UNIVERSITAT DE BARCELONA

Understanding Innovation within the context of the Integration of Management Systems

Alfonso Antonio Hernández Vivanco

PhD in Business

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A mis padres Alfonso y Mónica, por enseñarme que la vida es la realización de un sueño de juventud

A la Laura, la meva estimada dona, amb qui aquest i tots els somnis són la realització més plena de la vida

'The Earth is one but the world is not. We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impact on others'

World Commission on Environment and Development (1987)

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I obtained my bachelor's degree in Industrial Engineering in Quito, Ecuador. After a few years of being a practitioner in this field, I enrolled in the master's degree in Business Research at the Universitat de Barcelona (UB) in 2014. I wished to experience such an enriching academic stage abroad and learn beyond my background. I seized that opportunity, but one year goes by quickly, and I realized that I wished to get closer to science, continue learning and explore what seemed unachievable, a PhD in Business. Again, years went by very quickly, so here I am.

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SUMMARY

In an increasingly competitive world driven by fast changes, where resources are limited and where stakeholders are more and more demanding, societies, from individuals to companies and governments, are challenged to pursue sustainable development. This matter has led to the discussion about how organizations manage to innovate in a way that they meet with the requirements of several stakeholders effectively. Although this topic has increasingly caught the attention of scholars and practitioners, there are still major gaps regarding the best managerial practices that promote innovation within a sustainability-oriented framework. Amongst the most recently discussed practices, researchers have identified a potential opportunity in the way companies manage their systems. Therefore, this thesis aims to contribute to this research gap by relating two managerial practices in pursue of sustainability, namely, an effective way of managing systems and innovation.

Management systems (MSs) describe the procedures that organizations use in their operations to meet very specific requirements, including those related to quality, environmental, occupational health and safety, among others. Because each MS addresses the concerns of only a few stakeholders, their contribution to innovation and sustainability is often questioned among literature. As a result, companies might prefer integrating such MSs in a way that they could expand their vision of the different stakeholders. This might allow them to simultaneously save resources, eliminate bureaucracy, and attain innovation more smoothly. The integration of MSs (IMS) might also have the advantage of fostering a balanced priority amongst the goals proposed in each function-specific MS. As a result, companies that adopt IMS might be more prone to pursue corporate sustainability, which dimensions are contained, in a fragmented fashion, in each individual MS. Although researchers have acknowledged IMS as an innovative practice closely related to sustainability, the way in which it benefits innovation within this context remains one of the major research gaps in this field. This discussion is therefore one of the main topics analyzed in this work.

Moreover, in a globalized world dominated by the creation of knowledge and the exploitation of information, companies no longer operate in closed

environments or just looking at the world from the inside-out. Instead, companies might choose adopting business models that allow them to be open to collaborations. This might implicate benefits not only in terms of sharing knowledge, but also of gaining new capabilities, being more efficient innovating and creating new ways of profiting such as licensing, patenting, among others. This brief description of one of the most relevant innovation trends in the worldwide context corresponds to the open innovation (OI) business model. The existing research about OI is very extensive and involves a wide range of fields, including its relationship with innovation, organizational and environmental performance. However, researchers are still debating how OI interacts with the inner management systems and how this relationship contributes to corporate sustainability. Therefore, the interaction between OI and IMS is further analyzed throughout this research.

Grounded on the existing literature, this thesis develops specific hypothesis regarding the links between IMS, OI and innovation in pursue of sustainability, which are tested empirically in diverse samples obtained from European and Latin-American companies. Based on this evidence, it is found that the challenges to combine harmoniously the requirements of diverse business stakeholders and companies' internal procedures seem to be heeded by IMS. More specifically, companies that attain high levels of IMS might improve their innovation capabilities, innovate more efficiently by using less resources and favor corporate sustainability in terms of economic, environmental and social benefits. Moreover, OI seems to have a relevant role in this context, in particular concerning the new capabilities that it brings to open companies. Finally, this thesis intends to provide practitioners and researchers with new insights to manage diverse MSs and innovate in the challenging pursue of sustainability.

LIST OF ABBREVIATIONS

AECM	Association of European Candle Makers
ALAFAVE	Asociación Latinoamericana de Fabricantes de Velas (Latin-American Association of Candle Manufacturers)
AVE	Average Variance Extracted
$CERT_t$	Certifications held by a company in year *t*
CIS	Community Innovation Survey
CNAE	Clasificación Nacional de Actividades Económicas (National Classification of Economic Activities)
COTEC	Fundación para la Innovación (Spanish Foundation for the Technological Innovation)
CP	Cleaner production
CSR	Corporate social responsibility
DEA	Data Envelopment Analysis
DMU	Decision making unit
DTH	Depth
EC	External cooperation
ECA	European Candle Association
EMAS	European Union's Eco-Management and Audit Scheme
EMS	Environmental management system
FDH	Free Disposal Hull
FECYT	Fundación Española para la Ciencia y la Tecnología (Spanish Foundation for Science and Technology)
FP	Financial performance
GMM	Generalized-Method-of-Moments
HT	High technology industry
IAQ	International Academy for Quality

IC	Innovation capabilities
IC_{it}	Innovation capital expenses of firm *i* at time *t*
ICS	Innovation capital stock
IE	Innovation efficiency
IMS	Integration of management systems
INE	Instituto Nacional de Estadística (Spanish National Statistics Institute)
IPAC	Instituto Português de Acreditação (Portuguese Accreditation Institute)
ISO	International Organization for Standardization
KBV	Knowledge-Based View
LIMS	Level of integration of management systems
LMT	Low and medium technology industry
LV	Latent variable
MS	Management system
NCA	National Candle Association (United States)
OECD	Organization for Economic Co-operation and Development
OHSMS	Occupational health & safety management system
OI	Open innovation
PINN	Number of persons involved in the innovative process
PITEC	Panel de Innovación Tecnológica (Spanish Innovation Panel)
PLS	Partial Least Squares
QMS	Quality management system
R&D	Research and development
RBV	Resource-based view
ROA	Return on assets
ROCE	Return on common equity
ROS	Return on sales

SEM	Structural Equation Modelling
SME	Small and medium enterprise
TBL	Triple bottom line
TEC	Investment in external knowledge
TQM	Total Quality Management
UNEP DTIE	United Nations Environment Programme of the Division of Technology, Industry and Economics
WCED	World Commission on Environment and Development

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CHAPTER 1. INTRODUCTION

1.1. From sustainable development to corporate sustainability

In a threated world, not only business, but individuals, governments and societies are increasingly interested, and concerned, about the outlook of their future. In light of that reality, the United Nations World Commission on Environment and Development (WCED) first popularized the concept of sustainable development known as the Brundtland definition: 'Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs' (WCED, 1987). To this end, every level of society, from individuals to business, organizations and governments must share this vision (United Nations, 1992).

From the dissemination of sustainable development, its consciousness among the world population has had tops and downs and now appears to be passing through an upward wave, especially since globalization emerged (Elkington, 2006; Voegtlin and Scherer, 2017). The generalized attention given to sustainable development has led practitioners and scholars to develop diverse strategies to ensure its achievement both at the macro (see e.g., United Nations, 1992, 2017) and micro levels (see e.g., Lozano, 2012; Johnson and Schaltegger, 2016; Gianni *et al.*, 2017a).

Sustainable development is thus, a transversal concept and, as such, different aspects including the economic, social and environmental dimensions compose it. Such classification was coined by Elkington (1997), who named it the triple bottom line (TBL). According to the author, sustainable development is, therefore, the consequence of benefiting the TBL and to all business stakeholders. This implicates that sustainability is not –and cannot be– attained from the internal efforts done by isolated engaged organizations, but it depends 'on the progress of entire concentrations of industry, complete value chains, and whole economies' (Elkington, 1997). This requires constructing sustainable development from organizations, who ought to consider stakeholders (customers, employees, TBL campaigners, and others) as partners (Elkington, 1997). Thus, sustainability from the companies' perspective is of particular interest to this work.

The business approach to address sustainable development is termed the corporate sustainability (Johnson and Schaltegger, 2016). It is intended to integrate the economic, ecological and social aspects in an organizations' short and long term planning (Dyllick and Hockerts, 2002). It also requires addressing the companies' systems as well as their stakeholders proactively (Lozano, 2012).

Corporate sustainability has been commonly used as a concept equivalent (or at least related) to other ones such as corporate social responsibility (CSR) (Castka *et al.*, 2004; Dahlsrud, 2008; Johnson and Schaltegger, 2016). Such interchangeable use of words is mainly attributed to the inclusion of the TBL dimensions in the CSR definition (Dahlsrud, 2008; European Comission, 2011), whereas other authors refer to CSR to address solely social responsibility issues (Jørgensen *et al.*, 2006; Baumgartner, 2014; Nunhes *et al.*, 2016). In this study, the use of corporate sustainability and CSR will be distinguished, so sustainability will refer to the TBL (i.e., economic, environmental and social issues) and CSR exclusively to address social responsibility issues.

According to Dahlsrud (2008), the sustainability approach to companies is composed of five dimensions. Namely; (1) the environmental, (2) social, (3) economic, (4) stakeholder and (5) voluntariness dimensions. Regarding the latter, the author clarifies that companies ought to adopt a sustainability-oriented perspective beyond the accomplishment of laws or regulations. Hence the importance of proactivity rather than the fragile approach of just meeting requirements, standards (Lozano, 2012; Gianni *et al.*, 2017a) or developing (often unreliable) sustainability reports (Moneva *et al.*, 2006; Boiral, 2013).

Moreover, ever since businesses exist, they have always had social, environmental and economic impacts, been concerned with stakeholders (customers, owners, shareholders), been auto-governed (voluntarily opted to implement new practices), and dealt with regulations (Dahlsrud, 2008). Therefore, although corporate sustainability is not new to organizations, the real challenge lays on how to include all these dimensions when developing business strategy (Dahlsrud, 2008; Baumgartner and Ebner, 2010).

The corporate sustainability strategy integrates the social and environmental dimensions into the strategic management process of a company (Baumgartner and Ebner, 2010). This strategy determines business' practices at more operational levels and, therefore, it is reflected on innovation (Asif *et al.*, 2013; Boons *et al.*, 2013; Baumgartner, 2014) and continuous improvement practices implemented across all the corporate functions (Asif *et al.*, 2013; Baumgartner, 2014). Thus, companies should innovate effectively to maximize the value of meeting sustainability demands, making it necessary to have well-structured management systems (MSs) to meet this challenge (Wagner, 2007a).

Therefore, companies with a more mature profile of sustainability, reflect these strategies on innovation and technology regarding both processes and products, collaboration, and continuous improvement practices in all areas including environmental, health and safety and corporate social responsibility (Wagner, 2007a; Baumgartner and Ebner, 2010). Such practices, which are comprehended under the lead of MSs, provide companies of the managerial support to attain corporate sustainability (Wagner, 2007a; Baumgartner and Ebner, 2010; Baumgartner, 2014; Mustapha *et al.*, 2017).

Thus, **the aim of this thesis is to relate MSs and innovation with the final –and common– objective of reaching sustainability.**

1.2. The role of innovation in corporate sustainability

Innovation has been widely acknowledged as a necessary element to attain corporate sustainability (Elkington, 2006; Asif *et al.*, 2013; Boons *et al.*, 2013; Baumgartner, 2014). However, how to incorporate the TBL dimensions into the innovation dynamics of companies remains scarcely researched (Longoni and Cagliano, 2016). Thus, to analyze the role of innovation in corporate sustainability, firstly a brief introduction of the relevant concepts used in the innovation literature is presented.

1.2.1. A brief introduction to innovation

According to the Oslo Manual, innovation is ‘the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations’ (OECD, 2005). Thus, innovation can be classified in different categories according to their technological or organizational purposes, as follows (OECD, 2005):

- Product innovation: the market introduction of a new or significantly improved good or service.

- Process innovation: the implementation of a new or significantly improved production process, distribution method, or supporting activity (techniques, equipment and/or software).
- Organizational innovation: the implementation of a new organizational method in the enterprise's business practices, workplace organization or external relations.
- Marketing innovation: the implementation of a new marketing method or strategy.

It is worth noticing that the OECD (2005) distinguishes between new and significantly improved product and process innovations. This is because the literature differentiates between radical and incremental innovations (Prajogo and Sohal, 2001; OECD, 2005; Bernardo, 2014):

- Radical innovations are new products or processes that create a significant impact on the market, causing major disruptive changes.
- Incremental innovations present progressive advances in the process of change of the existing characteristics and costs of products and processes.

1.2.2. Innovation and sustainability

The literature relating innovation and sustainability is very extensive and has led researchers to develop various comprehensive literature reviews, the most relevant are summarized in Table 1.

As it can be evidenced from this table, most researchers agree that innovation is aligned with corporate sustainability. To this end, business must practice a sustainability management business approach to attain sustainable innovations (Kennedy *et al.*, 2017). However, there are still major gaps regarding the managerial practices that promote sustainability through innovation (Pacheco *et al.*, 2017; Xavier *et al.*, 2017).

Table 1. Innovation and sustainability literature reviews

Reference	Findings related to innovation and sustainability
del Brío and Junquera (2003)	Determinants of sustainable innovations: financial and human resources, organizational structure, management style, EMSs, manufacturing activity, technological approach, innovative capacity, and external cooperation.
Walker *et al.* (2008)	Drivers of sustainable innovation: voluntary engagement, stakeholders, collaboration, legislation, resources, motivation, and knowledge. Barriers: Business characteristics, resource availability and the owner-manager's personal motivation, and knowledge about sustainable innovation.
Adams *et al.* (2016)	Three stages to achieve sustainability, i) Operational optimization through incremental innovation, ii) organizational transformation towards new market opportunities and iii) systems building though radical innovations towards societal change, so the sustainability approach extends beyond the firm boundaries.
Klewitz and Hansen (2014)	Sustainability-rooted companies integrate the economic, environmental and social aspects from the core business strategy. They perform radical innovations and interact intensively with external organizations.
Hojnik and Ruzzier (2016)	The most critical factors to sustainable innovation are regulations and market pull. Other factors that also drive process, product and organizational innovations are MSs and cost savings.
Bonzanini Bossle *et al.* (2016)	Sustainable innovation is driven by both internal and external factors. Internal factors include efficiency, certifications, EMS, human resources, environmental capability. External factors include regulatory pressures, normative pressures, cooperation and technology. These innovations increase companies' performance.
Pacheco *et al.* (2017)	Critical determinants of sustainable innovation: Governmental policy; Availability of resources (people, technology, knowledge); Strategic relevance of sustainable innovation; Technological advisory; Innovation methods; Organizational structure and management support; Supplier and customer relations; R&D department focused on sustainability; Cooperation and partnership; Reputation, brand image and profit margin. Gaps: best practices for sustainable innovation; systems for effective cooperation in sustainable innovation

Reference	Findings related to innovation and sustainability
Xavier *et al.* (2017)	Identified gaps mainly related to the organizational practices that foster sustainable innovations, as well as the need to further study the social aspects of sustainability.
Kennedy *et al.* (2017)	A sustainability management strategy is required as a starting condition to harness the benefits of external collaborations and create value through sustainable innovation.
Behnam *et al.* (2018)	Innovations aimed at developing sustainable products can rely on established capabilities resulting of external cooperation. In this regard, all key actors should develop innovation capabilities or build a collaborative capability
Watson *et al.* (2018)	Engaging stakeholders to attain sustainable innovations has seven main benefits regarding the Environmental performance; Financial performance; Competitive advantage; Reputation; Risk management; Legitimacy; Employee brand. Gaps: Strategies to harmonize the needs of diverse stakeholders; How organizational systematically learn and embed external knowledge towards sustainable innovation.

Source: Own elaboration.

The sustainability-oriented literature emphasizes the need of collaborating closely and actively various partners (suppliers, R&D institutions, universities, among others) to really understand their needs, maximize the shared value of all the stakeholders and create innovative products and technologies in pursue of corporate sustainability (Baumgartner and Ebner, 2010; European Comission, 2011). This need has also been pointed out in the literature relating both innovation and sustainability as pointed out in Table 1 (Walker and Preuss, 2008; Klewitz and Hansen, 2014; Bonzanini Bossle *et al.*, 2016; Pacheco *et al.*, 2017).

From the viewpoint of innovation, the involvement of external parties in the innovative process is studied in the Open Innovation (OI) literature. The use of the term OI was first coined by Chesbrough (2003). Conscious with the need of embracing an external cooperation model in a complex world, the author defined OI as ‘a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology’ (Chesbrough, 2003). Thus, OI emerged as a model that promotes new ways to use outer knowledge and technologies, namely optimizing the resources used to innovate and creating new products that can be commercialized externally (Chesbrough, 2003, 2007). Since then, a very extensive literature has emerged and covered the process of externally sourcing innovation, but with still major gaps on how such innovation is integrated and related to other managerial practices in pursue of corporate sustainability (West and Bogers, 2014; Kennedy *et al.*, 2017; Xavier *et al.*, 2017; Behnam *et al.*, 2018; Watson *et al.*, 2018).

1.3. Management systems and sustainability

Various authors have identified MSs as a driver of innovation and sustainability (del Brío and Junquera, 2003; Bonzanini Bossle *et al.*, 2016; Hojnik and Ruzzier, 2016; Pacheco *et al.*, 2017). This is because they provide companies with a strategic sense to the routines and procedures of their daily operations and aim to improve them continuously (see e.g., Robson *et al.*, 2007; Sampaio *et al.*, 2009; Tarí *et al.*, 2012; Heras-Saizarbitoria and Boiral, 2013; ISO, 2018a). Thus, companies could certify their MSs to assure the accomplishment of the procedures demanded by stakeholders through the periodical external auditing carried out by independent bodies (Power, 1997; ISO, 2018b).

Thus, the International Organization for Standardization (ISO) defines MSs as 'the way in which an organization manages the inter-related parts of its business in order to achieve its objectives. These objectives can relate to a number of different topics, including product or service quality, operational efficiency, environmental performance, health and safety in the workplace and many more' (ISO, 2018a).

Regardless of whether MSs are certified or not, their objectives seem to be in line with those of sustainability. It is worth noticing that the MSs' objectives are focused on specific different topics, so they are commonly referred to as function-specific MSs (Karapetrovic, 2002; To *et al.*, 2012; Bernardo *et al.*, 2015; Gianni *et al.*, 2017b). According their objective, MSs are classified as quality (QMS), environmental (EMS), occupational health and safety (OHSMS), among others (Jørgensen *et al.*, 2006).

Implementing function-specific MSs might have some benefits as discussed in the relevant bibliometric studies focused on QMSs (Sampaio *et al.*, 2009), EMSs (Ferenhof *et al.*, 2014), QMSs & EMSs (Tarí *et al.*, 2012; Heras-

Saizarbitoria and Boiral, 2013) and OHSMSs (Robson *et al.*, 2007). According to these studies, MSs meet with the stakeholders dimension of sustainability (Dahlsrud, 2008), because they enhance the relationships with them. However, the voluntariness dimension seems not to be clearly accomplished, particularly when companies adopt MSs just to accomplish an external requirement with little regard for their underlying principles (Boiral and Gendron, 2011).

As shown in Table 2, the function-specific MSs seem to be positively related to corporate sustainability. Nonetheless, their most relevant limitation lays on the fact that a function-specific MSs cannot cover all the sustainability dimensions since they are too narrow and focus only on specific kinds of issues (Esquer-Peralta *et al.*, 2008). Thus, implementing a function-specific MS appears not to be enough to attain corporate sustainability (Darnall *et al.*, 2008b). Table 2 that each MS contributes to addressing specific aspects of sustainability, which is in good agreement with the previous arguments. For this reason, organizations that aim to implement sustainability best practices might require adopting more than one MS, harness their synergies and integrate them (Mustapha *et al.*, 2017) .

The integration of MSs (IMS) intends to unify several function-specific MSs (Jørgensen *et al.*, 2006) into one and more efficient 'system of systems' (Karapetrovic and Willborn, 1998b). This allows organizations to be simultaneously coherent and consistent in satisfying all stakeholders, both internal and external, in an optimal way (Salomone, 2008; Rebelo *et al.*, 2016). Thus, by collaborating with stakeholders and attending their needs both equally and voluntarily, IMS has been acknowledged as a relevant sustainable management approach (Jørgensen, 2008; Rebelo *et al.*, 2016; Siva *et al.*, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017).

Table 2. Literature reviews' results regarding QMS, EMS, OHSMS classified by their corporate sustainability dimensions

MS	Economic	Environmental	Social
QMS	(+) Quality, (+) Lower costs	-	-
EMS	(+) High market value of new products	(+) Environmental performance (+) Efficient use of resources (+) Facilitates impact mitigation (+) Environmental sustainability in the middle term (+) Fosters the development of sustainable product innovation (?) The effects can be different among countries	(+) Fosters ethical awareness
QMS and EMS common benefits	(+) Efficiency (+) Profitability (+) Increase of the Customer satisfaction (+) Better operational performance (+) Market share (?) Unclear casualty on firms' financial performance	-	(+) Enhances the relationship with the staff
OHSMS	(+) Evidence of positive economic effects (+) Increased firms' productivity	-	(+) Safety climate

(+) positive relationships, (?) unclear relationship.
Source: Based on Robson *et al.* (2007), Sampaio *et al.* (2009), Tarí et al. (2012), Heras-Saizarbitoria and Boiral (2013) and Ferenhof *et al.* (2014).

The fact that IMS integrates the viewpoint of different MSs and attends the needs of several stakeholders tackles directly the 'stakeholders' and 'voluntariness' dimensions of corporate sustainability (Dahlsrud, 2008). Unlike function specific MSs, IMS is not certifiable yet at the international level, so companies mostly adopt it voluntarily (Gianni *et al.*, 2017a).

Even IMS seems to be positively related to corporate sustainability, it is not a guarantee of sustainability mainly because this positive relationship largely depends on the level of IMS (Jørgensen, 2008). Otherwise, companies could abandon IMS (Gianni and Gotzamani, 2015) and could therefore stray from this sustainability management approach. Moreover, the means by which IMS contributes to corporate sustainability has to be further developed since the empirical evidence is still in the early stages (Nunhes *et al.*, 2016; Siva *et al.*, 2016; Gianni *et al.*, 2017a).

Regarding the level of IMS, different taxonomic approaches have been proposed in the recent literature. Some of the most relevant approaches according to Abad *et al.* (2014) are summarized in Table 3 (see Bernardo *et al.*, 2009 and Abad *et al.*, 2014 for a more complete view of the IMS-level taxonomic proposals). Most studies agree that the level of IMS across the organizations is determined by the importance given to MSs at the strategical level. However, although the proposals to determine the level of IMS are very complete and precise, most have the limitation that are based on standardized MSs (such as ISO 9001, ISO 14001, OHSAS 18001, among others). This restricts the application of results to certified organizations despite the lack of an international IMS certification (Gianni *et al.*, 2017a). Moreover, most of these approaches require an in-depth knowledge of companies or self-reported levels of IMS, which limits the possibilities of performing empirical studies based on larger samples, using objective measurements (e.g., existing records) or relating IMS to other concepts such as innovation and sustainability.

Hence, the first specific objective of this study is stated as follows:

> **Specific objective 1:** To develop a measurement for the level of IMS that can be applied to certified and non-certified MSs, based on the importance given to MSs at the strategical level.

Table 3. Relevant taxonomic proposals of IMS level

Author (year)	MSs	Taxonomic proposal
Beckmerhagen *et al.* (2003)	QMS: ISO 9001 EMS: ISO 14001 OHSMS: BS8800	- Harmonize MSs from the top management to the bottom. - Cooperation of documentation. - Amalgamation of MSs.
Karapetrovic (2003)	QMS: ISO 9001 EMS: ISO 14001 OHSMS: OHSAS 18001	- Partial: collaboration, alignment of objectives, processes and resources. - Full integration: complete amalgamation to a single multipurpose IMS.
Jørgensen *et al.* (2006)	QMS: ISO 9001 EMS: ISO 14001 OHSMS: OHSAS 18001 CSR: SA 8000	- Correspondence between standards: avoid bureaucracy, duplication of work tasks, and confusion between them. - Generic coordination: integrate policy, planning, implementation, control and common objectives. - Strategic and inherent integration: focus on sustainability.
Bernardo *et al.* (2009)	QMS: ISO 9001 EMS: ISO 14001 OHSMS: OHSAS 18001	Total, partial and no integration regarding: - Human resources: top management, functional and shop-floor. - Goals and procedures: goals are the first aspect to integrate. - Processes: documents, auditing.
Abad *et al.* (2014)	QMS: ISO 9001 EMS: ISO 14001 OHSMS: OHSAS 18001	- Documental harmonization. - Partial integration: documentation structure and one or two of the components (support, strategic and audit processes processes) of the process map. - Full integration: documentation structure and the three components of the process map are fully integrated. Considers the strategic orientation of the organization.

Source: Adapted from Abad *et al.* (2014).

1.4. The integration of management systems and innovation

In respect of the relationship between IMS and sustainability, Nunhes *et al.* (2016) and Siva *et al.* (2016) found an emerging research gap devoted to understand this relationship. Interestingly, most studies focused on this topic present some relevant reference to innovation, which is also a major research gap identified in the IMS literature (Nunhes *et al.*, 2016). As summarized in Table 4, even if both IMS and innovation seem to interact in pursue of sustainability, scarce research has been done to relate them explicitly in pursue of sustainability.

Table 4. References to innovation in sustainability-oriented IMS studies

Author (year)	**Reference to innovation**
Kurdve *et al.* (2014)	Identified that continuous improvement and innovation are important to create value in customers' operations.
Savino and Batbaatar (2015)	Found that innovation is an important factor to increase the organizations' operational performance.
Holm *et al.* (2015)	Identified the need of further researching into innovation
Witjes *et al.* (2016)	Discussed that innovation could be the power of more sustainable development especially to small and medium enterprises (SMEs).
Rebelo *et al.* (2016)	Discussed that value creation in organizations depends on the ability to potentiate the continuous improvement and innovation of products and processes.
Gianni *et al.* (2017a)	Concluded that IMS and corporate sustainability share innovation commonalities such as the structure, innovative skills and dynamic capabilities. However, the innovation perspective needs further exploration.
Mustapha *et al.* (2017)	Identified innovation as an indicator for organizations to evaluate their sustainability performance.

Source: Own elaboration.

1.4.1. The type of relationship between management systems and innovation

Given the strategical importance of innovation to sustainable development (Elkington, 2006; Asif *et al.*, 2013; Boons *et al.*, 2013; Baumgartner, 2014), it is not surprising to find that, since the onset of the IMS literature, innovation has been relevant to the discussions of most studies.

Wilkinson and Dale (1999) argued that, as MS standards introduce new requirements, they quickly become part of what stakeholders consider as 'good enough', so this 'conformance' level could hinder innovation. In the basis of this still very valid argument, scholars have not arrived to a unanimous agreement of whether function-specific MSs have any influence on innovation (Matias and Coelho, 2011; Palm *et al.*, 2016).

The discussion is open-ended regardless of the type of MS. Some studies report a positive relationship (Perdomo-Ortiz *et al.*, 2006; Kim *et al.*, 2012; Mir *et al.*, 2016); others suggest that it depends on other factors such as the culture (Moreno-Luzon *et al.*, 2013), the leadership support (Prajogo and Sohal, 2004; Hoang *et al.*, 2006), the firms' openness (Hoang *et al.*, 2006), the type of innovation (Wagner, 2008) or the diffusion of MSs across organizations (Prajogo *et al.*, 2014). Finally, there are others that cannot conclude whether this relationship is significant (Ziegler and Seijas Nogareda, 2009), or that even claim that MSs can be detrimental to innovation (Prajogo and Sohal, 2001).

Therefore, function-specific MSs seem to be far from being recognized as innovation boosters. Despite this lack of agreement, scholars seem to concur that IMS might be positively related to innovation (Wagner, 2007a; Matias and Coelho, 2011; Castillo-Rojas *et al.*, 2012; Simon and Petnji Yaya, 2012; Bernardo, 2014; Simon *et al.*, 2014; Palm *et al.*, 2016). Thus, **this research will be focused on studying the relationship between IMS an innovation.**

1.4.2. Relating management systems integration and innovation

In the beginnings of the IMS literature, Wilkinson and Dale (1999) suggested that a common management structure has to be introduced to foster continuous improvement in an integrated manner, which would be beneficial to innovation. In other words, it can be discussed that changes within the organization are required in order to have an integrated vision of the stakeholders' requirements and then focus on attaining innovation.

Since organizations have to change their current way of managing their internal systems in order to integrate them, Bernardo (2014) classified IMS as an internal, incremental and organizational innovation. According to the proposed theoretical model, companies with higher levels of IMS should have a better innovation management performance in terms of new products/processes, new capabilities, integration benefits and firm performance; such relationships are moderated by market turbulence.

Although the previous arguments are well stablished at the theoretical level, scarce empirical research has tested those relationships, so it remains a major research gap in the IMS and sustainability literature according to Nunhes *et al.* (2016).

Some of the few empirical studies relating both IMS and innovation have generally found a positive relationship as summarized in Table 5. As it can be evidenced from this table, the existing literature has still some gaps that need to be addressed. Firstly, most research is based on certified companies so non-certified companies remain scarcely researched. Secondly, Castillo-Rojas *et al.* (2012) considered innovation as a general concept without distinguishing the type of innovation. The authors also included the effects of adopting multiple MSs as a barrier to innovate into a single construct, so the effects of IMS on innovation remain unclarified. Finally, Simon and Penti Yaya (2012) and Simon *et al.* (2014) omitted the effects of IMS on product innovation.

Another limitation of most previous studies is that they have mostly neglected the role of OI, despite its relevance to innovation and sustainability (Behnam *et al.*, 2018; Watson *et al.*, 2018). According to those studies, OI might strengthen the links between partners and increase process and product innovation capabilities (Hung and Chou, 2013; Huang *et al.*, 2018). Consequently, OI seems to be a proper manner to deal with the moderating effect of market turbulence (Bernardo, 2014). Nonetheless scarce literature has analyzed the moderating effect of OI in these relationships, so the mechanisms for companies to embed the external knowledge towards innovation within a sustainability framework is still a gap in the existing literature (Watson *et al.*, 2018).

Table 5. Studies relating empirically IMS and innovation

Author (year) – Country (sample)	**Main findings related to IMS and innovation**	**Main limitations**
Castillo-Rojas *et al.* (2012) Spain (254 ISO-certified companies)	Firm adopting multiple MS standards to improve their performance do not see them as a barrier to innovate. Otherwise, they do.	The level of IMS is not studied. The definition of multiple MSs as a barrier to innovation is considered in one construct.
Simon and Petnji Yaya (2012) Spain (176 ISO-certified companies)	IMS has a positive influence on organizational and marketing innovations	Product innovations are not studied.
Simon *et al.* (2014) Spain (176 ISO-certified companies)	IMS level of documentation and human resources promote innovation, unlike procedures integration.	Product innovations are not studied.

Source: Own elaboration.

Thus, the second specific objective is stated as follows:

> **Specific objective 2:** To study empirically whether IMS fosters process and product innovation capabilities, considering the moderating role of open innovation.

Through this specific objective, the dimensions of new products/processes and new capabilities of the innovation management performance (Bernardo, 2014) will be analyzed.

1.4.3. Management systems integration and innovation: integration benefits and firm performance

IMS has a wide range of benefits since it not only improves the way MSs are managed, but also the operations efficiency and decision-making, the consumption of resources, better internal organization, better products and processes, better customer satisfaction (Santos *et al.*, 2011; Simon *et al.*, 2012; Olaru *et al.*, 2014; Nunhes *et al.*, 2017), among others (Sampaio *et al.*, 2012a; Abad *et al.*, 2014; Dahlin and Isaksson, 2017). According to the existing literature, scholars appear to agree that IMS provide of additional efficiency to the general management of resources across organizations (Wagner, 2007a; Simon and Douglas, 2013; Siva *et al.*, 2016). This might be due to the fact that IMS is considered one specific type of organizational innovation (Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo, 2014).

Following the main thread of this study, once the second specific objective is empirically tested, one might suspect that the IMS benefits related to the better use of resources and increased efficiency (Wagner, 2007a; Simon *et al.*, 2012; Simon and Douglas, 2013; Siva *et al.*, 2016) can also be related to the innovation management (Bernardo, 2014) by increasing the innovation efficiency (Bonzanini Bossle *et al.*, 2016). Nonetheless, such a relationship has been scarcely reported among the existing literature.

It is also worth noticing that OI aims to take advantage of the external knowledge to improve the internal knowledge base (Laursen and Salter, 2006) in order to obtain more innovation benefits using less resources (Chesbrough, 2007; Geum *et al.*, 2013). Thus, OI should be included in the analysis of increasing innovation efficiency and compared to what IMS can contribute to this end, as stated in the specific objective 3:

> **Specific objective 3:** To study empirically whether innovation efficiency can be boosted by the integration of management systems and open innovation.

Several studies have analyzed the effects of innovation efficiency on firm performance. In this line, it has been reported that companies innovating more efficiently improve their performance since they use less resources to innovate and create more outputs compared to their other market peers (Cruz-Cázares *et al.*, 2013; Wang *et al.*, 2016a).

Moreover, OI has a relevant role in this relationship as it is aimed to exploit innovation outputs faster than closed companies (i.e., those that do not collaborate with external organizations) in markets with high development costs and shorter life cycles (Chesbrough, 2007). As a result, OI seems to moderate the relationship between innovation efficiency and firm performance, but the empirical evidence on this subject remains scarcely researched (Kennedy *et al.*, 2017; Watson *et al.*, 2018). Thus, the specific objective 4 is stated as follows:

> **Specific objective 4:** To study empirically whether innovation efficiency leads to an increased firm performance, considering the moderating role of open innovation.

By testing empirically the specific objectives 2 through 4, this thesis will provide empirical evidence of some of the most relevant relationships proposed in Bernardo (2014), which remains a major research gap according to the specialized literature (Nunhes *et al.*, 2016). This part is thus, more related to the economic benefits of IMS and innovation as it will provide empirical evidence regarding the innovation capabilities, the proficiency of companies to innovate efficiently optimizing these resources and firm performance.

1.4.4. Management systems integration and innovation: tackling the environmental and social dimensions of sustainability

Sustainable innovations are aimed to benefit not only the environmental dimension of products and processes, but also their impacts on society (Kiefer *et al.*, 2017; Xavier *et al.*, 2017). To this end, companies have to innovate in the way they manage their organization (Hojnik and Ruzzier, 2016; Lozano *et al.*, 2016; Kiefer *et al.*, 2017) and attempt to meet the needs of their stakeholders (Longoni and Cagliano, 2016; Behnam *et al.*, 2018; Watson *et al.*, 2018). Thus, IMS appears to have a relevant role to promote sustainable innovation since it promotes both, organizational innovation (Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo, 2014) and meeting the stakeholders' requirements optimally (Salomone, 2008; Rebelo *et al.*, 2016). As previously discussed, both IMS and innovation seem to be positively related. However, despite the fact that both had been acknowledged as sustainability promotors (Castka *et al.*, 2004; Boons *et al.*, 2013; Longoni and Cagliano, 2016; Gianni *et al.*, 2017a; Kiefer *et al.*, 2017), the empirical evidence regarding the role of IMS to attain sustainable innovation remains nearly anecdotic, and is still a major research gap in the innovation literature (Pacheco *et al.*, 2017; Xavier *et al.*, 2017).
The research gaps regarding the relationships between IMS and innovation and that between IMS and sustainability (Nunhes *et al.*, 2016) are also reflected in the lack of studies relating IMS and sustainable innovation

(Pacheco *et al.*, 2017; Xavier *et al.*, 2017). Thus, the fifth specific objective of this thesis is stated next:

> **Specific objective 5:** To explore empirically whether the integration of management systems fosters sustainable innovation.

1.5. The adoption of multiple certifications and its effects on companies' financial performance

As it can be evidenced in most of the research into IMS, the adoption of multiple certifications is relevant to this topic. A very important number of relevant empirical studies have limited their samples to companies holding more than one certified MS (see e.g., Castka *et al.*, 2004; Zeng *et al.*, 2007; Salomone, 2008; Bernardo *et al.*, 2009; Simon *et al.*, 2014). Moreover, some authors have even considered that companies adopt an IMS approach just by holding more than one MS standard certification (Castillo-Rojas *et al.*, 2012; Ramos *et al.*, 2018).

Despite the widely reported benefits of IMS (see e.g., Santos *et al.*, 2011; Sampaio *et al.*, 2012a; Abad *et al.*, 2014; Dahlin and Isaksson, 2017; Nunhes *et al.*, 2017), the financial benefits of certifying MSs remains in serious question (Robson *et al.*, 2007; Sampaio *et al.*, 2009; Heras-Saizarbitoria and Boiral, 2013; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016).

This generalized lack of consensus regarding the relationship between MS certifications and financial performance (FP) is mainly attributed to studies focused on function-specific MS standards (Sampaio *et al.*, 2012b; Heras-Saizarbitoria and Boiral, 2013). Only few recent studies have researched into the FP effects of adopting multiple certifications, mostly finding a positive relationship (Ferrón-Vílchez and Darnall, 2016; Wang *et al.*, 2016b; Martí-Ballester and Simon, 2017).

Despite the relevant efforts of the existing literature to understand this relationship, most studies suffer of two limitations. Firstly, most have relied on perceptional measurements (e.g., surveys), which might lead to over-valued or biased conclusions (see e.g., Häversjö, 2000; Corbett *et al.*, 2005; Sharma, 2005; Sampaio *et al.*, 2011b; Heras-Saizarbitoria and Boiral, 2013). Secondly, companies can decide to certify dynamically of different MSs according to their integration strategy (see e.g, Karapetrovic and Willborn, 1998b; Labodová, 2004; Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012; Ivanova *et al.*, 2014). Although there is an increasing tendency of companies to adopt multiple MSs to meet with the requirements of more, and more demanding stakeholders (Boiral and Gendron, 2011; Fonseca *et al.*, 2017), scarce literature has considered this phenomenon when analyzing the effects of certifications of firms' financial performance. Thus, the sixth specific objective is formulated as follows:

> **Specific objective 6:** To study empirically whether adopting multiple certifications dynamically fosters companies' financial performance.

This objective was accomplished during an international research stay in Portugal. Due to this reason, it is considered in a different section. Nonetheless, it is relevant to this thesis as it tackles directly a relevant research gap related to the economic dimension of corporate sustainability.

1.6. Research overview

In this section, firstly the structure of the next chapters is presented, followed by a model summarizing the main objectives. Finally, the intermediate contributions of this thesis and their relationship with it are described.

1.6.1. Structure of the main-body chapters

Chapters 2 through 5 are written in the format of four stand-alone scientific articles. Each chapter is aimed to meet some of the specific objectives of this thesis with the ultimate end of contributing to the corporate sustainability literature. This structure is summarized in Table 6.

All chapters 2-5 are empirical research studies. Therefore, the development of the specific hypotheses, the description of the methodology used to select a population, select a sample and collect data, measure the concepts and the statistical support to accomplish the proposed objectives are detailed in each chapter.

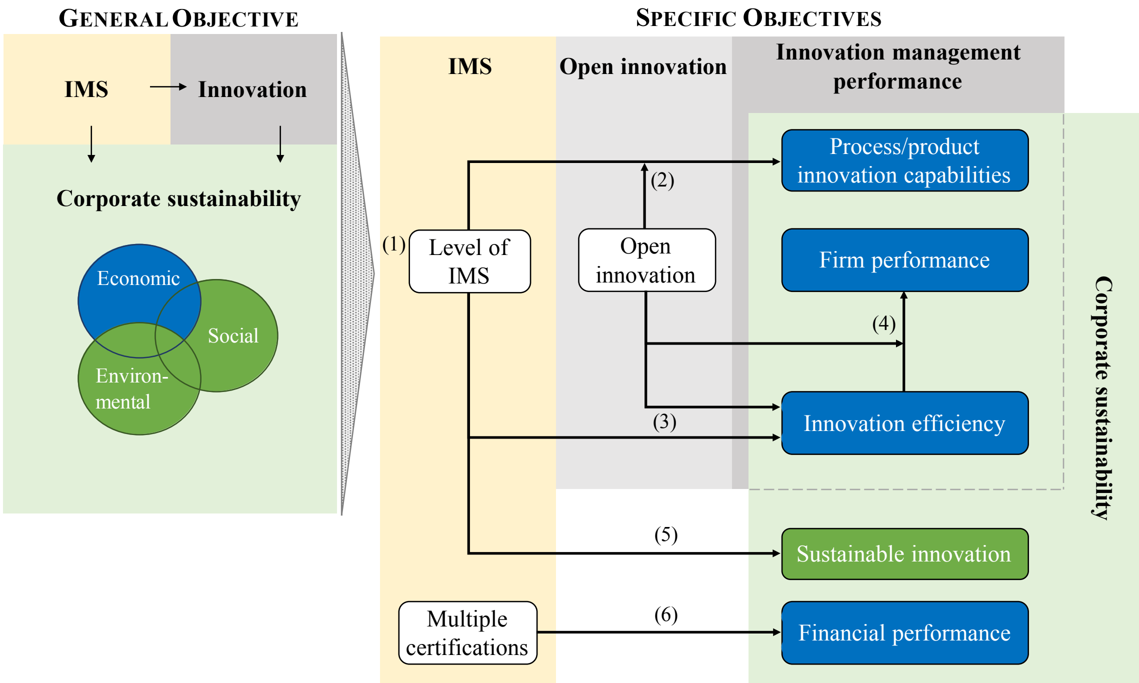
Table 6. Thesis main-body structure

Chapter	Specific objective	Studied research gaps	Sustainability dimension
2	(1)	- IMS level measurement applied to certified and non-certified companies.	Economic, Environmental and social
	(2)	- IMS level → process and product innovation capabilities - OI as a moderator of this relationship.	Economic
3	(3)	- IMS level → innovation efficiency - OI → innovation efficiency	Economic
	(4)	- Innovation efficiency → Firm performance - OI as a moderator of this relationship	Economic
4	(5)	- IMS → sustainable innovation	Environmental and social
5	(6)	- Dynamic adoption of multiple MS standards' certifications → Firms' financial performance	Economic

Source: Own elaboration.

1.7. Thesis research model

Figure 1 represents the research model of this thesis. It summarizes all its objectives to facilitate the reading and understanding of the studied relationships of this research.



Specific objectives (1) – (6) indicated in parentheses.
Source: Own elaboration.

Figure 1. Thesis research model

1.8. Contributions derived from this thesis

Table 7 shows the contributions that had been achieved throughout the development of this thesis. Such contributions are related to IMS, MSs, innovation and sustainability. Moreover, the relationship of these contributions with the chapters of this thesis are also summarized in Table 7.

Table 7. Contributions derived from this thesis

Authors	Title	Type	Status	Publication details	Relationship with this thesis
Hernandez-Vivanco, A., Domingues, P., Sampaio, P., Bernardo, M. and Cruz-Cázares, C.	Do multiple certifications leverage financial performance?	Journal article	Submitted	*International Journal of Production Economics*	Chapter 5
Hernandez-Vivanco, A., Domingues, P., Sampaio, P., Bernardo, M. and Cruz-Cázares, C.	Assessing the financial effects of adopting multiple certifications	Conference	Accepted on April 6, 2018	3rd ICQEM conference, Barcelona, July 11-13, 2018	Previous version of Chapter 5
Hernandez-Vivanco, A., Bernardo, M. and Cruz-Cázares, C.	Sustainable innovation through management systems integration	Journal article	Submitted (under review, R1)	*Journal of Cleaner Production*	Chapter 4
Hernandez-Vivanco, A., Bernardo, M. and Cruz-Cázares, C.	Integrating management systems in pursue of sustainability	Conference	Accepted on April 6, 2018	3rd ICQEM conference, Barcelona, July 11-13, 2018	Previous version of Chapter 4
Cabecinhas, M., Domingues, P., Sampaio, P., Bernardo, M., Franceschini, F., Galetto, M., Gianni, M., Gotzamani, K., Mastrogiacomo, L. and **Hernandez-Vivanco, A.**	Integrated Management Systems Diffusion Models in South European Countries	Journal article	Accepted on January 30, 2018	*International Journal of Quality & Reliability Management*	IMS contribution
Hernandez-Vivanco, A., Cruz-Cázares, C. and Bernardo, M.	Openness and management systems integration: pursuing innovation benefits	Journal article	Submitted (under review, R1)	*Journal of Engineering and Technology Management*	Chapter 3

Authors	Title	Type	Status	Publication details	Relationship with this thesis
Hernandez-Vivanco, A., Bernardo, M. and Cruz-Cázares, C.	Relating open innovation, innovation and management systems integration	Journal article	Published (Hernandez-Vivanco *et al.*, 2016a)	*Industrial Management and Data Systems*, pp-1540–1556	Chapter 2
Hernandez-Vivanco, A., Cruz-Cázares, C. and Bernardo, M.	Quality Innovation, Innovation Quality and Integration of Management Systems for pursuing sustainability: An efficiency perspective	Conference	Published (Hernandez-Vivanco *et al.*, 2016b)	*19th QMOD Proceedings*, pp. 1877–1882	Previous version of Chapter 3
Presas, P., Bernardo, M. and **Hernandez-Vivanco, A.**	Is the Biosphere certification increasing customers satisfaction in hotels?	Conference	Published (Presas *et al.*, 2016)	*Proceedings book of the 2nd ICQEM*, pp. 291–307	Sustainability-oriented MSs
Cabecinhas, M., Domingues, P., Sampaio, P., Bernardo, M., Franceschini, F., Galetto, M., Gianni, M., Gotzamani, K., Mastrogiacomo, L. and **Hernandez-Vivanco, A.**	Integrated Management Systems Diffusion Models in South European Countries	Conference	Published (Cabecinhas *et al.*, 2016)	*Proceedings book of the 2nd ICQEM*, pp. 729–749	Previous version of Cabecinhas *et al.* (Accepted)

Source: Own elaboration

CHAPTER 2. RELATING INNOVATION, OPEN INNOVATION AND MANAGEMENT SYSTEMS INTEGRATION[1]

[1] This chapter has been adapted from Hernandez-Vivanco *et al.* (2016a).

Abstract

Purpose: The aim of this article is to analyze the impact of the level of Integration of Management Systems (IMS) over product and process Innovation Capabilities (IC), by considering the role of Open Innovation (OI) activities as a moderating effect of those relationships.

Design/Methodology/Approach: A longitudinal empirical study was performed on an existing Spanish panel database that contains information related to innovation, where 9,765 companies were selected for the panel analysis. A logit approach with random effects was considered.

Findings: The level of IMS positively influences process and product IC. Moreover, external cooperation, and using it a high extent not only positively moderate the effects of the level of IMS over process IC, but also of process over product IC, where it becomes indispensable for its effect to be positive. Finally, investing in external knowledge is a positive moderator of the effects of the level of IMS over both: process and product IC.

Originality: This is one the first studies on empirically finding evidence of the impact of the level of IMS on process and product IC, and of the moderating effect of performing OI activities in order to achieve higher process and product IC through the IMS.

Keywords: Level of Integration of Management Systems, Open Innovation, Process and product innovation capabilities.

2.1. Introduction

When analyzing Management Systems (MSs), it has been broadly accepted to research on ISO 9001 as a Quality MS (QMS) and ISO 14001 as an Environmental MS (EMS) because of the great number of companies that have implemented it worldwide (ISO, 2017) and its traceability. Thereby, several studies have analyzed separately how each of them interact with process and product innovations.

On the one hand when relating ISO 9001 and innovation, existing literature has generally considered it as a part of the Total Quality Management (TQM) continuous improvement process, where empirical evidence shows that process innovations can be achieved by the adoption of more efficient MSs through organizational overhauls (Petroni *et al.*, 2003) and can even cause radical innovations when it has been able to achieve a cultural change (Moreno-Luzon *et al.*, 2013). Furthermore, its implementation does not always affect innovativeness, because its success is closely related to other factors including the process and strategic management and how open the organization is (Hoang *et al.*, 2006), which can also partially explain why in other studies innovation has not been found significantly influenced by the implementation of QMSs according to managers (Antunes *et al.*, 2009).

On the other hand, EMSs have been considered as a catalyzer for technological innovation activities (Radonjič and Tominc, 2006), and that its implementation can also have a positive influence on environmental product innovations even if it does not necessarily implicate the increment on patents (Wagner, 2007b). Moreover, the way of getting innovations is related to the level of adoption of the EMS and its structural innovations (Llach *et al.*, 2007) so that its adoption is not only an innovation itself but it also encourages for other innovations (Carruthers and Vanclay, 2012). Nonetheless, other studies have not been able to find a clear casualty of EMSs over process innovations (Ziegler and Seijas Nogareda, 2009), or on product innovations (Wagner, 2008). It has also been pointed out that the collaboration between companies among a Supply Chain when adopting EMSs is an important factor in order to get larger and wider innovations (Prajogo *et al.*, 2014) because of the importance not only of internal but also of external knowledge in this process (Gavronski *et al.*, 2012).

The concept of Integration of Management Systems (IMS) has been defined as the joint management of function specific MSs such as QMS, EMS, Occupational health and safety, Social Responsibility, among others (Jørgensen *et al.*, 2006) by means of a more effective and unique IMS (Beckmerhagen *et al.*, 2003) by using common resources (Bernardo *et al.*, 2009). Hence, integrating QMSs (e.g., TQM or ISO 9001) and EMSs (e.g., ISO 14001) is the main focus of study of this investigation due to their high acceptance among companies (ISO, 2017) and literature (e.g., Karapetrovic and Willborn, 1998a; Jørgensen *et al.*, 2006; Bernardo *et al.*, 2009).

Regarding the role of IMS on innovation, empirical evidence shows that integration characteristics are positively related to innovation and customer satisfaction, being both of them referred as the benefits of IMS. In this empirical research performed in Spanish companies, results, although exploratory, suggest that the IMS help enterprises to manage their MSs as well as to incorporate innovation as part of their systems (Simon and Petnji Yaya, 2012). From a different perspective relating IMS and innovation, the research carried out by Bernardo (2014) indicates that IMS can be classified as incremental, internal and organizational innovation, where integration aspects will determine the integration level, and that this in turn will implicate the innovation management performance which relationship is mediated by the market turbulence.

Even if the tendency of studying the relationships between the MS or IMS and innovation has been more analyzed during the last years, literature analyzing the effects of the level of IMS on the process and product innovations is anecdotic, especially when introducing open innovation (OI) effects. Hence, there are still no concluding results when analyzing each of the MSs separately nor of IMS, so a better understanding is required on how the level of IMS can lead to improving process and product IC by also considering the role of OI. Consequently, the aim of this study is to try to fill this gap with empirical evidence from the Spanish market, grounded on the resource-based view (RBV).

2.2. Theoretical framework

Innovations have been classified as process, product, organizational and marketing innovations, depending on the field in which it is developed, which can also lead to having relationships between them (OECD, 2005). Moreover, the RBV supports the concept of the transformation of resources into desirable outputs where capabilities are necessary to the creation of a competitive advantage – innovations – or superior performance (Cruz-Cázares *et al.*, 2013), so process and product Innovation Capabilities (IC) relationships are to be analyzed – although not how those IC are assembled – in the context of the IMS.

When relating innovation and IMS, previous researches have classified it as an organizational innovation (Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo, 2014) because, since it implicates managing systems on a single but more efficient way, it is a new organizational method in the firm business practices as defined by the OECD (2005). However, its effects on process and product innovations have been scarcely tested empirically.

From another angle, when relating the role of IMS on innovation, empirical evidence shows that the IMS benefits are positively related to innovation and customer satisfaction. Results, although exploratory, suggest that the IMS helps enterprises to manage their MSs as well as to incorporate innovation as part of their systems (Simon and Petnji Yaya, 2012). Additionally, the level of IMS can affect to the innovation management performance which could be evidenced by means of the benefits of the IMS, improved financial results, new processes and products and new capabilities and that moreover, this improvement would be affected by external market turbulence (Bernardo, 2014).

Furthermore, during the last years, ISO (2013) has reported to show a steady worldwide increase in certifications based on QMSs and EMSs and, since (i) the level of IMS can be measured from companies that have implemented at least two MSs, and (ii) the relationships between innovation and QMS and EMS have been mostly related from a function-specific MSs' standpoint, the next subsections will be based on the existing literature for analyzing and developing hypotheses regarding the relationships of the level of IMS with process and product innovations as well as the role of open innovation.

2.2.1. IMS and Process IC

When considering merely organizational innovations, it has been found that they have a positive and significant influence on process IC (Camisón and Villar-López, 2014), so this section will analyze IMS as an organizational innovation and its influence on process IC.

The adoption of more efficient MSs has been discussed to be the basis of improvements in productivity through important organizational overhauls that lead to the IC, which tendency has been found to be applied from the mid-80's in the US with the use of practices such as the TQM (Petroni *et al.*, 2003). In this sense, the adoption of QMS has been classified as an organizational innovation in many researches (Petroni *et al.*, 2003; Hoang *et al.*, 2006; Moreno-Luzon *et al.*, 2013) as well as related to the improvement of organizational performance (Prajogo and Sohal, 2004).

Moreover, it has been studied that the adoption of QMSs such as ISO 9001 – which has been widely applied worldwide but with varied success – have a significant positive effect on process innovation performance, specially due to the restructuring and application of the internal customer (Terziovski and Guerrero, 2014). Nevertheless, QMSs and its practices are not always related to innovativeness. Indeed, process and strategic management are some of the key factors that positively impact the firm's innovation performance, where quality is considered a critical strategic factor for achieving a sustainable competitive advantage as long as it can shifted from quality to innovation (Hoang *et al.*, 2006). The fact that even radical innovations can be achieved through the implementation of TQM when cultural change occurs within the company along with TQM implementation, implicates that companies shall not have a limited approach only based on quality assurance (Moreno-Luzon *et al.*, 2013).

Furthermore, other studies have focused on studying the relationships between EMSs and its impact on process innovations. Ziegler and Seijas Nogareda (2009) concluded that there are more complex relationships to be analyzed since the casualty of EMS on technological (process) innovations is ambiguous, which led to other researches where it has been found that programs such as the European Union's Eco-Management and Audit Scheme (EMAS) pressures firms to modify their processes in order to reduce resource waste which would necessarily promote process innovations (Lim and Prakash, 2014); also, companies that have implemented ISO 14001 and that additionally have it as a mature MS are more likely to implement more environmental R&D activities (Inoue *et al.*, 2013), giving as a result the innovation of processes; nonetheless, other issues such as the culture (Wagner, 2009) interact for explaining those complex relationships.

Since a cultural change is necessary so that innovation occurs (Wagner, 2009; Moreno-Luzon *et al.*, 2013), IMS becomes crucial by bringing with it a cultural change in the organization (Wilkinson and Dale, 1999). Moreover, the casualty of the utilization of QMS and EMS over process innovations is evident in various researches, so integrating them into a single and more effective IMS would implicate better structured processes (Olaru *et al.*, 2014). Consequently, the more integrated the MS (i.e. integrating goals and procedures (Bernardo *et al.*, 2009), the better process IC. Thus, H1 is formulated:

H1: The level of IMS has a positive effect on process IC.

2.2.2. IMS and Product IC

When studying QMSs, some studies have found a negative relationship between TQM and product innovation, because it claims TQM is more focused on accomplishing certain product requirements related to quality rather than product newness, which leads to hindering product innovation (Atuahene-Gima, 1996). However, other studies have found that process and strategic management have a positive and significant effect on the development of new products (Hoang *et al.*, 2006), so a better understanding is required about how process IC can be achieved by the implementation of QMSs, because in some cases it can happen when related to other factors that are still unclear.

From another perspective and at a macro level, empirical evidence suggests that the implementation of EMSs such as ISO 14001 has a positive effect on product innovations when they are measured through the number of patents implemented at the country level (Lim and Prakash, 2014); more specifically at the firm level, it has been found that companies that have implemented ISO 14001 and held it during more years are more likely to show an incremental ratio (relative of total R&D expenditures or sales) (Inoue *et al.*, 2013), which serves as evidence that it causes the development of new products.

Referring to TQM, Prajogo and Sohal (2006) indicate that product innovations cannot ignore quality aspects and that innovation should attempt to improve those aspects of quality, which is indeed a goal of the QMS; moreover, sustainable product innovations or green innovations occur when

EMS goals have been accomplished (see e.g., Van Bommel, 2011; Cuerva *et al.*, 2014). Notice that the process of IMS begins with the integration of goals (Bernardo, 2014). Consequently, if synergies (strategical, of resources and documentary) are achieved (Zeng *et al.*, 2007), the more integrated MS are, the higher product IC it will achieve. This is congruent and complements with other results where organizational innovations have been proved to influence product IC (Camisón and Villar-López, 2014), so H2 is developed as follows:

H2: The level of IMS has a positive effect on product IC.

2.2.3. Process IC and Product IC

Camisón and Villar-López (2014) analyzed this relationship and concludes that process IC have a positive significant effect on product IC, and Organizational IC are also important for getting product IC through the improvement of process IC. From another perspective, technological capabilities (process IC) help to satisfy customer demand for product and service innovation (Veryzer, 1998), so process innovation influences positively product innovations (Fritsch and Meschede, 2001). Consequently, a confirmation test is necessary to prove that, independently – but in the context – of the level of IMS and OI activities, product IC will be improved when having more process IC:

H3: Process IC have a positive influence on product IC

2.2.4. The role of Open Innovation (OI)

It has been defined that open business models use a different approach of innovation, by considering the creation of value from the raw materials to the final customer – i.e. process innovations applied to this study – to new product or services, where the idea is to focus on both: the creation of value and the retention of a portion of that value (Chesbrough, 2006).

Even if the concept of OI has not been profoundly analyzed within the context of IMS, certain studies regarding the influence of QMSs on innovation have considered the importance of how open the firm is for getting different innovation outputs (Hoang *et al.*, 2006); also, later studies have not found a direct effect of external collaborations on product innovations (Cuerva *et al.*, 2014) but this does not reflect its moderating role. Moreover, product innovations are also related to the information received from the customers through the implementation of EMSs (Wagner, 2008), which indicates that open innovation could affect the relationships formerly discussed.

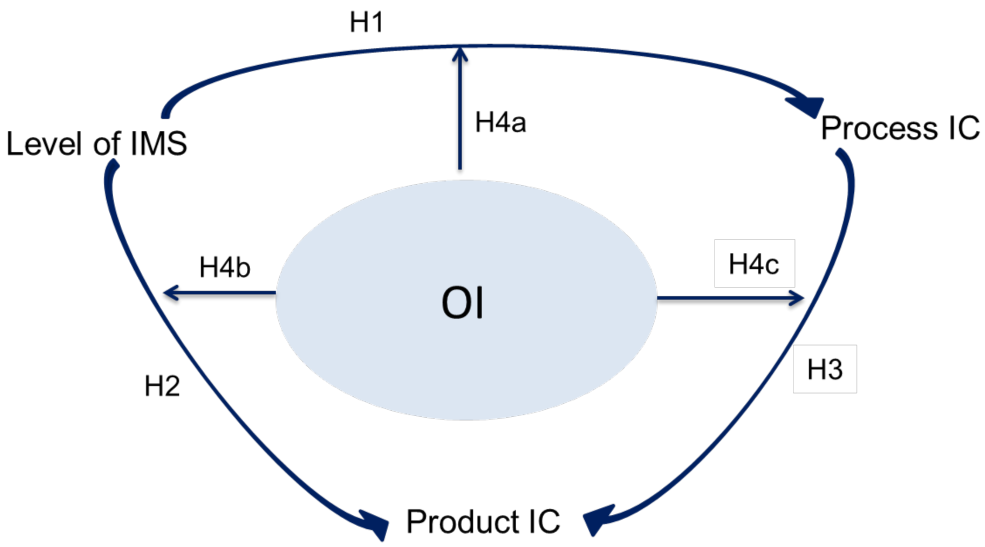
It has been proposed but scarcely analyzed that the combination of high internal cooperation and high external cooperation is the most successful combination between internal and external cooperation (Bouranta *et al.*, 2009), therefore, since internal coordination is required for achieving higher levels of IMS – higher internal cooperation – and because the IMS is required to be expanded to include the whole product chain and stakeholders – higher external cooperation – (Jørgensen *et al.*, 2006), the level of IMS and the use of OI activities are expected to interact in order to foster the IC discussed on H1 and H2. Fritsch and Lukas (1999) discussed that cooperation between companies may also induce or stimulate innovation, but those relationships are much more complex and deserve to be analyzed beyond the simple monocasual explanations, so the idea of what has been previously defined as OI becomes more important in the context where the IMS is considered as an organizational innovation, since depending on how open the organization is and on how strong is the interaction with the internal organization and processes, innovation outputs differ. Therefore, OI activities moderate the interactions of the previously discussed H1, H2 and H3.

H4a: The existence of OI activities moderates the effect of level of IMS on Process IC.

H4b: The existence of OI activities moderates the effect of level of IMS on Product IC.

H4c: The existence of OI activities moderates the effect of the process IC on product IC.

Figure 2 is useful in order to understand the stated relationships included in the hypotheses:



OI: Open Innovation activities
Source: Own elaboration

Figure 2. Model relating IMS, OI and innovation capabilities

2.3. Methodology

2.3.1. Population and sample selection

This study is focused in Spanish companies because of its high concentration of ISO certificated companies worldwide, adopting the greatest density of both QMSs (ISO 9001) and EMSs with around 40 thousand and 15 thousand companies that have implemented ISO 9001 and ISO 14001 respectively (ISO, 2017), so the total population of this study is focused on a market where the implementation of meta-standards has been widely accepted and that is familiar with these practices, being this fact of relevance since the approach of this study is on studying the level of IMS.

In order to study all of the relationships proposed in this work, PITEC database was chosen since it contains information of surveys performed by the Spanish Foundation for Science and Technology (FECYT) and directly applied to Spanish companies for measuring the evolution of their technological activities since 2003 (FECYT, 2008).

The original database considers 118,859 observations obtained from 12,838 companies, of which only those observations that contained quality, environmental, process and product innovation, and open innovation indicators were selected, giving as a result a panel database of a total of

12,802 companies with information since 2004 until 2007 from a total of 56 industries (2 digit CNAE-93 code). It is important to consider that, since this study is based on a panel data, only those firms that had continuous information where considered due to the nature of the lagged models that are used for estimations (see section 0), giving as a result the selection of years 2004 to 2007; next, cleaning data was done by eliminating missing values of the selected variables through the Stata statistical software, where year 2007 was not considered due to collinearity. Consequently, the final sample is an unbalanced panel of at least 2 consecutive years (from 2004 to 2006) consisting of 23,193 observations from 9,765 companies. The definition and selection of such variables is discussed in the next subsection.

2.3.2. Selection of variables

2.3.2.1. Dependent variables

This study contains two dependent variables: process and product IC. Based on the RBV, capabilities are mandatory for the creation of a competitive advantage (i.e. innovations) (Song *et al.*, 2007; Cruz-Cázares *et al.*, 2013), so the indicators for measuring whether IC have or have not improved are based on whether firms have or have not implemented process and product innovations. Both variables are taken directly from the PITEC database as dummies (0,1).

2.3.2.2. Independent variables

Level of IMS

The level of IMS is constructed from the data available in the PITEC database based on the fact that the dimensions for integrating are MS's resources, goals and processes (Karapetrovic and Willborn, 1998b; Bernardo *et al.*, 2009). However, the first aspect that must be integrated are goals (Karapetrovic, 2003), which relevance has also been pointed out in other empirical studies regarding the level of IMS (Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo *et al.*, 2009). Thus, given that IMS increases organizational efficiency (Bernardo, 2014) it is expected that firms having fully IMS achieve the highest results of their MSs goals, as opposite to whether they have not even implemented or do not consider relevant at least one of them (non-integrated MS); also, companies having partially integrated

MS: i) employ and consider relevant both MS and ii) do not have the highest score at least for one of the MS (see Table 8).

Moreover, it is important to mention that MSs can be integrated into a single integrated MS whether it is certifiable or not (Bernardo *et al.*, 2009) so QMS and EMS indicators for measuring each of them are, respectively, the "importance in the effect of the performance of quality and of the improvement of the environmental impact", which were both measured on a 4 point Likert-scale in the PITEC survey, and then deduced the level IMS by applying the following logic to each observation.

Open Innovation activities

Measuring OI requires different indicators in order to get a better understanding on the factors that interact in its definition. First, it has been discussed on case studies the importance of building up long term collaborations for achieving common goals (Szeto and Elson, 2000), so collaboration is the first indicator to be used for OI, which is also a dichotomous variable.

Table 8. Definition of the Level of IMS

Score of QMS and EMS indicators	PITEC scores combinations (QMS – EMS)	Level of IMS	Codifi-cation
Highest score for QMS and EMS	1 – 1	Fully integrated	3
Both are relevant and employed, but not having the highest score at least for one of the MS	1 – 2 1 – 3 2 – 1 2 – 2 3 – 1 3 – 2 3 – 3	Partially integrated	2
Not relevant or not employed at least for one MS	1 – 4 2 – 4 3 – 4 4 – 1 4 – 2 4 – 3 4 – 4	Non-integrated	1

Note: PITEC codifies 1 High, 2 Medium, 3 Low, 4 Not relevant or employed. Source: Own elaboration

Moreover, Laursen and Salter (2006) developed the concept of breadth and depth in order to investigate the range and profundity of open search strategies; thus, depth concept is of a special interest since the focus of this study is to research on the way OI moderates effects when external sources are used at a high degree. Depth "is defined in terms of the extent to which firms draw deeply from the different external sources or search channels" (Laursen and Salter, 2006), and accordingly for measuring it, nine different agents that serve as external sources have been identified: suppliers, clients, competitors, consultants or R&D private institutes, universities, public research centers, conferences, scientific journals and industry associations (Cruz-Cázares *et al.*, 2012). Hence depth variable was determined by:

$$(External\ Source)_i = \begin{cases} 1\ if\ highly\ important\ to\ the\ firm \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases}$$

$$Depth = \sum_{i=1}^{9} (External\ Source)_i$$

Where, $i = \{1,2,3 \ldots .9\}$ = {suppliers, clients, competitors, consultants or R&D private institutes, universities, public research centers, conferences, scientific journals and industry associations}.

Finally, and in order to get a better understanding given to the importance of R&D activities, the fact a firm invests in external knowledge has also been considered important for studies regarding OI (see e.g., Cruz-Cázares *et al.*, 2012). That is why the next variable to be measured as part of OI is whether the firm has invested or not in external knowledge, which is consequently a dummy variable.

2.3.2.3. Control Variables

Since this study aims to understand how relationships occur as a whole mechanism, the selected sample contains firms of different sizes and industries with data from 2004 to 2006, where all of the observations are continuous and contain no missing data among the panel. Consequently, these three factors are to be controlled.

Firms have been defined by the European Communities (2006) as Large, Medium and Small depending on the number of employees, under which, the characterization summarized in Table 9 was obtained:

Table 9. Size of the firms

Size	No. of employees	Percentage (%)	Codification
Large	≥ 250	18.96	3
Medium	< 250	30.51	2
Small	< 50	50.54	1

Source: Own elaboration

Additionally, the type of industries has been found to present different results on innovations (see e.g., Hoang *et al.*, 2006; Carruthers and Vanclay, 2012), and because this study considers all the 56 CNAE-93 industries, this is the next control variable to be measured. The last control variable is the year since this is a panel study. Finally, all the variables are summarized in Table 10.

Table 10. Summary of the selected variables

Type	Variable	Simplified Name	Mean	Std. Dev.	Min	Max
Dependent	Product innovation	PROD	0.67	0.47	0	1
	Process innovation	PROC	0.68	0.47	0	1
Independent	Level of IMS	LIMS	1.67	0.67	1	3
	Investment in external knowledge	TEC	0.07	0.26	0	1
	External cooperation	EC	0.37	0.48	0	1
	Depth	DTH	1.10	1.40	0	9
Control	Size	Size	1.68	0.77	1	3
	Industry	Ind	26.25	16.54	0	55

Source: Own elaboration

2.3.3. Model development

A logit model approach is selected in order to test the hypotheses, since process and product innovations are dichotomous dependent variables, so the resulting outputs are measured in accordance with the logistic function of each variable. With this approach, results allow to understand how odds of process and product innovations depend on the selected independent variables in terms of the direction (sign) as well as quantity (coefficients).

In order to identify the causal effects among the panel, it is taken into account the information of the available indicators during t (for dependent variables) and t-1 (for independent variables) in order to determine how the casualty relationships occur among those years, given that successful innovations are determined by prior management actions rather than current (Atuahene-Gima, 1996). However, even if data of year 2007 was available, it was not considered in the analysis in order to avoid co-linearity in the logit analysis, so the final estimation was done with the information from 2004 to 2006, taking as reference year 2004.

For process innovations, it has been defined that its causes depend on the level of IMS and the moderating effect of OI activities (i.e. its interactions with OI activities), so the following model is resulting:

$$L(PROC) = \beta_0 + \beta_1 LIMS_{t-1} + \beta_2 (LIMS * TEC)_{t-1} + \beta_3 (LIMS * EC)_{t-1} + \beta_4 (LIMS * DTH)_{t-1} + \beta_5 Size + \beta_6 Ind + \beta_7 Yr$$

Where, the expression $L(PROC)$ describes the logistic function for process innovation, β_1 is important for contrasting the fact that the level of IMS has a positive effect on process IC (hypothesis H1), and the interactions between the level of IMS and OI activities (i.e. β_2, β_3 and β_4) are used for studying the moderating effect of those activities on process IC as described in hypothesis H4a.

Similarly, the following expression $L(PROD)$ is defined as the logistic function for product innovations, which equation indicates the effects of process innovations, the level of IMS and the moderating effect OI activities (i.e., the interactions of process innovations and the level of IMS with those activities):

$$L(PROD) = \beta_0 + \beta_1 LIMS_{t-1} + \beta_2 PROC_{t-1} + \beta_3 (LIMS * TEC)_{t-1} + \beta_4 (LIMS * EC)_{t-1} + \beta_5 (LIMS * DTH)_{t-1} + \beta_6 (PROC * TEC)_{t-1} + \beta_7 (PROC * EC)_{t-1} + \beta_8 (PROC * DTH)_{t-1} + \beta_9 Size + \beta_{10} Ind + \beta_{11} Yr$$

β_1 is useful for contrasting the causality of the level of IMS on product IC (hypothesis H2), β_2 allows to understand the influence of process IC (hypothesis H3), and the interactions of OI activities with the level of IMS and process IC represented by $\beta_3, \beta_4 \dots \beta_8$ are crucial for contrasting its moderating effects on the level of IMS and on process IC, when studying product IC (hypotheses H4b and H4c respectively).

Both equations are solved using the statistical software Stata with Maximum Likelihood estimation and considering all of the control variables as categorical variables since each level could change the results.

2.4. Results

After proceeding with the methodology indicated above, results are shown in Table 11. It can be seen that models are accurate for explaining the dependent variables, since a Chi square (χ^2) for both process and product innovations regressions are significant at 1% ($p = 0.000$), which means that this is the probability of getting a χ^2 as large as 822.2 and 890.2 for process and product innovations respectively. The standard deviation of the models is 3.713 and 4.193 (referred as sigma_u) for process and product innovations, which gives as a result a significant model at 1%[2].

Results indicate that the odds of process innovations are more likely to increase when having a higher level of IMS and also with its interactions with open innovation activities, since all of the effects are significant and have a positive sign (see Table 11), hence the odds result all of the positive and significant as well. Given these relations, it is important to highlight that the greatest odds of getting process innovations occur when the level of IMS is the highest (i.e. fully IMS) (odds = 1.4492), and when they also use all the three OI activities, which moderate the effects of the level of IMS when: the company invests in external knowledge (odds = 1.4785), they cooperate with external firms (odds = 1.136), and the most external sources used in a high extent for innovation the better (the greater the Depth value, the better – odds = 1.0354).

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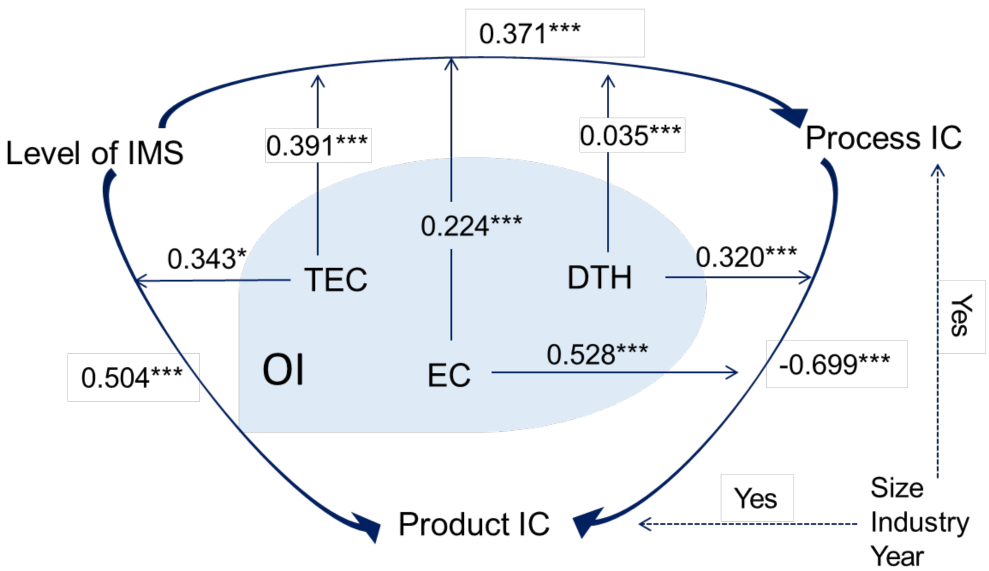
[2] Notice that $\ln sig2u = 2\log(sigma\_u^2)$

Regarding product IC, results show that their odds increase when having fully IMS (odds = 1.6553) as well as its combination with the investment on external knowledge (odds = 1.4092), and also when the firm has implemented process innovations in combination with EC (odds = 1.6955) and when using the most external sources at a high level (depth odds = 1.3711). Nonetheless, firms that have only implemented process innovations but that have not been involved in any of the OI activities (with focus on EC and number of external sources) are more likely to have lower product innovation capabilities (odds = 0.4971). It can also be seen that the fact that firms invest in external knowledge (TEC) does not moderate the effect of process IC; also, the two OI activities that do not moderate the effect of the level of IMS are depth and the use of EC.

Finally control variables results show that bigger companies are more likely to improve their process and product IC; also, the last year of the analysis shows a significantly higher probability of improving process and product IC, which evidences the existence of the previous years' experience influence; finally, most industries are more likely to improve their product IC rather than process IC. The significant coefficients resulting of the logit models are illustrated in Figure 3.



* p<0.05, ** p<0.01, *** p<0.001
OI: Open Innovation activities include: TEC, Investment in external knowledge; DTH, Depth; EC, External Cooperation
Yes indicates control variables are used.
Source: Own elaboration

Figure 3. Model significant coefficients

Table 11. Logit output

Variable	(1) Process innovation	(2) Product innovation	Process innovation odds	Product innovation odds
IMS_{t-1}	0.371***	0.504***	1.4492	1.6553
	(0.0601)	(0.0684)		
$IMSxEC_{t-1}$	0.224***	0.136	1.2511	ns
	(0.0411)	(0.0703)		
$IMSxDTH_{t-1}$	0.0348**	-0.0357	1.0354	ns
	(0.0129)	(0.0214)		
$IMSxTEC_{t-1}$	0.391***	0.343*	1.4785	1.4092
	(0.0709)	(0.139)		
$PROC_{t-1}$		-0.699***		0.4971
		(0.105)		
$PROCxEC_{t-1}$		0.528***		1.6955
		(0.149)		
$PROCxTEC_{t-1}$		-0.260		ns
		(0.280)		
$PROCxDTH_{t-1}$		0.320***		1.3771
		(0.0506)		
_cons	0.297	-0.987*		
	(0.366)	(0.415)		
Size	Yes	Yes		
Year	Yes	Yes		
Industry	Yes	Yes		
Constant	2.624***	2.867***		
	(0.0471)	(0.0471)		
N	23,193	23,193		
Ll	-11,192.3	-11,039.7		
chi2	822.2	890.2		
chi2_c	4685.6	5346.6		
sigma_u	3.713	4.193		
rho	0.807	0.842		

Source: Own elaboration

2.5. Discussion and conclusions

This study aims to analyze how the level of IMS influences on process and product IC, where the role of OI is analyzed as a moderating effect on those relationships, for which two logit models were used for testing all the hypotheses.

When considering process innovation as the dependent variable, H1 is confirmed, since the level of IMS increases the odds of getting higher innovations, and thus it has a positive effect on process IC. This result shows that when a firm has integrated MSs at a higher level, its chances of innovating in processes the next year are also significantly higher, which indicates the evidence of a cause effect relationship between the level of IMS and process IC. This outcome is coherent with the previously discussed literature, in which it has been proposed that the level of IMS would lead to process innovations (Bernardo, 2014) and also shed lights on understanding how the interactions within MS and, consequently, its level of integration is an important factor in order to improve process IC. When analyzed separately, MS have generated debate on the ambiguity of whether EMS can be a cause for innovations (Ziegler and Seijas Nogareda, 2009), or on how QMS are not enough if the company is only limited to quality (Moreno-Luzon *et al.*, 2013), so this result is relevant in order to complement those previous concerns.

It is also confirmed H2 since it can be seen that higher levels of IMS increase the odds of having product innovations on the next year, which gives as a result the conclusion that the level of IMS has a positive effect on product IC. This study is one of the first in demonstrating empirically this result and is also coherent with previous literature relating the level of IMS with product innovations (Bernardo, 2014). In this sense, it is also important to point out that, even if other studies have not found significant the effect of organizational innovations on product IC (Camisón and Villar-López, 2014), the level of IMS increases the chances of getting product IC, because in some cases, the sole fact of implementing MSs such as EMSs has been proved to have positive effects on product innovations (Rehfeld *et al.*, 2007) along with the fact that the improvement of IMS is achieved when goals are aligned between them (Karapetrovic, 2003). This could explain how product IC are positively increased when having higher levels of IMS.

As a result, by accepting H1 and H2, this study contributes to literature by demonstrating empirically that, even if function specific MSs increase process IC and in some cases product IC, when adopting more than one MS and integrating them, having fully integrated MS leads to higher process and product IC than when having partially or – even worse – non-integrated MS.

This is one of the first studies in contributing with empirical results about these relationships.

In the next two paragraphs the main contributions of this paper are discussed. Regarding the moderating effect of OI activities and the level of IMS when analyzing its effects on process IC, all of those interactions are significant, which indicates that investing in external knowledge, cooperating with external firms and using intensively the most external sources moderate positively the effect of the level of IMS on process IC. This result validates H4a and is coherent with other studies that have analyzed separately specific MSs, finding that QMSs are more effective for innovativeness depending on how open the organization is (Hoang *et al.*, 2006), and that the adoption of new technologies is also related to EMS, where external knowledge is also important (Gavronski *et al.*, 2012).

The interactions of OI activities and the level of IMS are also analyzed as a cause for product IC. Results show that the interaction of the level of IMS and investing in external knowledge is significant, but not with the use of external cooperation or the depth; therefore, H4b is partially accepted. Since studies for process innovations not necessarily apply for product innovations (Un and Asakawa, 2015), it can be argued that this happens because cooperating with other companies, even if it is a higher extent, not necessarily implicates product innovations, but also the position of the firm in those networks is important for the new product development process (Mazzola *et al.*, 2015).

The last result is obtained from the negative and significant effect of process IC on product IC, as opposite to what was specified in H3. Even if most of the investigations have found a positive relationship between both of them (Camisón and Villar-López, 2014), the existence of OI activities – specifically of external cooperation and depth – changes the direction of this relationship and then increases the odds of getting product IC when process IC interact with OI activities (since investing on external knowledge is not significant, H4c is partially accepted), which is an important upshot from which it can be concluded that when analyzing how product innovations occur through the enhancement of process IC in the context of the implementation of IMS, the existence of OI activities – specially using EC at high extent – is necessary for this relationship to be positive. Moreover, using the concept of OI activities sheds lights on the way a previously, but more ambiguous concept of market turbulence (Bernardo, 2014), moderates the effect of the level of IMS on innovation management performance.

This study has also implications for practitioners and researchers. The main managerial implication is related to the fact that the IMS is relevant in order to gain process and product IC on a more accurate way as if they would not do it. Additionally, results are not the same if enterprises do not perform OI activities, which give as a result the necessity for companies to implement and integrate MSs as well as using external sources in order to gain internal knowledge and then having a higher competitive advantage.

Research implications are mainly three. First, researchers must be aware of the importance of considering the IMS when analyzing MS, since this investigation sheds lights on the importance of analyzing the whole picture when enterprises have adopted more than one MS. Moreover, this consideration must also be done with OI activities, since the results of product IC show that not considering the moderating effect of OI could lead even a negative result of process IC on product IC, which result is not intuitive if not considered the role of OI activities. The second research implication is the need of constructing a more complete measurement quantitative model in order to determine how IMS could act as an exogenous or endogenous variable not only in its relationship with OI and process and product innovations, but also for studying its relationships with other constructs of interest such as financial performance, IMS benefits, Corporate Social Responsibility (CSR), among others. The third and last research implications is related to the fact that it has been detected there are different outputs on process and product IC when considering different industries (for process and product IC) and sizes (for process IC) of the companies, so further research must consider these differences in order to analyze concrete issues based on the showed results. Since this study is a first approach that has demonstrated empirically the importance of IMS and the role of OI as a moderating variable, researchers must analyze in-depth how this phenomenon occur, but focused on a specific industry and type of company.

Even if this study is based on theoretical and empirical evidence, it is not absent of limitations and therefore further investigation is required. Although the use of secondary databases is useful in order to have a first approach on new investigation lines, this is also a limitation since the information is not coded the same way it would have been defined on a specific survey; thus, product and process IC could be improved in future researches by using a continuous spectrum (Camisón and Villar-López, 2014), and also the level of IMS had to be constructed supported on literature but could not be measured directly as previous literature suggests (Karapetrovic, 2003; Jørgensen *et al.*, 2006; Bernardo, 2014). Nonetheless, all of the results suggest that, given the evidences of casualty, it is necessary to further investigate how the level of IMS produces the positive effects on process and product IC.

Due to the importance of OI activities related to IMS, it is also important to deeper investigate this relationship, since it has been lately analyzed in other contexts how the chosen partners may affect to process and product innovations (Un and Asakawa, 2015), so this idea must also be considered in further investigations related to IMS in order to have a deeper comprehension on the depth variable which was significant as a moderating effect in the causality of IMS over process innovations, as well as for the relationship between process and product IC. The same idea shall be considered for deeply understanding how External Cooperation acts as a moderating effect for the first equation.

It must also be pointed out that other empirical researches have considered that one of the benefits of the IMS is the better use of MS, which is a significant factor for improving process innovations (Simon and Petnji Yaya, 2012), but the relationships with the benefits of IMS was far from the scope of this study, so further research could also consider this point of view by taking into account a more complete innovation management performance concept involving the integration benefits, financial results, processes and product innovations and other capabilities (Bernardo, 2014). This approach could lead to have a better comprehension on the causalities among IMS, by also considering OI activities due to its relevance highlighted in this study.

Finally, other quantitative models are suggested for constructing a more complete causal model, such as Structural Equation Modelling (SEM), for which it would be necessary to define an accurate measuring model for the level of IMS. This investigation settles the importance of deepening on empirical researches regarding IMS and innovation, with special attention to OI.

CHAPTER 3. OPENNESS AND MANAGEMENT SYSTEMS INTEGRATION: PURSUING INNOVATION BENEFITS

Abstract

Purpose: The aim of this article is to relate innovation efficiency and firm performance considering the paradigms of Integration of Management Systems (IMS) and Open Innovation (OI). To this end, quality and innovation are related to define innovation efficiency.

Design/Methodology/Approach: A sample of 220 Spanish companies was studied using a secondary database. To measure efficiency, a partial frontier analysis was first performed, followed by parametrical and non-parametrical statistical analysis to test the hypothesis, including panel regressions.

Findings: Results suggest that companies that integrate their management systems to the highest level are more efficient innovating, unlike companies that practice OI. Such efficiency is significantly related to firm performance in terms of the sales productivity of innovative products. However, this influence is not affected by firms' openness.

Originality: To the best of the authors' knowledge, this is one of the first studies relating innovation efficiency and firm performance in the context of two prominent paradigms: IMS and OI. Thus, this research contributes to such increasing literature with a novel approach that provides new insights and opens avenues for further research.

Keywords: Innovation Efficiency; Management Systems Integration; Open Innovation; Firm Performance

3.1. Introduction

In a challenging world dominated by fast changes, firms are pushed to innovate efficiently, optimizing their limited resources to benefit their stakeholders through new products or processes (West and Anderson, 1996; Wong *et al.*, 2009). It is thus a primary managerial challenge to attain an efficient innovation process so that firms can keep growing. Stated differently, firms must adopt the accurate managerial practices that booster Innovation Efficiency (IE) and consequently, expect to grow sustainably.

Guided by efficiency, firms should produce the appropriate outputs that pay off the resources used in the innovative process (Fichman, 2004). Not only the firms' internal trade-offs are important, but also their performance compared to their key competitors'. In this line, IE is defined as the relative efficiency of firms for transforming resources (inputs) into innovations (outputs) (Deprins *et al.*, 1984), so firms with higher levels of IE are able to obtain more internal and external benefits as follows. Namely, firms innovating efficiently use less resources to innovate (George *et al.*, 2002; Cruz-Cázares *et al.*, 2013), create a stronger innovative basis due to their learning capabilities (Weerawardena *et al.*, 2006) and are able to obtain better commercial results (Hashimoto and Haneda, 2008; Guan and Chen, 2010; Wang and Wang, 2012; Wang *et al.*, 2016a).

Albeit IE has been positively related to increased firm performance, scarce research has focused on the managerial means that enable the optimization of such relationship. To this end, two relevant managerial practices designed to increase efficiency are further developed: Integration of Management Systems (IMS) and Open Innovation (OI).

In the innovative process, quality, environmental and other aspects must be considered and integrated for achieving the requirements of the new developments (von Ahsen, 2014). Given this scenario, Management Systems (MSs) determine the procedures that enable the fulfillment of such objectives (ISO, 2017a), and their integration (Quality, Environment, Health and Safety, among others) is a primary task to optimize resources and results (Karapetrovic, 2003; Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo *et al.*, 2009). Thus, the first part of this research focuses on the role of IMS as a potential driver of IE, which relationship in literature remains scarcely explored. Due to their relevance to IE, this study focuses on Quality MSs

(QMSs) (Haner, 2002; Palm *et al.*, 2016), and its integration with Environmental MSs (EMSs) (Simon *et al.*, 2014; von Ahsen, 2014).

Another relevant managerial practice that might enable IE is related to the innovative boundaries, which have expanded so now firms innovate based on external cooperation or knowledge sharing. With this new paradigm, OI was first proposed by Chesbrough (2003) as an innovation model that consists of searching knowledge outside the firm and selling (e.g., licensing, patenting) the underutilized internal developments to others. Since then, a very extensive literature related to OI has emerged and debated its benefits to innovation (West and Bogers, 2014), but its role in promoting IE when also compared to IMS has been scarcely studied.

Hence, this research aims to study the roles of IMS and OI in pursuit of IE so firms can attain a better performance. In this effort, firstly IE is analyzed in the context of IMS. Secondly, the relationship between IE and firm performance is analyzed from the viewpoint of innovative sales productivity. Finally, this study analyzes the role of OI in the relationship between IE and firm performance.

3.2. Theoretical Framework

Since efficiency was proposed as a relevant measure to assess how resources are optimized to produce outputs (Deprins *et al.*, 1984), its application on innovation has become increasingly important to countries (Acs *et al.*, 2002; Guan and Chen, 2010; Guan *et al.*, 2016; Liu *et al.*, 2017) and firms (Hashimoto and Haneda, 2008; Cruz-Cázares *et al.*, 2013; Wang *et al.*, 2016a). In the IE literature, studies highlight the need of measuring IE in order to optimize firm performance, but few have focused on the managerial implications of both managerial practices, IMS and OI.

Recent research has found positive associations between IMS and innovation (Matias and Coelho, 2011; Bernardo, 2014; Hernandez-Vivanco *et al.*, 2016a), whilst a different line proposed OI as a model through which firms could innovate more efficiently using external knowledge (Chesbrough, 2007). Although scarce literature has studied both practices together, there is empirical evidence suggesting that implementing both is aligned with the enhancement of innovation (Hernandez-Vivanco *et al.*, 2016a).

3.2.1. The Integration of Management Systems as a driver of Innovation Efficiency

In pursuit of innovation, the Knowledge-Based View (KBV) theory (Grant, 1996) postulates that firms must stablish the necessary coordination links that enable the specialists' knowledge integration. Nonetheless, this task involves several challenges, and minimizing goal conflicts between the different actors is critical. From a complementary perspective to deal with this challenge, MSs are "the way in which an organization manages the inter-related parts of its business in order to achieve its objectives" (ISO, 2017a). Thus, MSs should facilitate the links that enable knowledge integration through the accurate management of the different, but still inter-related parts of the business. Moreover, MSs are focused on achieving the business objectives, so they are intended to optimize firms' resources, which should enhance IE (Matias and Coelho, 2011). However, this relationship remains unclarified for QMSs and EMSs, as discussed next.

Several studies have found that a positive relationship between QMSs and innovation is conditioned to factors such as: i) the cultural changes achieved through its implementation (Moreno-Luzon *et al.*, 2013), ii) only specific dimensions of the MS including leadership and people management (Prajogo and Sohal, 2004; Hoang *et al.*, 2006), and iii) firms' openness (Hoang *et al.*, 2006), among others. Others state that virtually every dimension of QMSs is positively related to innovativeness (Perdomo-Ortiz *et al.*, 2006; Kim *et al.*, 2012) whilst a final trend is opposite, and suggests they are detrimental to innovation (Prajogo and Sohal, 2001).

A similar scenario can be found in the EMSs literature. Radonjic and Tominc (2006) suggest EMSs are catalyzers of technological innovations, in accordance to Wagner (2008). Other studies suggest positive associations with certain types of innovations (Wagner, 2007a; 2008), although such relationships could turn into negative if EMS is not diffused across the organization (Prajogo *et al.*, 2014). Lastly, Ziegler and Seijas Nogareda (2009) found no clear causality.

Despite the lack of consensus of the existing literature analyzing QMSs and EMSs independently, there seems to be less disagreement about the positive relationship between their integration and innovation. Thus, the role of IMS in the innovative performance is further developed based on the KBV theory.

IMS intends to unify several function-specific MSs (Jørgensen *et al.*, 2006) into one system (Karapetrovic, 2003). The derived integrated control allows firms to increase their competitiveness by focusing on their performance (Renzi and Cappelli, 2000). In this process, firms should first integrate the individual MSs' goals (Karapetrovic, 2003; Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo *et al.*, 2009), which is also one of the most complex management issues according to the KBV. By this means, IMS contributes to the optimization of resources (Salomone, 2008; Santos *et al.*, 2011; Abad *et al.*, 2014) and, analogously to the enhancement of 'organizational' efficiency (Wagner, 2007a; Simon *et al.*, 2012; Simon and Douglas, 2013), it could boost 'innovation' efficiency. Such benefits would become more noticeable as IMS levels increase; i.e., when firms integrate their most strategic goals, which leads to the extensive implementation of IMS across the firm, including operations and tactics. Thus, firms that integrate all the aspects of the individual MSs are fully integrated as opposite to those that manage each MS independently, called non-integrated (Bernardo *et al.*, 2009).

Regarding the relationship between IMS and IE, Matias and Coelho (2011) showed preliminary empirical results about the critical role of IMS as the starting point of innovating with added efficiency. The authors support that, through IMS, firms take advantage of the compatibility of the individual MSs. As a result, they reduce the amount of resources needed to pursue the goals of each of the systems, which are also closely related between them since all MSs pursue continuous improvement (i.e., promote innovation). Thus, according to the authors, firms that fully integrate their MSs locate innovation at the core of the integrated pool to promote widespread company innovation and the creation of competitive advantages. The authors also discuss that IMS promotes improving the management of resources, cost reduction and increased results, including those related to innovation. Therefore, IMS seems to be closely related to IE.

Bernardo (2014) supported theoretically the previous empirical results, and associated IMS with an enhanced innovation performance. Since IMS is itself an organizational innovation, its positive relationships with the whole innovative performance is due to: i) the integration of the benefits from each MS, ii) the introduction of new products/processes, iii) the development of new capabilities, and iv) the pursuit of an increased performance of the firm.

Although scarce empirical research has been done to support the previous arguments, studies oriented to IE report that innovation capabilities allow its improvement (Guan *et al.*, 2006). Such capabilities could be particularly influenced by the full IMS (Hernandez-Vivanco *et al.*, 2016a), which is in line with Bernardo (2014). Consequently, by fully integrating MSs, resources could be more efficiently used to produce innovation outputs. Thus, H1 is formulated:

> **H1:** The full integration of management systems is positively related to higher levels of innovation efficiency.

3.2.2. Innovation Efficiency and Firm Performance

Relating IE and firm performance is not a novel approach; however, there is an ongoing debate about how they are related (Cruz-Cázares et al., 2013). The empirical evidence relating IE and firm performance in the context of this paper is still limited and requires further examination. To this end, and guided by the definition of IE, its effects on firm performance are analyzed considering: i) innovation inputs, ii) outputs, and iii) the whole IE effects (i.e., considering the process of transforming innovation inputs into outputs) over firm performance.

Focusing on innovation inputs, George *et al.* (2002) found that firms can expend less resources for producing more outputs if they exploit their knowledge strengthening the links between the people involved in the innovative process. Weerawardena *et al.* (2006) complemented such results and reported that firms can enhance their learning capabilities, especially in competitive industries, to promote innovation though the optimization of resources. Nonetheless, Koellinger (2008) warned that if inputs do not result into outputs, firm performance may not be directly improved by inputs.

Outputs by themselves could directly produce negative effects on firm performance if companies are not able to compensate the costs needed to produce or protect them (Cruz-Cázares *et al.*, 2013). So, improving firm performance seems to be more linked to the efficiency of transforming innovation inputs into outputs rather than to each individual perspective. This is mainly due to the complexity of the innovative process, which is not only related to inputs or outputs as isolated factors (Tidd and Bessant, 2009).

Considering both innovation inputs and outputs, Klomp and Van Leeuwen (2001) discussed that even if innovation is important for the economic activity, it cannot be stated *a priori* that innovative firms perform better than non-innovative. Instead, it is the innovative process what leads to an enhanced overall performance. Although the authors made a significant progress in this field, they did not consider inputs and outputs from an efficiency perspective.

Regarding studies focused on IE, different approaches have been applied. In some cases, efficiency has been considered beyond the innovation practices by including measurements of performance as part of the outputs, such as market share, sales of new products, exports, profits, productivity, among others. In this line, Guan *et al.* (2006) focused on Chinese firms and revealed that there is a close relationship between firms with high IE and their enhanced competitiveness. According to the authors, this is particularly true when the invested inputs are proportional to firms' performance, which is generally the case. Nonetheless, if the obtained outputs exceed significantly to innovation inputs, such relationship is no longer significant. Such outcomes suggest that to most firms, their performance is directly related to their IE, while a minority attain a better performance through other mechanisms not directly related to IE. Later, Hashimoto and Haneda (2008) applied a similar IE approach in the Japanese pharmaceutical industry. The authors concluded that firms were inefficient when their innovation expenditures increase, but not in correspondence with their diffusion (i.e., sales of new products and technology), which in this case is insufficient. Thus, to attain higher levels of IE firms should focus on the efficient use of their innovative resources and subsequently on the sales of the resulting outputs.

The previous results suggest that there might be a close relationship between IE and firm performance. Following this reasoning, Guan and Chen (2010) considered that the innovation process was subdivided into the R&D and the commercialization sub-processes. Interestingly, their results unveil an unexpected matching relationship between both sub-processes, concluding that firms and governments must promote the whole process from innovation to final commercial outcomes so that IE can be profitable. Complementing the previous outcomes, Wang and Wang (2012) reported that firms with a superior IE achieve better performance compared to their competitors.

Accordingly, Cruz-Cázares *et al.* (2013) focused on this relationship and produced one of the first papers to state a positive causality between IE and firms' performance. The latter authors argued that firms that innovate efficiently perform better due to their proficiency for transforming innovation inputs into innovation outputs. As conferred previously, this would promote firm performance through the correspondence of the commercial activities.

More recently, Wang *et al.* (2016) went deeper into the relationship between IE and their firms' performance in commercial terms. The authors focused on the Chinese energy industry and found that in some cases, firms that devote excessive efforts to increase their performance could potentially jeopardize IE. The authors highlight that, in order to prevent such a risk, firms should implement managerial strategies to promote first their IE efficiency and subsequently their performance. Thus, in the context of this study, IE can be discussed to positively affect firms' performance as stated in H2:

H2: Innovating efficiently has a positive effect on firm performance.

3.2.3. The role of Open Innovation

In the early stages of the OI literature, Chesbrough (2007) discussed the increasing difficulty of traditional (closed) companies to justify innovation investments due to the rising of development costs and shorter life cycles. Thus, OI emerged as a model that promotes new ways to use outer knowledge and technologies. More specifically, it allows the optimization of innovation inputs (i.e., promotes IE) through such external sources, improving and enriching the existing knowledge base (Laursen and Salter, 2006). This would also allow the creation of new products that can be commercialized externally (Chesbrough, 2007).

According to Chesbrough and Bogers (2014), open firms can have inflows and outflows of knowledge. Through inflows, external knowledge sources act as levers of internal processes, which would increase IE through the optimization of the additional knowledge. To this end, firms must plan and balance in-depth both their internal and external resources (Geum *et al.*, 2013). Complementary, outflows are mainly the result of the internal knowledge being leveraged through external commercialization processes, resulting in the enhancement of their performance in commercial terms (Chesbrough and Bogers, 2014). Thus, in OI, both inflows and outflows are compatible by coupling external knowledge sources (which foster IE) and commercialization activities. Therefore, as a global hypothesis derived directly from the basis of OI, H3 is formulated as follows:

H3: Firms that adopt open innovation optimize their innovation efficiency. This, in turn, leads efficient firms to improve their performance.

The previous hypothesis requires further examination in the context of this paper. To this end, firstly the relationship between OI and IE is discussed followed by the role of OI on the effects of IE on firm performance.

Chesbrough and Bogers (2014) highlighted that OI is intended to be in line with the organization's business model. As stated previously, such structure would be involved in the firms' procedures described by MSs (ISO, 2017a). Thus, OI and IMS should be compatible managerial practices leading to increase IE.

Despite the scarce literature analyzing OI and MSs together, the existing empirical evidence seems to be in line with the previous arguments. Related to QMSs, Hoang *et al.* (2006) found that open organizations achieve a better innovation performance, supported on the quality aspects related to leadership, people management, process and strategic management. Similarly, Gavronski *et al.* (2012) found that when firms implement EMSs, the knowledge generated from external cooperation acts as a trade-off factor towards the adoption of new technologies and innovation. Such a compatibility also occurs when analyzing OI in the context of IMS. In fact, OI could coexist in synergy with IMS, increasing innovation capabilities (Hernandez-Vivanco *et al.*, 2016a), which are particularly useful to improve IE (Hashimoto and Haneda, 2008).

Thus, in the context of this paper, OI fosters innovation through the optimization of resources attained through the development of the internal knowledge base (Laursen and Salter, 2006) and capabilities (Cheng *et al.*, 2016). Hence, companies that practice OI use their resources more efficiently, as stated in H3a:

H3a: Open firms are positively related to high levels of innovation efficiency.

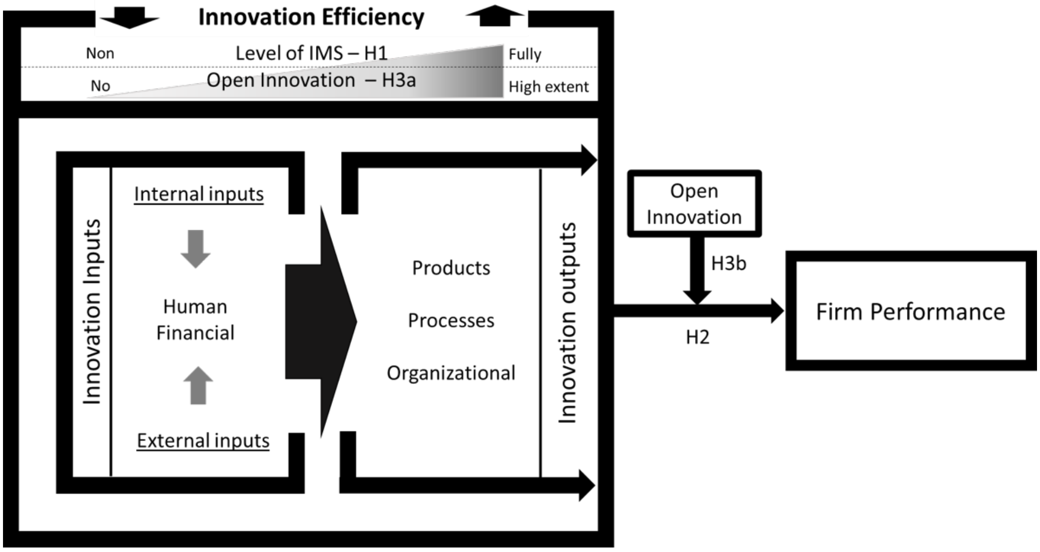
Regarding the role of OI in the relationship between IE and firm performance, several studies had been conducted with different backgrounds. While OI was in the early stages of becoming an official business model, authors like Klomp and Van Leeuwen (2001) and Belderbos *et al.* (2004) found that cooperating with different external sources fosters radical innovations through the complementation of the internal activities. Although such studies did not go deeper into the mechanisms later proposed by Chesbrough (2007), the authors found that external collaborations improve firm performance in commercial terms, more specifically in terms of sales and productivity.

Chesbrough (2007) considers that OI allows companies to capitalize their inventions through new sales. As a result, firms would increase their revenues exploiting new brands, creating spin-offs, licensing new products and generating new sales. Accordingly, Laursen and Salter (2006) found that although OI is an efficient way of innovating, an excess of ideas could lead to time and management problems that could potentially hinder this positive relationship. Complementing the previous work, Greco *et al.* (2016) found that firms that collaborate deeply with their sources, and are thus highly compromised with them, can persistently obtain better results, specially due to radical innovations.

Hence, OI emerged as a tool to increase IE, so firms that adopt it would balance their resources to perform better, contributing to the firm as a strategy to obtain optimum performance results out its innovative process (Wang *et al.*, 2016a). Thus, H3b is developed:

H3b: The effect of innovation efficiency over firm performance is higher for firms that practice OI than for closed firms.

Figure 4 schematizes the model to be tested:



Source: Own elaboration

Figure 4. Model relating the integration of management systems, innovation efficiency, open innovation and firm performance

3.3. Methods

3.3.1. Data and sample

Spanish industries are of special interest due to their familiarity with organizational innovations – namely, MSs – based on the high number of companies with ISO 9001/14001 certifications (ISO, 2017b). The Spanish Innovation Panel, PITEC[3], is selected for the analysis. It is compiled by the Spanish National Statistics Institute (INE) in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). This panel survey registers data of the Spanish Community Innovation Survey (CIS), following the Oslo Manual guidelines (OECD, 2005).

[3] The PITEC database is available free of charge for researchers in https://icono.fecyt.es/PITEC/Paginas/descarga_bbdd.aspx. Further methodological details regarding the actualization, accessibility and coding of PITEC can be found in https://icono.fecyt.es/PITEC/Documents/2016/DatabasePITEC%20(Septiembre%202016).pdf. The PITEC dataset codes QMS and EMS as the importance of the improvements of quality and of the environmental effects, respectively. Both variables are measured by a scale where 1=High importance, 2=Medium importance, 3=Low importance and 4=Not relevant or not employed.

The PITEC dataset was cleaned according to the criteria of the efficiency indicators detailed in the next subsection. All missing values with no consecutive information for at least two years were eliminated. As a result, a total of 570 observations from 220 companies of 13 industries (2 digit CNAE-93 code) were analyzed from 2003 to 2007 due to the availability of data included exclusively in this period. This occurs since the PITEC survey varies some questions across years.

3.3.2. Measurement of IE

A benchmark of the innovative performance represents an accurate measure of IE (Haner, 2002; Wang and Wang, 2012), so it is measured as the relative efficiency of firms for transforming innovation inputs into outputs (Deprins *et al.*, 1984). In this study, inputs are related to the investments and human resources used to innovate (Al-Hakim and Jin, 2014), whilst innovations are considered as the indicators for the outputs of the innovative process (Haner, 2002).

This research is based on proxies for measuring innovation inputs and outputs, which is a common approach in the IE literature (Acs *et al.*, 2002; Hashimoto and Haneda, 2008; Guan and Chen, 2010; Cruz-Cázares *et al.*, 2013; Guan *et al.*, 2016; Wang *et al.*, 2016a).

3.3.2.1. Inputs selection

The chosen inputs are Innovation Capital Stock (ICS) and the number of persons involved in the innovative process (PINN). ICS considers all the innovation expenses (Hashimoto and Haneda, 2008), which are highly correlated with knowledge generation (Romer, 1991). ICS is consistent with other studies using R&D Capital Stock as a proxy of Knowledge Stocks (see e.g., Guan *et al.*, 2016). Thus, ICS is used as a measure of innovation knowledge generation and is obtained by Equation 1. A conventional depreciation (γ) of 15% for Low and Medium Technology (LMT) industries and of 30% for High Technology (HT) (see e.g., Cruz-Cázares *et al.*, 2013) for each set of two years from 2003 to 2007 is considered, where IC_{it} represents the Innovation Capital Expenses of firm *i* at time *t*:

$$\text{(Equation 1)}\quad ICS_{it} = IC_{it} + (1\text{-}\alpha)IC_{i(t\text{-}1)}$$

Regarding PINN, it includes the number of persons involved in the innovative processes (Hashimoto and Haneda, 2008; Wang *et al.*, 2016). This is equivalent to measuring the R&D human resources (Guan and Chen, 2010; Lee *et al.*, 2010) at all stages of innovation. Other studies have focused on the number of high skilled staff (Cruz-Cázares *et al.*, 2013) and full time researchers (Guan *et al.*, 2016); however, PINN already englobes all the involved human resources.

3.3.2.2. Outputs selection

Process, product and organizational innovations are outputs of the innovative process. Patents are used as an indicator of product and process innovations. They have been previously used as a proxy for technological innovations (Cruz-Cázares *et al.*, 2013) and R&D Knowledge Stocks (Guan *et al.*, 2016). Moreover, they are a reliable indicator of innovative activity (Guan and He, 2007) and of the quality of such innovations (Griliches, 1990). Thus, the number of patents represent an accurate R&D output resulting from new inventions (Acs *et al.*, 2002; Guan and Chen, 2010; Cruz-Cázares *et al.*, 2013).

Process innovations bring with it significantly improved production methods (OECD, 2005), and most are intended to lower the cost of production (Klepper, 1996; Hashimoto and Haneda, 2008). To this end, firms must invest in innovation to improve their production capacity, which is a suitable strategic decision due to the improvement of the bargaining position gained through it, even when it might affect the efficiency of the system (Plambeck and Taylor, 2005). Thus, the importance of improving the production capacity is used as an output mainly related to process innovations. Respondents of the PITEC survey could choose among four possibilities, reporting this importance as null, low, medium or high.

Finally, the level of IMS is considered as a specific case of organizational innovation (Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo, 2014) and is thus included as an output of innovation. Among the several taxonomic schemes for classifying the level of IMS, Zeng *et al.* (2007) analyzed it at different stages of a company. According to the authors, at the strategic level the MSs objectives are given the top priority, which determines IMS at more operational stages. Thus, this study focuses on the strategic stage as a proxy for the overall level of IMS. More specifically, it focuses on the integration of the quality and environmental objectives based on their priority at the strategic level, using the methodology applied in Hernandez-Vivanco *et al.* (2016a). The importance of both the QMS and EMS were included in PITEC only from 2004 to 2007, so this study had to be limited to this period.

The level of IMS was measured as "fully", "partially" or "non-integrated", so Table 12 summarizes the coding procedure (Hernandez-Vivanco *et al.*, 2016). Firms that were integrated corresponded to 79.65% of the sample. This is in good agreement with the high integration level at the strategic stage –more than 78% in policy, objectives and planning– in most Spanish companies (Bernardo *et al.*, 2012). As expected, the level of IMS at the strategic stage determines the overall level of IMS previously reported in Spanish firms: more than 76% in most firms described by Bernardo *et al.* (2009; 2012) and a minimum of 78% according to Abad *et al.* (2014).

Table 12. Measurement of IMS

Score of QMS and EMS indicators [(a)]	**Level of IMS**	**Codification**	**Frequency**	**%**
Highest score for QMS and EMS	Fully integrated	3	88	15.44
Both are relevant and employed, but not having the highest score at least for one of the MS	Partially integrated	2	366	64.21
Not relevant or not employed at least for one MS	Non-integrated	1	116	20.35

Source: Own elaboration

3.3.2.3. Measurement model of IE

For measuring innovation efficiency scores, the Partial Frontier Approach, namely the *order-α* input oriented method is selected (Aragon *et al.*, 2005). This method is a generalization of the Free Disposal Hull (FDH) (Deprins *et al.*, 1984), but only assumes the input disposability of the Decision Making Units (DMUs – in this case, firms). In managerial terms, this assumption means using less inputs for obtaining more outputs. The *order-α* is less sensible to outliers compared to Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978).

Outliers are identified using different order-α (α = 95, 96, …, 100) (Daraio and Simar, 2007). Moreover, the potential economic issue of producing (non-zero) outputs without consuming resources (Thanassoulis *et al.*, 2008) is also solved. An intertemporal estimation is considered to get comparability between firms over years (Mittal *et al.*, 2005). The bootstrapping method is useful for estimating the standard errors (refer to Tauchmann (2012) for further econometrical details). The cleaning of the PITEC database is based on the former requirements, obtaining a final dataset of 570 observations.

3.3.3. Model for the comparison of IE based on IMS and OI

This subsection explains how H1 and H3a will be tested. This is, testing how IE is different whether firms are Fully integrated vs not (H1) and whether they are an open firm or not (H3a).

A proxy for IMS was obtained in Table 12. To measure OI, the OPEN variable indicates whether firms cooperated externally between $t-2$ and t for innovating (Barge-Gil, 2013); its descriptive statistics are summarized in Table 13, panel A. This variable is obtained directly from the PITEC survey and equals one if firms collaborated actively with at least one source among: i) suppliers, ii) clients or customers, iii) competitors, iv) consultants and labs, v) universities or other higher education institutions, vi) public research institutes, and vii) technological centers; otherwise OPEN is coded as zero.

The Mann-Whitney-Wilcoxon test (Wilcoxon, 1945; Mann and Whitney, 1947) will provide the likelihood of having higher IE depending on the level of IMS and openness. The Harrell's C statistic (Newson, 2006) will be applied for estimating the probability and the confidence intervals of: i) non-fully integrated firms to be more efficient than fully integrated (H1), and ii) firms that perform OI to be more efficient than their counterparts (H3a).

3.3.4. Model for measuring the effects on firm performance

In this subsection, a model for testing H2 and H3b is developed. This is, measuring the effect of IE on firm performance (H2) and the moderating effect of OI in the previous relationship (H3b).

3.3.4.1. Dependent variable

The innovative sales productivity is used as a proxy for firm performance, as it is directly related to IE through the market perspective (Wang *et al.*, 2016a). This measure reflects the productivity of the firms for transforming their innovations into sales, standardized in terms of their size (employees). Thus, the innovative sales productivity is a measure of the innovative sales per employee (Belderbos *et al.*, 2004; Tsai, 2009) as shown in equation 2. Its descriptive statistics are shown in Table 13, panel A.

(Equation 2) Innovative sales productivity = ln ((% of sales of new products / number of employees) + 1)

3.3.4.2. Independent variables

This model aims to determinate the effect of IE on firm performance (H2), and the moderating effect of OI (H3b). The IE scores are taken from section 3.2. and OI is measured in terms of the variable OPEN. Table 13, panel A summarizes the dependent and explanatory variables used in this model.

3.3.4.3. Control variables

Different industries produce different innovation results (Lanjouw and Schankerman, 2002; Hoang *et al.*, 2006). Moreover, the company size may vary IMS implementation (Zeng *et al.*, 2007), and might present different results in terms of IE and firm performance (Cruz-Cázares et al. 2013), so it is included as a dummy variable that equals 0 for Small and Medium Enterprises (SME) and 1 for Large. Finally, the variable Year is also considered since this is longitudinal study. Table 13, panel B summarizes the descriptive statistics of the control variables.

Table 13. Descriptive statistics of the panel regressions variables

PANEL A. INDEPENDENT AND DEPENDENT VARIABLES

Continuous Variables	**Mean**	**Std.Dev.**	**Min**	**Max**	**Proxy for**
Innovative sales productivity	0.3585	0.5195	0	3.0445	Firm Performance
Innovation Efficiency scores	0.6576	0.3313	0.0193	1	Innovation Efficiency
Dummy Variable	**Codification**	**Frequency**	%		**Proxy for**
OI between $t-2$ and t	*OPEN*				Open Innovation
Closed	0	233	39.12		
Open	1	347	60.88		

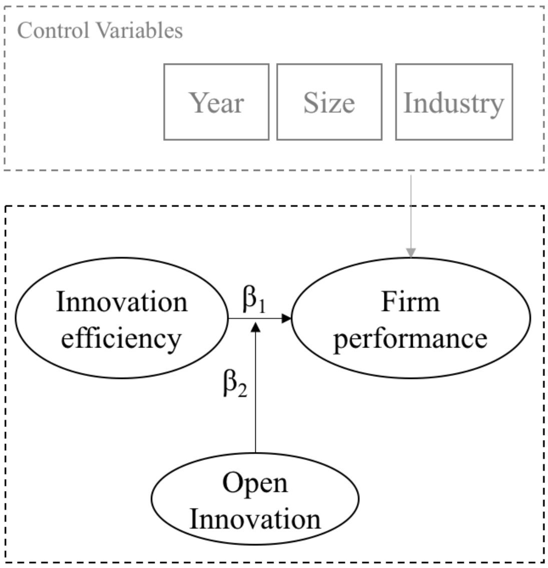
PANEL B. CONTROL VARIABLES

Dummy Variable	**Codification**	**Frequency**	%
Industry			
Food&beverages	0	42	7.37
Chemical	1	53	9.30
Pharmaceutical	2	45	7.89
Rubber & plastics	3	28	4.91
Metal	4	54	9.47
Machinery	5	112	19.65
Electrical equip.	6	54	9.47
Medical tools	7	46	8.07
Motor vehicles	8	17	2.98
Commerce	9	28	4.91
Software	10	14	2.46
R&D	11	63	11.05
Architecture	12	14	2.46
Size			
SME	0	398	69.82
Large	1	172	30.18
Year			
2005	2005	158	27.72
2006	2006	220	38.60
2007	2007	192	33.68

Source: Own elaboration

3.3.4.4. The model relating innovation efficiency and open innovation with firm performance

A panel regression analysis will be used to analyze how IE and OI are related to firm performance. The innovative sales productivity is used as a proxy of the performance in commercial terms. As previously shown in equation 2, its minimum value is zero when firms do not produce any sales from its new products, which means that data is censored or limited at this point. This characteristic can be controlled using the left-censored-Tobit approach (Tobin, 1958). The random-effect panel analysis is selected to avoid biased estimates of fixed-effects (Honore, 1992), and for obtaining conclusions about the whole population. Hence, the Censored-Tobit and non-censored panel regressions will be estimated using Stata/SE 14.0 to compare the robustness of these models. Figure 5 represents these analyses, where β_1 refers to H2 and β_2 to H3b.



Source: Own elaboration

Figure 5. Panel regression and Censored-Tobit representation

3.4. Results

First, the results of the efficiency scores are shown in Table 14. It is evidenced that LMT firms have a slightly lower efficiency mean compared to HT. Although on average such differences are not greatly different, this might be attributed to the fact that LMT base their innovations on their creativity to transform innovation inputs into outputs rather than on science.

Conversely, HT firms are more dependent on developing their competitive advantages from an efficient process of science-based innovations to survive in more turbulent environments (Bender and Laestadius, 2005; Cruz-Cázares *et al.* 2013). Regarding industries, it is not surprising to find different efficiency scores even within the same category of LMT or HT industries. This outcome can be mainly attributed to the fact that firms use resources and produce outputs that are mainly comparable with other firms from the same industry (Guan *et al.* 2006; Lee *et al.* 2010; Cruz-Cázares *et al.* 2013).

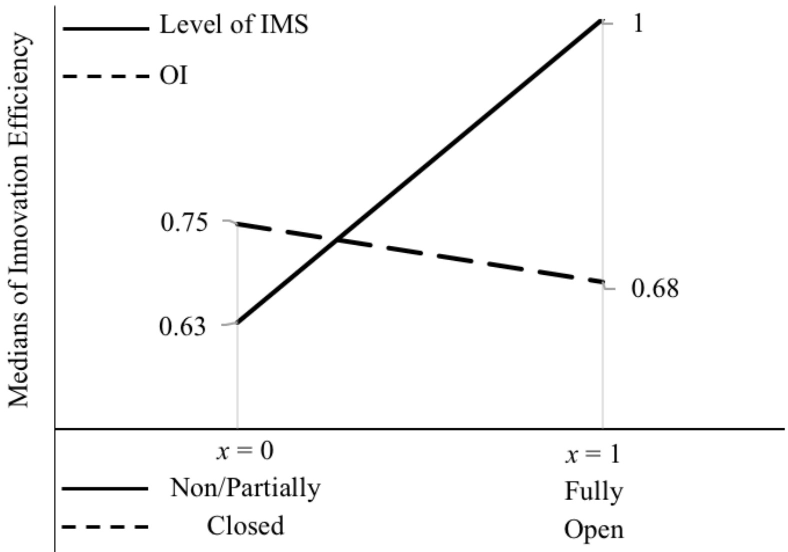
Table 14. Innovation Efficiency Scores

Industry	Obs	Mean	Std. Dev.	Min	Max
LMT	**166**	**0.7040**	**0.3236**	**0.0571**	**1**
Food & beverages	42	0.7742	0.3017	0.1154	1
Rubber & plastics	28	0.7681	0.3251	0.0827	1
Metal	54	0.6181	0.3193	0.0571	1
Commerce	28	0.5871	0.3431	0.1429	1
Architecture	14	0.9303	0.1498	0.5276	1
HT	**404**	**0.6385**	**0.3330**	**0.0193**	**1**
Chemical	53	0.5227	0.3582	0.0361	1
Pharmaceutical	45	0.8361	0.2396	0.2857	1
Machinery	112	0.6071	0.3439	0.0542	1
Electrical equipment	54	0.6153	0.3366	0.0958	1
Medical tools	46	0.6666	0.2956	0.0494	1
Motor vehicles	17	0.6919	0.4217	0.0193	1
Software	14	0.6337	0.3269	0.1854	1
R&D	63	0.6369	0.2978	0.0995	1
Total	**570**	**0.6576**	**0.3313**	**0.0193**	**1**

Source: Own elaboration

The results from the Mann-Whitney-Wilcoxon tests for H1 and H3a (Figure 6) suggest that IE of the fully integrated companies is significantly higher (median = 1) than non-fully integrated (median = 0.75) with an associated probability of 0.67, so H1 is supported.

Conversely, closed companies are significantly more efficient (median = 0.75) than open firms (median = 0.68) with an associated probability of 0.55, thus rejecting H3a.



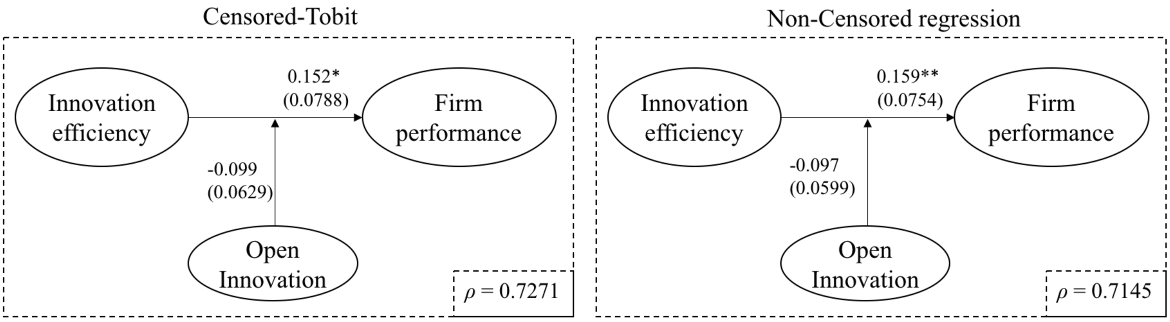
Harrell's C

x	$P(IE(x = 0) > IE(x = 1))$	95% CI
Level of IMS	0.3300*** (0.0278)	[0.2755, 0.3845]
OI	0.551** (0.0238)	[0.5044, 0.5978]

p-value for the Mann–Whitney–Wilcoxon test: ** p<0.05, *** p<0.01.
The H_0 is that the efficiency is the same
i) at any level of IMS and ii) for closed and open firms.
Source: Own elaboration.

Figure 6. Test of medians for EFF comparing Level of IMS and OI

Regarding the effects on firm performance, both the Censored-Tobit (34 censored observations) and the non-censored panel regressions are robust with high rho-values (ρ) (Pedroni, 2004), above 0.70 as summarized in Figure 7. The analyses evidence that IE positively affects firm performance in terms of innovative sales productivity, hence H2 is supported. However, even if ~60% of the firms are open, OI does not moderate the previous relationship, so H3b is not supported.



*p<0.06, **p<0.05. Standard errors in parentheses.
N=570. OPEN=0 is the reference.
Source: Own elaboration.

Figure 7. Panel Censored-Tobit and non-censored regressions' results of the main model.

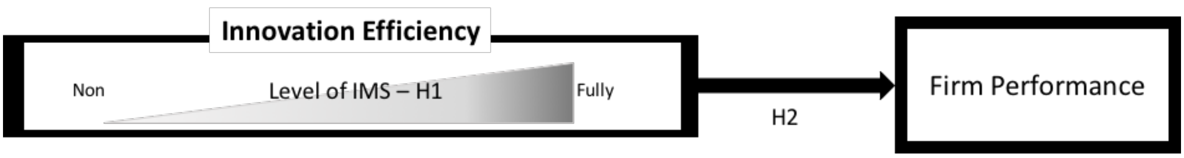
The results for control variables are summarized in Table 15. They suggest that SMEs perform better compared to Large companies since they devote less employees to create more innovative sales. This might be due to their market-driven rather than research-driven orientation that allows them to respond quicker to new opportunities (OECD, 1997). Industries have no significant differences of their innovative sales productivity respect to the reference (Food & beverages), except Software which performance is significantly higher. Finally, the variable year was not significant.

Figure 8 summarizes the hypotheses which results are empirically supported. Thus, results suggest that fully integrated companies are more efficient innovating (H1), and IE positively affects firm performance (H2). Moreover, H3a is not supported, and results are contrary to the hypothesis: companies that practice OI are found less efficient innovating. Finally, H3b is not supported since OI does not moderate the effect of IE over firm performance. Thus, H3 is not supported.

Table 15. Control variables and constant coefficients

	Firm Performance	
Variables	**Panel Censored-Tobit**	**Panel Non-Censored Regression**
Size		
1.Large	-0.294*** (0.070)	-0.310*** (0.0668)
Year		
2006	0.029 (0.028)	0.028 (0.027)
2007	0.002 (0.029)	0.003 (0.028)
Industry		
1.Chemical	0.111 (0.139)	0.112 (0.112)
2.Pharmaceutical	-0.045 (0.148)	-0.043 (0.141)
3.Rubber & plastics	-0.137 (0.145)	-0.133 (0.139)
4.Metal	-0.010 (0.144)	-0.007 (0.138)
5.Machinery	0.137 (0.127)	0.144 (0.121)
6.Electrical equip.	-0.100 (0.143)	-0.080 (0.137)
7.Medical tools	0.199 (0.153)	0.228 (0.146)
8.Motor vehicles	-0.091 (0.203)	-0.044 (0.191)
9.Commerce	-0.030 (0.166)	0.022 (0.157)
10.Software	1.172*** (0.214)	1.165*** (0.205)
11.R&D	0.204 (0.142)	0.215 (0.135)
12.Architecture	-0.121 (0.220)	-0.007 (0.204)
Constant	0.296** (0.127)	0.298** (0.122)

References are SME, Year 2005 and Industry=0 (Food & beverages) for Size, Year and Industry respectively. ** $p<0.05$, *** $p<0.01$. Standard errors in parentheses.
Source: Own elaboration.



Source: Own elaboration.

Figure 8. Empirically supported hypotheses

3.5. Discussion and conclusions

In this study, the Integration of Management Systems and Open Innovation are studied as two managerial drivers of innovation efficiency in pursuit of improving their performance. Using a sample of 220 Spanish companies, the results obtained are discussed as follows.

According to the results, H1 is supported, suggesting that full IMS drives IE. From the MSs viewpoint, IMS is discussed as a potential contributor to integrate the specialists' knowledge by stablishing common goals that result from the cooperative objectives of each of the function-specific MSs (Karapetrovic, 2003). Such way of organizing empowers the whole firm for completing their tasks focused on the common objectives, overcoming difficulties and innovating (Wong *et al.*, 2009). Thus, IMS seems to facilitate the creation of links between specialists proposed by the KBV theory. Thus, albeit only 15.44% of the firms were fully integrated, IMS benefits for increasing efficiency seem to go beyond the organizational standpoint (Wagner, 2007a; Simon *et al.*, 2012; Simon and Douglas, 2013). According to the results, IMS appears to create an accurate environment for achieving higher IE, which could be a consequence of the increased innovation capabilities obtained from full IMS (Hernandez-Vivanco *et al.*, 2016a).

A concern about MSs is they might hinder innovation (Prajogo and Sohal, 2001), so the adequate atmosphere in terms of culture and human resources must be created to address this issue from the structure to the daily practices (Palm *et al.*, 2016). In the innovative process, IMS promotes transparency and awareness of interdependences between function-specific MSs, while simultaneously optimizing new developments from a quality and environmental perspective (von Ahsen, 2014). Thus, results suggest that fully integrated firms not only innovate more efficiently, but also optimize both quality aspects and environmental impacts of their inventions.

Confirming H2 suggests that companies that are more efficient innovating have better chances of translating that efficiency into sales productivity of new products. Wang and Wang (2012) found a similar influence in intensity and significance when asking firms to evaluate both factors from their own perspective. This study confirms the former results and diminishes subjectivity by benchmarking (measuring efficiency) objectively, finding results in line with previous literature (Guan and Chen, 2010; Cruz-Cázares *et al.*, 2013; Wang *et al.*, 2016a).

Regarding OI, H3 is not empirically supported. Results suggest that open firms are significantly less efficient innovating than closed firms, contrary to H3a. Although the difference is significant, the probability of open firms being more efficient than closed firms is 45%. Such probability, although close to having non-significant differences, might be due to the requirement of more resources to innovate compared to closed firms (Laursen and Salter, 2006; Greco *et al.*, 2016), which results on a limited increase of innovation outputs (Cuerva *et al.*, 2014). Nonetheless, such relatively small difference in IE seems to be manageable through the same innovation capabilities resulting from OI (Cheng *et al.*, 2016).

H3b is also rejected, suggesting that OI does not moderate the relationship between IE and firm performance. Previous studies found empirical evidence of the direct positive influence of external cooperation on firm performance (see e.g., Belderbos *et al.*, 2004). Nonetheless, even if open firms are found less efficient innovating, the effect of IE over firm performance is not statistically different for both open and closed companies. Thus, the inefficiency derived from the additional inputs used in OI is not transmitted to firms' innovative sales productivity.

Rejecting H3 (H3a and H3b) does not implicate that OI should not be performed. In fact, the ability of companies to recognize, assimilate and apply the information derived from OI, named absorptive capacity (Cohen and Levinthal, 1990), cannot always be captured by all the areas from the different sources for innovating (Bogers and Lhuillery, 2011). This capacity largely depends on the firms' prior knowledge, experience and history (Cohen and Levinthal, 1990). Consequently, there is a strong need of further researching into other aspects of OI, due to the high complexity of its interactions with IMS.

This research has three main implications for the academia. Firstly, this paper analyzes IMS minimizing subjectivity since firms were not asked to assess directly their level of IMS; instead, the latter was measured based on their quality and environmental performance, with the data provided by the PITEC survey. Thus, results led to conclude that full integration could act as a relevant driver of IE. This might be attributed to the links provided by such integration, which fosters the optimization of human and financial resources by aligning the firms' goals. Secondly, IE means optimizing resources for obtaining more innovation outputs (process, product and organizational), which in turn promotes firms' performance. Hence, the efforts invested in innovation pay off through resources optimization and higher productivity of sales of new products. Finally, this study evidences the necessity of understanding to what extent OI might be beneficial and detrimental depending on the level of IMS.

The managerial implications of this study are mainly four. Firstly, companies that have implemented more than one MS (not necessarily certified) must be aware that the benefits of full IMS go beyond the operational efficiency, since it also enhances the firms' innovation efficiency. Secondly, the former outcome leads to a performance, hence increasing the firms' competitiveness efficiently. Thirdly, full IMS fosters the optimization of resources through the unification of goals; this permits a more efficient execution of innovation activities. Finally, although results suggest that OI might hinder IE, it is also remarked that such differences are manageable, so firms must seek for efficient sources of knowledge according to their needs and exploit the resulting knowledge and capabilities. To this end, clear objectives must be defined consistently with external sources to promote the creation of additional innovation outputs and thus, minimize the risk of devoting excessive resources compared to their closed peers.

This is one of the first studies finding empirical evidence of two managerial practices seeking to foster IE: OI and IMS. It also contributes to the IE literature by measuring product, process and organizational innovations. Finally, this research sheds light on understanding the relationships of IE with firm performance in the context of IMS and OI.

Despite the contributions of this study, it is not absent of limitations. Firstly, using a secondary database limited this study to the available information, so it was not possible to consider: i) other MSs (e.g., Accounting Sustainability, Operational Health and Safety, among others), ii) other important aspects related to sustainability, and iii) extend the study to more recent observations. Secondly, even if measuring the variables of this study minimized subjectivity, some proxies had to be used based on the existing literature. Finally, only the Spanish firms that were included in the PITEC survey were considered, so these conclusions might not be representative of other populations in which MSs have not been widely implemented.

Future research will be focused on analyzing the role of OI and IMS when IE increases, as well as analyzing differences among sectors.

CHAPTER 4. SUSTAINABLE INNOVATION THROUGH MANAGEMENT SYSTEMS INTEGRATION

Abstract

Purpose: Sustainable development requires voluntary actions and a strong commitment, and cleaner production is one of the most adopted sustainability practices across organizations. Moreover, the integration of management systems (IMS) and innovation are two strategic promotors of sustainable development. However, how both IMS and innovation are related in pursue of sustainability remains scarcely researched. Thus, the aim of this article is to explore if IMS promotes sustainability-oriented innovations within the framework of cleaner production.

Design/Methodology/Approach: This is based on 40 surveys of Latin-American and European candle manufacturers. A model for measuring IMS at the strategic level was developed considering quality, environmental, corporate social responsibility and health & safety management systems. Data was analyzed using Partial Least Squares to assess simultaneously the relationships between IMS, the adoption of cleaner production technologies and sustainable product innovation.

Findings: Results suggest that IMS is closely related to the adoption of cleaner production technologies and that, through this factor, IMS fosters the development of sustainable products. The positive relationship between the adoption of cleaner production technologies and sustainable product innovation is also evidenced.

Originality: This is one of the first studies that considers different continents to research into the relationships between IMS and sustainable innovation.

Keywords: Management systems integration; innovation; sustainability; cleaner production.

4.1. Introduction

The global concern about environmental care, social awareness and sustainability has increasingly caught the attention of practitioners and researchers (Oskarsson and Malmborg, 2005; Gianni *et al.*, 2017a). In light of the current business environment, sustainable development emerged as a new competitive advantage, including sustainable initiatives and a wider perspective of profitability, that involves environmental and social values (Sroufe, 2017). Thus, companies in real pursue of sustainability are required to innovate, change their organizational structure and integrate their strategies to overcome barriers and become more sustainability-oriented (Lozano *et al.*, 2016).

From the organizational perspective, the integration of management systems (IMS) is defined as a 'system of systems' (Karapetrovic and Willborn, 1998b) that provides a systematic approach to amalgamate different perspectives, including environmental (EMS), quality (QMS), corporate social responsibility (CSR) and occupational health and safety (OHSMS) management systems (MSs) (Zwetsloot, 1995). Thus, IMS seems to provide the necessary holistic framework to achieve corporate sustainability (Vieira and Amaral, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017; Sroufe, 2017). More specifically, it promotes isomorphism across the organization by giving all the MSs the same importance to internalize their underlying principles (Zeng *et al.*, 2007; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). Moreover, IMS has the advantage that its certification remains inexistent, so its implementation seems not to be symbolic (Gianni *et al.*, 2017a).

Furthermore, sustainable companies reflect this approach through the improvement and creation of new processes and products (Boons *et al.*, 2013). This strategy allows companies to maximize the benefits of the triple bottom line (TBL); i.e., economic, environmental and social benefits (Elkington, 1997). To this end, the Cleaner Production (CP) basis has been recognized as a remarkable voluntary corporate initiative to sustainability (Bonilla *et al.*, 2010; Lozano, 2012). This strategy seeks to continuously applicate integrated preventive actions to increase companies' efficiency and reduce at the source (in processes and products) the environmental and social risks (UNEP DTIE, 1996). To this end, companies utilize technological solutions to minimize the environmental and social impacts of their operations before they leave a production process (UNEP DTIE, 1996; Kemp and Volpi, 2008; Vieira and Amaral, 2016). This objective is in line with sustainable product innovations, which seek to reduce, from the design, the environmental and social impacts over their entire life cycle (UNEP DTIE, 1996; Rebelo *et al.*, 2016).

Since both IMS and innovation are relevant to sustainable development, they seem to be closely related (Gianni *et al.*, 2017a). Recent theoretical (Bernardo, 2014) and empirical studies (Simon and Petnji Yaya, 2012; Hernandez-Vivanco *et al.*, 2016a), have generally found a positive association between both IMS and innovation. Nonetheless, scarce research has related these concepts in pursue of sustainability (Nunhes *et al.*, 2016; Gianni *et al.*, 2017a) and the debate of a positive relationship is open-ended (Ramos *et al.*, 2018). Hence, the aim of this article is to contribute to the state-of-the-art by exploring, with an intercontinental scope, if IMS acts as a promotor of CP-oriented process and product innovations.

4.2. Theoretical framework

In this section, firstly sustainable innovation is analyzed in the context of CP to relate the adoption of CP technologies and sustainable product innovation. Then, the relationship between IMS and the adoption of CP technologies, and sustainable product innovation are analyzed.

4.2.1. Sustainable process and product innovations

According to the OECD (2005), both process and product innovations have different objectives; the former is related to the implementation of a new or significantly improved production or delivery methods. The latter is related to significant changes in the capabilities of goods or services. To become sustainably oriented, such innovations must benefit the TBL with measurable improvements (Sroufe, 2017). Thus, companies are challenged to manage the existing trade-offs between the economic, environmental and social impacts so that process and product innovations do not have (negative) consequences between them or in another area (Rocha *et al.*, 2007). To this end, companies should implement radical innovations embedded in the companies' wider socio-economic context (Boons *et al.*, 2013).

From the operations standpoint, Muñoz-Villamizar *et al.* (2018) suggested that, in order to assess and improve their sustainable performance, companies should consider four factors: i) complying with their location's regulations and certifications, ii) rationalizing their resources across the value chain, iii) improving their raw materials through the implementation of circular economy strategies, and iv) improving their production processes. According to the authors, the latter is often the factor that has the greatest environmental impact since this is what companies can best manage directly. As a consequence, companies aiming to become sustainability-oriented seem to prefer beginning their transition from process innovations and then move forward to the other factors. In this line, Sroufe (2017) discussed that process improvements that enable energy conservation as well as waste reductions at source are necessary to bring new sustainable products to the market. According to the author, such new products would be designed using ecological and less hazardous new materials.

Given the strategic importance of adopting a sustainable management approach, Boons *et al.* (2013) identified that companies should be forthcoming to make great efforts to successfully achieve the required transitions. This means that, the more innovations related to the technical and sustainability attributes of new products, the larger the effort that companies must make. Thus, as long as creating sustainable products is profitable and customer oriented, companies ought to invest in such innovations and in actions to preserve the environment (Ramos *et al.*, 2018). Such approach would foster, from the design, waste and emissions reductions, as well as the minimization of risks to the environment and society, in accordance with CP (UNEP DTIE, 1996; Kemp and Volpi, 2008; Vieira and Amaral, 2016).

Adopting a new technology, in particular if it is CP oriented, requires a great effort and a strong strategical commitment since it might implicate changing radically the companies' operations (Boons *et al.*, 2013). According to the CP framework, such changes would be related to both: process and product innovations. Thus, it can be expected that companies that adopt CP technologies in pursue of sustainability will also introduce sustainable product innovations aiming to benefit the TBL, as stated in H1:

> **H1:** The adoption of cleaner production technologies is positively related to sustainable product innovation.

4.2.2. *The integration of managements systems and the adoption of cleaner production technologies*

Companies are continuously challenged to comply with the different requirements of the multiple stakeholders. To this end, they implement individual MSs –such as QMS, EMS, OHSMS and CSR– aimed to respond to their specific demands. In the course of this process, companies are faced with a “puzzle” of MSs that should be integrated into a unique and more efficient integrated MS (Rebelo *et al.*, 2016). For this purpose, companies must firstly give the same (high) importance to all the MSs (certified or not) within the organization (Zeng *et al.*, 2007; Gianni and Gotzamani, 2015; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). To analyze how IMS is related to the adoption of CP technologies, the contributions of each MS are analyzed as follows.

EMSs are adopted to deal with the environmental dimension of the companies’ operations, with the advantage that it promotes the better use of resources, which usually leads to cost reductions (Lozano, 2012). To reach this benefit, companies have to necessarily change and improve their current operations, so they must modify or introduce new processes (Lim and Prakash, 2014). When such innovations occur in the framework of an EMS strategy, companies aim to eliminate any potential environmental risk at source, which promotes the adoption of CP technologies (Radonjič and Tominc, 2006).

Even if the environmental motivations seem to be clear for implementing CP technologies, companies are usually more conscious about the quality dimension of their operations (Ramos *et al.*, 2018). Interestingly, and from the QMSs’ perspective, pollution could be considered as a ‘quality defect’ that should be reduced or eliminated at the source instead of just being controlled (Khanna *et al.*, 2009). Although this objective is in line with the CP approach, it also demands companies to step further. To effectively obtain process innovations oriented to improve quality, the latter should be considered beyond the limited scope of control and inspection. Its adoption should be widened to the strategic vision of continuous improvement (Hoang *et al.*, 2006; Moreno-Luzon *et al.*, 2013).

Besides fostering environmental care, CP technologies should also pursue the minimization of risks posed to society, including workforce (UNEP DTIE, 1996). Thus, OHSMSs have a relevant role. Since adopting a new technology usually implicates new or different workforce risks, OHSMSs are useful to provide companies of the necessary means to manage them (Bottani *et al.*, 2009; Santos *et al.*, 2013). Simultaneously, OHSMSs contribute to the reduction of wastes and the improvement of quality, which complements the contributions of the other MSs (Zwetsloot, 1995; Lo *et al.*, 2014).

Moreover, CSR is in line with EMSs and OHSMSs' goals, but expanding its frontiers outside the organization, so it takes place under the aegis strategic management (Lozano, 2012). Thus, it is not surprising that CSR and EMS are being increasingly adopted and integrated due to both, internal motivations (higher effectiveness) and external demands calling for more information regarding environmental and social performance (Oskarsson and Malmborg, 2005). According to the latter study, the adoption of CSR and EMS could foster innovation if (and only if) companies act proactively rather than just responding to the legal demands or the demands in the standards. Otherwise, such MSs might hinder instead of promote innovation (Oskarsson and Malmborg, 2005). Henceforth, companies dealing with such proactive approach regarding environmental and social practices are replacing other companies with more traditional strategies such as low-price oriented. Thus, it seems that CSR, besides being aligned to the CP framework, reinforces the other MSs providing the organization of a more holistic strategy that includes sustainability priorities (Longoni and Cagliano, 2015). As a result, the CSR adoption seems to act a strategical support to promote the adoption of CP technologies through its sustainability-oriented framework.

By giving a high importance to all MSs, IMS captures their synergies to promote process innovations (Simon and Petnji Yaya, 2012; Bernardo, 2014; Hernandez-Vivanco *et al.*, 2016a). Moreover, IMS provides a sound focus and clear insights towards sustainability goals (Mustapha *et al.*, 2017); i.e., to use efficiently resources/costs (Zwetsloot, 1995) and minimize environmental and social impacts (Gianni *et al.*, 2017a) through innovation (Rebelo *et al.*, 2016). Thus, IMS seems to give companies the necessary managerial support to adopt CP technologies (Vieira and Amaral, 2016; Mustapha *et al.*, 2017; Ramos *et al.*, 2018) as stated in H2:

> **H2:** The integration of management systems is positively related to the adoption of cleaner production technologies.

4.2.3. *The integration of management systems and sustainable product innovation*

Mustapha *et al.* (2017) recognized IMS as a sustainable green MS that stimulates companies to move towards a sustainability approach through the optimization of costs and time. The authors attributed such IMS benefits to the abatement of redundancies and the simultaneous enhancement of productivity. According to the conclusions of that study, it seems that IMS is more related to sustainable process innovation rather than product innovation.

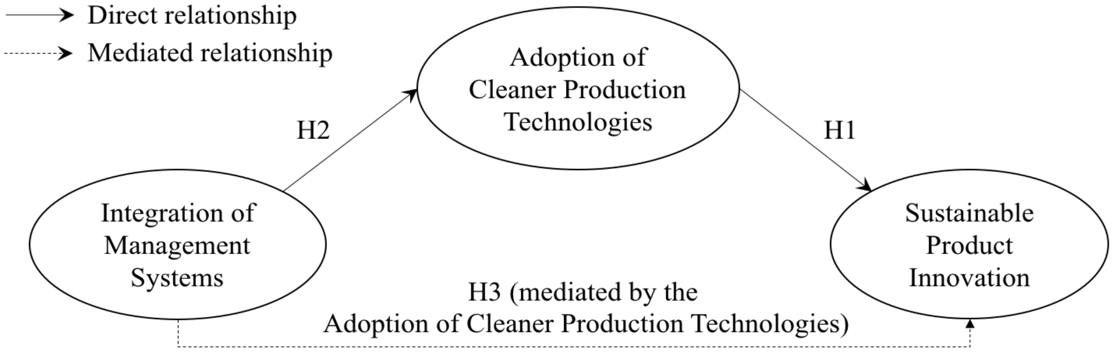
In spite of the direct relationships between IMS and process innovations, sustainability professionals are well aware of the imperative need of applying this strategy across the value chain and involving both processes and products (Rebelo *et al.*, 2016; Sroufe, 2017). On this basis, sustainable innovation is required not only to meet with the internal (process) CP requirements, but also to attend the needs of the different stakeholders across the value chain (Muñoz-Villamizar *et al.*, 2018). It is in this process that IMS becomes crucial by its purpose of attending equally the needs and goals of the diverse stakeholders across the value chain (Jørgensen, 2008). Thus, the relationship between IMS and (sustainable) product innovation is plausible (Tarí and Molina-Azorín, 2010; Bernardo, 2014), but it seems not to be direct. Thus, the path of the relationship between IMS and sustainable product innovation has to be further developed.

Although IMS and innovation have been generally positively related (Bernardo, 2014; Gianni *et al.*, 2017a), most studies have focused on a general definition of 'innovation' rather than the specific types of innovation proposed by the OECD (2005). Simon and Petnji Yaya (2012) present one of the first studies attempting to disentangle the IMS effects on the different types of innovations, namely process, organizational and marketing innovations. According to the authors, the better use of systems resulting of IMS fosters all three types of innovation, which in turn, improve customer satisfaction. These latter effects might be instrinsically atribitued to new and improved products (innovation). Although this last argument was not empirically tested in Simon and Petnji Yaya (2012), the significant relationship between IMS and product innovation was later found in Hernandez-Vivanco *et al.* (2016a). The authors conclude that IMS improves the odds of innovating in both processes and products, but they also observe that companies must be open to collaborate with external parties –including the stakeholders of the supply chain, where IMS is particularly relevant– so that both process and product innovations are positively related; otherwise, process innovations might hinder product innovations. Thus, it seems that a previous relationship between IMS and process innovations is required so that both contribute to create new or improved products. This indirect relationship could be suspected to maintain when focusing on sustainable innovations.

To create sustainable products and achieve excellence, organizations must be proactive regarding continuous improvement and should implement organizational and process innovations (Rebelo *et al.*, 2016). In this line, IMS not only that is a relevant an organizational innovation that endorses organizational efficiency (Bernardo, 2014), but it also fosters the adoption of sustainable process innovations, namely CP technologies (Vieira and Amaral, 2016; Mustapha *et al.*, 2017; Ramos *et al.*, 2018). The latter, as previously discussed, promotes sustainable product innovations, which integrate the technical, environmental and social dimensions of the new products (Rebelo *et al.*, 2016). As a result, it can be hypothesized that IMS is significantly related to sustainable product innovations, but its relationship is mediated by the adoption of CP technologies. Hence, hypothesis H3 is stated as follows:

> **H3:** The adoption of cleaner production technologies mediates the positive relationship between the integration of management systems and sustainable product innovation.

To sum up, Figure 9 shows a scheme of the studied relationships.



Source: Own elaboration

Figure 9. Model relating IMS and sustainable innovation

4.3. Research methodology

This section presents the methodological approach to test the hypotheses of this research. To this end, firstly the target population is presented together with the sample selection and its characteristics. Next, a statistical model is selected to test the hypotheses simultaneously. Finally, the measurement of variables, namely IMS, adoption of CP technologies, sustainable product innovation and control variables is described.

4.3.1. Population and sample selection

The candle industry is selected in this study for three main reasons. Firstly, because from the ancient times candles have been involved in the debate of their potential indoor pollution and health effects (Faraday, 2001; Karataş and Gülder, 2012), which degree of danger depends on the process and raw materials used in their elaboration (Orecchio, 2011; Derudi *et al.*, 2012; Manigrasso *et al.*, 2017; Skovmand *et al.*, 2017). Secondly, due to its traditional consumption among human history (Nordhaus, 1996), being nowadays widely used in the worldwide population. It is estimated that half of Europeans use candles at least once a week (ComRes/AECM, 2015), while in the US, the annual retail sales are estimated at $2 billion (Derudi *et al.*, 2012). Finally, there are few official reports concerning the candle sector (Knight *et al.*, 2001), and the scientific literature studying these issues from a managerial perspective is almost anecdotal.

In order to have a significant sample of the sector, this study surveyed the top-management of the most representative candle associations' members. Namely, the Latin American Candle Association (ALAFAVE), the European Candle Association (ECA), the Association of European Candle Makers (AECM) and the National Candle Association of the United States (NCA) allowed us to contact their members for this research. All the contestants were part of the top-management, and their companies had a direct link with one of the abovementioned associations. The total number of candle manufacturers that met both requirements were 174: 61 linked to ALAFAVE, 22 to ECA, 64 to AECM and 27 to NCA. However, only European and Latin-American firms were willing to participate in this study.

The questionnaires were mainly based on the structure of the Community Innovation Survey (CIS, 2012) and the Spanish Innovation Panel (PITEC, 2007), both following the OECD (2005) guidelines. A version in English and in Spanish was prepared using Survey Monkey, which were firstly assessed by the candle associations' board. Then it was improved and pre-tested in five firms that validated it, so no further changes had to be done. The questionnaire was sent via email in three rounds between October 2016 and February 2017, obtaining 40 valid answers: 20 Latin-Americans and 20 Europeans. The valid answers resulted in an overall response rate of 27.21% with a sampling response error of ±8.0% at 95% confidence. Table 16 summarizes the main characteristics of this questionnaire.

Table 16. Descriptive summary of the questionnaire.

Target Population:	Candle Manufacturers linked to ALAFAVE, AECM and ECA
Total registered companies:	147
Valid responses:	40
Response rate:	27%
Sampling error:	±8.0% at 95% confidence
Method for data collection:	Online questionnaire (Survey Monkey)
Dates of collection:	October 2016 to February 2017

Source: Own elaboration.

4.3.2. Data analysis

The Partial Least Squares (PLS) approach to Structural Equation Modeling (SEM) was selected to test the model using SmartPLS 2.0 beta version (Ringle *et al.*, 2005). This technique is preferable to other covariance-based methods because: i) it does not assume any distribution of the data, and ii) it is suitable for exploratory research based on small samples (Chin, 1998).

4.3.3. Measurement of the Variables

4.3.3.1. Integration of management systems

Researchers have commonly based on the integration of certified MSs to measure IMS (Bernardo *et al.*, 2017; Ramos *et al.*, 2018). However, companies can implement and integrate non-certified MSs and, moreover, IMS is non-certifiable yet at the international level (Gianni *et al.*, 2017a). According to the survey of this research, holding a certified MSs is not common among candle manufacturers. Even if 72.5% of the sample applied at least one MS (out of the four studied), only 22.5% hold at most one certification (mostly a QMS). Thus, a measure of IMS was constructed based on literature as follows.

The basis of IMS lays on the importance given to MSs at the top-management level, which determines IMS for the whole organization (Zeng *et al.*, 2007; Gianni and Gotzamani, 2015; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). Based on this argument, IMS is measured as a construct composed of two variables that depend on the importance given to MSs by the top-management: IMS-*breadth* and IMS-*depth*. These measurements were adapted from the widely used definitions proposed by Laursen and Salten (2006) in the Open Innovation literature. Thus, IMS-*breadth* is defined as the accumulated importance of all the individual MSs for representing how broad they are applied across the organization, (i.e., how spread can their IMS be applied). So,

$$\text{IMS-}\mathit{breath} = \text{QMS\_importance} + \text{EMS\_importance} + \text{OHSMS\_importance} + \text{CSR\_importance}$$

where the importance of each MS was coded as 0 ‘not relevant’, 1 ‘Low’, 2 ‘Medium’ and 3 ‘Highly important’. Therefore, companies that consider ‘Not relevant' all of the MSs have an IMS-*breadth* equal to zero, while those considering all (four) MSs 'Highly important' punctuate 12.

Next, IMS-*depth* is defined as the number of MSs considered highly important, suggesting how internalized are those MSs. To measure IMS-*depth*, firstly, each of the four MSs was coded as a binary variable equal to one such MS was 'Highly important' to the top-management and zero otherwise, and then, such variables were added up. Thus, IMS-*depth* equals zero when firms do not consider highly important any of the MSs, while it scores four if all the MSs are considered highly important (i.e., how deeply can their IMS be internalized).

4.3.3.2. The adoption of cleaner production technologies

CP technologies are a specific kind of process innovations (Kemp and Volpi, 2008) that occur in organizations moving towards CP (Vieira and Amaral, 2016; Mustapha *et al.*, 2017; Ramos *et al.*, 2018), so firms were firstly explained the 'process innovation' definition in accordance to the OECD (2005). Then, firms were asked if they introduced any process innovation during 2014-15, in which case they were asked to specify in which technology they innovated. Finally, they were asked to assess the importance of those innovations to: i) control pollution (CPT1), ii) have zero emissions out of their manufacturing processes (CPT2) and iii) reduce wastes such as energy and raw materials (CPT3) (Kemp and Volpi, 2008; CIS, 2012; Gavronski *et al.*, 2012; Severo *et al.*, 2015). Regarding firms that did not introduce any process innovation, it could be reasonably assumed that their processes did not change during 2014-15, so CPT1, CPT2 and CPT3 were classified as 'Not relevant'.

4.3.3.3. Sustainable product innovation

Firms were firstly introduced to the 'product innovation' definition according to the OECD (2005) and asked whether they introduced any during 2014-15. Firms that answered in the affirmative were then asked to assess the importance of such innovations related to the technical and sustainable dimensions. Firstly, the main technical aspects of a candle were assessed. According to the pre-testing, the selected variables were the introduction or improvement of: i) waxes (PI1.1.), ii) fragrances (PI1.2.), and iii) colors/lacquers (PI1.3.) (Orecchio, 2011; Derudi *et al.*, 2012; ECA, 2017; NCA, 2017). Secondly, several studies warn that candles could be a source of indoor pollution, which could potentially produce negative effects on health (Knight *et al.*, 2001; Ahn *et al.*, 2015). Thus, the importance of the environmental care (PI2.1.) and social responsibility (PI2.2.) in the development of new products were asked to assess the sustainable dimensions of product innovation.

Changing –or innovating in– a technical factor (PI1.1.–PI1.3.) could produce different effects on indoor pollution and thus potentially on health (Orecchio, 2011; Derudi *et al.*, 2012). This implicates a one-to-one correspondence between the product innovation construct, and both the technical (PI1.1.-PI1.3.) and sustainable dimensions (PI2.1. and PI2.2.). Due to the existent correspondence that reflects the first-order latent variables (LVs), the molecular approach is well suited for this second-order construct rather than the molar approach. On the contrary, a molar approach would have been suitable for other cases where the LV is formed by first-order constructs that are not necessarily correlated (Chin and Gopal, 1995).

If companies did not introduce any product innovation, it could be reasonably assumed that no improved or new products were introduced, so the abovementioned indicators were classified as 'Not relevant'. In other words, since products remained the same during 2014-15, any improvement or introduction of new products was relevant.

4.3.3.4. Control variables

This sample consists of Latin-American and European firms, which could condition the results of adopting CP technologies and product innovation (Frondel *et al.*, 2007). Thus, the continent was applied as a control variable coded as zero for Latin-American and one for European companies. As a dichotomous variable, it was immediately used as an indicator in the PLS-SEM model (Henseler *et al.*, 2016).

4.4. Results

In this section, firstly, the general results related to the importance of the individual MSs and of the IMS indicators are presented, followed by the types of technological process innovations adopted by candle manufacturers. Then, the PLS-SEM results are presented, consisting of the measurement model and the structural model.

4.4.1. Results of the management systems importance and integration

Table 17 summarizes the MSs importance and IMS-*breath* and -*depth* results across the 40 valid responses. Regarding the importance of MSs, candle manufacturers give the highest importance to QMSs, followed by OHSMSs, EMSs and finally CSR. Regarding the IMS indicators, the IMS-*breadth* mean of 8.75 (out of 12) suggests that candle manufacturers integrated their MSs broadly, which seems to corroborate the idea that companies not necessarily have to be certified to integrate MSs. Moreover, the mean of IMS-*depth* is 2.05 (the maximum punctuation is four), suggesting that, on average, these companies integrated in depth, or internalized, two MSs, mainly QMSs and OHSMSs. More specifically, firms deeply internalized QMSs (76.9%), followed by OHSMSs (57.89%), EMSs (39,47%) and CSR (39,47%).

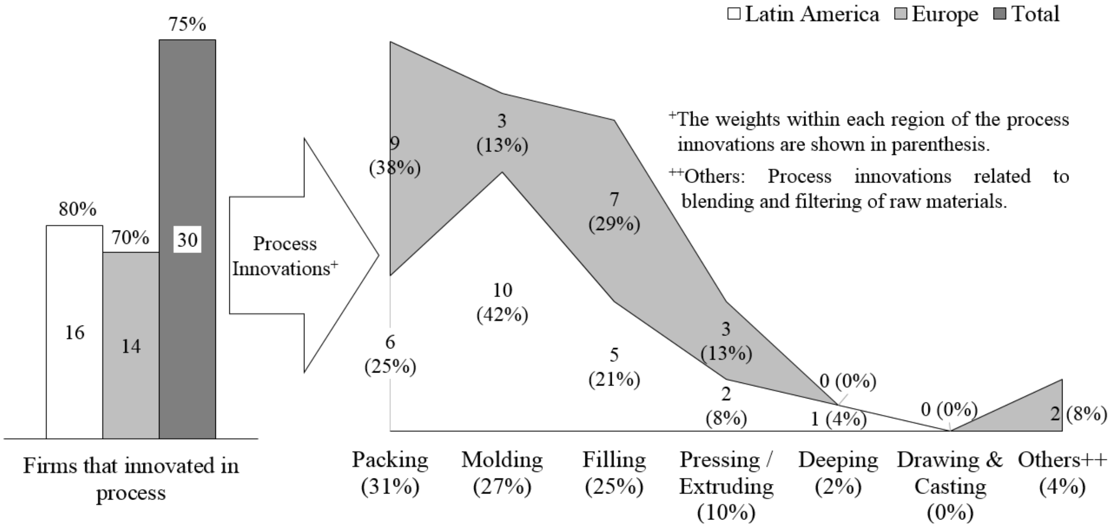
Table 17. MSs importance and IMS statistics and correlations (N=40)

	Variable	Mean	Median	SD	1	2	3	4	5	6
MSs importance	1. QMS	2.63	3	0.77	1					
	2. EMS	1.98	2	1.05	0.56	1				
	3. OHSMS	2.28	3	0.99	0.68	0.65	1			
	4. CSR	1.88	2	1.09	0.49	0.53	0.63	1		
IMS	5. IMS-*breadth*	8.75	9	3.25	0.79	0.83	0.89	0.82	1	
	6. IMS-*depth*	2.05	2	1.43	0.62	0.70	0.75	0.73	0.85	1

Source: Own elaboration

4.4.2. Process innovation results

Regarding process innovations, 75% of the companies (30 out of 40) declared that they innovated in at least one process during 2014–15. As shown in Figure 10, most of the companies innovated in new packing solutions, molding (mainly in Latin-America) and filling. On average, companies that innovated in process, adopted between one and two innovations during this two-year period.



Source: Own elaboration.

Figure 10. Process Innovations in the candle industry (N=40)

4.4.3. PLS-SEM results

In this section, firstly the measurement model results are presented, followed by the structural model.

4.4.3.1. Measurement model results

In PLS-SEM models, the validity and reliability of the measurement model are firstly assed (Hair *et al.*, 2011). As shown in Table 18, all the items show high loadings (above 0.70) on their corresponding LVs (Carmines and Zeller, 1979; Hair *et al.*, 2011). Secondly, the composite reliability scores for all the LVs are above the minimum recommended value of 0.90 (Nunnally, 1967). Thirdly, the LV with the lowest Cronbach's alpha corresponds to the 'CP technologies' construct (Cronbach's alpha = 0.88), which is above the minimum recommended of 0.6 (Hair *et al.*, 2016). Finally, the communalities for each indicator and the average communality scores for all the LVs are higher than 0.70. Such values are also adequate according to the specialized literature (Wetzels *et al.*, 2009).

Table 18. Main outcomes of the measurement model

Variables	Loadings	Communalities	Average Communality	Composite Reliability	Cronbach's alpha	AVE
IMS			0.922	0.960	0.917	0.922
IMS-*breadth*	0.951**	0.904				
IMS-*depth*	0.970**	0.941				
CP technologies			0.818	0.931	0.890	0.818
CPT1	0.875**	0.766				
CPT2	0.891**	0.794				
CPT3	0.946**	0.895				
Sustainable product innovation			0.933	0.966	0.930	0.933
Technical	0.961**	0.924				
Sustainable	0.971**	0.943				
Continent	1.000**	1.000	-	-	-	-

** p-value < 0.001 (resampling bootstrapping procedure with 5,000 subsamples).
Source: Own elaboration

To assess the validity of the model, the Average Variance Extracted (AVE) is equal to the LVs' communality, as expected in PLS path modeling (Wetzels *et al.*, 2009). The minimum AVE value is 0.82, which is higher than the recommended 0.5 (Hair *et al.*, 2011). Moreover, the cross loading discriminant validity requires each indicator to load the highest on its corresponding LV (Hair *et al.*, 2011). As shown in Table 19, this condition is successfully accomplished.

Table 19. Cross loading discriminant validity

Item	**Construct**	**IMS**	**Cleaner production technology**	**Sustainable Product Innovation**	**Continent**
IMS-*breadth*	IMS	**0.951**	0.282	0.203	0.000
IMS-*depth*	IMS	**0.970**	0.306	0.318	0.000
CPT1	Cleaner production technologies	0.338	**0.875**	0.533	0.000
CPT2	Cleaner production technologies	0.244	**0.891**	0.341	-0.184
CPT3	Cleaner production technologies	0.235	**0.946**	0.428	-0.197
Technical	Sustainable product Innovation	0.227	0.444	**0.961**	-0.059
Sustainable	Sustainable product Innovation	0.305	0.503	**0.972**	0.006
Continent	Continent	0.000	-0.129	-0.025	**1.000**

The loadings of the LV corresponding to each indicator are shown in bolds.
Source: Own elaboration.

Finally, the square root of AVE is higher than the correlations between LVs (see Table 20) in accordance with the Fornell-Larcker criterion for discriminant validity between LVs (Fornell and Larcker, 1981; Hair *et al.*, 2011).

Table 20. Comparison of the AVE square root and inter-factor correlations

Latent variables	**IMS**	**Cleaner production technologies**	**Sustainable product innovation**
IMS	**0.960**		
Cleaner production technologies	0.307	**0.904**	
Sustainable product innovation	0.278	0.492	**0.966**

The diagonal (in bolds) corresponds to the AVE square root.
Source: Own elaboration.

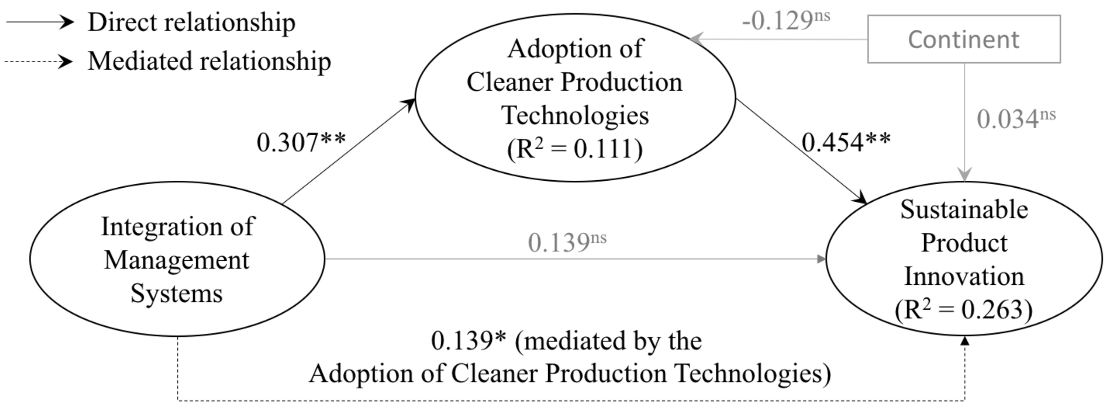
4.4.3.2. Structural model

The R^2 of the endogenous constructs is recommended to be ≥ 0.1 (Falk and Miller, 1992: 80). This criterion is accomplished for both, the adoption of CP technologies and sustainable product innovation (see Figure 11). As shown in Table 21, all hypotheses are accomplished. Moreover, it is evidenced that the continent does not significantly affect the results of the model.

Table 21. Results of the PLS-SEM

Effects	**Path Coefficient**	**t-value**	**Conclusion**
Direct effects			
IMS → CP technologies	0.307**	3.533	H2 supported
CP technologies → Sustainable product innovation	0.454**	5.136	H1 supported
IMS → Product innovation	0.139^{ns}	1.417	
Indirect effects			
IMS → CP technologies → Sustainable product innovation	0.139*	2.649	H3 supported
Control			
Continent → CP technologies	-0.129^{ns}	1.317	
Continent → Sustainable product innovation	0.034^{ns}	0.364	
Continent → CP technologies → Sustainable product innovation	-0.059^{ns}	0.271	

** $p < 0.001$; * $p < 0.01$; 'ns' not significant ($p > 0.1$).
Source: Own elaboration.



** $p < 0.001$; * $p < 0.01$; 'ns' not significant ($p < 0.1$).
Source: Own elaboration.

Figure 11. Results of the model relating IMS and sustainable innovation

4.5. Discussion and conclusions

The aim of this article is to explore whether the integration of management systems acts as a driver of sustainable innovation, within the framework of cleaner production. To this end, the relationships between the integration of management systems, the adoption of cleaner production technologies and sustainable product innovation were analyzed.

According to the results, adopting CP technologies is positively related to sustainable product innovation, which supports H1. This result is in line with previous research suggesting that companies must radically switch their internal operations to reduce any pollution or social effects at source (Boons *et al.*, 2013) to subsequently create sustainable products aiming to integrate the technical, environmental and social implications (Rebelo *et al.*, 2016). Only then, companies would have a real focus on the objectives of cleaner production, which aims to minimize the environmental and social impacts (UNEP DTIE, 1996; Kemp and Volpi, 2008; Vieira and Amaral, 2016).

To test hypotheses H2 and H3, firstly, IMS had to be measured objectively, so the IMS-*breadth* and IMS-*depth* indicators were introduced in this study based on the widely used definitions proposed by Laursen and Salten (2006). Both IMS-*breadth* and -*depth* are overall measures of the extent at which MSs are integrated at the strategic level, based on the importance given to all

MSs by the top-management (Zeng *et al.*, 2007; Gianni and Gotzamani, 2015; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a)

The higher the IMS-*breadth* and IMS-*depth*, the broader (spread) and deeper (internalized) IMS. This methodological contribution allows to have an IMS proxy even when MSs are not formally certified, so it complements other approaches regarding the difficulty of assessing IMS (Gianni *et al.*, 2017a).

Using the previous measurement of IMS, a positive and significant relationship is evidenced between IMS and the adoption of CP technologies, which supports hypothesis H2. This suggests that IMS not only fosters process innovations (Simon and Petnji Yaya, 2012; Bernardo, 2014; Hernandez-Vivanco *et al.*, 2016a), but it also provides the necessary strategical support so that such innovations are sustainable (Gianni *et al.*, 2017a). Particularly, IMS fosters the elimination of pollution and social effects (including workforce) at source, which is in good agreement with the cleaner production objectives, as concluded in Vieira and Amaral (2016) and Mustapha *et al.* (2017).

Moreover, it is evidenced that IMS has a positive effect on sustainable product innovation; however, this relationship is not direct, but mediated by the adoption of CP technologies, in accordance with hypothesis H3. In this line, Hernandez-Vivanco *et al.* (2016a) used a general framework (i.e., without focusing on sustainable innovations) and found that both IMS and product innovations are significantly related. Nonetheless, it could not be explicitly concluded from that study whether this relationship was direct or not, given the indirect path suggested in Simon and Petnji Yaya (2012). Thus, this empirical research based on candle manufacturers contributes new insights regarding the path of this relationship with the aim of creating sustainable products. More specifically, it can be concluded that IMS supports sustainable product innovation (Rebelo *et al.*, 2016), but it is firstly required to make the necessary in-house sustainability-oriented improvements (Boons *et al.*, 2013) to consequently achieve this objective.

Moreover, the results of this study suggest that adopting IMS across the organization and internalizing the underlying principles embedded in all the MSs is relevant to CP. This finding is of particular relevance given the open-ended debate of whether IMS supports sustainability-oriented practices. As reported by Ramos *et al.* (2018), IMS seems to be closely related to the adoption of CP-related practices. However, the authors also found that, even if this positive relationship happens in most cases, a minority of companies that adopted multiple certifications applied CP-related practices (only) to a limited extent. The authors clarify that in those cases, companies sought to satisfy the requirements of the multiple stakeholders; however, they failed to report the importance of such companies to meet those requirements. Thus, measuring IMS just as the adoption of multiple certifications might not be a reliable indicator. That measurement should be complemented with other approaches such as the presented in this manuscript. In spite of such methodological differences, the positive relationship between IMS and CP-related practices is also observed, which is in good agreement with the existing literature (Vieira and Amaral, 2016; Mustapha *et al.*, 2017; Ramos *et al.*, 2018).

Regarding the effect of location, it is evidenced that both Latin-American and European companies have similar results. Although other studies have shown that there might be some differences between countries (Frondel *et al.*, 2007), it is a remarkable result that IMS promotes sustainable innovation irrespective of companies' location. This might be attributed to the isomorphism across organizations promoted by IMS, achieved through the homogenous and high internalization of all the MSs' objectives (Zeng *et al.*, 2007; Gianni and Gotzamani, 2015; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). To this end, the top-management is required to be highly committed with all the MSs and with its integration (Bernardo et al., 2017).

To summarize, the results of this research show that the involvement of the top-management in the application and internalization of QMSs, EMSs, OHSMSs and CSR is critical to promote IMS. This, in turn, fosters sustainable innovation.

Given the debate of the environmental and social effects of candles' use, manufacturers might consider adopting cleaner production technologies not only to meet regulations, but also because this promotes the introduction of sustainable products. This means innovating with a long-term perspective by continuously improving the technical, environmental and social aspects. Thus, candle manufacturers should adopt a sustainability-oriented development through the minimization of indoor pollution, the development of new products, and environmental and social care. These aspects are supported on the deep and broad integration and application of MSs.

Regarding the contribution of this research, this is one of the first studies to relate empirically IMS, the adoption of cleaner production technologies and product innovation in pursue of sustainable development. It also contributes to literature by shedding light on the importance of IMS to promote the reduction of indoor pollution and thus, potentially benefiting consumers' health, from the sustainable management perspective.

Despite its contributions, this article has some limitations. It is an exploratory study of the current status of candle manufacturers and thus, results shall be interpreted with caution. Moreover, its conclusions apply to the most representative European and Latin-American candle manufacturers, so smaller firms or from other industries and regions might not be represented.

Finally, further research will focus on measuring the real effects of candles comparing the emission of potentially dangerous substances of companies that have adopted IMS vs. those that have not. Moreover, further studies shall consider IMS and innovation in other industries involved in the debate of indoor pollution.

CHAPTER 5. DO MULTIPLE CERTIFICATIONS LEVERAGE FINANCIAL PERFORMANCE? A DYNAMIC APPROACH

Abstract

Purpose: In a dynamic environment where firms are continuously exposed to change, being financially robust, strong and competitive is a major task. The aim of this article is to study the impacts of adopting multiple certifications on firms' financial performance, by considering the dynamics involved in this process.

Design/Methodology/Approach: A sample of 247 Portuguese firms that had adopted multiple certifications by 2015 encompassing the ISO 9001, ISO 14001 and OHSAS 18001 standards were analyzed. Their historical certification records were matched with their financial indicators to create a panel dataset from 2004 to 2015. The research into the causal effects of the certifications on firms' performance was based on a panel dynamic approach, namely the system generalized method of moments.

Findings: The following three combinations show consistent leverage on firms' financial performance: ISO 9001, ISO 9001 + ISO 14001 and ISO 9001 + ISO 14001 + OHSAS 18001. Being ISO 9001 the common factor and the first standard adopted by most firms, results suggest that it might be the main driver towards improving performance.

Originality: By considering the dynamics of firms' certifications and performance simultaneously, this research reveals new insights of the multiple certifications' benefits in a changing and often turbulent environment where firms can be expected to certify dynamically according to the requirements of new and emergent standards.

Keywords: ISO 9001; ISO 14001; OHSAS 18001; multiple certification; financial performance; panel dynamic model

5.1. Introduction

Firms are continuously challenged to satisfy their wide range of stakeholders, with different visions and objectives, and many of them see certifications as a milestone of legitimacy (Boiral and Gendron, 2011). Firms first define a strategy to achieve such objectives managing the inter-related parts of their business, according to their function-specific Management Systems (MSs) (ISO, 2018a). Amongst the most implemented, firms adopt Quality (QMS), Environmental (EMS) and Occupational Health & Safety (OHSMS) MSs (Zeng *et al.*, 2007; Bernardo *et al.*, 2009; Domingues *et al.*, 2017). Certifying them is supposed to assure the accomplishment of the procedures demanded by stakeholders through the periodical external auditing carried out by independent bodies (Power, 1997; ISO, 2018b).

ISO 9001 and ISO 14001 are the most popular QMS and EMS standards with presence in more than 190 countries (ISO, 2017), and OHSAS 18001 is following similar diffusion patterns (Lo *et al.*, 2014; Domingues *et al.*, 2017). Therefore, it is not surprising to find a extensive literature analyzing different perspectives of MS standards, including their potential effects on firms' Financial Performance (FP).

Notwithstanding the efforts to understand how certifications are related to firms' FP, there is a generalized lack of consensus regarding their effects –if any– on the direction of the connections and whether a causal relationship actually exists (Robson *et al.*, 2007; Sampaio *et al.*, 2009; Heras-Saizarbitoria and Boiral, 2013; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016). The existing literature is mostly focused on function-specific MS standards, but only a few have considered the dynamics involved in adopting multiple MS standards (Karapetrovic and Willborn, 1998b; Labodová, 2004; Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012; Ivanova *et al.*, 2014) and its impacts on FP (Ferrón-Vílchez and Darnall, 2016; Wang *et al.*, 2016b; Martí-Ballester and Simon, 2017). Although firms are increasingly adopting multiple MS standards, managing more complex certification structures can be challenging due to possible conflict of interests of several stakeholders, which might hinder firms' FP (Wiengarten *et al.*, 2017).

Another concern is related to the high amount of studies relying on perceptional measurements (e.g., surveys). Although they play a dominant role in the existing literature (Sampaio *et al.*, 2012b; Heras-Saizarbitoria and Boiral, 2013), researchers have pointed out that it is preferred to rely on existing records to avoid over-valued or biased conclusions (Häversjö, 2000; Corbett *et al.*, 2005; Sharma, 2005; Heras-Saizarbitoria and Boiral, 2013).

To the best of the authors' knowledge, scarce research has simultaneously considered both, i) the dynamics involved in the adoption of multiple certifications, and ii) its effects on FP, measured objectively with existing records. This study aims to contribute to this research gap with longitudinal empirical evidence of a country where firms are increasingly adopting multiple MSs standards.

5.2. Theoretical Framework

The main research gap lays on the causal (or not) relationship between the adoption of multiple certifications and FP. Table 22 summarizes the empirical research analyzing this complex relationship from the year 1999, when most literature relying on objective FP indicators emerged (Simmons and White, 1999; Sharma, 2005). Thus, Table 22 encompasses the empirical support to be further developed throughout this section.

As evidenced from this table, the debate remains unsolved for all the analyzed certifications and regardless of the FP indicator, so further examination is required. To this end, this section is divided in two parts, the impact of i) single, and ii) multiple certifications on firms' FP.

Table 22. Empirical articles relating MSs certifications and FP

	Reference	Sample origin	N; Analyzed years	Main research tool related to FP[a], [b]	FP[c]	Certifications impacts[d] ISO 9001	ISO 14001	OHSAS 18001
Dynamic approach	Abad *et al.* (2013)	Spain	149; 2006 – 2009	Generalized Least Square	Labor productivity			(+)
	Goedhuys and Sleuwaegen (2013)	Africa, Latin America, Europe, Central Asia (59 countries)	7320; 2002 – 2007	Survey and database analysis, IV	Productivity, Sales	(+)	(+)	
	He *et al.* (2015)	China	967*; 2004 – 2007	Survey and database analysis, IV	ROA, ROE, ROS, Sales, Costs		x	
	Su *et al.* (2015)	USA	101; 1995 – 2007	Generalized Least Square	ROA, ROI, ROS	o	(+)	
Non-Dynamic approach	Simmons and White (1999)	USA	126; 1995	ANOVA	ROA, Sales/Equity, Foreign sales	o		
	Häversjö (2000)	Denmark	644;1989 – 1995	Mean differences statistics	Sales, ROCE	o		
	Singels *et al.* (2001)	Holland	192; 1994	Survey: SEM	Perceptional costs, assets, market share, PM	x		
	Heras *et al.* (2002)	Spain	800;1994 – 1998	Mean differences statistics	ROA	o		
	Wagner *et al.* (2002)	Germany, Italy, Netherlans, UK	37;1995 – 1997	Simultaneous equations: 3SLS	ROS, ROE, ROCE		(-)	

	Reference	Sample origin	N; Analyzed years	Main research tool related to FP[(a), (b)]	FP[(c)]	Certifications impacts[(d)] ISO 9001	ISO 14001	OHSAS 18001
Non-Dynamic approach	Corbett *et al.* (2005)	USA	7238;1987 – 1997	Event-study	ROA, ROS, COGS/Sales, SOA, Tobins' Q	o		
	Sharma (2005)	Singapore	70;1991 – 1998	Mean differences statistics and OLS	Sales, Earning per Sahre, PM	(+)		
	Naveh and Marcus (2007)	USA	40; N/A	Correlations	ROA	o		
	Darnall *et al.* (2008a)	Canada, US, Germany, Hungary	2108; 2003	Survey: 2SLS	Perceptional profitability and growth		(+)	
	McGuire and Dilts (2008)	USA	204;1999 – 2002	Event-study: mean differences statistics	Market value of the firm's equity	o		
	Heras-Saizarbitoria *et al.* (2011)	Spain	196;2000 – 2005	Event-study: median differences statistics and panel regression	Sales, ROA		o	
	Lo et al. (2012)	USA	61;1994 – 2008	Event-study: Median differences statistics	ROA, ROS, SOA		(+)	
	Sampaio *et al.* (2012)	Portugal	6;2000 – 2007	Case studies	Sales, unit price, costs (production & certification)	o		
	Agan *et al.* (2013)	Turkey	500; N/A	Survey: SEM and ANOVA	Perceptional profitability, market share, image, competitive advantage		o	

	Reference	Sample origin	N; Analyzed years	Main research tool related to FP[(a), (b)]	FP[(c)]	Certifications impacts[(d)] ISO 9001	ISO 14001	OHSAS 18001
Non-Dynamic approach	Dora *et al.* (2013)	Belgium, Hungary, Germany	35; 2010	Survey: Descriptive statistics and ANOVA	Perceptional profitability, cost reduction	o		
	de Jong *et al.* (2014)	USA	219; 1996 – 2005	Event-study: median differences statistics	ROA, COGS/Sales, SOA			
	Lo *et al.* (2014)	USA	211; 1999 – 2011	Long-horizon event-study: OLS	Sales, ROA			
	Teng *et al.* (2014)	Taiwan	975; 1996 – 2008	Quadratic panel regressions	ROA, ROE, Corporate Value, Market value to book value		(+)	
	Amores-Salvadó *et al.* (2015)	Spain	157; 2009 – 2010	Survey: SEM	Perceptional market share, sales, labor productivity			
	Lisi (2015)	Italy	91; N/A	Survey and database analysis: PLS	ROCE		o	
	Chatzoglou *et al.* (2015)	Greece	168;	Survey: SEM	Perceptional overall financial performance	(+)	(+)	
	Cândido *et al.* (2016)	Portugal	143; 2007 – 2008	Event study	ROA, ROS, sales	x		
	Ferrón-Vílchez and Darnall (2016)	Germany, Japan, Norway, France, Canada	2619; N/A	OECD Survey: Heckman regression	Perceptional overall business performance	(+)	o	

	Reference	Sample origin	N; Analyzed years	Main research tool related to FP(a), (b)	FP(c)	Certifications impacts(d) ISO 9001	ISO 14001	OHSAS 18001
Non-Dynamic approach	Wang *et al.* (2016)	China	73; 2009 – 2012	Efficiency approach (DEA), comparison of means and panel Tobit regression	Triple-bottom-line (financial, environment. and social) efficiency score	(+)	(+)	(+)
	Bianchini *et al.* (2017)	Italy	9; 2014	Case studies	Occupational health & safety related costs			o
	Ionaşcu *et al.* (2017)	Romania	60; 2013 – 2015	Panel regression	ROA	(+)	(+)	(+)
	Martí-Ballester and Simon (2017)	Spain	50; 2010	Survey: PLS	ROA, ROE, ROS	(+)	(+)	

(a) All studies are based on database analysis, except if indicated explicitly as "Survey"
(b) DEA: Data Envelopment Analysis; IV: Instrumental Variable; OLS: Multiple ordinary least squares; PLS: Partial least squares; SEM: Structural equation modelling; 2SLS: Two-stage least squares; 3SLS: Three-stage least squares.
(c) COGS: Cost of goods; Labor Productivity: Sales/Employees; PM: Profit Margin; ROCE: Return on Common Equity, also referred as Return on Capital Employed; ROE: Return on Equity; ROS: Return on sales; SOA: Sales performance (Sales/Assets).
(d) (+) – Positive effect; o – Unclear effect; x – No effect; (-) – Negative effect; blank – Not studied

*Authors report a total of 3,868 observations throughout the years 2004-2007, but fail to report the number of firms included in their sample.
Source: Own elaboration.

5.2.1. The relationship between single certification and firms' financial performance

Focusing on ISO 9001, Simmons and White (1999) were one of the first to rely on existing records, concluding that certified companies are more profitable than non-certified. Nonetheless, they found non-significant effects in terms of operational performance and foreign sales. The cross-sectional nature of their analysis was insufficient to provide definitive conclusions. Later, Häversjö (2000) found that the positive relationship between the ISO 9001 certification and FP were attributable to the innovative management rather than the certification itself. Heras *et al.* (2002) pointed out that, although there are signs of positive links between the certification and FP, it was not possible to claim for a causal relationship. However, Sharma (2005) was critical about the methods adopted by Heras *et al.* (2002) and, although he improved the models by accurately controlling for the pre-certification performance, the paper does not present explicitly any control for the dynamics involved in the certification process. The study concluded that ISO 9001 is positively related to FP, especially due to the improvements achieved in the business processes, which gives credibility to the self-rated benefits of this standard.

By that time, authors like Corbett *et al.* (2005) and Sampaio *et al.* (2011) pointed out some of the limitations of relying on self-reported data, such as the lack of independence and biases in the responses, so they emphasized the need of using existing and objective FP measures. Although surveys are still the most adopted research tool, most studies report different and still inconclusive outcomes (Sampaio *et al.*, 2012b; Heras-Saizarbitoria and Boiral, 2013). For instance, Singels *et al.* (2001) found no evidence of a direct effect of the ISO 9001 certification by itself. Instead, the relationship is significant only to firms adopting it with the aim of improving their organizational processes. Later, Dora *et al.* (2013) could only determine the existence of a positive relationship mainly based on descriptive statistics. Moreover, Naveh and Marcus (2007) concluded that ISO 9001 provides firms the necessary support to improve their operational performance. This in turn, would allow them to be more profitable and certify if not certified yet. Conversely, Chatzoglou *et al.* (2015) concluded that implementing ISO 9001 is directly associated with significant improvements in FP as well as quality awareness.

Another trend of analysis is based on event-studies in which Corbett *et al.* (2005) is one of the most influential. The authors found evidence of 'abnormal' improvements in FP after implementing ISO 9001. Although in the short term the timing and magnitude of such effects vary according to different factors (size, industry, FP before the certification), the effects in the long-term are always strongly significant. The authors also stress the need of implementing the ISO 9001 certification in a rigorous and comprehensive manner to boost such benefits. Although this technique allows to detect changes in FP after the certification, it might not be enough to state a causal relationship (McGuire and Dilts, 2008). In this line, Cândido *et al.* (2016) concluded that after de-certification, firms continue to be as profitable as those that maintained it. Although such outcomes are certainly revealing, it is not clear whether their conclusions would maintain in the long-run beyond the two-year span analyzed. Thus, in the short term, firms that lost their certification seem to maintain their quality-related practices, leading them to be as competitive as certified firms.

Based on case studies Sampaio *et al.* (2012) studied six Portuguese firms, concluding that firms that adopt ISO 9001 with the aim of improving their performance increased their FP more than those that implemented it due to external pressures. Although in most cases there was an increased FP after the certification, they concluded that it is not clear whether firms would have been less profitable if they were not certified.

Despite the existing lack of agreement, a positive association is less arguable, which might suggest causality. To this end, firms must be committed in the long-term to the underlying principles of ISO 9001 (Singels *et al.*, 2001; Corbett *et al.*, 2005; Sampaio *et al.*, 2012b; Chatzoglou *et al.*, 2015). Thus, H1 is developed as follows:

H1: ISO 9001 positively impacts firms' financial performance.

The lack of agreement is similar for studies focused on ISO 14001. Based on surveys, Darnall *et al.* (2008a) found that firms applying its framework, regardless of being certified or not, obtained better FP scores. Therefore, committed is critical to succes rather than just gaining external recognition. Later, Agan *et al.* (2013) concluded that firms implementing an EMS based on ISO 14001 achieve long-term financial benefits due to their improved image, increasing market share and gaining competitive advantage. According to Amores-Salvadó *et al.* (2015) the positive relationship is mainly due to the creation of environmental innovations. The previous results are not in line with He *et al.* (2015), who found that ISO 14001 has non-significant effects on FP, since firms adopt it due to external pressures and gains in their image rather than in pursuit of financial benefits. Similarly, Lisi (2015) concluded that the improved environmental performance increased FP rather than the certification.

Based on event-studies, Heras-Saizarbitoria *et al.* (2011) researched into firms' FP before and after the certification considering two independent models. They concluded that firms with better than FP are more likely to certify, but there is no evidence to state that the improvements in performance could be entirely attributed to the certification. Concurrently, de Jong *et al.* (2014) did not find evidence for consistent FP improvements immediately after following the ISO 14001 guidelines or certification. They also detected minor FP improvements in the short-term and significant effects in the long-run, so they finally conclude that environmental management indeed pays off.

With different methodological approaches, but still focused on secondary datasets, Wagner *et al.* (2002) based on longitudinal data and concluded that ISO 14001 affects negatively FP while simultaneously improving its environmental performance, so firms are challenged to find a profitable manner to manage such trade-off. Teng *et al.* (2014) tested a similar model but with a larger sample (975 firms). The authors concluded that although in the short-term the high maintenance costs of ISO 14001 would decrease FP, firms might be end-up with beneficial results in the long-term. Therefore, it seems that, after a period of adaptation, firms adopting ISO 14001 might obtain financial benefits.

He *et al.* (2015) adopted a dynamic approach to control the effects of the previous years' FP and found no evidence of causality because firms adopt ISO 14001 for market-oriented reasons rather than to gain FP. Despite their contributions, two limitations should be pointed out: i) the certifications' year was self-reported and, ii) the study does not evidence any control of whether firms had multiple certifications. Su *et al.* (2015) overcame both limitations and concluded that ISO 14001 positively affects FP, especially when they have prior experience with MSs.

Most research seems to agree that positive effects of ISO 14001 occur when firms aim to maintain it in the long-term through a strong commitment to its principles. Thus, H2 is stated as follows:

H2: ISO 14001 positively impacts firms' financial performance.

Studies assessing empirically the effects of OHSAS 18001 on FP are limited (Robson *et al.*, 2007), since it is usually implemented in combination with other certifications (Bernardo *et al.*, 2012; Domingues *et al.*, 2017). Bianchini *et al.* (2017) based on case studies, and concluded that investing in an OHSMS is profitable particularly for large firms. This might be due to the high costs associated to implementing and maintaining OHSMSs, which provoke unprofitable results in smaller firms. The authors attribute such perceptions to the lack of an effective implementation of the OHSMSs. Firms could enjoy the benefits of OHSMSs, which are mainly related to the assurance of exemption of responsibility –in case of accident– for employers (specially in smaller firms), together with an adequate return of investments.

Firms that successfully implement OHSAS 18001 across the organization and are committed to its principles can achieve higher levels of workforce productivity (Robson *et al.*, 2007). Besides the enhancement of the safety conditions, its strategic value supports creating a competitive advantage and consolidate business operations (Abad *et al.*, 2013). Additionally, its implementation positively impacts on FP through operational efficiency and increase of sales, which occurs consistently for firms operating in environments with stringent safety regulations and with complex production systems (Lo *et al.*, 2014).

The benefits of implementing OHSMSs can be reinforced when it covers broadly the whole organization in a proactive manner, and the certification legitimizes this through auditing (Mohammadfam *et al.*, 2016). Thus, firms that strategically decide to implement and maintain OHSAS 18001 seem to obtain FP benefits, as stated in H3:

H3: OHSAS 18001 positively impacts firms' financial performance.

5.2.2. Multiple certifications: do they leverage firms' financial performance?

The strategies for adopting multiple certifications are well reported in literature (see e.g., Karapetrovic and Willborn, 1998b; Labodová, 2004; Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012; Ivanova *et al.*, 2014). According to it, firms can adopt different MSs dynamically; for instance, firms that are only certified by ISO 9001 in year *t* can adopt ISO 14001 in year *t*+*k*, and continue to certify subsequently (or simultaneously) by other MSs such as OHSAS 18001. The phenomenon related to multiple certifications becomes more complex as it involves changes that depend not only on the current certifications, but on firms' certifications strategy and FP (Corbett *et al.*, 2005). The impacts of the different combinations of certifications have been scarcely studied and require further examination (Gianni *et al.*, 2017a).

According to Hillary (2004), most scholars agree that EMSs standards are positively associated to firm financial and commercial performance. According to the author, EMSs have the potential to improve QMSs, so the synergies of both boost their joint benefits. This was empirically supported by Su *et al.* (2015), who found that ISO 14001 without the previous experience of ISO 9001 could be detrimental to FP, especially in more competitive environments.

Adopting ISO 14001 allows decreasing the consumption of resources (Melnyk *et al.*, 2002) and to follow-up costs and savings (Llach *et al.*, 2013). This mechanism is better achieved if firms integrate both quality and environmental perspectives (Khanna *et al.*, 2009; Deltas *et al.*, 2014). Goedhuys and Sleuwaegen (2013) considered the effects of both certifications on firms' FP at a global scale. The authors performed a massive global survey considering jointly the ISO 9001 and ISO 14001 certifications within a unified variable. They justified such approach arguing that the motives, benefits, and international diffusion patterns of both certifications are compatible worldwide. They concluded that through certifications, firms gain efficiency and quality signaling (i.e., 'signal' to external parties that the firm is a reliable supplier and partner).

Measuring QMSs and EMSs as different MSs, Ferrón-Vílchez and Darnall (2016) reported that adopting both is better than adopting only one. The authors argue that both MSs are complementary and, to some extent, symbiotic since each promotes the development of internal capabilities related to their function-specific objectives. This in turn, enables the adoption and daily operationalization of the other, while maintaining their individual goals. This mechanism would improve the firms' strategic value and FP. Therefore, ISO 9001 seem to support ISO 14001 in pursuit of economic and environmental sustainability (Siva *et al.*, 2016). Moreover, the positive effects of the integrated procedures in firms that adopt both MSs overweight the negative ones related to their bureaucracy, giving as a result an improved FP (Martí-Ballester and Simon, 2017). Thus, H4 is developed as follows:

> **H4:** Being simultaneously certified by ISO 9001 and ISO 14001 positively impacts firms' financial performance.

Regarding OHSMSs, Robson *et al.* (2007) pointed out that its adoption increases productivity and, when done voluntarily, firms experience decreases in disability-related costs. As the OHSMS implementation is increased over time, such benefits might boost FP. The authors also discussed that, typically, the firms' commitment to QMSs is higher compared to that of OHSMSs. To deal with this issue, firms would prefer to integrate them and improve their results by giving both MSs equal priority and pursue common goals (Zeng *et al.*, 2007).

Empirical research supports that firms with ISO 9001 could also achieve higher levels of safety, which might be attributed to the innovative management practices (Naveh and Marcus, 2007; Lim and Prakash, 2017). Thus, firms that correct the inefficiencies that jeopardize product quality, must also look after the enhancement of working conditions avoiding the labor costs associated to injury compensation, working days lost and training of replacement workers (Lim and Prakash, 2017). Therefore, firms attain FP improvements by addressing their internal safety concerns, and considering simultaneously the customers' requirements (Naveh and Marcus, 2007).

Additionally, both MSs complement each other with compatible objectives, and combining them promotes learning (Silva *et al.*, 2017), continuous improvement and motivates employees (Pun and Hui, 2002). Thus, implementing both ISO 9001 and OHSAS 18001 might have positive effects on FP as indicated in H5:

H5: Being simultaneously certified by ISO 9001 and OHSAS 18001 positively impacts firms' financial performance.

The implementation of ISO 14001 and OHSAS 18001 is scarcely reported among firms that adopt multiple certifications (Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012; Domingues *et al.*, 2017), so it is difficult to assess their FP effects. Labodová (2004) was one of the first to study the compatibilities between OHSMSs and EMSs. The author found that both standards are fully compatible. Thus, firms can integrate them i) by assessing the current situation regarding risks and their technology and organizational reality, and ii) based on the PDCA-approach and saving resources.

Implementing OHSAS 18001 along with other MSs provides workforce and the organization of new learning capabilities to prevent further and future accidents, which occurs when reporting and analyzing an occurrence, and then communicating efficiently the outcomes throughout the organization (Silva *et al.*, 2017). The management of the former mechanism requires exploring the synergies of having both certifications, which leads firms to perceive their benefits more efficiently (Karapetrovic, 2002). Therefore, firms could obtain financial benefits of implementing both ISO 14001 and OHSAS 18001 as hypothesized in H6:

H6: Being simultaneously certified by ISO 14001 and OHSAS 18001 positively impacts firms' financial performance.

Regarding the triple certification, Ionașcu *et al.* (2017) reported that firms simultaneously certified by ISO 9001, ISO 14001 and OHSAS 18001 perform better than others with less certifications. These conclusions are in line with Wang *et al.* (2016), who adopted a more rigorous approach that consisted on measuring the efficiency to obtain better financial, environmental and social results using less resources. The study concluded that firms with triple certifications had the highest performance while non-certified had the lowest. Moreover, the high costs associated to the certification in the first years were compensated with greater benefits in the long-term.

Although the empirical evidence is still limited, it seems that triple certifications can have beneficial effects in FP. In fact, firms that implement more certifications learn from the different perspectives (Silva *et al.*, 2017). They also find innovative management practices that allow them to take advantage of the MSs common structure and optimize the use of resources through their integration (Zeng *et al.*, 2007; Salomone, 2008; Bernardo *et al.*, 2009). Hence, holding the three studied certifications seem to boost their FP, especially if they are highly committed to them and intend to be certified in the long-term (Salomone, 2008; Bernardo *et al.*, 2009; Nunhes *et al.*, 2017). Thus, H7 is formulated as follows:

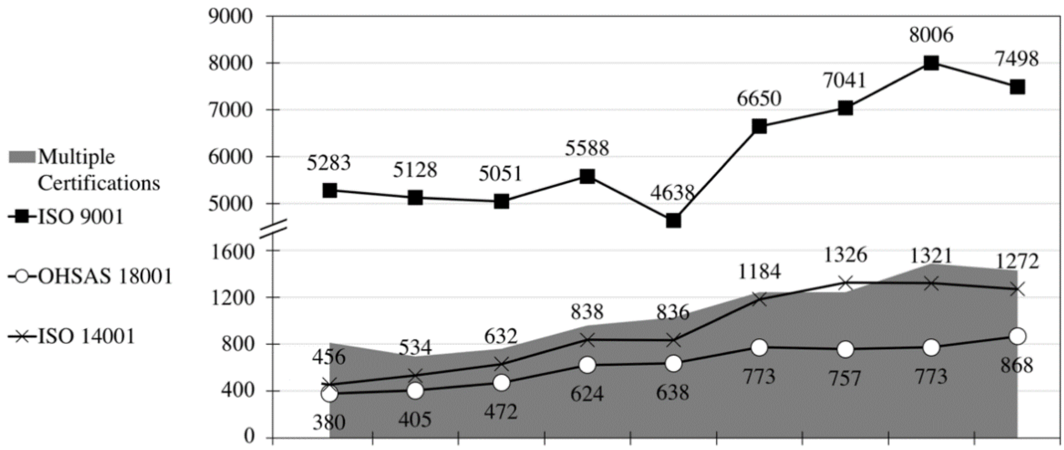
> **H7:** Being simultaneously certified by ISO 9001, ISO 14001 and OHSAS 18001 positively impacts firms' financial performance.

5.3. Methodology

5.3.1. Population and sample selection

The World State of Quality report (Saraiva *et al.*, 2017) provides a rank of the 'macro-quality' level of 28 European countries. In 2016, Portugal was ranked among the top 10 in terms of the number of International Academy for Quality (IAQ) members, environmental wellbeing results, ecological footprint and ISO 9001 certified organizations. Therefore, Portuguese firms seem to be reckoning the potential of quality and environment as pillars to their development. Such orientation is evidenced by the evolution of certifications.

As shown in Figure 12, Portugal has increased the number of ISO 9001, ISO 14001 and OHSAS 18001 certifications (Domingues et al., 2017) during the last decade. The evolution of ISO certifications seem to be in a mature stage, similar to other European countries (Sampaio et al., 2011a; To and Lee, 2014; Domingues et al., 2017). Furthermore, OHSAS 18001 certifications in Portugal maintain a persistent growth rate from 2007. Finally, the evolution of multiple certifications continuously increased until 2014, and since then it seems to be in a steady stage, which may be ascribed to maturity (Domingues et al., 2016). Therefore, Portugal represents an interesting environment for studying the dynamics of certifications.



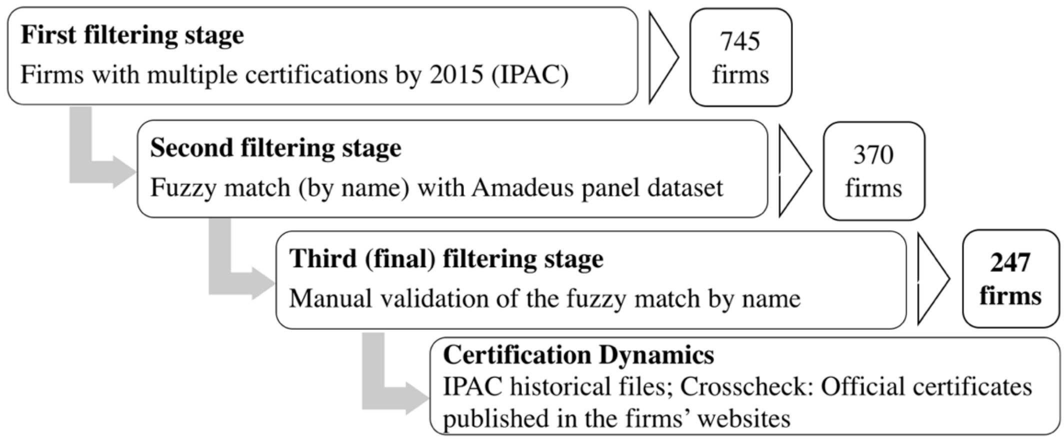
Multiple certifications	2007	2008	2009	2010	2011	2012	2013	2014	2015
ISO9001+ISO14001	436	309	312	366	402	483	508	539	586
ISO9001+OHSAS18001	88	93	150	127	120	137	118	120	123
ISO14001+OHSAS18001	6	27	27	39	41	49	29	42	41
Triple certification	281	268	271	429	468	577	589	789	679
Total (2 or 3 MSs)	**811**	**697**	**760**	**961**	**1,031**	**1,246**	**1,244**	**1,490**	**1,429**

Source: Data extracted from i) ISO Survey (2017) and ii) yearly registers obtained from the Portuguese Accreditation Institute (Instituto Português de Acreditação – IPAC) (IPAC, 2017) since December 2007.

Figure 12. Portuguese certifications' dynamics in the period 2004-2015

The sampling procedure consisted of four stages, as summarized in Figure 13. Firstly, 745 unique firms holding multiple certifications in 2015 were identified based on the Portuguese Accreditation Institute (IPAC, 2017). Then, their financial information was collected through the Amadeus records published by the Bureau Van Dijk (2017), which were matched with the previous dataset. The former procedure resulted in a gross match of 370 companies. After verifying manually their names, official certificates and firms' certificates, the final sample encompassed 247 companies.

Then, the certifications' historical evolution of the sample was built using the IPAC past records and the official certificates published in the firms' websites, obtaining their complete certifications' dynamics from 2004. None de-certification case was detected so the sample solely considers firms that have continuously certified and maintained their certifications. Therefore, the panel consisted of 247 companies with the certifications' evolution from 2004 and with financial information from 2007 until 2015.



Source: Own elaboration

Figure 13. Sampling Procedure

5.3.2. Measurement of variables

5.3.2.1. Dependent variables

In this study, FP is measured in terms of Return on Sales (ROS), Return on Common Equity (ROCE) and Return on Assets (ROA). These indicators reflect the organization's internal efficiency and have been commonly included in studies related to MSs (Corbett *et al.*, 2005; He *et al.*, 2015; see e.g., Lisi, 2015; Su *et al.*, 2015; Martí-Ballester and Simon, 2017). Briefly, the following interpretations of the specific indicators are presented, based on Pendlebury and Groves (2004) and Reid and Myddelton (2005).

ROS measures the profitability that firms make out of their sales by maximizing revenues and minimizing costs, and it is measured as the ratio between the profits before tax and the revenues. ROCE refers to the efficiency of using capital in producing income and is measured as the ratio between the earnings before interest and taxes and net assets. Finally, ROA indicates the efficiency in exploiting firms' assets to create profits, and it is measured as the ratio of the net profits and the total assets. Table 23, Panel A summarizes the descriptive statistics of the FP indicators.

Table 23. Independent, explanatory and control variables (N=247)

PANEL A. DEPENDENT VARIABLES						
FP	**N**	**Obs.**	**Mean**	**Median**	**Standard deviation**	**Std. error of the mean**
ROS	242	1,993	4.3112	3.4400	13.0263	0.2917
ROCE	218	1,731	11.3807	10.0660	31.8276	0.7650
ROA	243	2,028	3.3183	2.6005	8.9149	0.1980

PANEL B. EXPLANATORY AND CONTROL VARIABLES			
Categorical Variable	**Value**	**Percentage**	**Frequency**
Certifications	*CERT*		
None	0	26.39%	779
ISO9001	1	19.17%	566
ISO14001	2	1.36%	40
OHSAS18001	3	0.47%	14
ISO9001+ISO14001	4	22.69%	670
ISO9001+OHSAS18001	5	3.59%	106
ISO14001+OHSAS18001	6	0.44%	13
Triple certification	7	25.91%	765
Industry	*IND*		
Mining and quarrying	1	0.81%	24
Manufacturing	2	46.15%	1,368
Electr., gas, steam & air cond. supply	3	1.62%	48
Water supply	4	6.97%	180
Construction	5	13.36%	396
Wholesale and retail trade	6	4.86%	144
Transportation and storage	7	8.50%	252
Accommodation and food service	8	1.62%	48
Information and communication	9	2.43%	72
Finances and insurance	10	3.24%	96
Real estate	11	0.40%	12
Professional, scientific and technic.	12	3.64%	108
Administrative and support service	13	5.26%	156
Human health and social work	14	0.81%	24
Arts. entertainment and recreation	15	0.81%	24
Other service activities	16	0.40%	12
Size	*Size*		
Large	0	76.52%	2,268
Very Large	1	23.48%	696
Year	*Year*		
2004 – 2015	2004-2015	8.33%/year	247/year

Source: Own elaboration.

5.3.2.2. Explanatory and control variables

The certifications held by a firm represent the main explanatory variable. The selected firms hold two or three certifications by 2015; i.e. ‘ISO9001+ISO14001’, ‘ISO9001+ISO14001’, ‘ISO14001+OHSAS18001’ or ‘ISO9001+ISO14001+OHSAS18001’. To this end, firms could adopt different strategies. The seven different combinations of certifications identified in this sample are considered in the *CERT* categorical variable as summarized in Table 23, panel B. The ‘None’ certification level, that accounts for 26.39% of the observations, is considered the control category. Since all the analyzed certifications must be renewed each three years, until three year lags were included (i.e. $CERT_{t-1}$, $CERT_{t-2}$ and $CERT_{t-3}$) (see e.g., Abad *et al.*, 2013, Corbett *et al.*, 2005, Heras-Saizarbitoria *et al.*, 2011, Su *et al.*, 2015).

Industry dummies are included to control potential differences in the levels of FP (see e.g., Heras-Saizarbitoria *et al.*, 2011). The company size is also controlled (see e.g., Corbett *et al.*, 2005). The size category provided by Amadeus (Bureu Van Dijk, 2017), which is based on the firms’ employees, revenues and assets is included directly. Firms are very large or large following these criteria. Very large firms report an operating revenue ≥ 100 million EUR, total assets ≥ 200 million EUR and more than 1000 employees. Large firms report an operating revenue ≥ 10 million EUR, total assets ≥ 20 million EUR and more than 150 employees. Finally, the year is also included. The descriptive statistics of these variables are summarized in Table 23, Panel B.

Finally, Table 24 presents the Spearman (ρ) correlation coefficients between all the included variables. ρ is preferred rather than the Pearson coefficient due to the inclusion of categorical variables. Certifications are significantly correlated to ROS but not to ROCE nor ROA. They are also positively correlated to the industry, size and year; being the latter due to the adoption of multiple certifications throughout the period of study. The variable Industry shows a positive correlation with ROCE and ROA, and Size is negatively correlated to ROS. Moreover, there is a significant correlation between all the FP indicators. Regarding the lagged variables, the previous year’s FP is significantly correlated with the current, and the Certifications variable, CERT, is highly correlated with its previous three years, mainly due to the renewal periodicity.

Table 24. Correlation coefficients between explanatory and dependent variables

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
Variables	1.ROS	1												
	2.ROCE	0.7410	1											
	3.ROA	0.8810	0.8346	1										
	4.Certification	0.0591	0.0318	0.0179	1									
	5.Industry	0.0394	0.1993	0.0491	0.0753	1								
	6.Size	-0.0595	0.0034	-0.0362	0.0740	0.1758	1							
	7.Year	0.0625	-0.0403	0.0120	0.4011	-0.0208	0.0154	1						
Lagged variables	8.ROS_{t-1}	0.7313	0.5177	0.6471	0.0496	0.0331	-0.0492	0.0281	1					
	9.$ROCE_{t-1}$	0.5278	0.7227	0.6176	0.0289	0.1800	-0.0107	-0.0940	0.7299	1				
	10.ROA_{t-1}	0.6320	0.5903	0.7128	0.0252	0.0465	-0.0334	-0.0466	0.8674	0.8194	1			
	11.$CERT_{t-1}$	0.0764	0.0368	0.0437	0.8536	0.0403	0.0509	0.4127	0.0637	0.0276	0.0339	1		
	12.$CERT_{t-2}$	0.0537	-0.0009	0.0279	0.6923	-0.0007	0.0472	0.4213	0.0560	0.0078	0.0328	0.8194	1	
	13.$CERT_{t-3}$	0.0551	-0.0030	0.0275	0.5800	-0.0404	0.0486	0.4398	0.0433	-0.0160	0.0231	0.6808	0.8292	1

Correlations higher than |0.0700|, |0.0530| and |0.0460| are significant at 0.01, 0.05 and 0.10, respectively.
Source: Own elaboration

5.3.3. Model specification

The lagged FP_i (i.e., $FP_{i,t-1}$, referring to $ROS_{i,t-1}$, $ROCE_{i,t-1}$ and $ROA_{i,t-1}$) captures the effects of the omitted variables, such as the interdependencies between themselves, instead of adding such effect to the variables of interest. The certifications are renewed every three years, so the effect of $CERT_i$ on FP_i is analyzed for $t – 1$ and controlled for $t – 2$ and $t – 3$.

The two-step system Generalized-Method-of-Moments (system-GMM) panel estimators is the main research tool. A detailed description of this method is provided by Arellano and Bover (1995) and Blundell and Bond (1998). The following reasons justify the adoption of this technique. Firstly, FP_i and $CERT_i$ are not strictly exogenous but dependent on their own past observations. Moreover, this work aims to estimate the fixed individual effects of the certifications. The two-step system-GMM addresses the two previous situations by instrumenting i) the independent endogenous variables ($IND_{i,t}$, $Size_{i,t}$, $Year_{i,t}$), ii) the lagged independent variables ($CERT_{i,t-1}$, $CERT_{i,t-2}$, $CERT_{i,t-3}$), and iii) the lagged dependent variable ($FP_{i,t-1}$), with past observations uncorrelated with the fixed effects. Secondly, this method allows controlling the unobserved firm-specific effects correlated with the regressors, while controlling heteroskedasticity and autocorrelation within firms. Finally, this technique is well suited for a large sample compared with the size of the panel, so no specific distribution is assumed for its estimation (Greene, 2003, pp. 201, 525–527, 555). The main model is represented in (1).

$$FP_{i,t}=\alpha_0+\alpha_1 FP_{i,t-1}+\beta_1 CERT_{i,t-1}+\beta_2 CERT_{i,t-2}+\beta_3 CERT_{i,t-3} +\beta_4 IND_{i,t}+\beta_5 Size_{i,t}+\beta_6 Year_{i,t}+\mu_t + \nu_{i,t}$$

$$\nu_{i,t}=\varepsilon_i+\sigma_{i,t} \qquad (1)$$

Where $FP_{i,t}$ denotes the three equations related to i) ROS, ii) ROCE and iii) ROA; i=1,…,N and t=1,…,T represent, respectively, the firms and time periods; μ_t is the time-specific effect and $\nu_{i,t}$ stands for the time-invariant error term. The latter depends on the firm-specific effect and controls unobservable heterogeneity (ε_i); $\nu_{i,t}$ also depends on the stochastic error term varying cross-time and cross-section ($\sigma_{i,t}$).

The development of the main model took into account the analysis of different system-GMM dynamic alternatives, including the year when certifications were implemented as shown in equation 2 (see e.g., Heras-Saizarbitoria *et al.*, 2011; He *et al.*, 2015).

$$\begin{aligned} FP_{i,t} = {} & \alpha_0 + \alpha_1 FP_{i,t-1} + \beta_1 Certification\_ISO9001_{i,t-1} \\ & + \beta_2 Certification\_ISO9001_{i,t-2} \quad + \beta_3 Certification\_ISO9001_{i,t-3} \\ & + \beta_4 Certification\_ISO14001_{i,t-1} \quad + \beta_5 Certification\_ISO14001_{i,t-2} \\ & + \beta_6 Certification\_ISO14001_{i,t-3} \\ & + \beta_7 Certification\_OHSAS18001_{i,t-1} \\ & + \beta_8 Certification\_OHSAS18001_{i,t-2} \\ & + \beta_9 Certification\_OHSAS18001_{i,t-3} + \beta_{10} IND_{i,t} \\ & + \beta_{11} Size_{i,t} + \beta_{12} Year_{i,t} + \mu_t + \nu_{i,t} \end{aligned}$$

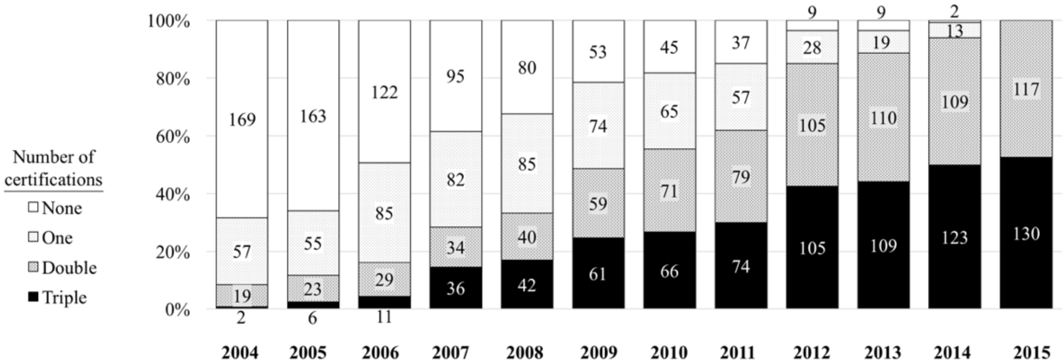
$$\nu_{i,t} = \varepsilon_i + \sigma_{i,t} \qquad (2)$$

Where, the *Certification* variables are dummies coded as one if the company obtained the certification (of ISO 9001, ISO 14001 or OHSAS 18001) in year *t* and 0 otherwise. Regarding *FP*, the control variables and the other variables related to the system-GMM, the notation remains the same as in the main model.

The two-step system-GMM represented in (1) and (2) were solved using Stata/SE 14.0 with the xtabond2 command (Roodman, 2009). In order to control the downward bias usually produced in two-step results, the finite sample correction for asymptotic variance proposed by Windmeijer (2005) was applied. The option "collapse" (Roodman, 2009) was adopted to reduce instrument count for decreasing the average bias produced in two-step estimators (Windmeijer, 2005). Finally, years 2004-2006 were omitted due to lack of FP indicators during this period.

5.4. Results

As summarized in Figure 14, 68% (169 firms) of the sample did not hold any certification by 2004 and, at the beginning of the dynamic study, in 2007, this percentage was 38% (95 firms). Across the dynamic panel study, such firms were increasingly certifying by one, two or three MSs. By 2015, 53% (130 firms) were certified in accordance with the requirements of the three MSs, followed by 38% (95 firms) that adopted ‘ISO9001+ISO14001’. The combinations ‘ISO9001+OHSAS18001’ and ‘ISO14001+OHSAS18001’ were a minority (9% of the sample). Although the sample considers only firms that by 2015 held at least two certifications, the aforementioned tendencies are representative of the country-level reality as shown previously in Figure 12.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
ISO 9001	55	53	80	76	79	67	57	49	23	16	11	0	One certification
ISO 14001	2	2	4	4	4	4	5	5	5	3	2	0	
OHSAS18001	0	0	1	2	2	3	3	3	0	0	0	0	
ISO9001+ISO14001	19	23	28	31	37	52	62	65	86	89	88	96	Double certification
ISO9001+OHSAS18001	0	0	1	2	3	7	9	14	17	18	18	17	
ISO14001+OHSAS18001	0	0	0	1	0	0	0	0	2	3	3	4	

Source: Own elaboration

Figure 14. Certification dynamics of the sample (N=247)

Table 25 summarizes the different strategies adopted in this sample to obtain multiple certifications (Bernardo *et al.*, 2012). The ISO 9001 certification is the first certification adopted by most firms (55%; strategies 1, 4 and 6), followed by the simultaneous implementation of the triple certification (30%; strategy 7) and the simultaneous implementation of ISO 9001 + ISO 14001 (14%; strategy 3). Hence, 88% of the sample included ISO 9001 as part of their first certified MS standards. Moreover, the percentage of firms implementing simultaneously more than one MS standard is around 35% of the sample, which might ease their integration,(Bernardo *et al.*, 2012).

Table 25. Multiple certification strategies (N=247)

Strategy	Firms	%
1. ISO 9001 first, ISO 14001 second	55	22%
2. ISO 14001 first, ISO 9001 second	5	2%
3. ISO 9001 + ISO 14001 simultaneously	34	14%
4. ISO 9001 first, OHSAS 18001 second	8	3%
5. ISO 9001 and OHSAS 18001 simultaneously	6	2%
6. ISO 9001 first, ISO 14001 second, OHSAS 18001 third	74	30%
7. ISO 9001 + ISO 14001 + OHSAS 18001 simultaneously	46	19%
8. Other strategies	19	8%

Source: Own elaboration

Table 26 shows the results of the two-step system-GMM estimators.

To interpret the results, first the validity of the models is assessed, followed by the estimated coefficients.

Both, the main (1) and the alternative (2) dynamic models for each FP indicator (ROS, ROCE and ROA) are valid according to the assumptions of the two-step system-GMM estimators. The Hansen (1982) *J* statistic for overidentifying restrictions is non-significant, suggesting the validity of the instruments exogeneity assumption. To test for autocorrelation aside from the fixed effects, the Arellano-Bond test applied to the second-order correlation, AR(2), shows no evidence to invalidate instruments through autocorrelation, so there is no evidence of serial first-order correlation. The AR(1) is significant by construction, so its significance is uninformative in the validity assessment of this model. Finally, there are no major concerns regarding the instruments count, which is considerably smaller compared to the sample size in all cases.

Table 26. Two-step system-GMM results of the alternative model

Variables	ROS		ROCE		ROA	
	(1)	(2)	(1)	(2)	(1)	(2)
FP_{t-1}	0.4087***	0.4578***	0.3902***	0.551***	0.4181***	0.4351***
	[0.0953]	[0.0818]	[0.1157]	[0.1466]	[0.0791]	[0.1134]
Certifications						
$ISO9001_{t-1}$	**4.8463****	1.727	**8.6094****	**14.9585***	**12.4869***	0.5451
	[1.8965]	[1.132]	**[3.4963]**	**[8.9083]**	**[7.2807]**	[0.6734]
$ISO9001_{t-2}$	-0.8192	0.6845	0.5009	5.5973	-6.0328	**1.2923****
	[0.9208]	[1.0718]	[2.2615]	[8.1846]	[13.0275]	**[0.6044]**
$ISO9001_{t-3}$	0.7137	1.0953	0.5409	1.1585	-2.8776	-0.1078
	[1.0116]	[0.796]	[1.5705]	[1.9723]	[8.7992]	[0.646]
$ISO14001_{t-1}$	-0.8339	0.7726	6.0121	-4.8778	0.4679	0.34
	[2.095]	[0.9304]	[7.8279]	[10.1761]	[21.5734]	[0.6743]
$ISO14001_{t-2}$	1.724	0.5868	0.7027	-5.3368	-5.5734	0.1904
	[1.7702]	[1.2273]	[5.0983]	[12.6283]	[16.3057]	[0.7299]
$ISO14001_{t-3}$	-2.0174	-0.2791	2.4544	-1.5135	1.4188	-0.0078
	[1.6681]	[0.9655]	[3.8404]	[2.0897]	[22.3848]	[0.6035]
$OHSAS18001_{t-1}$	3.7576	0.548	5.9208	16.9946	12.0411	0.2802
	[11.9774]	[1.5177]	[5.9295]	[10.6819]	[23.033]	[0.7234]
$OHSAS18001_{t-2}$	-2.0094	-1.7494	-2.3907	0.9681	-7.8222	-1.1706
	[10.5017]	[1.3238]	[4.7835]	[6.7573]	[28.8987]	[0.7132]

Variables	ROS		ROCE		ROA	
	(1)	(2)	(1)	(2)	(1)	(2)
$OHSAS18001_{t-3}$	5.6644	**3.2705*** **	4.4053	1.2891	1.019	1.1775
	[4.0365]	**[1.1782]**	[4.5084]	[3.6189]	[14.8785]	[0.7795]
$ISO9001+ISO14001_{t-1}$	**3.6052** **		**5.6229***		**13.7824***	
	[1.6275]		**[3.2442]**		**[7.3234]**	
$ISO9001+ISO14001_{t-2}$	-0.7067		-0.7285		-7.7057	
	[1.0163]		[1.9948]		[10.0256]	
$ISO9001+ISO14001_{t-3}$	0.9111		1.8846		-2.6094	
	[1.2176]		[2.5807]		[8.2428]	
$ISO9001+OHSAS18001_{t-1}$	3.1477		5.1311		**26.2746** **	
	[3.1446]		[3.4815]		**[13.1962]**	
$ISO9001+OHSAS18001_{t-2}$	-2.4154		2.1042		-12.6112	
	[4.5614]		[3.6591]		[22.4807]	
$ISO9001+OHSAS18001_{t-3}$	5.3016		1.4362		-8.0065	
	[6.1549]		[3.0941]		[13.0439]	
$ISO14001+OHSAS18001_{t-1}$	1.2257		9.0596		6.3076	
	[4.9596]		[11.8829]		[19.9511]	
$ISO14001+OHSAS18001_{t-2}$	6.6327		8.8722		-4.3751	
	[6.7671]		[8.0075]		[18.0665]	
$ISO14001+OHSAS18001_{t-3}$	1.2582		18.7367		10.1164	
	[10.3207]		[27.0658]		[21.6099]	

Variables	ROS		ROCE		ROA	
	(1)	(2)	(1)	(2)	(1)	(2)
Triple certificiation$_{t-1}$	**4.8837*****		**7.4854****		**16.0009****	
	[1.8983]		**[3.0702]**		**[7.4378]**	
Triple certificiation$_{t-2}$	-0.8946		-1.4897		-9.627	
	[1.0046]		[1.4301]		[10.1678]	
Triple certificiation$_{t-3}$	1.3784		1.0486		-1.6805	
	[1.3199]		[2.2023]		[7.9176]	
Size	0.182	-0.3156	-3.4931*	-2.6667*	-0.336	-0.8096
	[0.8763]	[0.7925]	[2.1206]	[1.7404]	[0.8392]	[0.5615]
Year and industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	32.5082	6.8998	25.1946	-13.0714	23.1919	13.3644*
	[20.1899]	[9.2207]	[71.9938]	[102.8186]	[37.3628]	[8.0204]
Observations	1,726	1734	1,366	1374	1,762	1770
N	242	243	218	219	243	244
Instruments	110	60	103	52	93	64
Wald (df)LL	248.17***	472.57***	87.72***	219.89***	210.03***	370.35***
	(49)	(46)	(49)	(46)	(49)	(46)
AR(1)	-3.59***	-3.77***	-1.96**	-2.13**	-2.51**	-2.69***
AR(2)	-0.32	-0.32	-0.99	-1.02	0.04	0.89
Hansen test (p-value)	50.62	198.46	45.68	118.23	40.15	191.56
	(0.801)	(0.304)	(0.752)	(0.781)	(0.596)	(0.615)

Source: Own elaboration

Regarding the alternative models (2), results suggest that if firms were certified of ISO 9001 on year *t*-1, they obtained ROCE benefits on *t*, while to gain ROA benefits, firms must have been certified on year *t*-2. The ISO 9001 certification is not significant in any other case. Regarding ISO 14001, there is no evidence of significant effects. Finally, OHSAS 18001 was only significant to ROS if firms certified on year *t*-3. Thus, there is some evidence that certifications might impact FP, but with this model it is not yet clear whether such impacts are solely attributable to the individual certifications, or if the dynamics involved in multiple certifications might play a role, which is more clearly shown in the main model.

In the main model (1), results suggest that not all the possible combinations of certifications have a positive impact on FP. Indeed, only 'ISO9001', 'ISO9001+ISO14001' and the triple certification consistently and positively affect all the analyzed indicators. Additionally, the 'ISO9001+OHSAS18001' certifications appear to improve ROA but neither ROCE nor ROS.

The impacts on FP in year *t* are persistently caused by the certifications that firms held during year *t*-1 (i.e., $CERT_{t-1}$), whereas the certifications held during the other years (i.e., $CERT_{t-2}$ nor $CERT_{t-3}$) show no significant effect on any FP indicator. This means that if firms: i) adopt more than one certification over time, and ii) are committed to maintain their certifications in the long term (this study analyses an eight-year-span), they benefit in financial terms in year *t* from the certifications they held during the prior year (*t*-1), for any year *t*. Complementing the results of the alternative models, this means that the results evidenced in (2) do not represent accurately the effects of the certifications since they are mixed (confused) with the dynamics of adopting multiple certifications (e.g., as in Goedhuys and Sleuwaegen, 2013 or He *et al.*, 2015). The main model (2) surpasses such limitation and shows the effects of the different possibilities of holding different certifications.

Regarding control variables, FP_{t-1} is significant in all cases, meaning that persistence and inertia effects were detected and controlled in all models. Consequently, FP_{t-1} captures the effect of other variables that might not be included in this research and that consistently affect FP over time (Arellano and Bover, 1995; Blundell and Bond, 1998; Roodman, 2009). Moreover, the firms' size is significant solely for ROCE in the main and alternative models (similarly to Lisi, 2015). Finally, year and industry dummies were included as control variables.

5.5. Discussion and conclusions

The aim of this article is to research into the effects of multiple certifications considering: i) the dynamics involved in the adoption of multiple certifications, and ii) its impacts on firms' financial performance, measured objectively with existing records.

The most revealing finding lies on ISO 9001 being the common factor in all the certifications combinations that leverage FP, which is also the first standard adopted by most firms. According to the results, the positive relationship between ISO 9001 and FP is not only related to improvements in the first years of certification (Sharma, 2005; Goedhuys and Sleuwaegen, 2013), but it continuously and persistently occurs even when implementing other certifications, thus confirming H1. This might be related to the strong and lasting cumulative improvements achieved over time that leverage FP (Corbett *et al.*, 2005).

Regarding ISO 14001, H2 is rejected as its only adoption does not significantly impact FP. However, its effect is positive when combined with ISO 9001, in accordance with H4. This is in good agreement with Su *et al.* (2015), who reported that ISO 14001 provides additional performance benefits (especially in terms of ROS and ROA) only if firms had previous experience in ISO 9001, due to competitive advantage gained with it. Otherwise, firms would perform better without ISO 14001. The evidence that 'ISO9001+ISO14001' leads to FP improvements (especially in terms of ROS), suggests that profits might be boosted by the reputational motivations of implementing ISO 14001 (Heras-Saizarbitoria *et al.*, 2011). This could move their adopters closer to effectively become a benchmark company, and consequently improve their ROS. 'ISO9001+ISO14001' also improves FP in terms of ROCE and ROA. This could be attributed to the optimization of resources attained through the implementation of ISO 14001 (Melnyk *et al.*, 2002; Llach *et al.*, 2013), and the quality support provided by ISO 9001 (Siva *et al.*, 2016), which improves FP compared to adopting only ISO 14001 (Ferrón-Vílchez and Darnall, 2016).

Regarding OHSAS 18001, results show no evidence of significant changes in FP when held solely, so H3 is rejected. Moreover, there is no evidence of OHSAS affecting ROS or ROCE in any case, whereas its positive effect on ROA is significant, but only if it coexists with ISO 9001; thus, H5 is partially supported. This is in good agreement with Lo *et al.* (2014), which is complemented by the dynamic models used in this manuscript. Moreover, OHSAS 18001, among other benefits, could contribute to increasing labor productivity, diminish the rate of accidents (Abad *et al.*, 2013) and improve working conditions (Santos *et al.*, 2013). Such benefits are combined with the increased operational performance achieved through ISO 9001, which might be the cause of the positive impact of 'ISO9001+OHSAS18001' on ROA. In addition, the high costs associated with OHSAS 18001 maintenance (Santos *et al.*, 2013) seem to be compensated with the sales growth achieved through its certification (Lo *et al.*, 2014), which might explain why ROS and ROCE are not affected. This can also explain the lack of significant effects of OHSAS 18001 (alone) on all FP indicators.

Firms simultaneously certified by 'ISO14001+OHSAS18001' do not perform significantly better (financially), thus H6 cannot be confirmed. As expected, this combination is scarcely reported (Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012), which could be the main cause for the lack of noticeable effects on FP compared to other more adopted certification combinations.

Results also imply that the triple certification is positively associated to improvements in all FP indicators, so H7 is confirmed. This finding complements the previous discussion, suggesting that it is possible to achieve a better FP even with a more complex certification structure. Wiengarten *et al.* (2017) argued that adopting more than two certifications might be challenging since conflicts of interest might arise when dealing with different stakeholders related to each certification. The evidence presented in this study suggests that firms can efficiently deal with such complexity and take advantage of it. In fact, firms seem to find the proper balance and synergy between MSs in pursuit of FP, for which ISO 9001 might have a major role according to the results (Siva *et al.*, 2016).

Firms adopting multiple certifications can harness the existing synergies among them. One advantage of the three analyzed MSs is the same structure derived from the Plan-Do-Check-Act cycle, so firms can integrate various systems at different levels based on it (Zeng *et al.*, 2007; Bernardo *et al.*, 2009). Different taxonomic approaches have been proposed in literature and tested empirically, so the integration can be classified as full, partial or no integration, indicating the degree to which the different MSs have been assimilated to the firm as a single system (Salomone, 2008; Bernardo *et al.*, 2009). Ribeiro et al. (2017) recently reported that 95% of Portuguese firms are at least partially integrated. This is also coherent with the expected behavior of firms adopting simultaneously more than one certification (Bernardo *et al.*, 2009), which is the case of this sample (see Table 25). Among other benefits, integrating MSs fosters costs reduction, efficiency, cleaner production, increased productivity (Bernardo *et al.*, 2015; Mustapha *et al.*, 2017; Ribeiro *et al.*, 2017) and increased FP (Martí-Ballester and Simon, 2017). Therefore, it could be expected that the multiple-certifications effects on FP might be attributed –at least partly– to their integration.

To summarize, results suggests that ISO 9001 could be the main driver in multiple certifications to leverage FP in terms of profiting from sales (ROS), assets (ROA) and using capital efficiently (ROCE). More specifically, firms that were certified by ISO9001, ISO9001 + ISO14001, and ISO9001 + ISO14001 + OHSAS18001 improved their financial performance in all the studied dimensions. The adoption of ISO 9001 + OHSAS 18001 was only significantly related to ROA improvements. Therefore, the main implications to academia and practitioners, as well as the limitations and contributions of this paper are further developed in the next paragraphs.

This article has two main implications for academia. Firstly, researchers might consider dynamic models for researching into the effects of adopting multiple MSs. Firms operate in a dynamic environment, they have their own basal performance, and they can decide to adopt new certifications dynamically. Including these factors into the research leads to a better understanding of the interactions; for instance, if each certification is analyzed as an independent factor, ISO 9001 had only a significant effect on ROCE and ROA. However, after implementing the dynamic approach with the different possible combinations of certifications (i.e., ISO 9001, ISO 9001 + ISO 14001 and so on), results unveiled the fixed effects of the certifications held by firms on FP. Secondly, the literature related to the integration of MSs might consider the role of ISO 9001 as a factor for further researching into the benefits of MSs integration.

This article has two main managerial implications. Firstly, practitioners should be aware that adopting a certification does not necessarily implicate improving their FP. Firms must see certifications as a strategic decision to maintain in the long term and pursue excellence by practicing and interiorizing the philosophy embedded in the standards. Secondly, managers could look at ISO 9001 as a driving MS in pursue of excellence. More specifically, this standard could act as the basis for incorporating other MSs, so that the benefits of a more efficient integrated management system could be a prevailing means to leverage FP.

The main limitation of this study lies in the sample itself. It is focused on Portuguese companies whose FP indicators were included in the secondary dataset. Thus, despite finding evidence of casualty, results may not be universal in scope and extension, especially for populations with less tradition of adopting multiple certifications. However, although the statistical generalization of the findings may be precluded there is no reason that prevents its analytical generalization.

To conclude, further investigation will focus on discerning the main attributes of multiple certifications that leverage FP, like their integration strategy and methodology. It will consider the dynamics as well as the level and maturity of MSs integration. Further research will also consider other countries to extend the applicability of the conclusions.

CHAPTER 6. DISCUSSION AND CONCLUSIONS

The aim of this thesis is to relate the integration of management systems and innovation with the final –and common– objective of reaching corporate sustainability. To this end, this work was divided into four chapters (2 through 5), each aimed to address empirically the specific objectives defined in the introduction of this work. In this chapter, the conclusions of this thesis will be developed according to these objectives and focused to their relationship with corporate sustainability.

This chapter is structured as follows. Firstly, the conclusions obtained from each of the specific objectives are summarized below. Secondly, a general discussion derived from the results obtained throughout this thesis is developed. Thirdly, the implications of this thesis are settled, followed by its contributions. Finally, some insights for future research are proposed.

6.1. Summarizing the conclusions of the specific objectives

Each chapter, 2 through 5, contains a detailed section that discusses the empirical results and that obtains comprehensive conclusions regarding the specific objectives of this thesis. This section summarizes such conclusions, which are then schematized in Figure 15 based on the research model of this thesis.

i. The first specific objective was aimed to develop a measurement for the level of IMS that can be applied to certified and non-certified MSs, based on the importance given to MSs at the strategical level. Based on the results obtained from Chapters 2 and 4, it can be concluded that IMS does not necessarily require companies to be certified of any standard. Instead, companies can achieve high levels of IMS through the deep internalization and broad application of the function-specific MSs principles across the organization. To this end, the involvement of the top management is not only necessary, but critical to achieve high levels of IMS.

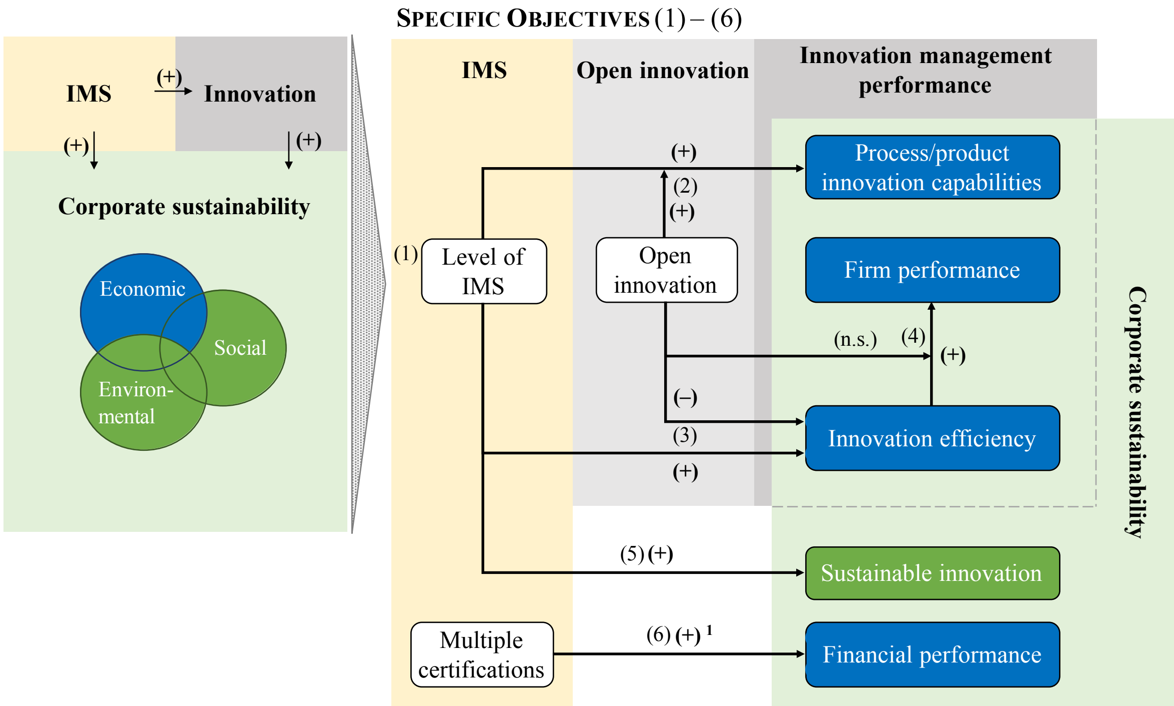
ii. The aim of the second specific objective was to study empirically whether IMS fosters process and product innovation capabilities, considering the moderating role of open innovation. This objective was addressed empirically in Chapter 3. According to the results, it can be concluded that high levels of IMS are beneficial for increasing process and product innovation capabilities. To this end, IMS interacts with OI, creating a synergetic relationship between them towards the enhancement of these capabilities.

iii. The third specific objective was focused on studying empirically whether innovation efficiency can be boosted by the integration of management systems and open innovation. These relationships were analyzed in Chapter 3, from which it can be concluded that IMS benefits innovation in terms of the better use of resources, optimization of the quality and environmental aspects of innovations and, as a result, added innovation efficiency. However, OI might implicate having innovation inefficiencies as a result of the lack of innovation outputs in spite of the additional efforts invested in external collaborations.

iv. The fourth specific objective was to study empirically whether innovation efficiency leads to an increased firm performance, considering the moderating role of open innovation. Since this objective considered innovation efficiency measurements, it was also studied in Chapter 3. Based on those results, it can be concluded that innovation efficiency leads to an increased firm performance through the enhancement of the innovative sales productivity. Moreover, the innovation inefficiencies of OI seem to be offset by an unaltered firm performance.

v. Based on the aim of the fifth specific objective, Chapter 4 was developed to explore empirically whether the integration of management systems fosters sustainable innovation. The results obtained from this study lead to the conclusion that IMS seem to support the development of sustainable process and product innovations regardless of companies' location. Thus, companies would be able to attain technically, environmentally and socially responsible innovations through the deep and broad application of IMS.

vi. The sixth specific objective was to study empirically whether adopting multiple certifications dynamically fosters firms' financial performance. Chapter 5 was devoted to studying this research gap empirically. Based on the results obtained in this study, it can be concluded that companies that adopt and succeed to maintain sustainably (i.e., in the long term) multiple MSs' certifications are able to improve their financial performance. To this end, QMSs seem to have a relevant role related to continuous improvement and to IMS strategy.



(+) Positive, (-) Negative, (n.s.) Not significant. Specific objectives (1)–(6) in parentheses.
[1]Only when certified of ISO 9001; ISO 9001 + ISO 14001; ISO 9001 + OHSAS 18001 or the triple certification.
Source: Own elaboration

Figure 15. Main conclusions of the thesis

6.2. Discussion

In this section, the main conclusions obtained throughout this thesis are discussed within the framework of corporate sustainability. To this end, this discussion is subdivided into two subsections: (1) a more technical one regarding the level of IMS, and another one (2) focusing on the holistic relationships between IMS and innovation in pursue of sustainability. The first part of this discussion is important to contextualize the means for operationalizing the level of IMS with an empirical focus to relate IMS to other concepts. Then, the second part of this discussion focuses on the main objective of this manuscript: to relate IMS and innovation in pursue of sustainability.

6.2.1. The level of IMS

IMS is an important milestone to attain corporate sustainability (Jørgensen, 2008; Rebelo *et al.*, 2016; Siva *et al.*, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017). However, IMS by itself is not a guarantee of sustainability, but it requires companies to integrate MSs at high and balanced levels (Jørgensen, 2008).

The existing literature provides comprehensive taxonomic proposals to measure the level of IMS (see e.g., Beckmerhagen *et al.*, 2003; Karapetrovic, 2003; Jørgensen *et al.*, 2006; Bernardo *et al.*, 2009; Abad *et al.*, 2014). Most of such approaches rely on certified MSs and usually require performing specific surveys or case studies. This might limit the capacity of researchers to relate IMS to other managerial concepts, especially since IMS is non-certifiable yet at the international level (Gianni *et al.*, 2017a). To overcome this limitation, a proxy measure for the level of IMS was developed.

This measurement was firstly designed based on the integration of QMSs and EMSs due to its wide application in this field (see e.g., Karapetrovic and Willborn, 1998b; Ferrón-Vílchez and Darnall, 2016; Bernardo *et al.*, 2017; Martí-Ballester and Simon, 2017). To this end, the measurement was mainly grounded on the fact that companies integrating their MSs have to first integrate their goals and strategies, giving a high and balanced priority to both MSs (Karapetrovic, 2003; Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo *et al.*, 2009). Thus, the measurement was constructed according to the following criteria. To achieve full integration, both MSs have to be given the highest importance at the strategical level. Conversely, non-integrated companies do not consider important at least one out of the two MSs. Finally, partially integrated companies consider both MS important, but none of them imperative.

The importance given to both the quality and environmental performance of the company are included in innovation secondary datasets such as the Spanish Innovation Panel (PITEC, 2007; FECYT, 2008). For this reason, this measurement could be used to relate IMS to innovation based on a widely used secondary dataset in the field of innovation (see e.g., Barge-Gil, 2013; Cruz-Cázares *et al.*, 2013; Bayona-Saez *et al.*, 2017). However, it has the limitation of not considering other widely adopted MSs such as OHSMS or those related to CSR (see e.g., Castka *et al.*, 2004; Bernardo *et al.*, 2012; Asif *et al.*, 2013; Nunhes *et al.*, 2017), so it was further developed.

IMS requires the top-management to give a high importance to all MSs, which determines the IMS boundaries for the whole organization (Zeng *et al.*, 2007; Gianni and Gotzamani, 2015; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). In other words, the strategic importance given to MSs promotes or limits IMS. Something similar occurs with the application of OI across companies. In this line, Laursen and Salten (2006) proposed two indicators to measure this complex concept. Namely, they proposed the OI-depth and OI-breadth indicators to measure OI relying on how broad and how deep companies collaborate with external parties to innovate. These measurements are based on the importance given to such external collaborators at the companies' strategic level; moreover, they are broadly accepted in the specialized literature.

Therefore, in this thesis, the IMS-breadth and IMS-depth indicators were defined analogously. Thus, they represent, respectively, how broad and how internalized MSs are applied across companies. Consequently, these measurements can be used as proxy measures to determine the level of IMS without asking managers to assess this factor directly. This should minimize biases and provide researchers more reliable indicators of this complex concept, similarly to Laursen and Salten (2006).

This work relied on the abovementioned proxy measures of the level of IMS to relate IMS and innovation to achieve corporate sustainability. Such results are further discussed in the next subsection.

6.2.2. Attaining sustainability through IMS and innovation

In this part of the discussion, it is firstly presented the relevance of the research gap analyzed in this work. Then, grounded on the empirical evidence presented in this study, the discussion focuses on how IMS and innovation foster the economic dimension of sustainability. To this end, the relationship between IMS and innovation to improve the innovative management performance is discussed. Moreover, since IMS has been widely related to the adoption of multiple certifications, its implications to the companies' financial performance are discussed. Finally, the discussion centers on the explorative results regarding the role of IMS and innovation towards attaining environmental and social sustainability.

Both IMS (Jørgensen, 2008; Rebelo *et al.*, 2016; Siva *et al.*, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017) and innovation (Elkington, 2006; Asif *et al.*, 2013; Boons *et al.*, 2013; Baumgartner, 2014) have been considered sustainability promotors. However, how they contribute to sustainability has been mostly analyzed independently and irrespective of their interactions. Thus, this thesis was developed aiming to address a relevant research gap recently identified in the IMS (Nunhes *et al.*, 2016; Siva *et al.*, 2016) and innovation literature (Pacheco *et al.*, 2017; Xavier *et al.*, 2017). Namely, this work studies the relationships between IMS and innovation with the aim of attaining corporate sustainability. Therefore, this section firstly analyzes the economic dimension of sustainability, followed by the environmental and social dimensions.

6.2.2.1. Tackling the economic dimension of sustainability through IMS and innovation

IMS and innovation had been scarcely related as pointed out by recent research (Nunhes *et al.*, 2016; Gianni *et al.*, 2017a). The empirical evidence found in literature suggests that IMS fosters innovation better than function-specific MSs (Castillo-Rojas *et al.*, 2012). It also suggests that IMS promotes organizational and marketing innovations (Simon and Petnji Yaya, 2012), specially though the enhancement of documentation and the management of the human resources (Simon *et al.*, 2014). Moreover, IMS has been acknowledged as an organizational innovation by itself, since it promotes organizational changes, continuous improvement and cultural change (Jørgensen *et al.*, 2006; Salomone, 2008; Bernardo, 2014).

With this background, Bernardo (2014) developed one of the first studies relating the level of IMS and the innovation management performance. This theoretical model, although well stablished based on the existing literature, remains scarcely tested empirically, giving as a result a major research gap in the IMS literature (Nunhes *et al.*, 2016). This thesis aimed to overcome this limitation. Moreover, this model provides the necessary framework to address the economic benefits derived from this relationship. This is because it stablishes that high levels of IMS foster innovation capabilities, the better use of resources (innovation efficiency) and firm performance.

Furthermore, the sustainability-oriented literature emphasizes the need of collaborating actively with external partners to create products and technologies in pursue of sustainability (Baumgartner and Ebner, 2010;

European Comission, 2011; Behnam *et al.*, 2018; Watson *et al.*, 2018). The field of innovation that deals with these collaborative practices is defined as OI (Chesbrough, 2003). Therefore, this thesis studied its role in the relationship between IMS and innovation in pursue of sustainability.

The empirical results obtained in this thesis are in accordance with the relationships proposed in Bernardo (2014). Moreover, they contribute to better understand the paths involved in such complex relationships. Therefore, the different aspects of the innovation management performance are discussed more in detail as follows.

Regarding the effects on innovation capabilities, results suggest that the level of IMS is positively related to both process and product innovation capabilities. More specifically, integrating MSs to a high extent seems to increase the odds of developing new or significantly improved products and processes. This means that companies that fully integrate their MSs have better chances to innovate than those adopting partial or non-integrated MSs. These results are in good agreement with the previous empirical research that has also found a positive relationship between IMS and innovation (Castillo-Rojas *et al.*, 2012; Simon and Petnji Yaya, 2012; Simon *et al.*, 2014).

The role of OI in the latter relationships was also analyzed. Results suggest that collaborating in depth with external organizations is required so that process innovations lead to increased product innovation capabilities; otherwise, the latter could be hindered by process innovations. This finding might explain the means by which process innovations are positively related to product innovations (Camisón and Villar-López, 2014; Hojnik and Ruzzier, 2016). Moreover, investing in external knowledge seems to moderate positively the effect of IMS on process and product innovation capabilities. In the latter case, collaborating in depth seems to interact with IMS in order to increase process innovation capabilities. This might be attributed to the improvement of the internal knowledge base gained through OI (Laursen and Salter, 2006), which seems to be complemented by the internal support provided by IMS (Nunhes *et al.*, 2017). Thus, IMS seems to be an appropriate sustainability-oriented management approach since it enables companies to harness the benefits of OI (Kennedy *et al.*, 2017).

The relationship between IMS and innovation efficiency, considering the role of OI, was also studied. Results suggest that fully integrated companies are more efficient innovating compared to other companies that are not integrated. As a result, IMS seems to be an accurate manner of improving innovation efficiency. To this end, IMS promotes the optimization of resources (Wagner, 2007b; Simon *et al.*, 2012; Simon and Douglas, 2013), the unification of the function-specific MSs knowledge through the creation of common objectives (Karapetrovic, 2003), and the optimization of the quality and environmental aspects of new inventions (von Ahsen, 2014).

Moreover, the results regarding the role of OI with reference to innovation efficiency are opposite to what was expected. They suggest that openness could be detrimental to innovation efficiency. Therefore, the additional efforts invested in external collaborations (Laursen and Salter, 2006; Greco *et al.*, 2016) seem not to be compensated by the creation of additional innovation outputs (Cuerva *et al.*, 2014). However, results evidence that these inefficiencies, although significant, are small, which suggests that companies might be able to deal with such drawback through the same innovation capabilities gained with OI (Cheng *et al.*, 2016; Behnam *et al.*, 2018).

The next relationship to improve the innovative management performance is through the enhancement of firm performance (Bernardo, 2014). To this end, companies might prefer firstly promoting their innovation efficiency and subsequently their performance (Wang *et al.*, 2016a; Kennedy *et al.*, 2017). This relationship has been researched in previous empirical studies, generally finding a positive association between innovation efficiency and firm performance (Guan and Chen, 2010; Cruz-Cázares *et al.*, 2013; Wang *et al.*, 2016a). In this thesis, firm performance was studied based on the productivity of the sales of new products (Belderbos *et al.*, 2004; Tsai, 2009). This measurement was suitable to this study since the commercial success of new products conditions the economic benefits of the overall firm performance attained through innovation efficiency (Guan and Chen, 2010; Wang *et al.*, 2016a). The results obtained in this study are in good agreement with the previous arguments, since it is evidenced that innovation efficiency is positively related to firm performance. Thus, it can be inferred that firms that innovate efficiently perform better due to their proficiency for transforming innovation inputs into innovation outputs (Cruz-Cázares *et al.*, 2013). This would promote firm performance through the new sales obtained with the use of optimized resources (Guan and Chen, 2010; Wang *et al.*, 2016a).

As previously discussed, the empirical evidence showed negative effects of practicing OI regarding innovation efficiency, so its role in the relationship between innovation efficiency and performance was also studied. According to the results, companies that practice OI perform similarly to those that do not. This suggests that the inefficiency observed in the innovative process for open firms is compensated by the effectiveness of exploiting their innovations in the market (Chesbrough and Bogers, 2014) and their enhanced innovation capabilities gained with the interchange of knowledge (Cheng *et al.*, 2016; Behnam *et al.*, 2018), so their firm performance is not affected. However, the results are still inconclusive regarding the means to harness the benefits of OI in pursue of sustainability, which remains a major research gap according to the specialized literature (Pacheco *et al.*, 2017; Watson *et al.*, 2018).

As a result of the previous discussion, it can be concluded that high levels of IMS foster the innovative management performance, and therefore, the economic dimension of sustainability. Moreover, OI plays a relevant role to complement the internal support of IMS towards innovation, by providing firms of enhanced innovation capabilities. However, this thesis highlights the need of further studying OI and its interactions with IMS in pursue of sustainability.

Furthermore, most scholars seem to agree that innovation is required to attain corporate sustainability (Elkington, 2006; Asif *et al.*, 2013; Boons *et al.*, 2013; Baumgartner, 2014; Bonzanini Bossle *et al.*, 2016; Kennedy *et al.*, 2017). Conversely, an analogous statement related to the adoption of certified MSs is often subjected to serious question, especially regarding their financial effects (Robson *et al.*, 2007; Sampaio *et al.*, 2009; Heras-Saizarbitoria and Boiral, 2013; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016). Moreover, adopting more than two certifications poses firms an additional challenge of having to deal with different stakeholders related to each certification (Wiengarten *et al.*, 2017). In this thesis, these concerns were addressed considering the dynamics and strategies of adopting multiple certifications (Karapetrovic and Willborn, 1998b; Karapetrovic, 2002; Pun and Hui, 2002; Labodová, 2004; Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012; Ivanova *et al.*, 2014).

The empirical evidence found in this work suggests that not every possible combination of multiple certifications enhances firms' financial performance, which might explain the lack of consensus in the existing literature. More specifically, it suggests that the IMS strategy has a relevant role to attain sustainable economic benefits through certifications. Thus, companies that adopt first a QMS certification, then adopt simultaneously or in future years other certifications and, finally, succeed to maintain their multiple certifications in the long term seem to attain significant financial benefits.

According to Gianni and Gotzamani (2015) the level of IMS in the long term is determined by the IMS strategy approach originally adopted by the organization. Thus, since the ISO 9001 was included in the original approach of most of the studied firms, this certification seems to provide relevant insights of continuous improvement across organizations in the long term, which strategy allows these companies to attain higher levels of IMS. Therefore, the quality approach to IMS based on continuous improvement may be expanded across all the organization, following a commonly used strategy of implementing QMSs firstly or simultaneously with other MSs (see e.g., Karapetrovic, 2002; Zeng *et al.*, 2007; Simon and Douglas, 2013; Bernardo *et al.*, 2017). These results are in good agreement with the recent literature aiming to study the financial effects of adopting multiple certifications, but that have failed to consider the companies' dynamics in the long run and the different IMS strategies (Ferrón-Vílchez and Darnall, 2016; Wang *et al.*, 2016b; Martí-Ballester and Simon, 2017).

Thus, it can be concluded that adopting single or multiple MS standards do not foster automatically economic sustainability. Instead, companies ought to see certifications as a strategic decision to maintain in the long term and pursue excellence by practicing and internalizing the continuous improvement philosophy embedded in the standards.

6.2.2.2. Tackling the environmental and social dimensions of sustainability through IMS and sustainable innovation

Sustainable development goes beyond the economic viewpoint as it also requires considering the environmental and social dimensions of business, including those of new products and processes (Elkington, 2006; Asif *et al.*, 2013; Boons *et al.*, 2013; Baumgartner, 2014). However, the way to attain sustainability within the innovation dynamics remains a challenge to practitioners and researchers (Boons *et al.*, 2013; Longoni and Cagliano, 2016; Pacheco *et al.*, 2017; Xavier *et al.*, 2017).

IMS seems to provide companies of the necessary holistic framework to achieve corporate sustainability (Vieira and Amaral, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017; Sroufe, 2017) by giving the environmental, social and economic priorities a high importance through MSs (Zeng *et al.*, 2007; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). Moreover, the existing research suggests that IMS and innovation are positively associated (Castillo-Rojas *et al.*, 2012; Simon and Petnji Yaya, 2012; Bernardo, 2014; Simon *et al.*, 2014; Hernandez-Vivanco *et al.*, 2016a). Thus, this thesis explored the scarcely studied relationship between IMS and sustainable innovation.

To this end, IMS and sustainable innovation were related based on the cleaner production framework, which is one of the most adopted voluntary practices towards sustainability (Bonilla *et al.*, 2010; Lozano, 2012). Results suggest that IMS is a driver of sustainability-oriented innovations. More specifically, companies that have broadly spread and deeply internalized IMS are more prone to adopt cleaner production technologies that minimize the impacts to the environment at source. This positive association can be attributed to the support of IMS towards sustainability goals, the increased innovation efficiency and the added productivity of integrated companies (Hernandez-Vivanco *et al.*, 2016b; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017) that also seek to preserve the environment through the adoption of these technologies (Vieira and Amaral, 2016; Ramos *et al.*, 2018).

In addition, results suggest that IMS is positively related to sustainable product innovation. The latter is aimed to minimize both the environmental and social of impacts of new products (UNEP DTIE, 1996). However, in contrast to the direct relationship between IMS and regular product innovations (i.e., not necessarily sustainability-oriented) found in Hernandez-Vivanco *et al.* (2016a), this relationship is not direct, but mediated by the adoption of cleaner production technologies. This supports the fact that, in pursue of sustainability, companies are firstly required to change radically their internal operations (i.e., adopt cleaner production technologies) to consequently develop innovations that benefit directly the market through product innovations (Boons *et al.*, 2013; Klewitz and Hansen, 2014; Kennedy *et al.*, 2017).

Finally, the positive relationships reported above occur irrespective of the location of the companies. This is a revealing result since other studies have found that location could condition the effects of MSs on innovation (Frondel *et al.*, 2007). Thus, it can be discussed that the IMS approach provide a robust strategy to promote sustainable innovation. Namely, because it promotes isomorphism across organizations, which is achieved through the homogeneity and high internalization among all the MSs objectives (Zeng *et al.*, 2007; Gianni and Gotzamani, 2015; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). Therefore, IMS can be identified as a managerial best practice to attain sustainable innovation. This finding explores a major research gap of the innovation literature (Pacheco *et al.*, 2017; Xavier *et al.*, 2017).

Hence, it can be concluded that the broad application and deep internalization of the function-specific MSs is critical to promote IMS. This, consequently, seem to foster the necessary enhancements required in organizations to develop technically, environmentally and socially responsible process and product innovations.

6.3. Implications

In this section, the main implications to academy, practitioners, stakeholders and decision makers are developed.

6.3.1. Implications to academy

This thesis has five main research implications, which are detailed below.

Firstly, researchers might consider **IMS as a sustainability-oriented management approach beyond the traditional viewpoint of certified organizations**. According to the empirical results obtained in this thesis, companies seem to be able to obtain high levels of IMS irrespective of their certifications. To this end, the strategical support of the top management is critical (Zeng *et al.*, 2007; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a), especially when it comes to achieve a deep internalization and broad application of the MSs' principles across organizations. Researchers might deem this outcome as a complementary factor to consider in addition to the existing taxonomic proposals of IMS based on certifiable MSs standards.

Secondly, **the level of IMS might be considered in studies relating MSs with innovation**. The debate regarding the still inconclusive effects of function-specific MSs on innovation (see e.g., Prajogo and Sohal, 2001; Matias and Coelho, 2011; Palm *et al.*, 2016) might be due to, at least partially, the lack of attention given to their interaction with other MSs. To overcome this issue, IMS provides an accurate framework to better estimate how MSs impact on innovation performance (Bernardo, 2014). More specifically, IMS promotes continuous improvement (Wilkinson and Dale, 1999; Kurdve *et al.*, 2014; Rebelo *et al.*, 2016), enables knowledge sharing through the alignment of the different MSs goals (Karapetrovic, 2003; Zeng *et al.*, 2007) and, in addition, it facilitates the efficient use of human and financial resources in the innovative process (von Ahsen, 2014). Thus, results point out that higher levels of IMS foster the enhancement of the innovation management performance. This implies that, when organizations are highly integrated, they seem to gain more innovation capabilities, improve their innovation efficiency and, consequently, enhance their firm performance. Thus, less integrated organizations might end up having less innovation benefits derived from their MSs practices.

Thirdly, the empirical evidence presented in this thesis supports the fact that **IMS is a sustainability management approach that benefits the TBL through innovation**. This is because IMS is a voluntary practice adopted strategically and with the support of the top management (Bernardo *et al.*, 2017; Gianni *et al.*, 2017a). Moreover, it centralizes the needs of diverse stakeholders under a common umbrella, which promotes innovations to meet such needs (Jørgensen *et al.*, 2006; Bernardo, 2014). Economically, IMS seems to be a relevant driver to increase the odds of innovating and, thus, integrated organizations are able to use less resources to produce more innovation outputs. The resulting innovation efficiency leads to improved firms' performance through the increase of sales related to new products.

Furthermore, the positive relationship between IMS and innovation seems to go beyond the economical viewpoint since it promotes sustainable innovation. More specifically, IMS endows organizations with the strategical framework so that their process innovations are environmentally friendly; in particular, IMS promotes the adoption of cleaner production technologies. This is because IMS intends to benefit the internal organizational efficiency as well as to minimize the environmental effects (Mustapha *et al.*, 2017; Ramos *et al.*, 2018). Moreover, such innovations lead organizations to develop sustainable products, which are consistent with their technical, environmental and social aspects. To this end, it is firstly necessary to improve the in-house operations through cleaner production technologies in order to develop sustainable products. According to the exploratory results obtained from two different continents (Europe and Latin-America), the aforementioned relationships appear to be similar regardless of the company location. Thus, IMS benefits seem to be a robust best practice towards sustainable innovation, providing homogenous results and likely to be reproducible in diverse locations and industries.

Fourthly, **OI seems to have a relevant role in the relationship between IMS and innovation in pursue of sustainability**. More specifically, OI is critical so that companies that improve their process innovation capabilities can also increase their odds of developing new product innovation capabilities. Otherwise, companies seem to limit their vision to improve their in-house processes and, consequently, diminish their capacity of innovating in products. Moreover, OI interacts with IMS in order to increase process and product innovation capabilities. This is because both IMS (Jørgensen *et al.*, 2006; Salomone, 2008; Rebelo *et al.*, 2016) and OI (Walker and Preuss, 2008; Behnam *et al.*, 2018; Watson *et al.*, 2018) truly seek the involvement of diverse (but common) stakeholders so they can complement each other. OI particularly promotes the exploitation of inflows and outflows of knowledge, so this vision enriches the way IMS favors innovation capabilities from within the organization.

Despite this beneficial synergy between IMS and OI, it is evidenced that open firms might require more resources to innovate, which could hinder their innovation efficiency. Nonetheless, such inefficiency is not transferred to firm performance as it is compensated with the innovation capabilities gained by the active collaboration with external organizations. However, results are not conclusive and this thesis evidences empirically the need of further researching into the role of OI in the relationship between IMS and sustainable development (Kennedy *et al.*, 2017; Pacheco *et al.*, 2017).

Finally, **studies aiming to research into the effects of adopting multiple MS certifications might consider implementing dynamic models**. Companies have different certification strategies and are increasingly adopting multiple standards to meet the requirements of new and more demanding stakeholders (Boiral and Gendron, 2011; Fonseca *et al.*, 2017). Thus, studying static models and neglecting this reality might lead to an uncomplete vision of the underlying effects of MSs certifications. In this line, a dynamic approach was applied in this thesis to detect the effects of adopting multiple certifications on companies' financial performance. Interestingly, not every combination of certifications leads to improved financial indicators. More specifically, the ISO 9001 certification seems to have a major role as it was mostly the first certification adopted, or simultaneously with other MSs certifications (ISO 14001 or OSHAS 18001), so the integration strategy might be relevant in sustaining multiple certifications and integration in the long term (Gianni and Gotzamani, 2015). Similar trends could occur when analyzing other sustainability dimensions. Thus, studies relying on certified companies to study IMS benefits might consider these dynamics for a better understanding of the phenomena.

6.3.2. Implications to practitioners

This thesis has four main managerial implications, described as follows.

Firstly, **practitioners might consider relevant that it is not always necessary to hold a certified MS to integrate them and experience IMS' benefits**. Instead, what is crucial to IMS relays on the strategical support sponsored by the top management (Zeng *et al.*, 2007; Bernardo *et al.*, 2017; Gianni *et al.*, 2017a), in particular regarding the deep internalization and broad application of MSs across the organization.

Secondly, it becomes apparent that **IMS benefits lay beyond the purely operational**. This thesis has evidenced that IMS promotes an enhanced innovation management performance and the development of sustainable innovations. The latter implicates that IMS fosters the adoption of cleaner production technologies, as well as the development of sustainable products; i.e., technically, environmentally and socially friendly products. Furthermore, the innovation management performance gained with IMS comprises the enhancement of innovation capabilities, the efficient use of resources to innovate and, thus, the improvement of firm performance. Hence, companies can adopt IMS as a best practice towards attaining sustainable innovation (Pacheco *et al.*, 2017; Xavier *et al.*, 2017).

Thirdly, **companies are challenged to seek the right level of openness to exploit the external knowledge of practicing OI activities without hindering their innovation efficiency**. OI and IMS are two complementary and synergic managerial practices that involve different stakeholders and improve together innovation capabilities (Behnam *et al.*, 2018). In this sense, companies might see OI as a way to the exploit external knowledge in order to favor the internal support provided by IMS to innovate. However, companies ought to be cautious when investing in an OI strategy, especially when the efforts invested on external collaborations are not producing significant additional innovation output (e.g., new or improved processes, products, new patents, among others).

Finally, **managers might deem MS standards as a support to their managerial practices rather than a precondition to enhance their performance**. In this sense, companies should not expect to improve their financial performance just by adopting a set of certifications (Robson *et al.*, 2007; Sampaio *et al.*, 2009; Heras-Saizarbitoria and Boiral, 2013; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016). Instead, they should attempt to apply broadly and deeply their MSs (whether certified or not) in an integrated and efficient manner (Sampaio *et al.*, 2012a; Abad *et al.*, 2014; Nunhes *et al.*, 2017). This might allow companies to improve their performance through continuous improvement (Wilkinson and Dale, 1999; Kurdve *et al.*, 2014; Rebelo *et al.*, 2016), meeting the needs of diverse stakeholders (Jørgensen *et al.*, 2006; Bernardo, 2014), innovating and growing sustainably (Kennedy *et al.*, 2017; Pacheco *et al.*, 2017).

6.3.3. Implications to stakeholders

Stakeholders are of particular relevance to this study as evidenced throughout this document. Therefore, the following implications to shareholders, innovation collaborators, clients, employees, the environment and society are stated.

Firstly, **shareholders might (1) promote the use of financial resources efficiently through IMS and, (2) prefer investing on companies with a proven capacity and/or engagement to sustain their MSs' principles in the long term**. IMS has been traditionally acknowledged as a promotor of operational benefits (Santos *et al.*, 2011; Sampaio *et al.*, 2012a; Abad *et al.*, 2014; Olaru *et al.*, 2014; Dahlin and Isaksson, 2017). This research has evidenced empirically that IMS benefits are beyond operational as they also promote innovation benefits with a sustainability orientation. Therefore, it might be of the shareholders' interest to promote the efficient use of founds through IMS rather than fostering operations with fragmented and isolated

MSs. Moreover, although companies attempt to provide prove to shareholders that they manage their company efficiently through certifications, this fact remains in serious question (Robson *et al.*, 2007; Sampaio *et al.*, 2009; Heras-Saizarbitoria and Boiral, 2013; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016). However, shareholders might see the long-term historical dynamics of the companies' certifications, integration strategy and previous financial performance as potential predictors of their current performance. This might provide shareholders of better criteria to allocate funds on a specific company rather than merely relying on the fact that companies hold or not a certification.

Secondly, **companies applying OI might attempt to seek for their sustainability, but also that of their collaborators**. This research has found that companies practicing OI might devote excessive resources that seem not to be compensated with more innovation outputs. Therefore, innovation collaborators ought to attempt understanding the objectives and boundaries of their innovation partners to decide the strategy that benefit both, the internal and external collaborators (Chesbrough and Bogers, 2014). To this end, IMS might provide the internal sustainability-oriented support to OI practitioners to harness external knowledge. By creating synergies between the internal and external knowledge, innovation collaborators might be able to benefit not only of added innovation efficiency (Greco *et al.*, 2017), but also of their conjoint sustainable growth (Watson *et al.*, 2018).

Finally, **employees, clients, the environment and society are beneficiaries of harnessing the benefits of IMS and innovation**. This research found that IMS seems to foster the adoption of cleaner production technologies, which is favorable to enhance the work environment and safety, as well as to the environment and society (UNEP DTIE, 1996; Kemp and Volpi, 2008; Vieira and Amaral, 2016). After engaging with enhancing their internal operations, companies would also seek to transfer their sustainability-oriented perspective to the development of new products (Boons *et al.*, 2013; Sroufe, 2017). Therefore, companies might consider these findings to assess the relevance of IMS and innovation as this contributes to other stakeholders beyond their own boundaries.

6.3.4. Implications to decision makers

Based on empirical evidence, this research has pointed out the relevance of IMS, OI and innovation in pursue of corporate sustainability. However, the isolated efforts of individual companies to become sustainable is not enough to sustainable development, since it requires the involvement of individuals, companies, entire concentrations of industry, complete value chains, the society and whole economies (United Nations, 1992; Elkington, 1997). Therefore, decision makers might deem the findings of this research to (1) promote the use and creation of sustainability-oriented management standards or frameworks, which could be based on the IMS principles; (2) facilitate the collaborations between innovative companies, industries, cities and countries; (3) create policies that foster the creation of sustainability-oriented innovations, including the adoption of cleaner production technologies, the use of sustainable raw materials, the minimization of the effects of new products on the environment and society and; (4) promote among markets, consumers and citizens the use of sustainability-oriented products.

6.4. Contribution of this thesis

All in all, this thesis has contributed to evidence empirically that both IMS and innovation are beneficial to corporate sustainability. In particular, the following contributions are obtained from this work.

This thesis has contributed to **measuring the level of IMS** regardless of whether companies are certified or not. This is particularly relevant to sustainability-oriented research due to three main reasons. Firstly, because high levels of IMS are required to attain sustainability (Jørgensen, 2008); otherwise, companies could abandon IMS (Gianni and Gotzamani, 2015) and could therefore stray from this sustainability management approach (Jørgensen, 2008; Rebelo *et al.*, 2016; Siva *et al.*, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017). Secondly, because the lack of an international IMS certification (Gianni *et al.*, 2017a) requires applying IMS measurements to all organizations regardless of their certifications. Finally, because high levels of IMS are obtained when it is adopted voluntarily (Gianni *et al.*, 2017a), which diminishes the risk of adopting this practice with little regard on the underlying principles of MSs (Boiral and Gendron, 2011). Thus, this thesis has tested empirically that companies are able to deeply internalize and broadly apply IMS across organizations without having to hold a certified MS as a previous condition to integration.

This research also comprises one of the first studies **testing empirically the relationship between IMS and innovation management performance** (Bernardo, 2014). This contributes to addressing a major research gap in the IMS literature (Nunhes *et al.*, 2016).

Moreover, this thesis relates IMS and innovation in pursue of sustainability. The relationship between IMS and sustainability is also a major research gap according to the comprehensive literature reviews found in Nunhes *et al.* (2016) and Siva *et al.* (2016). Although this gap has been recently addressed by valuable research, most of these studies have the limitation of frequently neglecting the relationships between IMS and innovation in pursue of sustainability, or threating these interactions at a general level (see e.g., Rebelo *et al.*, 2016; Gianni *et al.*, 2017a; Mustapha *et al.*, 2017; Ramos *et al.*, 2018). Thus, this work contributes to filling this gap by providing empirical evidence that supports that IMS benefits innovation in pursue of corporate sustainability. To this end, this work is based on diverse sources comprising both primary and secondary data gathered at a country and also at an intercontinental level, thus providing robust results of the studied relationships. Therefore, it contributes to the emerging discussion of the managerial tools to attain sustainable innovation (Longoni and Cagliano, 2016; Kiefer *et al.*, 2017).

From the viewpoint of the innovation literature, this thesis contributes to **identifying a relevant best practice to foster sustainable innovation** (Pacheco *et al.*, 2017; Xavier *et al.*, 2017). Namely, it provides empirical evidence to support that IMS can be considered a relevant best practice to attain sustainable innovation.

Moreover, this work is one of the first to **bring into discussion the role of OI in the relationships between IMS and innovation in pursue of sustainability**. OI is a relevant practice that enables companies to integrate the stakeholders perspectives into their innovation practices, so OI is being increasingly adopted across companies in pursue of sustainability (Adams *et al.*, 2016; Watson *et al.*, 2018). In this line, this thesis contributes to revealing the existing synergies between IMS and OI to increase innovation capabilities by embedding new knowledge into their innovation practices.

However, this discussion has to be further developed as pointed out by the emerging literature regarding the role OI in pursue of sustainability (Kennedy *et al.*, 2017; Behnam *et al.*, 2018; Watson *et al.*, 2018).

Finally, this thesis contributes to **better understanding the financial effects of adopting multiple certifications by modelling the dynamics involved throughout this process.** The existing literature has mostly focused on the financial effects of adopting single certifications, with still inconclusive outcomes (Robson *et al.*, 2007; Sampaio *et al.*, 2009; Heras-Saizarbitoria and Boiral, 2013; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016). Moreover, the limited literature focused on multiple certifications has mostly relied on self-reported data (Ferrón-Vílchez and Darnall, 2016; Martí-Ballester and Simon, 2017), which might lead to over-valued or biased conclusions (Häversjö, 2000; Corbett *et al.*, 2005; Sharma, 2005; Heras-Saizarbitoria and Boiral, 2013). Moreover, the existing literature on this topic has mostly neglected the dynamics involved in the adoption of multiple certifications (Karapetrovic and Willborn, 1998b; Karapetrovic, 2002; Pun and Hui, 2002; Labodová, 2004; Karapetrovic and Casadesús, 2009; Bernardo *et al.*, 2012; Ivanova *et al.*, 2014), which might occur dynamically among years and could condition the financial effects of adopting multiple certifications (Su *et al.*, 2015). Thus, this thesis attempted to address this gap by relying on existing records rather than self-reported financial indicators, as well as considering the dynamics derived from the integration strategy. This approach contributes to literature with new insights of a relevant discussion regarding MS standards and economic sustainability. Thus, similar approaches could be considered in future research considering the economic, environmental and social effects of these strategic decisions (Wang *et al.*, 2016b).

6.5. Future research

Future research might focus on diverse aspects derived from this thesis. Thus, the following research lines will be further developed.

Firstly, future research will **relate IMS to innovation and sustainability considering all the sustainability dimensions simultaneously** (Elkington, 1997; Jørgensen *et al.*, 2006; Baumgartner, 2014; Nunhes *et al.*, 2016). In this thesis, the economic dimension and the social & environmental dimensions were mostly addressed in different articles and using different samples. Moreover, the social & environmental dimensions were studied by means of an exploratory research which needs to be confirmed. Thus, future research will further explore the way in which IMS fosters sustainable innovation by assessing simultaneously the three dimensions: economic, environmental and social sustainability, but preserving their individual characteristics in different factors. This research line would contribute to confirm the exploratory results of IMS as a promotor of sustainable innovation, as well as to better understand the interrelations between the different sustainability dimensions within this context.

Secondly, future research will study more in depth **how IMS and OI interact in pursue of sustainability** (Pacheco *et al.*, 2017; Watson *et al.*, 2018). In this work, OI was measured as a factor mainly based on the importance given to external entities to innovate. However, there are other factors that might condition how OI acts within an organization. In line with the synergies found between OI and IMS, this research line will focus on how these factors complement the companies' internal knowledge in order to exploit the new capabilities in pursue of sustainable development (Behnam *et al.*, 2018). To this end, the absorptive capacity and the preferences of companies to adopt OI and/or IMS will be studied (Cohen and Levinthal, 1990; Bogers and Lhuillery, 2011; Behnam *et al.*, 2018). This line of research would contribute to understand to what extent OI can be favorable to sustainability, considering the internal managerial practices derived from IMS.

Thirdly, the **relationships between IMS, OI and the innovation management performance will be studied in other countries and regions**. In this research, these relationships where mostly based on Spanish companies. This country has a large tradition of adopting certifications (ISO, 2017), integrating MSs (Jørgensen *et al.*, 2006; Bernardo *et al.*, 2009; Abad *et al.*, 2014), and it is one of the countries that has mostly contributed to the IMS literature in terms of number of articles and citations (Nunhes *et al.*, 2016). Therefore, this research line would contribute to understanding whether the conclusions obtained in this manuscript maintain or differ in other countries with a different profile of their IMS experience.

Finally, the **effects on sustainability of adopting multiple certifications in a dynamic environment** will be further developed. Based on the still inconclusive debate of the financial effects of MS certifications (Sampaio *et al.*, 2009; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016), this thesis has provided new insights to assess this relationship in a dynamic environment. This includes the dynamics involved in obtaining multiple certifications, as well as the natural dynamics of the companies' performance. Thus, future research will consider the environmental or social dimensions of sustainability beyond the financial effects. This research line would contribute to expand the understating about how MS standards are related to corporate sustainability

REFERENCES

Abad, J., Dalmau, I. and Vilajosana, J. (2014) 'Taxonomic proposal for integration levels of management systems based on empirical evidence and derived corporate benefits', *Journal of Cleaner Production*, 78, pp. 164–173.

Abad, J., Lafuente, E. and Vilajosana, J. (2013) 'An assessment of the OHSAS 18001 certification process: Objective drivers and consequences on safety performance and labour productivity', *Safety Science*, 60, pp. 47–56.

Acs, Z. J., Anselin, L. and Varga, A. (2002) 'Patents and innovation counts as measures of regional production of new knowledge', *Research Policy*, 31(7), pp. 1069–1085.

Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D. and Overy, P. (2016) 'Sustainability-oriented Innovation: A Systematic Review', *International Journal of Management Reviews*, 18(2), pp. 180–205.

Agan, Y., Acar, M. F. and Borodin, A. (2013) 'Drivers of environmental processes and their impact on performance: a study of Turkish SMEs', *Journal of Cleaner Production*, 51, pp. 23–33.

Ahn, J. H., Kim, K. H., Kim, Y. H. and Kim, B. W. (2015) 'Characterization of hazardous and odorous volatiles emitted from scented candles before lighting and when lit', *Journal of Hazardous Materials*, 286, pp. 242–251.

von Ahsen, A. (2014) 'The Integration of Quality, Environmental and Health and Safety Management by Car Manufacturers - a Long-Term Empirical Study', *Business Strategy and the Environment*, 23(6), pp. 395–416.

Al-Hakim, L. and Jin, C. (2014) *Quality Innovation: Knowledge, Theory, and Practices*. IGI Global.

Amores-Salvadó, J., Martin-de Castro, G. and Navas-López, J. E. (2015) 'The importance of the complementarity between environmental management systems and environmental innovation capabilities: A firm level approach to environmental and business performance benefits', *Technological Forecasting and Social Change*, 96, pp. 288–297.

Antunes, G., Pires, A. and Machado, V. (2009) 'Process improvement measures in social area organisations: A study in institutions for elderly: survey results', *The TQM Journal*, 21(4), pp. 334–352.

Aragon, Y., Daouia, A. and Thomas-Agnan, C. (2005) 'Nonparametric Frontier Estimation: a Conditional Quantile-Based Approach', *Econometric Theory*, 21(2), pp. 358–389.

Arellano, M. and Bover, O. (1995) ‘Another look at the instrumental variable estimation of error-components models’, *Journal of Econometrics*, 68(1), pp. 29–51.

Asif, M., Searcy, C., Zutshi, A. and Fisscher, O. A. M. (2013) ‘An integrated management systems approach to corporate social responsibility’, *Journal of Cleaner Production*, 56, pp. 7–17.

Atuahene-Gima, K. (1996) ‘Market orientation and innovation’, *Journal of Business Research*, 35(2), pp. 93–103.

Barge-Gil, A. (2013) ‘Open Strategies and Innovation Performance’, *Industry & Innovation*, 20(7), pp. 585–610.

Baumgartner, R. J. (2014) ‘Managing Corporate Sustainability and CSR: A Conceptual Framework Combining Values, Strategies and Instruments Contributing to Sustainable Development’, *Corporate Social Responsibility and Environmental Management*, 21(5), pp. 258–271.

Baumgartner, R. J. and Ebner, D. (2010) ‘Corporate sustainability strategies: sustainability profiles and maturity levels’, *Sustainable Development*, 18(2), pp. 76–89.

Bayona-Saez, C., Cruz-Cázares, C., García-Marco, T. and Sánchez García, M. (2017) ‘Open innovation in the food and beverage industry’, *Management Decision*, 55(3), pp. 526–546.

Beckmerhagen, I. A., Berg, H. P., Karapetrovic, S. V. and Willborn, W. O. (2003) ‘Integration of management systems: focus on safety in the nuclear industry’, *International Journal of Quality & Reliability Management*, 20(2), pp. 210–228.

Behnam, S., Cagliano, R. and Grijalvo, M. (2018) ‘How should firms reconcile their open innovation capabilities for incorporating external actors in innovations aimed at sustainable development?’, *Journal of Cleaner Production*, 170, pp. 950–965.

Belderbos, R., Carree, M. and Lokshin, B. (2004) ‘Cooperative R&D and firm performance’, *Research Policy*, 33(10), pp. 1477–1492.

Bernardo, M. (2014) ‘Integration of management systems as an innovation: a proposal for a new model’, *Journal of Cleaner Production*, pp. 132–142.

Bernardo, M., Casadesus, M., Karapetrovic, S. and Heras, I. (2009) ‘How integrated are environmental, quality and other standardized management systems? An empirical study’, *Journal of Cleaner Production*, 17(8), pp. 742–750.

Bernardo, M., Casadesus, M., Karapetrovic, S. and Heras, I. (2012) 'Integration of standardized management systems: does the implementation order matter?', *International Journal of Operations & Production Management*, 32(3), pp. 291–307.

Bernardo, M., Gianni, M., Gotzamani, K. and Simon, A. (2017) 'Is there a common pattern to integrate multiple management systems? A comparative analysis between organizations in Greece and Spain', *Journal of Cleaner Production*, 151, pp. 121–133.

Bernardo, M., Simon, A., Tarí, J. J. and Molina-Azorín, J. F. (2015) 'Benefits of management systems integration: a literature review', *Journal of Cleaner Production*, 94, pp. 260–267.

Bianchini, A., Donini, F., Pellegrini, M. and Saccani, C. (2017) 'An innovative methodology for measuring the effective implementation of an Occupational Health and Safety Management System in the European Union', *Safety Science*, 92, pp. 26–33.

Blundell, R. and Bond, S. (1998) 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of Econometrics*, 87(1), pp. 115–143.

Bogers, M. and Lhuillery, S. (2011) 'A Functional Perspective on Learning and Innovation: Investigating the Organization of Absorptive Capacity', *Industry & Innovation*, 18(6), pp. 581–610.

Boiral, O. (2013) 'Sustainability reports as simulacra? A counter-account of A and A+ GRI reports', *Accounting, Auditing & Accountability Journal*, 26(7), pp. 1036–1071.

Boiral, O. and Gendron, Y. (2011) 'Sustainable Development and Certification Practices: Lessons Learned and Prospects', *Business Strategy and the Environment*, 20(5), pp. 331–347.

Van Bommel, H. W. M. (2011) 'A conceptual framework for analyzing sustainability strategies in industrial supply networks from an innovation perspective', *Journal of Cleaner Production*, 19(8), pp. 895–904.

Bonilla, S. H., Almeida, C. M. V. B., Giannetti, B. F. and Huisingh, D. (2010) 'The roles of cleaner production in the sustainable development of modern societies: an introduction to this special issue', *Journal of Cleaner Production*, 18(1), pp. 1–5.

Bonzanini Bossle, M., Dutra de Barcellos, M., Marques Vieira, L. and Sauvée, L. (2016) 'The drivers for adoption of eco-innovation', *Journal of Cleaner Production*, 113, pp. 861–872.

Boons, F., Montalvo, C., Quist, J. and Wagner, M. (2013) ‘Sustainable innovation, business models and economic performance: an overview’, *Journal of Cleaner Production*, 45, pp. 1–8.

Bottani, E., Monica, L. and Vignali, G. (2009) ‘Safety management systems: Performance differences between adopters and non-adopters’, *Safety Science*, 47(2), pp. 155–162.

Bouranta, N., Chitiris, L. and Paravantis, J. (2009) ‘The relationship between internal and external service quality’, *International Journal of Contemporary Hospitality Management*, 21(3), pp. 275–293.

del Brío, J. Á. and Junquera, B. (2003) ‘A review of the literature on environmental innovation management in SMEs: implications for public policies’, *Technovation*, 23(12), pp. 939–948.

Bureu Van Dijk (2017) *Amadeus - Company information across Europe*. Available at: https://www.bvdinfo.com/ (Accessed: 10 April 2017).

Cabecinhas, M., Domingues, P., Sampaio, P., Bernardo, M., Franceschini, F., Galetto, M., Gianni, M., Gotzamani, K., Mastrogiacomo, L. and Hernandez-Vivanco, A. (2016) ‘Integrated Management Systems diffusion in South European countries’, in *Proceedings book of the 2nd International Conference on Quality Engineering and Management*. University of Minho, Guimarães (Portugal), pp. 729–749.

Cabecinhas, M., Domingues, P., Sampaio, P., Bernardo, M., Franceschini, F., Galetto, M., Gianni, M., Gotzamani, K., Mastrogiacomo, L. and Hernandez-Vivanco, A. (Accepted) ‘Integrated Management Systems Diffusion Models in South European Countries’, *International Journal of Quality & Reliability Management*.

Camisón, C. and Villar-López, A. (2014) ‘Organizational innovation as an enabler of technological innovation capabilities and firm performance’, *Journal of Business Research*, 67(1), pp. 2891–2902.

Cândido, C. J. F., Coelho, L. M. S. and Peixinho, R. M. T. (2016) ‘The financial impact of a withdrawn ISO 9001 certificate’, *International Journal of Operations & Production Management*, 36(1), pp. 23–41.

Carmines, E. G. and Zeller, R. A. (1979) *Reliability and Validity Assessment*. Newbury Park, CA: Sage publications.

Carruthers, G. and Vanclay, F. (2012) ‘The intrinsic features of Environmental Management Systems that facilitate adoption and encourage innovation in primary industries’, *Journal of Environmental Management*, 110, pp. 125–134.

Castillo-Rojas, S. M., Casadesús, M., Karapetrovic, S., Coromina, L., Heras, I. and Martín, I. (2012) 'Is implementing multiple management system standards a hindrance to innovation?', *Total Quality Management & Business Excellence*, 23(9–10), pp. 1075–1088.

Castka, P., Bamber, C. J., Bamber, D. J. and Sharp, J. M. (2004) 'Integrating corporate social responsibility (CSR) into ISO management systems – in search of a feasible CSR management system framework', *The TQM Magazine*, 16(3), pp. 216–224.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units', *European Journal of Operational Research*, 2(6), pp. 429–444.

Chatzoglou, P., Chatzoudes, D. and Kipraios, N. (2015) 'The impact of ISO 9000 certification on firms' financial performance', *International Journal of Operations & Production Management*, 35(1), pp. 145–174.

Cheng, C. C. J., Yang, C. and Sheu, C. (2016) 'Effects of open innovation and knowledge-based dynamic capabilities on radical innovation: An empirical study', *Journal of Engineering and Technology Management*, 41, pp. 79–91.

Chesbrough, H. and Bogers, M. (2014) 'Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation Keywords', in Chesbrough, H., Vanhaverbeke, W., and West, J. (eds) *New Frontiers in Open Innovation*. Oxford, England: Oxford University Press, pp. 3–28.

Chesbrough, H. W. (2003) *Open innovation: The new imperative for creating and profiting from technology*, *Harvard Business School Press*. Boston, MA.

Chesbrough, H. W. (2006) *Open Business Models: How to Thrive in the New Innovation Landscape*, *Harvard Business School Press*.

Chesbrough, H. W. (2007) 'Why Companies Should Have Open Business Models', *MIT Sloan Management Review*, 48(2), pp. 22–28.

Chin, W. W. (1998) 'The partial least squares approach to structural equation modeling', *Modern methods for business research*. Edited by G. A. Marcoulides, pp. 295–336.

Chin, W. W. and Gopal, A. (1995) 'Adoption intention in GSS', *Database*, 26(2–3), pp. 42–64.

CIS (2012) 'The Community Innovation Survey 2012', *Eurostat*, 2012.

Cohen, W. M. and Levinthal, D. A. (1990) ‘Absorptive Capacity: A New Perspective on Learning and Innovation’, *Administrative Science Quarterly*, 35(1), p. 128.

ComRes/AECM (2015) *Research into the European Candles Market*. Available at: http://europecandles.org/uploads/kcFinder/files/aecm-2015-comres-executive-summary.pdf (Accessed: 30 July 2016).

Comunidades Europeas (2006) *La nueva definición de PYME*. Available at: http://europa.eu.int/comm/enterprise/enterprise_policy/sme_definition/index_es.htm.

Corbett, C. J., Montes-Sancho, M. J. and Kirsch, D. A. (2005) ‘The Financial Impact of ISO 9000 Certification in the United States: An Empirical Analysis’, *Management Science*, 51(7), pp. 1046–1059.

Cruz-Cázares, C., Bayona-Sáez, C. and García-Marco, T. (2013) ‘You can’t manage right what you can’t measure well: Technological innovation efficiency’, *Research Policy*, 42(6–7), pp. 1239–1250.

Cruz-Cázares, C., Smits, A., Berends, H., Reymen, I., Anzola, P., Bayona-Sáez, C., García-Marco, T., Schubert, M. and Sturm, F. (2012) *BMOI Report - A Regional Comparison of Open Innovation Practices*.

Cuerva, M. C., Triguero-Cano, Á. and Córcoles, D. (2014) ‘Drivers of green and non-green innovation: Empirical evidence in Low-Tech SMEs’, *Journal of Cleaner Production*, 68, pp. 104–113.

Dahlin, G. and Isaksson, R. (2017) ‘Integrated management systems – interpretations, results, opportunities’, *The TQM Journal*, 29(3), pp. 528–542.

Dahlsrud, A. (2008) ‘How corporate social responsibility is defined: an analysis of 37 definitions’, *Corporate Social Responsibility and Environmental Management*, 15(1), pp. 1–13.

Daraio, C. and Simar, L. (2007) *Advanced Robust and nonparametric methods in efficiency analysis: methodology and applications*. Springer Science & Business Media.

Darnall, N., Henriques, I. and Sadorsky, P. (2008a) ‘Do environmental management systems improve business performance in an international setting?’, *Journal of International Management*, 14(4), pp. 364–376.

Darnall, N., Jolley, G. J. and Handfield, R. (2008b) ‘Environmental management systems and green supply chain management: complements for sustainability?’, *Business Strategy and the Environment*, 17(1), pp. 30–45.

Deltas, G., Harrington, D. R. and Khanna, M. (2014) ‘Green management and the nature of pollution prevention innovation’, *Applied Economics*. Routledge, 46(5), pp. 465–482.

Deprins, D., Simar, L. and Tulekns, H. (1984) ‘Measuring laborefficiency in post office’, in Marchand, M., Pestieau, P., and Tulkens, H. (eds) *The Performance of Public Enterprises: Concepts and Measurement*. Amsterdam: North-Holland, pp. 243–268.

Derudi, M., Gelosa, S., Sliepcevich, A., Cattaneo, A., Rota, R., Cavallo, D. and Nano, G. (2012) ‘Emissions of air pollutants from scented candles burning in a test chamber’, *Atmospheric Environment*, 55, pp. 257–262.

Domingues, J. P. T., Sampaio, P. and Arezes, P. (2016) ‘Integrated management systems assessment: A maturity model proposal’, *Journal of Cleaner Production*, 124, pp. 164–174.

Domingues, J. P. T., Sampaio, P. and Arezes, P. M. (2017) ‘Analysis of certified occupational health and safety management systems in Portugal’, *International Journal of Occupational and Environmental Safety*, 1, pp. 11–28.

Dora, M., Kumar, M., Van Goubergen, D., Molnar, A. and Gellynck, X. (2013) ‘Food quality management system: Reviewing assessment strategies and a feasibility study for European food small and medium-sized enterprises’, *Food Control*, 31(2), pp. 607–616.

Dyllick, T. and Hockerts, K. (2002) ‘Beyond the business case for corporate sustainability’, *Business Strategy and the Environment*, 11(2), pp. 130–141.

ECA (2017) *European Candle Association*. Available at: http://www.eca-candles.com (Accessed: 22 February 2017).

Elkington, J. (1997) ‘Partnerships from Cannibals with Forks : The Triple Bottom line of 21 st Century Business’, *Environmental Quality Management*, Autumn 199, pp. 37–51.

Elkington, J. (2006) ‘Governance for Sustainability’, *Governance for Sustainability*, 14(6), pp. 522–529.

Esquer-Peralta, J., Velazquez, L. and Munguia, N. (2008) ‘Perceptions of core elements for sustainability management systems (SMS)’, *Management Decision*, 46(7), pp. 1027–1038.

European Comission (2011) *A renewed EU strategy 2011-14 for Corporate Social Responsibility*. COM(2011) 681 final, 25.10.2011. EC: Brussels.

Faraday, M. (2001) *The Chemical History of a Candle*. Edited by C. W. Eliot. New York, NY: Bartleby.com. Available at: http://www.bartleby.com/30/8.html (Accessed: 25 January 2016).

FECYT (2008) *Panel de Informacion Tecnológica - PITEC*. Available at: http://icono.fecyt.es/PITEC/Paginas/por_que.aspx (Accessed: 30 July 2016).

Ferenhof, H. A., Vignochi, L., Selig, P. M., Lezana, Á. G. R. and Campos, L. M. S. (2014) 'Environmental management systems in small and medium-sized enterprises: an analysis and systematic review', *Journal of Cleaner Production*, 74, pp. 44–53.

Ferrón-Vílchez, V. and Darnall, N. (2016) 'Two are Better Than One: The Link Between Management Systems and Business Performance', *Business Strategy and the Environment*, 25(4), pp. 221–240.

Fichman, R. G. (2004) 'Going Beyond the Dominant Paradigm for Information Technology Innovation Research: Emerging Concepts', *Journal of the Association for Information Systems*, 5(8), pp. 314–355.

Fonseca, L. M. C. M., Domingues, J. P. T., Baylina Machado, P. and Calderón, M. (2017) 'Management system certification benefits: where do we stand?', *Journal of Industrial Engineering and Management*, 10(3), p. 476.

Fornell, C. and Larcker, D. F. (1981) 'Evaluating Structural Equation Models with Unobservable Variables and Measurement Error', *Journal of Marketing Research*, 18(1), p. 39.

Fritsch, M. and Lukas, R. (1999) 'Innovation, Cooperation and the Region', in Audretsch, D. and Thurik, R. (eds) *Innovation, Industry Evolution and Employment*. Cambridge: Cambridge University Press, pp. 157–181.

Fritsch, M. and Meschede, M. (2001) 'Product Innovation, Process Innovation, and Size', *Review of Industrial Organization*, 19(3), pp. 335–350.

Frondel, M., Horbach, J. and Rennings, K. (2007) 'End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries', *Business Strategy and the Environment*, 16(8), pp. 571–584.

Gavronski, I., Klassen, R. D., Vachon, S. and Machado do Nascimento, L. F. (2012) 'A learning and knowledge approach to sustainable operations', *International Journal of Production Economics*, 140(1), pp. 183–192.

George, G., Zahra, S. A. and Wood, D. R. (2002) ‘The effects of business–university alliances on innovative output and financial performance: a study of publicly traded biotechnology companies’, *Journal of Business Venturing*, 17(6), pp. 577–609.

Geum, Y., Kim, J., Son, C. and Park, Y. (2013) ‘Development of dual technology roadmap (TRM) for open innovation: Structure and typology’, *Journal of Engineering and Technology Management*, 30(3), pp. 309–325.

Gianni, M. and Gotzamani, K. (2015) ‘Management systems integration: lessons from an abandonment case’, *Journal of Cleaner Production*, 86, pp. 265–276.

Gianni, M., Gotzamani, K. and Tsiotras, G. (2017a) ‘Multiple perspectives on integrated management systems and corporate sustainability performance’, *Journal of Cleaner Production*, 168, pp. 1297–1311.

Gianni, M., Gotzamani, K. and Vouzas, F. (2017b) ‘Food integrated management systems: dairy industry insights’, *International Journal of Quality & Reliability Management*, 34(2), pp. 194–215.

Goedhuys, M. and Sleuwaegen, L. (2013) ‘The Impact of International Standards Certification on the Performance of Firms in Less Developed Countries’, *World Development*, 47, pp. 87–101.

Grant, R. M. (1996) ‘Toward a Knowledge-Based Theory of the Firm’, *Strategic Management Journal*, 17(Winter Special Issue), pp. 109–122.

Greco, M., Grimaldi, M. and Cricelli, L. (2016) ‘An analysis of the open innovation effect on firm performance’, *European Management Journal*, 34(5), pp. 501–516.

Greco, M., Grimaldi, M. and Cricelli, L. (2017) ‘Hitting the nail on the head: Exploring the relationship between public subsidies and open innovation efficiency’, *Technological Forecasting and Social Change*, 118, pp. 213–225.

Greene, W. (2003) *Econometric Analysis*. 5th edn. Upper Saddle River, NJ: Prentice Hall.

Griliches, Z. (1990) ‘Patent Statistics as Economic Indicators: A Survey’, *Journal of Economic Literature*. Cambridge, MA, 28(4), pp. 1661–1707.

Guan, J. and Chen, K. (2010) ‘Measuring the innovation production process: A cross-region empirical study of China’s high-tech innovations’, *Technovation*, 30(5–6), pp. 348–358.

Guan, J. and He, Y. (2007) 'Patent-bibliometric analysis on the Chinese science - Technology linkages', *Scientometrics*, 72(3), pp. 403–425.

Guan, J., Yam, R. C. M., Mok, C. K. and Ma, N. (2006) 'A study of the relationship between competitiveness and technological innovation capability based on DEA models', *European Journal of Operational Research*, 170(3), pp. 971–986.

Guan, J., Zuo, K., Chen, K. and Yam, R. C. M. (2016) 'Does country-level R&D efficiency benefit from the collaboration network structure?', *Research Policy*, 45(4), pp. 770–784.

Hair, J., Celsi, M., Money, A., Samouel, P. and Page, M. (2016) *Essentials of Business Research Methods*. 3rd ed. New York, NY: Routledge.

Hair, J. F., Ringle, C. M. and Sarstedt, M. (2011) 'PLS-SEM: Indeed a Silver Bullet', *The Journal of Marketing Theory and Practice*, 19(2), pp. 139–152.

Haner, U.-E. (2002) 'Innovation quality—a conceptual framework', *International Journal of Production Economics*, 80(1), pp. 31–37.

Hansen, L. P. (1982) 'Large sample properties of generalised method of moments estimators', *Econometrica*, 50(4), pp. 1029–1054.

Hashimoto, A. and Haneda, S. (2008) 'Measuring the change in R&D efficiency of the Japanese pharmaceutical industry', *Research Policy*, 37(10), pp. 1829–1836.

Häversjö, T. (2000) 'The financial effects of ISO 9000 registration for Danish companies', *Managerial Auditing Journal*, 15(1/2), pp. 47–52.

He, W., Liu, C., Lu, J. and Cao, J. (2015) 'Impacts of ISO 14001 adoption on firm performance: Evidence from China', *China Economic Review*, 32, pp. 43–56.

Henseler, J., Hubona, R. and Ash, P. (2016) 'Using PLS path modeling in new technology research: updated guidelines', *Industrial Management & Data Systems*, 116(1), pp. 2–20.

Heras-Saizarbitoria, I. and Boiral, O. (2013) 'ISO 9001 and ISO 14001: Towards a Research Agenda on Management System Standards*', *International Journal of Management Reviews*, 15(1), pp. 47–65.

Heras-Saizarbitoria, I., Molina-Azorín, J. F. and Dick, G. P. M. (2011) 'ISO 14001 certification and financial performance: Selection-effect versus treatment-effect', *Journal of Cleaner Production*, 19(1), pp. 1–12.

Heras, I., Dick, G. P. M. and Casadesús, M. (2002) 'ISO 9000 registration's impact on sales and profitability', *International Journal of Quality & Reliability Management*, 19(6), pp. 774–791.

Hernandez-Vivanco, A., Bernardo, M. and Cruz-Cázares, C. (2016a) 'Relating open innovation, innovation and management systems integration', *Industrial Management & Data Systems*, 116(8), pp. 1540–1556.

Hernandez-Vivanco, A., Cruz-Cázares, C. and Bernardo, M. (2016b) 'Quality Innovation, Innovation Quality and Integration of Management Systems for pursuing sustainability: An efficiency perspective', in *19th QMOD Proceedings*. Roma Tre University, Rome (Italy): Lund University Library Press, pp. 1877–1882.

Hillary, R. (2004) 'Environmental management systems and the smaller enterprise', *Journal of Cleaner Production*, 12(6), pp. 561–569.

Hoang, D. T., Igel, B. and Laosirihongthong, T. (2006) 'The impact of total quality management on innovation: Findings from a developing country', *International Journal of Quality & Reliability Management*, 23(9), pp. 1092–1117.

Hojnik, J. and Ruzzier, M. (2016) 'The driving forces of process eco-innovation and its impact on performance: Insights from Slovenia', *Journal of Cleaner Production*, 133, pp. 812–825.

Holm, T., Vuorisalo, T. and Sammalisto, K. (2015) 'Integrated management systems for enhancing education for sustainable development in universities: a memetic approach', *Journal of Cleaner Production*, 106, pp. 155–163.

Honore, B. Y. B. E. (1992) 'Trimmed Lad and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects', *Econometrica*, 60(3), pp. 533–565.

Huang, S., Chen, J. and Liang, L. (2018) 'How open innovation performance responds to partner heterogeneity in China', *Management Decision*, 56(1), pp. 26–46.

Hung, K. P. and Chou, C. (2013) 'The impact of open innovation on firm performance: The moderating effects of internal R&D and environmental turbulence', *Technovation*, 33(10–11), pp. 368–380.

Inoue, E., Arimura, T. H. and Nakano, M. (2013) 'A new insight into environmental innovation: Does the maturity of environmental management systems matter?', *Ecological Economics*, 94, pp. 156–163.

Ionașcu, M., Ionașcu, I., Săcărin, M. and Minu, M. (2017) ‘Exploring the impact of ISO 9001, ISO 14001 and OHSAS 18001 certification on financial performance : the case of the companies listed on the Bucharest Stock Exchange’, *Amfiteatru Economic*, 16(2), pp. 166–180.

IPAC (2017) *Instituto Português de Acreditação*. Available at: http://www.ipac.pt (Accessed: 15 April 2017).

ISO (2013) *Integrated management systems*. Available at: http://www.iso.org/iso/home/news_index/news_archive/news.htm?Refid=Ref1709.

ISO (2017) *cISO Survey*. Available at: http://www.iso.org/iso/iso-survey (Accessed: 25 September 2017).

ISO (2018a) *aManagement system standards*. Available at: https://www.iso.org/management-system-standards.html (Accessed: 15 February 2018).

ISO (2018b) *bCertification*. Available at: https://www.iso.org/certification.html (Accessed: 4 February 2018).

Ivanova, A., Gray, J. and Sinha, K. (2014) ‘Towards a unifying theory of management standard implementation’, *International Journal of Operations & Production Management*, 34(10), pp. 1269–1306.

Johnson, M. P. and Schaltegger, S. (2016) ‘Two Decades of Sustainability Management Tools for SMEs: How Far Have We Come?’, *Journal of Small Business Management*, 54(2), pp. 481–505.

de Jong, P., Paulraj, A. and Blome, C. (2014) ‘The Financial Impact of ISO 14001 Certification: Top-Line, Bottom-Line, or Both?’, *Journal of Business Ethics*, 119(1), pp. 131–149.

Jørgensen, T. H. (2008) ‘Towards more sustainable management systems: through life cycle management and integration’, *Journal of Cleaner Production*, 16(10), pp. 1071–1080.

Jørgensen, T. H., Remmen, A. and Mellado, M. D. (2006) ‘Integrated management systems - Three different levels of integration’, *Journal of Cleaner Production*, 14, pp. 713–722.

Karapetrovic, S. (2002) ‘Strategies for the integration of management systems and standards’, *The TQM Magazine*, 14(1), pp. 61–67.

Karapetrovic, S. (2003) ‘Musings on integrated management systems’, *Measuring Business Excellence*, 7(1), pp. 4–13.

Karapetrovic, S. and Casadesús, M. (2009) 'Implementing environmental with other standardized management systems: Scope, sequence, time and integration', *Journal of Cleaner Production*, 17(5), pp. 533–540.

Karapetrovic, S. and Willborn, W. (1998a) 'Integrated audit of management systems', *International Journal of Quality & Reliability Management*, 15(7), pp. 694–711.

Karapetrovic, S. and Willborn, W. (1998b) 'Integration of quality and environmental management systems', *The TQM Magazine*, 10(3), pp. 204–213.

Karataş, A. E. and Gülder, Ö. L. (2012) 'Soot formation in high pressure laminar diffusion flames', *Progress in Energy and Combustion Science*, 38(6), pp. 818–845.

Kemp, R. and Volpi, M. (2008) 'The diffusion of clean technologies: a review with suggestions for future diffusion analysis', *Journal of Cleaner Production*, 16(1 SUPPL. 1), pp. 14–21.

Kennedy, S., Whiteman, G. and van den Ende, J. (2017) 'Radical Innovation for Sustainability: The Power of Strategy and Open Innovation', *Long Range Planning*, 50(6), pp. 712–725.

Khanna, M., Deltas, G. and Harrington, D. R. (2009) 'Adoption of pollution prevention techniques: The role of management systems and regulatory pressures', *Environmental and Resource Economics*, 44(1), pp. 85–106.

Kiefer, C. P., Carrillo-Hermosilla, J., Del Río, P. and Callealta Barroso, F. J. (2017) 'Diversity of eco-innovations: A quantitative approach', *Journal of Cleaner Production*, 166, pp. 1494–1506.

Kim, D.-Y., Kumar, V. and Kumar, U. (2012) 'Relationship between quality management practices and innovation', *Journal of Operations Management*, 30(4), pp. 295–315.

Klepper, S. (1996) 'Entry, exit, growth, and innovation over the product life cycle', *American Economic Review*, 86(3), pp. 562–583.

Klewitz, J. and Hansen, E. G. (2014) 'Sustainability-oriented innovation of SMEs: A systematic review', *Journal of Cleaner Production*, 65, pp. 57–75.

Klomp, L. and Van Leeuwen, G. (2001) 'Linking Innovation and Firm Performance: A New Approach', *International Journal of the Economics of Business*, 8(3), pp. 343–364.

Knight, L., Levin, A. and Mendenhall, C. (2001) *Candles and Incense as Potential Sources of Indoor Air Pollution: Market Analysis and*

Literature Review (EPA/600/R-01/001), *EPA Research and Development*. Washington, D.C.

Koellinger, P. (2008) 'The relationship between technology, innovation, and firm performance—Empirical evidence from e-business in Europe', *Research Policy*, 37(8), pp. 1317–1328.

Kurdve, M., Zackrisson, M., Wiktorsson, M. and Harlin, U. (2014) 'Lean and green integration into production system models - Experiences from Swedish industry', *Journal of Cleaner Production*, 85, pp. 180–190.

Labodová, A. (2004) 'Implementing integrated management systems using a risk analysis based approach', *Journal of Cleaner Production*, 12(6), pp. 571–580.

Lanjouw, J. O. and Schankerman, M. (2002) 'Research productivity and patent quality: measurement with multiple indicators', *The Economic Journal*, 114(495), pp. 441–465.

Laursen, K. and Salter, A. (2006) 'Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms', *Strategic Management Journal*, 27(2), pp. 131–150.

Lee, S. K., Mogi, G., Lee, S. K., Hui, K. S. and Kim, J. W. (2010) 'Econometric analysis of the R&D performance in the national hydrogen energy technology development for measuring relative efficiency: The fuzzy AHP/DEA integrated model approach', *International Journal of Hydrogen Energy*, 35(6), pp. 2236–2246.

Lim, S. and Prakash, A. (2014) 'Voluntary regulations and innovation: The Case of ISO 14001', *Public Administration Review*, 74(2), pp. 233–244.

Lim, S. and Prakash, A. (2017) 'From Quality Control to Labor Protection: ISO 9001 and Workplace Safety, 1993–2012', *Global Policy*, 8(May), pp. 66–77.

Lisi, I. E. (2015) 'Translating environmental motivations into performance: The role of environmental performance measurement systems', *Management Accounting Research*, 29, pp. 27–44.

Liu, Z., Chen, X., Chu, J. and Zhu, Q. (2017) 'Industrial development environment and innovation efficiency of high-tech industry: analysis based on the framework of innovation systems', *Technology Analysis & Strategic Management*, pp. 1–13.

Llach, J., de Castro, R., Bikfalvi, A. and Marimon, F. (2007) 'The Relationship between Environmental Management Systems and

Organizational Innovations', *Human Factors and Ergonomics in Manufacturing*, 17(5), pp. 475–484.

Llach, J., Perramon, J., Alonso-Almeida, M. D. M. and Bagur-Femenías, L. (2013) 'Joint impact of quality and environmental practices on firm performance in small service businesses: an empirical study of restaurants', *Journal of Cleaner Production*, 44, pp. 96–104.

Lo, C. K. Y., Pagell, M., Fan, D., Wiengarten, F. and Yeung, A. C. L. (2014) 'OHSAS 18001 certification and operating performance: The role of complexity and coupling', *Journal of Operations Management*, 32(5), pp. 268–280.

Lo, C. K. Y., Yeung, A. C. L. and Cheng, T. C. E. (2012) 'The impact of environmental management systems on financial performance in fashion and textiles industries', *International Journal of Production Economics*, 135(2), pp. 561–567.

Longoni, A. and Cagliano, R. (2015) 'Environmental and social sustainability priorities', *International Journal of Operations & Production Management*, 35(2), pp. 216–245.

Longoni, A. and Cagliano, R. (2016) 'Sustainable Innovativeness and the Triple Bottom Line: The Role of Organizational Time Perspective', *Journal of Business Ethics*, pp. 1–24.

Lozano, R. (2012) 'Towards better embedding sustainability into companies' systems: An analysis of voluntary corporate initiatives', *Journal of Cleaner Production*, 25, pp. 14–26.

Lozano, R., Nummert, B. and Ceulemans, K. (2016) 'Elucidating the relationship between Sustainability Reporting and Organisational Change Management for Sustainability', *Journal of Cleaner Production*, 125, pp. 168–188.

Manigrasso, M., Vitali, M., Protano, C. and Avino, P. (2017) 'Temporal evolution of ultrafine particles and of alveolar deposited surface area from main indoor combustion and non-combustion sources in a model room', *Science of the Total Environment*, 598, pp. 1015–1026.

Mann, H. B. and Whitney, D. R. (1947) 'On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other', *The Annals of Mathematical Statistics*, 18(1), pp. 50–60.

Martí-Ballester, C. P. and Simon, A. (2017) 'Union is strength', *Management Decision*, 55(1), pp. 81–102.

Matias, J. C. D. O. and Coelho, D. A. (2011) ‘Integrated total quality management: Beyond zero defects theory and towards innovation’, *Total Quality Management & Business Excellence*, 22(8), pp. 891–910.

Mazzola, E., Perrone, G. and Kamuriwo, D. S. (2015) ‘Network embeddedness and new product development in the biopharmaceutical industry: The moderating role of open innovation flow’, *International Journal of Production Economics*, 160, pp. 106–119.

McGuire, S. J. and Dilts, D. M. (2008) ‘The financial impact of standard stringency: An event study of successive generations of the ISO 9000 standard’, *International Journal of Production Economics*, 113(1), pp. 3–22.

Melnyk, S. A., Sroufe, R. P. and Calantone, R. L. (2002) ‘Assessing the effectiveness of US voluntary environmental programmes: An empirical study’, *International Journal of Production Research*, 40(8), pp. 1853–1878.

Mir, M., Casadesús, M. and Petnji, L. H. (2016) ‘The impact of standardized innovation management systems on innovation capability and business performance: An empirical study’, *Journal of Engineering and Technology Management*, 41, pp. 26–44.

Mittal, V., Anderson, E. W., Sayrak, A. and Tadikamalla, P. (2005) ‘Dual Emphasis and the Long-Term Financial Impact of Customer Satisfaction’, *Marketing Science*, 24(4), pp. 544–555.

Mohammadfam, I., Kamalinia, M., Momeni, M., Golmohammadi, R., Hamidi, Y. and Soltanian, A. (2016) ‘Developing an integrated decision making approach to assess and promote the effectiveness of occupational health and safety management systems’, *Journal of Cleaner Production*, 127, pp. 119–133.

Moneva, J. M., Archel, P. and Correa, C. (2006) ‘GRI and the camouflaging of corporate unsustainability’, *Accounting Forum*, 30(2), pp. 121–137.

Moreno-Luzon, M. D., Gil-Marques, M. and Valls-Pasola, J. (2013) ‘TQM, innovation and the role of cultural change’, *Industrial Management & Data Systems*, 113(8), pp. 1149–1168.

Muñoz-Villamizar, A., Santos, J., Viles, E. and Ormazábal, M. (2018) ‘Manufacturing and environmental practices in the Spanish context’, *Journal of Cleaner Production*, 178, pp. 268–275.

Mustapha, M. A., Manan, Z. A. and Wan Alwi, S. R. (2017) ‘Sustainable Green Management System (SGMS) – An integrated approach towards organisational sustainability', *Journal of Cleaner Production*, 146, pp. 158–172.

Naveh, E. and Marcus, A. (2007) 'Financial performance, ISO 9000 standard and safe driving practices effects on accident rate in the U.S. motor carrier industry', *Accident Analysis and Prevention*, 39(4), pp. 731–742.

NCA (2017) *National Candle Association*. Available at: http://candles.org/ (Accessed: 22 February 2017).

Newson, R. (2006) 'Confidence intervals for rank statistics: Somers' D and extensions', *Stata Journal*, 6(3), pp. 309–334.

Nordhaus, W. D. (1996) 'Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not', in Bresnahan, T. F. and Gordon, R. J. (eds) *The Economics of New Goods*. University of Chicago Press, pp. 27–70.

Nunhes, T. V., Ferreira Motta, L. C. and de Oliveira, O. J. (2016) 'Evolution of integrated management systems research on the Journal of Cleaner Production: Identification of contributions and gaps in the literature', *Journal of Cleaner Production*, 139, pp. 1234–1244.

Nunhes, T. V., Motta Barbosa, L. C. F. and de Oliveira, O. J. (2017) 'Identification and analysis of the elements and functions integrable in integrated management systems', *Journal of Cleaner Production*, 142, pp. 3225–3235.

Nunnally, J. C. (1967) *Psychometric theory*. New York, NY: McGraw-Hill.

OECD (1997) *Small businesses, job creation and growth: facts, obstacles and best practices*. Edited by OECD. Paris. Available at: https://www.oecd.org/cfe/smes/2090740.pdf (Accessed: 20 January 2017).

OECD (2005) *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition*. OECD Publishing (The Measurement of Scientific and Technological Activities).

Olaru, M., Maier, D., Nicoară, D. and Maier, A. (2014) 'Establishing the basis for Development of an Organization by Adopting the Integrated Management Systems: Comparative Study of Various Models and Concepts of Integration', *Procedia - Social and Behavioral Sciences*, 109, pp. 693–697.

Orecchio, S. (2011) 'Polycyclic aromatic hydrocarbons (PAHs) in indoor emission from decorative candles', *Atmospheric Environment*, 45(10), pp. 1888–1895.

Oskarsson, K. and Malmborg, F. (2005) ‘Integrated Management Systems as a Corporate Response to Sustainable Development’, *Corporate Social Responsibility and Environmental Management*, 12, pp. 121–128.

Pacheco, D. A. de J., ten Caten, C. S., Jung, C. F., Ribeiro, J. L. D., Navas, H. V. G. and Cruz-Machado, V. A. (2017) ‘Eco-innovation determinants in manufacturing SMEs: Systematic review and research directions’, *Journal of Cleaner Production*, 142, pp. 2277–2287.

Palm, K., Lilja, J. and Wiklund, H. (2016) ‘The challenge of integrating innovation and quality management practice’, *Total Quality Management & Business Excellence*, 27(1), pp. 34–47.

Pedroni, P. (2004) ‘Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis’, *Econometric Theory*. Universitat De Barcelona UB, 20, pp. 597–625.

Pendlebury, M. and Groves, R. (2004) *Company accounts: analysis, interpretation and understanding*. 6th edn. London: Thomson.

Perdomo-Ortiz, J., González-Benito, J. and Galende, J. (2006) ‘Total quality management as a forerunner of business innovation capability’, *Technovation*, 26(10), pp. 1170–1185.

Petroni, G., Dormio, A. I., Nosella, A. and Verbano, C. (2003) ‘The TQM trajectories in research and development: two Italian cases’, *European Journal of Innovation Management*, 6(4), pp. 239–252.

PITEC (2007) *Encuesta sobre innovación en las empresas 2007*. Available at: https://www.fecyt.es/ (Accessed: 11 July 2016).

Plambeck, E. L. and Taylor, T. A. (2005) ‘Sell the Plant? The Impact of Contract Manufacturing on Innovation, Capacity, and Profitability’, *Management Science*, 51(1), pp. 133–150.

Power, M. (1997) *The audit society: Rituals of verification*. Oxford, England: Oxford University Press.

Prajogo, D. I. and Sohal, A. S. (2001) ‘TQM and innovation: a literature review and research framework’, *Technovation*, 21(9), pp. 539–558.

Prajogo, D. I. and Sohal, A. S. (2004) ‘The multidimensionality of TQM practices in determining quality and innovation performance - An empirical examination’, *Technovation*, 24(6), pp. 443–453.

Prajogo, D. I. and Sohal, A. S. (2006) ‘The integration of TQM and technology/R&D management in determining quality and innovation performance’, *Omega*, 34(3), pp. 296–312.

Prajogo, D., Tang, A. K. Y. and Lai, K.-H. (2014) 'The diffusion of environmental management system and its effect on environmental management practices', *International Journal of Operations & Production Management*, 34(5), pp. 565–585.

Presas, P., Bernardo, M. and Hernandez-Vivanco, A. (2016) 'Is the Biosphere certification increasing customers satisfaction in hotels?', in *Proceedings book of the 2nd International Conference on Quality Engineering and Management*. University of Minho, Guimarães (Portugal), pp. 291–307.

Pun, K.-F. and Hui, I.-K. (2002) 'Integrating the safety dimension into quality management systems: A process model', *Total Quality Management*, 13(3), pp. 373–391.

Radonjič, G. and Tominc, P. (2006) 'The impact and significance of ISO 14001 certification on the adoption of new technologies', *Management of Environmental Quality: An International Journal*, 17(6), pp. 707–727.

Ramos, A. R., Ferreira, J. C. E., Kumar, V., Garza-Reyes, J. A. and Cherrafi, A. (2018) 'A lean and cleaner production benchmarking method for sustainability assessment: A study of manufacturing companies in Brazil', *Journal of Cleaner Production*, 177, pp. 218–231.

Rebelo, M. F., Santos, G. and Silva, R. (2016) 'Integration of management systems: towards a sustained success and development of organizations', *Journal of Cleaner Production*, 127, pp. 96–111.

Rehfeld, K. M., Rennings, K. and Ziegler, A. (2007) 'Integrated product policy and environmental product innovations: An empirical analysis', *Ecological Economics*, 61(1), pp. 91–100.

Reid, W. and Myddelton, D. R. (2005) *The Meaning of Company Accounts*. 8th edn. Routledge: Gower.

Renzi, M. F. and Cappelli, L. (2000) 'Itegration between ISO 9000 and ISO 14000: Opportunities and limits', *Total Quality Management*, 11(4–6), pp. 849–856.

Ribeiro, F., Santos, G., Rebelo, M. F. and Silva, R. (2017) 'Integrated Management Systems: Trends for Portugal in the 2025 horizon', *Procedia Manufacturing*, 13(November), pp. 1191–1198.

Ringle, C. M., Wende, S. and Will, A. (2005) 'SmartPLS'. Hamburg, Germany. Available at: https://www.smartpls.com/smartpls2.

Robson, L. S., Clarke, J. A., Cullen, K., Bielecky, A., Severin, C., Bigelow, P. L., Irvin, E., Culyer, A. and Mahood, Q. (2007) 'The effectiveness of occupational health and safety management system interventions: A systematic review', *Safety Science*, 45(3), pp. 329–353.

Rocha, M., Searcy, C. and Karapetrovic, S. (2007) 'Integrating Sustainable Development into Existing Management Systems', *Total Quality Management & Business Excellence*, 18(1–2), pp. 83–92.

Romer, P. (1991) 'Endogenous technological change', *Journal of Political Economy*, 98(5), pp. S71–S102.

Roodman, D. (2009) 'How to do xtabond2: An introduction to difference and system GMM in Stata', *Stata Journal*, 9(1), pp. 86–136.

Salomone, R. (2008) 'Integrated management systems: experiences in Italian organizations', *Journal of Cleaner Production*, 16(16), pp. 1786–1806.

Sampaio, P., Saraiva, P. and Domingues, J. P. T. (2012a) 'Management systems: integration or addition?', *International Journal of Quality & Reliability Management*, 29(4), pp. 402–424.

Sampaio, P., Saraiva, P. and Guimarães Rodrigues, A. (2009) 'ISO 9001 certification research: questions, answers and approaches', *International Journal of Quality & Reliability Management*, 26(1), pp. 38–58.

Sampaio, P., Saraiva, P. and Guimarães Rodrigues, A. (2011a) 'ISO 9001 certification forecasting models', *International Journal of Quality & Reliability Management*, 28(1), pp. 5–26.

Sampaio, P., Saraiva, P. and Guimarães Rodrigues, A. (2011b) 'The economic impact of quality management systems in Portuguese certified companies', *International Journal of Quality & Reliability Management*, 28(9), pp. 929–950.

Sampaio, P., Saraiva, P. and Monteiro, A. (2012b) 'ISO 9001 certification pay-off: myth versus reality', *International Journal of Quality & Reliability Management*, 29(8), pp. 891–914.

Santos, G., Barros, S., Mendes, F. and Lopes, N. (2013) 'The main benefits associated with health and safety management systems certification in Portuguese small and medium enterprises post quality management system certification', *Safety Science*, 51(1), pp. 29–36.

Santos, G., Mendes, F. and Barbosa, J. (2011) 'Certification and integration of management systems: The experience of Portuguese small and medium enterprises', *Journal of Cleaner Production*, 19(17–18), pp. 1965–1974.

Saraiva, P., Sampaio, P., Cubo, C., Reis, M. and João, D. (2017) *World State of Quality: 2016 European Quality Scoreboard*.

Savino, M. M. and Batbaatar, E. (2015) 'Investigating the resources for Integrated Management Systems within resource-based and contingency perspective in manufacturing firms', *Journal of Cleaner Production*, 104, pp. 392–402.

Severo, E. A., De Guimarães, J. C. F., Dorion, E. C. H. and Nodari, C. H. (2015) 'Cleaner production, environmental sustainability and organizational performance: An empirical study in the Brazilian metal-mechanic industry', *Journal of Cleaner Production*, 96, pp. 118–125.

Sharma, D. S. (2005) 'The association between ISO 9000 certification and financial performance', *International Journal of Accounting*, 40(2), pp. 151–172.

Silva, S. A., Carvalho, H., Oliveira, M. J., Fialho, T., Guedes Soares, C. and Jacinto, C. (2017) 'Organizational practices for learning with work accidents throughout their information cycle', *Safety Science*, 99, pp. 102–114.

Simmons, B. L. and White, M. A. (1999) 'The relationship between ISO 9000 and business performance: does registration really matter?', *Journal of Managerial Issues*, 11(3), pp. 330–343.

Simon, A. and Douglas, A. (2013) 'Integrating management systems: does the location matter?', *International Journal of Quality & Reliability Management*, 30(6), pp. 675–689.

Simon, A., Karapetrovic, S. and Casadesús, M. (2012) 'Difficulties and benefits of integrated management systems', *Industrial Management & Data Systems*, 112(5), pp. 828–846.

Simon, A. and Petnji Yaya, L. H. (2012) 'Improving innovation and customer satisfaction through systems integration', *Industrial Management & Data Systems*, 112(7), pp. 1026–1043.

Simon, A., Petnji Yaya, L. H., Karapetrovic, S. and Casadesus, M. (2014) 'Can integration difficulties affect innovation and satisfaction?', *Industrial Management & Data Systems*, 114(2), pp. 183–202.

Singels, J., Ruël, G. and van de Water, H. (2001) 'ISO 9000 series: Certification Performance', *International Journal of Quality & Reliability Management*, 18(1), pp. 62–75.

Siva, V., Gremyr, I., Bergquist, B., Garvare, R., Zobel, T. and Isaksson, R. (2016) 'The support of Quality Management to sustainable development: a literature review', *Journal of Cleaner Production*, 138, pp. 148–157.

Skovmand, A., Damiao Gouveia, A. C., Koponen, I. K., Møller, P., Loft, S. and Roursgaard, M. (2017) 'Lung inflammation and genotoxicity in mice lungs after pulmonary exposure to candle light combustion particles', *Toxicology Letters*, 276(January), pp. 31–38.

Song, M., Di Benedetto, C. A. and Nason, R. W. (2007) 'Capabilities and financial performance: the moderating effect of strategic type', *Journal of the Academy of Marketing Science*, 35(1), pp. 18–34.

Sroufe, R. (2017) 'Integration and organizational change towards sustainability', *Journal of Cleaner Production*, 162, pp. 315–329.

Su, H.-C., Dhanorkar, S. and Linderman, K. (2015) 'A competitive advantage from the implementation timing of ISO management standards', *Journal of Operations Management*, 37, pp. 31–44.

Szeto and Elson (2000) 'Innovation capacity: working towards a mechanism for improving innovation within an inter-organizational network', *The TQM Magazine*, 12(2), pp. 149–158.

Tarí, J. J., Molina-Azorín, J. F. and Heras, I. (2012) 'Benefits of the ISO 9001 and ISO 1400 Standards: A Literature Review', *Journal of Industrial Engineering and Management*, 5(2), pp. 297–323.

Tarí, J. J. and Molina-Azorín, J. F. (2010) 'Integration of quality management and environmental management systems', *The TQM Journal*. Edited by S. Karapetrovic, 22(6), pp. 687–701.

Tauchmann, H. (2012) 'Partial frontier efficiency analysis', *Stata Journal*, 12(3), pp. 461–478.

Teng, M. J., Wu, S. Y. and Chou, S. J. H. (2014) 'Environmental commitment and economic performance - short-term pain for long-term gain', *Environmental Policy and Governance*, 24(1), pp. 16–27.

Terziovski, M. and Guerrero, J.-L. (2014) 'ISO 9000 quality system certification and its impact on product and process innovation performance', *International Journal of Production Economics*, 158, pp. 197–207.

Thanassoulis, E., Portela, M. C. S. and Despic, O. (2008) 'DEA—the mathematical programming approach to efficiency analysis', in Fried, H., Lovell, C. A. K., and S. Schmidt, S. (eds) *The measurement of productive efficiency and productivity growth*. New York, NY: Oxford University Press, pp. 251–420.

Tidd, J. and Bessant, J. (2009) *Managing innovation; integrating technological, market and organizational change*. 4th ed. Chichester, England: John Wiley & Sons Ltd.

To, W. M. and Lee, P. K. C. (2014) 'Diffusion of ISO 14001 environmental management system: global, regional and country-level analyses', *Journal of Cleaner Production*, 66, pp. 489–498.

To, W. M., Lee, P. K. C. and Yu, B. T. W. (2012) 'Benefits of implementing management system standards: A case study of certified companies in the Pearl River Delta, China', *The TQM Journal*, 24(1), pp. 17–28.

Tobin, J. (1958) 'Estimation of Relationships for Limited Dependent Variables', *Econometrica*, 26(1), pp. 24–36.

Tsai, K.-H. (2009) 'Collaborative networks and product innovation performance: Toward a contingency perspective', *Research Policy*, 38(5), pp. 765–778.

Un, C. A. and Asakawa, K. (2015) 'Types of R&D Collaborations and Process Innovation: The Benefit of Collaborating Upstream in the Knowledge Chain', *Journal of Product Innovation Management*, 32(1), pp. 138–153.

UNEP DTIE (1996) *Cleaner Production: a Resource Training Package*. first ed. United Nations Publication, Paris.

United Nations (1992) 'Agenda 21'. Rio de Janeiro, (June). Available at: https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf.

United Nations (2017) *World Economic and Social Survey 2017*. New York, NY. Available at: https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/WESS_2017-FullReport.pdf.

Veryzer, R. W. (1998) 'Discontinuous Innovation and the New Product Development Process', *Journal of Product Innovation Management*. Blackwell Publishing, 15(4), pp. 304–321.

Vieira, L. C. and Amaral, F. G. (2016) 'Barriers and strategies applying Cleaner Production: A systematic review', *Journal of Cleaner Production*, 113, pp. 5–16.

Voegtlin, C. and Scherer, A. G. (2017) 'Responsible Innovation and the Innovation of Responsibility: Governing Sustainable Development in a Globalized World', *Journal of Business Ethics*, 143(2), pp. 227–243.

Wagner, M. (2007a) 'Integration of Environmental Management with Other Managerial Functions of the Firm', *Long Range Planning*, 40(6), pp. 611–628.

Wagner, M. (2007b) 'On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms', *Research Policy*, 36(10), pp. 1587–1602.

Wagner, M. (2008) 'Empirical influence of environmental management on innovation: Evidence from Europe', *Ecological Economics*, 66(2–3), pp. 392–402.

Wagner, M. (2009) 'National culture, regulation and country interaction effects on the association of environmental management systems with environmentally beneficial innovation', *Business Strategy and the Environment*, 18(2), pp. 122–136.

Wagner, M., Phu, N. Van, Azomahou, T. and Wehrmeyer, W. (2002) 'The relationship between the environmental and economic performance of firms: an empirical analysis of the European paper industry', *Corporate social responsibility and Environmental Management*, 146(9), pp. 133–146.

Walker, H. and Preuss, L. (2008) 'Fostering sustainability through sourcing from small businesses: public sector perspectives', *Journal of Cleaner Production*, 16(15), pp. 1600–1609.

Wang, Q., Hang, Y., Sun, L. and Zhao, Z. (2016a) 'Two-stage innovation efficiency of new energy enterprises in China: A non-radial DEA approach', *Technological Forecasting and Social Change*, 112, pp. 254–261.

Wang, X., Lin, H. and Weber, O. (2016b) 'Does Adoption of Management Standards Deliver Efficiency Gain in Firms? Pursuit of Sustainability Performance? An Empirical Investigation of Chinese Manufacturing Firms', *Sustainability*, 8(7), p. 694.

Wang, Z. and Wang, N. (2012) 'Knowledge sharing, innovation and firm performance', *Expert Systems with Applications*, 39(10), pp. 8899–8908.

Watson, R., Wilson, H. N., Smart, P. and Macdonald, E. K. (2018) 'Harnessing Difference: A Capability-Based Framework for Stakeholder Engagement in Environmental Innovation', *Journal of Product Innovation Management*, 35(2), pp. 254–279.

Weerawardena, J., O'Cass, A. and Julian, C. (2006) 'Does industry matter? Examining the role of industry structure and organizational learning in innovation and brand performance', *Journal of Business Research*, 59(1), pp. 37–45.

West, A. M. and Anderson, R. N. (1996) 'Innovation in Top Management Teams', *Journal of Applied Psychology*, 81(6), pp. 680–693.

West, J. and Bogers, M. (2014) 'Leveraging external sources of innovation: A review of research on open innovation', *Journal of Product Innovation Management*, 31(4), pp. 814–831.

Wetzels, Odekerken-Schröder and van Oppen (2009) 'Using PLS Path Modeling for Assessing Hierarchical Construct Models: Guidelines and Empirical Illustration', *MIS Quarterly*, 33(1), p. 177.

Wiengarten, F., Humphreys, P., Onofrei, G. and Fynes, B. (2017) 'The adoption of multiple certification standards: perceived performance implications of quality, environmental and health & safety certifications', *Production Planning & Control*, 28(2), pp. 131–141.

Wilcoxon, F. (1945) 'Individual Comparisons by Ranking Methods', *International Biometric Society*, 1(6), pp. 80–83.

Wilkinson, G. and Dale, B. G. (1999) 'Integrated management systems: an examination of the concept and theory', *The TQM Magazine*, 11(2), pp. 95–104.

Windmeijer, F. (2005) 'A finite sample correction for the variance of linear efficient two-step GMM estimators', *Journal of Econometrics*, 126(1), pp. 25–51.

Witjes, S., Vermeulen, W. J. V. and Cramer, J. M. (2016) 'Exploring corporate sustainability integration into business activities. Experiences from 18 small and medium sized enterprises in the Netherlands', *Journal of Cleaner Production*, 153, pp. 528-538.

Wong, A., Tjosvold, D. and Liu, C. (2009) 'Innovation by teams in Shanghai, China: Cooperative goals for group confidence and persistence', *British Journal of Management*, 20(2), pp. 238–251.

Xavier, A. F., Naveiro, R. M., Aoussat, A. and Reyes, T. (2017) 'Systematic literature review of eco-innovation models: Opportunities and recommendations for future research', *Journal of Cleaner Production*, 149, pp. 1278–1302.

Zeng, S. X., Shi, J. J. and Lou, G. X. X. (2007) 'A synergetic model for implementing an integrated management system: an empirical study in China', *Journal of Cleaner Production*, 15(18), pp. 1760–1767.

Ziegler, A. and Seijas Nogareda, J. (2009) 'Environmental management systems and technological environmental innovations: Exploring the causal relationship', *Research Policy*, 38(5), pp. 885–893.

Zwetsloot, G. I. J. M. (1995) 'Improving cleaner production by integration into the management of quality, environment and working conditions', *Journal of Cleaner Production*, 3(1–2), pp. 61–66.