
NIRS	1,00	1,00	1,00	1,00	0,33
Outs.	1,00	1,00	1,00	1,00	0,33

1.7. Access to distribution channels

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,11	0,33	0,33	0,07
NIRS	9,00	1,00	7,00	3,98	0,79
Outs.	3,00	0,14	1,00	0,75	0,15

1.8. Environmental consciousness

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,33	0,36	0,08
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	3,00	0,14	1,00	0,75	0,16

2. Subcriteria pairwise comparison with respect to the corresponding criterion

2.1. Human capital

HC1: Skilled labour/knowhow
HC2: Entrepreneurial spirit

	HC1	*HC2*	*Geometric mean*	*Local weights*
HC1	1,00	0,20	0,45	0,17
HC2	5,00	1,00	2,24	0,83

2.2. Structural capital

SC1: Product quality
SC2: Manufacturing flexibility
SC3: Lead time

	SC1	*SC2*	*SC3*	*Geometric mean*	*Local weights*
SC1	1,00	3,00	3,00	2,08	0,58
SC2	0,33	1,00	3,00	1,00	0,28
SC3	0,33	0,33	1,00	0,48	0,14

2.3. Relational capital

RC1: Access to distribution channels
RC2: Environmental consciousness

	RC1	*RC2*	*Geometric mean*	*Local weights*
RC1	1,00	5,00	2,24	0,83
RC2	0,20	1,00	0,45	0,17

3. Criteria pairwise comparison

HC: Human capital
SC: Sctructural capital
RC: Relational capital

	HC	*SC*	*RC*	*Geometric mean*	*Local weights*
HC	1,00	1,00	3,00	1,44	0,43
SC	1,00	1,00	3,00	1,44	0,43
RC	0,33	0,33	1,00	0,48	0,14

4. Financial and nonfinancial value pairwise comparison

FC: Financial capital
NFC: Non financial capital

	FC	*NFC*	*Geometric mean*	*Global weights*
FC	1,00	3,00	1,73	0,75
NFC	0,33	1,00	0,58	0,25

5. Subcriteria global weights

	NPV	HC1	HC2	SC1	SC2	SC3	RC1	RC2
Lab	0,319	0,076	0,076	0,088	0,135	0,333	0,066	0,076
NIRS	0,460	0,766	0,766	0,669	0,281	0,333	0,785	0,766
Outs.	0,221	0,158	0,158	0,243	0,584	0,333	0,149	0,158
Global weights	*75,00%*	*1,79%*	*8,93%*	*6,26%*	*3,01%*	*1,45%*	*2,98%*	*0,60%*

6. Value creation of each alternative. Additive function

Lab	0,239	0,001	0,007	0,006	0,004	0,005	0,002	0,000	*0,264*
NIRS	0,345	0,014	0,068	0,042	0,008	0,005	0,023	0,005	*0,510*
Outs.	0,166	0,003	0,014	0,015	0,018	0,005	0,004	0,001	*0,226*

FIRM C

1. Alternatives pairwise comparison with respect to each subcriterion

1.1. NPV

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,33	0,36	0,08
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	3,00	0,14	1,00	0,75	0,16

1.2. Skilled labour/knowhow

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	7,00	7,00	3,66	0,78
NIRS	0,14	1,00	1,00	0,52	0,11
Outs.	0,14	1,00	1,00	0,52	0,11

1.3. Entrepreneurial spirit

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,20	0,31	0,08
NIRS	7,00	1,00	1,00	1,91	0,49
Outs.	5,00	1,00	1,00	1,71	0,44

1.4. Product quality

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	0,33	0,36	0,08
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	3,00	0,14	1,00	0,75	0,16

1.5. Manufacturing flexibility

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	1,00	0,52	0,11
NIRS	7,00	1,00	7,00	3,66	0,78
Outs.	1,00	0,14	1,00	0,52	0,11

1.6. Lead time

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	1,00	0,52	0,11
NIRS	7,00	1,00	7,00	3,66	0,78
Outs.	1,00	0,14	1,00	0,52	0,11

1.7. Access to distribution channels

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	1,00	0,52	0,11
NIRS	7,00	1,00	7,00	3,66	0,78
Outs.	1,00	0,14	1,00	0,52	0,11

1.8. Environmental consciousness

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	1,00	0,52	0,11
NIRS	7,00	1,00	7,00	3,66	0,78
Outs.	1,00	0,14	1,00	0,52	0,11

2. Subcriteria pairwise comparison with respect to the corresponding criterion

2.1. Human capital

HC1: Skilled labour/knowhow
HC2: Entrepreneurial spirit

	HC1	*HC2*	*Geometric mean*	*Local weights*
HC1	1,00	0,14	0,38	0,13
HC2	7,00	1,00	2,65	0,88

2.2. Structural capital

SC1: Product quality
SC2: Manufacturing flexibility
SC3: Lead time

	SC1	*SC2*	*SC3*	*Geometric mean*	*Local weights*
SC1	1,00	7,00	7,00	3,66	0,78
SC2	0,14	1,00	1,00	0,52	0,11
SC3	0,14	1,00	1,00	0,52	0,11

2.3. Relational capital

RC1: Access to distribution channels
RC2: Environmental consciousness

	RC1	*RC2*	*Geometric mean*	*Local weights*
RC1	1,00	7,00	2,65	0,88
RC2	0,14	1,00	0,38	0,13

3. Criteria pairwise comparison

HC: Human capital
SC: Sctructural capital
RC: Relational capital

	HC	*SC*	*RC*	*Geometric mean*	*Local weights*
HC	1,00	7,00	3,00	2,76	0,69
SC	0,14	1,00	1,00	0,52	0,13
RC	0,33	1,00	1,00	0,69	0,17

4. Financial and nonfinancial value pairwise comparison

FC: Financial capital
NFC: Non financial capital

	FC	*NFC*	*Geometric mean*	*Global weights*
FC	1,00	5,00	2,24	0,83
NFC	0,20	1,00	0,45	0,17

5. Subcriteria global weights

	NPV	HC1	HC2	SC1	SC2	SC3	RC1	RC2
Lab	0,076	0,778	0,078	0,076	0,111	0,111	0,111	0,111
NIRS	0,766	0,111	0,487	0,766	0,778	0,778	0,778	0,778
Outs.	0,158	0,111	0,435	0,158	0,111	0,111	0,111	0,111
Global weights	*83,33%*	*1,45%*	*10,12%*	*1,70%*	*0,24%*	*0,24%*	*2,54%*	*0,36%*

6. Value creation of each alternative. Additive function

Lab	0,063	0,011	0,008	0,001	0,000	0,000	0,003	0,000	*0,087*
NIRS	0,639	0,002	0,049	0,013	0,002	0,002	0,020	0,003	*0,729*
Outs.	0,132	0,002	0,044	0,003	0,000	0,000	0,003	0,000	*0,184*

FIRM D

1. Alternatives pairwise comparison with respect to each subcriterion

1.1. NPV

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	5,00	0,14	0,89	0,17
NIRS	0,20	1,00	0,11	0,28	0,05
Outs.	7,00	9,00	1,00	3,98	0,77

1.2. Skilled labour/knowhow

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	7,00	7,00	3,66	0,77
NIRS	0,14	1,00	3,00	0,75	0,16
Outs.	0,14	0,33	1,00	0,36	0,08

1.3. Entrepreneurial spirit

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,33	7,00	1,33	0,30
NIRS	3,00	1,00	7,00	2,76	0,63
Outs.	0,14	0,14	1,00	0,27	0,06

1.4. Product quality

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	7,00	1,00	1,91	0,47
NIRS	0,14	1,00	0,14	0,27	0,07
Outs.	1,00	7,00	1,00	1,91	0,47

1.5. Manufacturing flexibility

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	7,00	1,00	1,91	0,47
NIRS	0,14	1,00	0,14	0,27	0,07
Outs.	1,00	7,00	1,00	1,91	0,47

1.6. Lead time

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,33
NIRS	1,00	1,00	1,00	1,00	0,33
Outs.	1,00	1,00	1,00	1,00	0,33

1.7. Access to distribution channels

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,33
NIRS	1,00	1,00	1,00	1,00	0,33
Outs.	1,00	1,00	1,00	1,00	0,33

1.8. Environmental consciousness

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	1,00	0,52	0,11
NIRS	7,00	1,00	7,00	3,66	0,78
Outs.	1,00	0,14	1,00	0,52	0,11

2. Subcriteria pairwise comparison with respect to the corresponding criterion

2.1. Human capital

HC1: Skilled labour/knowhow
HC2: Entrepreneurial spirit

	HC1	*HC2*	*Geometric mean*	*Local weights*
HC1	1,00	0,14	0,38	0,13
HC2	7,00	1,00	2,65	0,88

2.2. Structural capital

SC1: Product quality
SC2: Manufacturing flexibility
SC3: Lead time

	SC1	*SC2*	*SC3*	*Geometric mean*	*Local weights*
SC1	1,00	7,00	7,00	3,66	0,77
SC2	0,14	1,00	0,33	0,36	0,08
SC3	0,14	3,00	1,00	0,75	0,16

2.3. Relational capital

RC1: Access to distribution channels
RC2: Environmental consciousness

	RC1	*RC2*	*Geometric mean*	*Local weights*
RC1	1,00	7,00	2,65	0,88
RC2	0,14	1,00	0,38	0,13

3. Criteria pairwise comparison

HC: Human capital
SC: Sctructural capital
RC: Relational capital

	HC	*SC*	*RC*	*Geometric mean*	*Local weights*
HC	1,00	1,00	1,00	1,00	0,33
SC	1,00	1,00	1,00	1,00	0,33
RC	1,00	1,00	1,00	1,00	0,33

4. Financial and nonfinancial value pairwise comparison

FC: Financial capital
NFC: Non financial capital

	FC	*NFC*	*Geometric mean*	*Global weights*
FC	1,00	0,33	0,58	0,25
NFC	3,00	1,00	1,73	0,75

5. Subcriteria global weights

	NPV	HC1	HC2	SC1	SC2	SC3	RC1	RC2
Lab	0,173	0,766	0,304	0,467	0,467	0,333	0,333	0,111
NIRS	0,055	0,158	0,633	0,067	0,067	0,333	0,333	0,778
Outs.	0,772	0,076	0,063	0,467	0,467	0,333	0,333	0,111
Global weights	*25,00%*	*3,13%*	*21,88%*	*19,16%*	*1,90%*	*3,95%*	*21,88%*	*3,13%*

6. Value creation of each alternative. Additive function

Lab	0,043	0,024	0,067	0,089	0,009	0,013	0,073	0,003	*0,322*
NIRS	0,014	0,005	0,138	0,013	0,001	0,013	0,073	0,024	*0,281*
Outs.	0,193	0,002	0,014	0,089	0,009	0,013	0,073	0,003	*0,397*

FIRM E

1. Alternatives pairwise comparison with respect to each subcriterion

1.1. NPV

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	3,00	0,75	0,16
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	0,33	0,14	1,00	0,36	0,08

1.2. Skilled labour/knowhow

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	7,00	9,00	3,98	0,79
NIRS	0,14	1,00	3,00	0,75	0,15
Outs.	0,11	0,33	1,00	0,33	0,07

1.3. Entrepreneurial spirit

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,20	7,00	1,12	0,23
NIRS	5,00	1,00	9,00	3,56	0,72
Outs.	0,14	0,11	1,00	0,25	0,05

1.4. Product quality

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	3,00	0,75	0,16
NIRS	7,00	1,00	7,00	3,66	0,77
Outs.	0,33	0,14	1,00	0,36	0,08

1.5. Manufacturing flexibility

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,14	5,00	0,89	0,17
NIRS	7,00	1,00	9,00	3,98	0,77
Outs.	0,20	0,11	1,00	0,28	0,05

1.6. Lead time

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,33
NIRS	1,00	1,00	1,00	1,00	0,33
Outs.	1,00	1,00	1,00	1,00	0,33

1.7. Access to distribution channels

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	1,00	1,00	1,00	0,33
NIRS	1,00	1,00	1,00	1,00	0,33
Outs.	1,00	1,00	1,00	1,00	0,33

1.8. Environmental consciousness

	Lab	*NIRS*	*Outs.*	*Geometric mean*	*Local weights*
Lab	1,00	0,20	1,00	0,58	0,14
NIRS	5,00	1,00	5,00	2,92	0,71
Outs.	1,00	0,20	1,00	0,58	0,14

2. Subcriteria pairwise comparison with respect to the corresponding criterion

2.1. Human capital

HC1: Skilled labour/knowhow
HC2: Entrepreneurial spirit

	HC1	*HC2*	*Geometric mean*	*Local weights*
HC1	1,00	0,33	0,58	0,25
HC2	3,00	1,00	1,73	0,75

2.2. Structural capital

SC1: Product quality
SC2: Manufacturing flexibility
SC3: Lead time

	SC1	*SC2*	*SC3*	*Geometric mean*	*Local weights*
SC1	1,00	0,20	5,00	1,00	0,22
SC2	5,00	1,00	7,00	3,27	0,71
SC3	0,20	0,14	1,00	0,31	0,07

2.3. Relational capital

RC1: Access to distribution channels
RC2: Environmental consciousness

	RC1	*RC2*	*Geometric mean*	*Local weights*
RC1	1,00	7,00	2,65	0,88
RC2	0,14	1,00	0,38	0,13

3. Criteria pairwise comparison

HC: Human capital
SC: Sctructural capital
RC: Relational capital

	HC	*SC*	*RC*	*Geometric mean*	*Local weights*
HC	1,00	0,33	3,00	1,00	0,28
SC	3,00	1,00	3,00	2,08	0,58
RC	0,33	0,33	1,00	0,48	0,14

4. Financial and nonfinancial value pairwise comparison

FC: Financial capital
NFC: Non financial capital

	FC	*NFC*	*Geometric mean*	*Global weights*
FC	1,00	7,00	2,65	0,88
NFC	0,14	1,00	0,38	0,13

5. Subcriteria global weights

	NPV	HC1	HC2	SC1	SC2	SC3	RC1	RC2
Lab	0,158	0,785	0,227	0,158	0,173	0,333	0,333	0,143
NIRS	0,766	0,149	0,722	0,766	0,772	0,333	0,333	0,714
Outs.	0,076	0,066	0,051	0,076	0,055	0,333	0,333	0,143
Global weights	*87,50%*	*0,88%*	*2,63%*	*1,60%*	*5,22%*	*0,49%*	*1,48%*	*0,21%*

6. Value creation of each alternative. Additive function

Lab	0,138	0,007	0,006	0,003	0,009	0,002	0,005	0,000	*0,169*
NIRS	0,670	0,001	0,019	0,012	0,040	0,002	0,005	0,002	*0,751*
Outs.	0,066	0,001	0,001	0,001	0,003	0,002	0,005	0,000	*0,079*

Anexo 4.
Cuestionario empleado para la implementación del modelo ANP en las almazaras del caso de estudio

Primera parte. Comparación entre las tres alternativas de sistemas de gestión ambiental.

Cuestiones 1, 2 y 3. En su opinión, para el caso de su almazara, ¿cuál de las siguientes alternativas considera que tendría un *coste total mayor*? ¿y, en qué grado?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	
SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	
ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Cuestiones 4, 5 y 6. En su opinión, ¿cuál de las siguientes alternativas incrementaría en mayor medida los *beneficios por ventas y por la mejora de la eficiencia* de su empresa? ¿y en qué medida?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	
SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	
ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Cuestión 7. En su opinión, ¿cuál de los siguientes atributos del capital humano influye más en los *beneficios por ventas y por la mejora de la eficiencia* de su empresa? ¿y, en qué medida?

Conocimientos y habilidades										Motivación y compromiso
	9	7	5	3	1	3	5	7	9	

Cuestiones 8, 9, 10. En su opinión, ¿cuál de las siguientes alternativas mejoraría más los *conocimientos y habilidades de sus empleados*? ¿y en qué medida?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	

SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	

ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Cuestiones 11, 12, 13. En su opinión, ¿cuál de las siguientes alternativas mejoraría más la *motivación y el compromiso de los empleados con su organización*? ¿y en qué medida?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	

SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	

ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Cuestiones 14, 15, 16. En su opinión, ¿qué alternativa influiría más en la *mejora de la organización interna y la documentación de su almazara*? ¿y en qué medida?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	

SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	

ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Cuestiones 17, 18, 19. En su opinión, ¿cuál de las siguientes alternativas mejoraría más la *imagen y la reputación de su empresa*? ¿y en qué medida?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	

SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	

ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Cuestiones 20, 21, 22. En su opinión, ¿cuál de las siguientes alternativas influiría más en la mejora de las *relaciones de su almazara con las AA.PP.*? ¿y en qué medida?

SGA no certificado										ISO 14001
	9	7	5	3	1	3	5	7	9	

SGA no certificado										EMAS
	9	7	5	3	1	3	5	7	9	

ISO 14001										EMAS
	9	7	5	3	1	3	5	7	9	

Segunda parte. Ponderación de los subcriterios que influyen en la decisión de implantar un SGA

Cuestión 1. En su opinión, en la decisión de implantar un sistema de gestión ambiental en su almazara, ¿qué criterio considera que influye más, su *coste total* o los *beneficios* que pueden derivarse del incremento de las ventas y de mejora de la eficiencia? ¿y en qué medida?

Coste total	9	7	5	3	1	3	5	7	9	Beneficios ventas y eficiencia

Cuestión 2. En su opinión, en la decisión de implantar un sistema de gestión ambiental en su almazara, ¿qué criterio considera que influye más, los *conocimientos y habilidades* de los empleados, o su *motivación y compromiso*? ¿y en qué medida?

Conocimientos y habilidades	9	7	5	3	1	3	5	7	9	Motivación y compromiso

Cuestión 3. En su opinión, en la decisión de implantar un sistema de gestión ambiental en su almazara, ¿qué criterio considera que influye más, la *imagen y la reputación* corporativa, o las *relaciones con las AA.PP.*? ¿y en qué medida?

Imagen y reputación	9	7	5	3	1	3	5	7	9	Relaciones con AA.PP.

Cuestión 4. En su opinión, si en su almazara se planteara la implantación de EMAS, ¿considera que influiría positivamente el hecho de que la empresa ya tuviera un *sistema de gestión ambiental no certificado* o que tuviera *ISO 14001*? ¿y en qué medida?

SGA no certificado	9	7	5	3	1	3	5	7	9	ISO 14001

Tercera parte. Ponderación de los criterios.

Cuestión 1. En su opinión, en la decisión de implantar un *SGA* en su almazara, ¿en qué medida *–desde 1, no influencia, hasta 9, absoluta influencia–* cree que influye cada uno de los siguientes criterios?

- Capital financiero:
- Capital humano:
- Capital estructural:
- Capital relacional:
- Sistemas de gestión ambiental:

Cuestión 2. En su opinión, en el *valor financiero* de su empresa, ¿en qué medida *–desde 1, no influencia, hasta 9, absoluta influencia–* cree que influye cada uno de los cuatro siguientes criterios?

- Capital humano:
- Capital estructural:
- Capital relacional:
- Sistemas de gestión ambiental:

Cuestión 3. En su opinión, en el *valor del capital humano* de su organización, ¿en qué medida *–desde 1, no influencia, hasta 9, absoluta influencia–* cree que influye cada uno de los cuatro siguientes criterios?

- Capital estructural:
- Capital relacional:
- Sistemas de gestión ambiental:
- Capital humano:

Cuestión 4. En su opinión, en el valor del *capital relacional* de su empresa, ¿qué criterio considera que influye más, el capital humano o el tener un sistema de gestión ambiental? ¿y en qué medida?

Capital humano										Sistema de gestión ambiental
	9	7	5	3	1	3	5	7	9	

Cuestión 5. En su opinión, en las *relaciones de su empresa con los agentes externos*, ¿qué criterio considera que influye más, la imagen y la reputación corporativa o el contar con un sistema de gestión ambiental? ¿y en qué medida?

Imagen y reputación										Sistema de gestión ambiental
	9	7	5	3	1	3	5	7	9	

Cuestión 6. En su opinión, en las *relaciones de su empresa con los agentes externos*, ¿qué criterio considera que influye más, la imagen y la reputación corporativa o el capital humano? ¿y en qué medida?

Imagen y reputación										Capital humano
	9	7	5	3	1	3	5	7	9	

Cuestión 7. En su opinión, en el *valor del capital estructural* de su empresa, ¿qué criterio considera que influye más, el capital humano o el contar con un sistema de gestión ambiental? ¿y en qué medida?

Capital humano										Sistema gestión ambiental
	9	7	5	3	1	3	5	7	9	

Annex 5.

ANP-based model detailed results

FIRM A

Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.27969	0.17135	0.35748	0.35219	0.24374	0.33252	0.35219
ISO 14	0.85714	0.00000	0.00000	0.09362	0.75041	0.56746	0.55907	0.68709	0.52784	0.55907
NC EMS	0.14286	1.00000	0.00000	0.62670	0.07825	0.07507	0.08875	0.06917	0.13965	0.08875
FC1	0.12500	0.12500	0.12500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.87500	0.87500	0.87500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.14286	0.14286	0.14286	1.00000	0.14286	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.85714	0.85714	0.85714	0.00000	0.85714	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.85714	0.85714	0.85714	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.14286	0.14286	0.14286	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.222200	0.166670	0.250000	0.728584	0.142857
FCV	0.148200	0.000000	0.000000	0.000000	0.000000
HCV	0.185200	0.291670	0.285720	0.108836	0.857143
RCV	0.222200	0.291660	0.178570	0.162579	0.000000
SCV	0.222200	0.250000	0.285710	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.06581	0.02856	0.16682	0.12327	0.24374	0.24227	0.05031
ISO 14	0.19046	0.00000	0.00000	0.02203	0.12507	0.26482	0.19567	0.68709	0.38457	0.07987
NC EMS	0.03174	0.22220	0.00000	0.14746	0.01304	0.03503	0.03106	0.06917	0.10175	0.01268
FC1	0.01853	0.01853	0.02382	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.12968	0.12968	0.16672	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.02646	0.02646	0.03401	0.41177	0.04167	0.00000	0.40001	0.00000	0.10884	0.85714
HC2	0.15874	0.15874	0.20409	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.19046	0.19046	0.24487	0.00000	0.29166	0.00000	0.25000	0.00000	0.16258	0.00000
RC2	0.03174	0.03174	0.04081	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.22220	0.22220	0.28568	0.35294	0.25000	0.53333	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.08492	0.08492	0.08492	0.08492	0.08492	0.08492	0.08492	0.08492	0.08492	0.08492
ISO 14	0.18392	0.18392	0.18392	0.18392	0.18392	0.18392	0.18392	0.18392	0.18392	0.18392
NC EMS	0.06575	0.06575	0.06575	0.06575	0.06575	0.06575	0.06575	0.06575	0.06575	0.06575
FC1	0.00655	0.00655	0.00655	0.00655	0.00655	0.00655	0.00655	0.00655	0.00655	0.00655
FC2	0.04582	0.04582	0.04582	0.04582	0.04582	0.04582	0.04582	0.04582	0.04582	0.04582
HC1	0.22344	0.22344	0.22344	0.22344	0.22344	0.22344	0.22344	0.22344	0.22344	0.22344
HC2	0.06755	0.06755	0.06755	0.06755	0.06755	0.06755	0.06755	0.06755	0.06755	0.06755
RC1	0.09938	0.09938	0.09938	0.09938	0.09938	0.09938	0.09938	0.09938	0.09938	0.09938
RC2	0.01122	0.01122	0.01122	0.01122	0.01122	0.01122	0.01122	0.01122	0.01122	0.01122
SC1	0.21145	0.21145	0.21145	0.21145	0.21145	0.21145	0.21145	0.21145	0.21145	0.21145

FIRM B

Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.11111	0.46667	0.45454	0.46667	0.47059	0.45454	0.47059
ISO 14	0.87500	0.00000	0.00000	0.11111	0.46667	0.45454	0.46667	0.47059	0.45454	0.47059
NC EMS	0.12500	1.00000	0.00000	0.77778	0.06667	0.09091	0.06667	0.05882	0.09091	0.05882
FC1	0.14286	0.14286	0.14286	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.85714	0.85714	0.85714	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.50000	0.50000	0.50000	1.00000	0.25000	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.50000	0.50000	0.50000	0.00000	0.75000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.87500	0.87500	0.87500	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.12500	0.12500	0.12500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.206890	0.150000	0.100000	0.076842	0.250000
FCV	0.103460	0.000000	0.000000	0.000000	0.000000
HCV	0.241380	0.350000	0.350000	0.381631	0.750000
RCV	0.206890	0.200000	0.250000	0.541527	0.000000
SCV	0.241380	0.300000	0.300000	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.02083	0.07000	0.11364	0.06667	0.47059	0.03493	0.11765
ISO 14	0.18103	0.00000	0.00000	0.02083	0.07000	0.11364	0.06667	0.47059	0.03493	0.11765
NC EMS	0.02586	0.20689	0.00000	0.14583	0.01000	0.02273	0.00952	0.05882	0.00699	0.01471
FC1	0.01478	0.01478	0.01864	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.08868	0.08868	0.11181	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.12069	0.12069	0.15217	0.43750	0.08750	0.00000	0.50000	0.00000	0.38163	0.75000
HC2	0.12069	0.12069	0.15217	0.00000	0.26250	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.18103	0.18103	0.22825	0.00000	0.20000	0.00000	0.35714	0.00000	0.54153	0.00000
RC2	0.02586	0.02586	0.03261	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.24138	0.24138	0.30435	0.37500	0.30000	0.75000	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.10648	0.10648	0.10648	0.10648	0.10648	0.10648	0.10648	0.10648	0.10648	0.10648
ISO 14	0.12576	0.12576	0.12576	0.12576	0.12576	0.12576	0.12576	0.12576	0.12576	0.12576
NC EMS	0.04517	0.04517	0.04517	0.04517	0.04517	0.04517	0.04517	0.04517	0.04517	0.04517
FC1	0.00427	0.00427	0.00427	0.00427	0.00427	0.00427	0.00427	0.00427	0.00427	0.00427
FC2	0.02565	0.02565	0.02565	0.02565	0.02565	0.02565	0.02565	0.02565	0.02565	0.02565
HC1	0.27889	0.27889	0.27889	0.27889	0.27889	0.27889	0.27889	0.27889	0.27889	0.27889
HC2	0.04163	0.04163	0.04163	0.04163	0.04163	0.04163	0.04163	0.04163	0.04163	0.04163
RC1	0.07640	0.07640	0.07640	0.07640	0.07640	0.07640	0.07640	0.07640	0.07640	0.07640
RC2	0.00748	0.00748	0.00748	0.00748	0.00748	0.00748	0.00748	0.00748	0.00748	0.00748
SC1	0.28827	0.28827	0.28827	0.28827	0.28827	0.28827	0.28827	0.28827	0.28827	0.28827

FIRM C

Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.18839	0.17135	0.36135	0.35219	0.28974	0.36135	0.27896
ISO 14	0.83333	0.00000	0.00000	0.08096	0.75041	0.57361	0.55907	0.65536	0.57361	0.64912
NC EMS	0.16667	1.00000	0.00000	0.73064	0.07825	0.06504	0.08875	0.05490	0.06504	0.07193
FC1	0.16667	0.16667	0.16667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.83333	0.83333	0.83333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.12500	0.12500	0.12500	1.00000	0.12500	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.87500	0.87500	0.87500	0.00000	0.87500	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.50000	0.50000	0.50000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.50000	0.50000	0.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.120000	0.250000	0.333334	0.259921	0.166667
FCV	0.120000	0.000000	0.000000	0.000000	0.000000
HCV	0.280000	0.250000	0.047620	0.412599	0.833333
RCV	0.200000	0.250000	0.285713	0.327480	0.000000
SCV	0.280000	0.250000	0.333333	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.06280	0.04284	0.18068	0.17610	0.28974	0.09392	0.04649
ISO 14	0.10000	0.00000	0.00000	0.02699	0.18760	0.28680	0.27953	0.65536	0.14909	0.10819
NC EMS	0.02000	0.12000	0.00000	0.24355	0.01956	0.03252	0.04437	0.05490	0.01691	0.01199
FC1	0.02000	0.02000	0.02273	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.10000	0.10000	0.11364	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.03500	0.03500	0.03977	0.33333	0.03125	0.00000	0.07143	0.00000	0.41260	0.83333
HC2	0.24500	0.24500	0.27841	0.00000	0.21875	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.10000	0.10000	0.11364	0.00000	0.25000	0.00000	0.42857	0.00000	0.32748	0.00000
RC2	0.10000	0.10000	0.11364	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.28000	0.28000	0.31818	0.33333	0.25000	0.50000	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.09458	0.09458	0.09458	0.09458	0.09458	0.09458	0.09458	0.09458	0.09458	0.09458
ISO 14	0.18806	0.18806	0.18806	0.18806	0.18806	0.18806	0.18806	0.18806	0.18806	0.18806
NC EMS	0.04557	0.04557	0.04557	0.04557	0.04557	0.04557	0.04557	0.04557	0.04557	0.04557
FC1	0.00669	0.00669	0.00669	0.00669	0.00669	0.00669	0.00669	0.00669	0.00669	0.00669
FC2	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344
HC1	0.20916	0.20916	0.20916	0.20916	0.20916	0.20916	0.20916	0.20916	0.20916	0.20916
HC2	0.08925	0.08925	0.08925	0.08925	0.08925	0.08925	0.08925	0.08925	0.08925	0.08925
RC1	0.09100	0.09100	0.09100	0.09100	0.09100	0.09100	0.09100	0.09100	0.09100	0.09100
RC2	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344	0.03344
SC1	0.20881	0.20881	0.20881	0.20881	0.20881	0.20881	0.20881	0.20881	0.20881	0.20881

FIRM D

Unweighted supermatrix

	EMAS	ISO	NC	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.09091	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333
ISO	0.50000	0.00000	0.00000	0.09091	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333
NC	0.50000	1.00000	0.00000	0.81818	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333
FC1	0.16667	0.16667	0.16667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.83333	0.83333	0.83333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.83333	0.83333	0.83333	1.00000	0.50000	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.16667	0.16667	0.16667	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.88889	0.88889	0.88889	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.11111	0.11111	0.11111	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.090900	0.045400	0.050000	0.051328	0.166667
FCV	0.272700	0.000000	0.000000	0.000000	0.000000
HCV	0.090900	0.318200	0.350000	0.366651	0.833333
RCV	0.454600	0.318200	0.250000	0.582022	0.000000
SCV	0.090900	0.318200	0.350000	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.00605	0.01513	0.04167	0.02564	0.33333	0.01711	0.05556
ISO 14	0.04545	0.00000	0.00000	0.00605	0.01513	0.04167	0.02564	0.33333	0.01711	0.05556
NC EMS	0.04545	0.09090	0.00000	0.05448	0.01513	0.04167	0.02564	0.33333	0.01711	0.05556
FC1	0.04545	0.04545	0.04999	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.22725	0.22725	0.24997	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.07575	0.07575	0.08332	0.46671	0.15910	0.00000	0.53846	0.00000	0.36665	0.83333
HC2	0.01515	0.01515	0.01666	0.00000	0.15910	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.40409	0.40409	0.44449	0.00000	0.31820	0.00000	0.38461	0.00000	0.58202	0.00000
RC2	0.05051	0.05051	0.05556	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.09090	0.09090	0.09999	0.46671	0.31820	0.87500	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.06942	0.06942	0.06942	0.06942	0.06942	0.06942	0.06942	0.06942	0.06942	0.06942
ISO 14	0.07257	0.07257	0.07257	0.07257	0.07257	0.07257	0.07257	0.07257	0.07257	0.07257
NC EMS	0.07967	0.07967	0.07967	0.07967	0.07967	0.07967	0.07967	0.07967	0.07967	0.07967
FC1	0.01044	0.01044	0.01044	0.01044	0.01044	0.01044	0.01044	0.01044	0.01044	0.01044
FC2	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218	0.05218
HC1	0.28230	0.28230	0.28230	0.28230	0.28230	0.28230	0.28230	0.28230	0.28230	0.28230
HC2	0.01178	0.01178	0.01178	0.01178	0.01178	0.01178	0.01178	0.01178	0.01178	0.01178
RC1	0.12068	0.12068	0.12068	0.12068	0.12068	0.12068	0.12068	0.12068	0.12068	0.12068
RC2	0.01160	0.01160	0.01160	0.01160	0.01160	0.01160	0.01160	0.01160	0.01160	0.01160
SC1	0.28936	0.28936	0.28936	0.28936	0.28936	0.28936	0.28936	0.28936	0.28936	0.28936

FIRM E

Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.11111	0.47368	0.46667	0.46667	0.47368	0.46667	0.46667
ISO 14	0.87500	0.00000	0.00000	0.11111	0.47368	0.46667	0.46667	0.47368	0.46667	0.46667
NC EMS	0.12500	1.00000	0.00000	0.77778	0.05263	0.06667	0.06667	0.05263	0.06667	0.06667
FC1	0.11111	0.11111	0.11111	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.88889	0.88889	0.88889	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.16667	0.16667	0.16667	1.00000	0.25000	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.83333	0.83333	0.83333	0.00000	0.75000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.87500	0.87500	0.87500	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.12500	0.12500	0.12500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.187500	0.240000	0.241380	0.157056	0.333333
FCV	0.156250	0.000000	0.000000	0.000000	0.000000
HCV	0.218750	0.280000	0.275860	0.593634	0.666667
RCV	0.218750	0.240000	0.241380	0.249310	0.000000
SCV	0.218750	0.240000	0.241380	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.03509	0.11368	0.23333	0.14849	0.47368	0.07329	0.15556
ISO 14	0.16406	0.00000	0.00000	0.03509	0.11368	0.23333	0.14849	0.47368	0.07329	0.15556
NC EMS	0.02344	0.18750	0.00000	0.24561	0.01263	0.03333	0.02121	0.05263	0.01047	0.02222
FC1	0.01736	0.01736	0.02137	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.13889	0.13889	0.17094	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.03646	0.03646	0.04487	0.36842	0.07000	0.00000	0.36363	0.00000	0.59363	0.66667
HC2	0.18229	0.18229	0.22436	0.00000	0.21000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.19141	0.19141	0.23558	0.00000	0.24000	0.00000	0.31818	0.00000	0.24931	0.00000
RC2	0.02734	0.02734	0.03365	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.21875	0.21875	0.26923	0.31579	0.24000	0.50000	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.14420	0.14420	0.14420	0.14420	0.14420	0.14420	0.14420	0.14420	0.14420	0.14420
ISO 14	0.16786	0.16786	0.16786	0.16786	0.16786	0.16786	0.16786	0.16786	0.16786	0.16786
NC EMS	0.05514	0.05514	0.05514	0.05514	0.05514	0.05514	0.05514	0.05514	0.05514	0.05514
FC1	0.00660	0.00660	0.00660	0.00660	0.00660	0.00660	0.00660	0.00660	0.00660	0.00660
FC2	0.05277	0.05277	0.05277	0.05277	0.05277	0.05277	0.05277	0.05277	0.05277	0.05277
HC1	0.18089	0.18089	0.18089	0.18089	0.18089	0.18089	0.18089	0.18089	0.18089	0.18089
HC2	0.08034	0.08034	0.08034	0.08034	0.08034	0.08034	0.08034	0.08034	0.08034	0.08034
RC1	0.11354	0.11354	0.11354	0.11354	0.11354	0.11354	0.11354	0.11354	0.11354	0.11354
RC2	0.01039	0.01039	0.01039	0.01039	0.01039	0.01039	0.01039	0.01039	0.01039	0.01039
SC1	0.18830	0.18830	0.18830	0.18830	0.18830	0.18830	0.18830	0.18830	0.18830	0.18830

FIRM F

Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.08767	0.55907	0.52784	0.15706	0.55907	0.24931	0.11252
ISO 14	0.16667	0.00000	0.00000	0.13916	0.35219	0.33252	0.24931	0.35219	0.15706	0.17862
NC EMS	0.83333	1.00000	0.00000	0.77317	0.08875	0.13965	0.59363	0.08875	0.59363	0.70886
FC1	0.83333	0.83333	0.83333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.16667	0.16667	0.16667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.16667	0.16667	0.16667	1.00000	0.25000	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.83333	0.83333	0.83333	0.00000	0.75000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.16667	0.16667	0.16667	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.83333	0.83333	0.83333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.217400	0.277800	0.227277	0.708856	0.833333
FCV	0.217400	0.000000	0.000000	0.000000	0.000000
HCV	0.217400	0.277800	0.318168	0.112524	0.166667
RCV	0.130400	0.166700	0.136386	0.178620	0.000000
SCV	0.217400	0.277700	0.318168	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.02923	0.15531	0.21994	0.05235	0.55907	0.17672	0.09377
ISO 14	0.03623	0.00000	0.00000	0.04639	0.09784	0.13855	0.08310	0.35219	0.11133	0.14885
NC EMS	0.18117	0.21740	0.00000	0.25776	0.02465	0.05819	0.19788	0.08875	0.42080	0.59071
FC1	0.18117	0.18117	0.23149	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.03623	0.03623	0.04630	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.03623	0.03623	0.04630	0.33337	0.06945	0.00000	0.46664	0.00000	0.11252	0.16667
HC2	0.18117	0.18117	0.23149	0.00000	0.20835	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.02173	0.02173	0.02777	0.00000	0.16670	0.00000	0.20003	0.00000	0.17862	0.00000
RC2	0.10867	0.10867	0.13885	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.21740	0.21740	0.27779	0.33325	0.27770	0.58332	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.08685	0.08685	0.08685	0.08685	0.08685	0.08685	0.08685	0.08685	0.08685	0.08685
ISO 14	0.08291	0.08291	0.08291	0.08291	0.08291	0.08291	0.08291	0.08291	0.08291	0.08291
NC EMS	0.22537	0.22537	0.22537	0.22537	0.22537	0.22537	0.22537	0.22537	0.22537	0.22537
FC1	0.08293	0.08293	0.08293	0.08293	0.08293	0.08293	0.08293	0.08293	0.08293	0.08293
FC2	0.01658	0.01658	0.01658	0.01658	0.01658	0.01658	0.01658	0.01658	0.01658	0.01658
HC1	0.12544	0.12544	0.12544	0.12544	0.12544	0.12544	0.12544	0.12544	0.12544	0.12544
HC2	0.08638	0.08638	0.08638	0.08638	0.08638	0.08638	0.08638	0.08638	0.08638	0.08638
RC1	0.03888	0.03888	0.03888	0.03888	0.03888	0.03888	0.03888	0.03888	0.03888	0.03888
RC2	0.04974	0.04974	0.04974	0.04974	0.04974	0.04974	0.04974	0.04974	0.04974	0.04974
SC1	0.20492	0.20492	0.20492	0.20492	0.20492	0.20492	0.20492	0.20492	0.20492	0.20492

FIRM G

Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.16342	0.64498	0.64498	0.78539	0.45454	0.73519	0.64912
ISO 14	0.90000	0.00000	0.00000	0.29696	0.29657	0.29657	0.14882	0.45454	0.20669	0.27895
NC EMS	0.10000	1.00000	0.00000	0.53961	0.05844	0.05844	0.06579	0.09091	0.05811	0.07193
FC1	0.25000	0.25000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.75000	0.75000	0.75000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.16667	0.16667	0.16667	1.00000	0.12500	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.83333	0.83333	0.83333	0.00000	0.87500	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.10000	0.10000	0.10000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.90000	0.90000	0.90000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.259260	0.310350	0.272730	0.733384	0.875000
FCV	0.259260	0.000000	0.000000	0.000000	0.000000
HCV	0.111110	0.241380	0.272730	0.067545	0.125000
RCV	0.333330	0.310340	0.242420	0.199071	0.000000
SCV	0.037040	0.137930	0.212120	0.000000	0.000000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.07354	0.20017	0.36280	0.27187	0.45454	0.53918	0.56798
ISO 14	0.23333	0.00000	0.00000	0.13363	0.09204	0.16683	0.05151	0.45454	0.15159	0.24409
NC EMS	0.02593	0.25926	0.00000	0.24283	0.01814	0.03288	0.02278	0.09091	0.04262	0.06294
FC1	0.06481	0.06481	0.08750	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.19445	0.19445	0.26250	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.01852	0.01852	0.02500	0.35000	0.03017	0.00000	0.34616	0.00000	0.06754	0.12500
HC2	0.09259	0.09259	0.12500	0.00000	0.21121	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.03333	0.03333	0.04500	0.00000	0.31034	0.00000	0.30769	0.00000	0.19907	0.00000
RC2	0.30000	0.30000	0.40500	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.03704	0.03704	0.05000	0.20000	0.13793	0.43750	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.21648	0.21648	0.21648	0.21648	0.21648	0.21648	0.21648	0.21648	0.21648	0.21648
ISO 14	0.15637	0.15637	0.15637	0.15637	0.15637	0.15637	0.15637	0.15637	0.15637	0.15637
NC EMS	0.07741	0.07741	0.07741	0.07741	0.07741	0.07741	0.07741	0.07741	0.07741	0.07741
FC1	0.03094	0.03094	0.03094	0.03094	0.03094	0.03094	0.03094	0.03094	0.03094	0.03094
FC2	0.09282	0.09282	0.09282	0.09282	0.09282	0.09282	0.09282	0.09282	0.09282	0.09282
HC1	0.06221	0.06221	0.06221	0.06221	0.06221	0.06221	0.06221	0.06221	0.06221	0.06221
HC2	0.06380	0.06380	0.06380	0.06380	0.06380	0.06380	0.06380	0.06380	0.06380	0.06380
RC1	0.09286	0.09286	0.09286	0.09286	0.09286	0.09286	0.09286	0.09286	0.09286	0.09286
RC2	0.14321	0.14321	0.14321	0.14321	0.14321	0.14321	0.14321	0.14321	0.14321	0.14321
SC1	0.06389	0.06389	0.06389	0.06389	0.06389	0.06389	0.06389	0.06389	0.06389	0.06389

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Unweighted supermatrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.20000	0.33333	0.42857	0.42857	0.42857	0.55907	0.33333
ISO 14	0.75000	0.00000	0.00000	0.20000	0.33333	0.42857	0.42857	0.42857	0.35219	0.33333
NC EMS	0.25000	1.00000	0.00000	0.60000	0.33333	0.14286	0.14286	0.14286	0.08875	0.33333
FC1	0.75000	0.75000	0.75000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.25000	0.25000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.50000	0.50000	0.50000	1.00000	0.50000	0.00000	1.00000	0.00000	1.00000	1.00000
HC2	0.50000	0.50000	0.50000	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.25000	0.25000	0.25000	0.00000	1.00000	0.00000	1.00000	0.00000	1.00000	0.00000
RC2	0.75000	0.75000	0.75000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000

Cluster matrix

	ALT	FCV	HCV	RCV	SCV
ALT	0.176470	0.100000	0.250000	0.636986	0.166667
FCV	0.294120	0.000000	0.000000	0.000000	0.000000
HCV	0.176470	0.300000	0.250000	0.104729	0.833333
RCV	0.176470	0.300000	0.250000	0.258285	0.000000
SCV	0.176470	0.300000	0.250000	0.000000	0.00000

Weighted matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.00000	0.00000	0.00000	0.02857	0.03333	0.21429	0.14286	0.42857	0.35612	0.05556
ISO 14	0.13235	0.00000	0.00000	0.02857	0.03333	0.21429	0.14286	0.42857	0.22434	0.05556
NC EMS	0.04412	0.17647	0.00000	0.08571	0.03333	0.07143	0.04762	0.14286	0.05653	0.05556
FC1	0.22059	0.22059	0.26786	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
FC2	0.07353	0.07353	0.08929	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HC1	0.08823	0.08823	0.10714	0.42857	0.15000	0.00000	0.33333	0.00000	0.10473	0.83333
HC2	0.08823	0.08823	0.10714	0.00000	0.15000	0.00000	0.00000	0.00000	0.00000	0.00000
RC1	0.04412	0.04412	0.05357	0.00000	0.30000	0.00000	0.33333	0.00000	0.25828	0.00000
RC2	0.13235	0.13235	0.16071	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SC1	0.17647	0.17647	0.21429	0.42857	0.30000	0.50000	0.00000	0.00000	0.00000	0.00000

Limit matrix

	EMAS	ISO 14	NC EMS	FC1	FC2	HC1	HC2	RC1	RC2	SC1
EMAS	0.10947	0.10947	0.10947	0.10947	0.10947	0.10947	0.10947	0.10947	0.10947	0.10947
ISO 14	0.11843	0.11843	0.11843	0.11843	0.11843	0.11843	0.11843	0.11843	0.11843	0.11843
NC EMS	0.07380	0.07380	0.07380	0.07380	0.07380	0.07380	0.07380	0.07380	0.07380	0.07380
FC1	0.07004	0.07004	0.07004	0.07004	0.07004	0.07004	0.07004	0.07004	0.07004	0.07004
FC2	0.02335	0.02335	0.02335	0.02335	0.02335	0.02335	0.02335	0.02335	0.02335	0.02335
HC1	0.26397	0.26397	0.26397	0.26397	0.26397	0.26397	0.26397	0.26397	0.26397	0.26397
HC2	0.03152	0.03152	0.03152	0.03152	0.03152	0.03152	0.03152	0.03152	0.03152	0.03152
RC1	0.04237	0.04237	0.04237	0.04237	0.04237	0.04237	0.04237	0.04237	0.04237	0.04237
RC2	0.04202	0.04202	0.04202	0.04202	0.04202	0.04202	0.04202	0.04202	0.04202	0.04202
SC1	0.22504	0.22504	0.22504	0.22504	0.22504	0.22504	0.22504	0.22504	0.22504	0.22504