IS INFORMATION SYSTEMS INTEROPERABILITY AN INNOVATION DRIVER? AN EMPIRICAL INVESTIGATION

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Abstract

Most of the research that has been conducted on the business value of information systems (IS) interoperability focuses mainly on the efficiency related benefits it can generate, but deals much less with its potential to drive innovations in firms' products/services and processes. Our study contributes to filling this research gap by empirically investigating the effect of interoperability of firm's IS (meant as compliance with various types of relevant standards) on firm's innovation performance. It is based on a large dataset from 14.065 European firms (from 25 countries and 10 sectors), which has been collected through the e-Business W@tch Survey of the European Commission, and is used for estimating product/service and process innovation models. It has been concluded that IS interoperability has strong positive effects both on product/service and process innovation, which are weaker than the corresponding effects of the degree of development of firms' IS, but stronger than the effects of the degree of functional development of firm's e-Sales IS; also they are stronger than the corresponding effects of R&D and competition (regarded as important innovation drivers according to previous literature). Finally, a comparison among different types of IS interoperability standards shows that their positive effects on firms' innovation activity differ, with the industry-specific and the XML-horizontal standards having stronger effects of similar magnitudes, while the proprietary standards have weaker ones.

Keywords: Information Systems (IS), Interoperability, Standards, Innovation.

1 INTRODUCTION

Though information and communication technologies (ICT) were initially regarded as drivers of efficiency (by automating existing business processes), subsequently it was realised that they also have big potential for driving important innovations in firms' business processes, products and services; this motivated the development of a considerable research stream concerning the effects of ICT on various forms of innovation, which is briefly reviewed in section 2.1. This research has produced interesting literature, which is mainly theoretical and much less empirical; furthermore, the latter views firm's ICT as a single and unidimensional entity, operationalizes it through too simple measures, such as firm's ICT investment (total or per employee), share of employees using computers, or functionality provided, etc., and does not examine the effects of various dimensions/characteristics of firm's ICT (such as its interoperability) on its innovation performance. Another smaller research stream studies the business value of information systems (IS) interoperability, which is briefly reviewed in section 2.2; however, it focuses mainly on the efficiency related benefits it can generate, and deals much less with its potential to drive innovations in firms' products/services and processes. Furthermore, the literature produced by this research stream is mainly theoretical, and only a very limited number of empirical studies have been

conducted in this area, investigating mainly the effects of IS interoperability on firm's efficiency, and not dealing with its effects on innovation.

This paper contributes to bridging the two abovementioned research streams and to filling these research gaps, by presenting an empirical study of the effects of interoperability of firm's IS (meant as compliance with various types of relevant standards) on its innovation performance. In particular, in our study we consider the following three fundamental types of IS interoperability standards ((Nurmilaakso 2008a and 2008b; Lampathaki *et al.*, 2009):

- The vertical/industry – specific standards, which are usually created by industry associations or sectoral standardization bodies, in order to enable the electronic exchange of important business documents (e.g. quotations, orders, shipment notes, invoices, payment notes) between firms of a specific industry, their suppliers, customers and business partners (Zhao *et al.*, 2005; Markus *et al.*, 2006); as example of this type of IS interoperability standards we can mention the RosettaNet for high-tech industry, the CIDX for the chemicals industry, the MISMO for the mortgage industry, and the ACORD for the insurance industry. Such industry-specific standards are usually 'tailored' to meet the needs of the firms of the specific sector, so they have the whole needed "depth and breadth" for this sector: they include all the range of required documents and elements.
- The XML – horizontal or industry-neutral standards, which are typically open cross-sectoral (horizontal) specifications of business documents' interchange formats, which have been developed based on the XML (eXtensible Markup Language), aiming to be used by firms of all sectors (Zhao *et al.*, 2005). They are broad enough to cover many important aspects of the documents that need to be exchanged among firms, but lack the needed depth for representing sector-specific characteristics and information elements, as they include mainly elements that are common across sectors. Due to the fast adoption of XML, many vertical/industry-specific standards (and also some proprietary ones) have been ported to XML as well; however, at the time when the data of this study were collected, XML was used mainly for cross-sectoral (horizontal) standards.
- The proprietary standards, are typically created and maintained by large strong firms, which can impose such de-facto specifications for business documents' exchange with their own customers, suppliers or business partners. These interconnection standards usually have extensive depth and breadth, but include mainly the documents and elements required by the creator firm.

Initially we investigate empirically the effect of a composite firm's IS interoperability index (average of three dichotomous variables measuring whether the firm has adopted each of the above three types of IS interoperability standards for exchanging data with its customers and suppliers) on product/service and process innovation. Then, we empirically investigate and compare the individual effects of these three types of standards, in order to understand to what extent the impact of IS interoperability on firm's innovation activity depends on the type and the characteristics of the adopted standards. Finally, we compare these IS interoperability effects on innovation with the corresponding effects of one of the ICT variables/dimensions used in previous relevant empirical research as independent variable (see section 2.1), the functionality provided by the IS (measured through the degree of the functional development of firms' internal and e-Sales IS – see section 4). The present empirical study is based on a large dataset collected from 14.065 European firms (from 25 countries and 10 sectors) collected through the e-Business W@tch Survey of the European Commission. We expect that our findings will be useful to individual firms for making more informed decisions concerning their IS interoperability related investments, taking into account not only technical, but also business value factors, and also to consulting and ICT firms offering IS interoperability related products and services; furthermore, our findings will provide guidance to the technological IS interoperability research, in order to focus on the most valuable directions.

This paper consists of six sections. The following section 2 outlines the background of our study, while in section 3 the research hypotheses are formulated. Then in section 4 the data and method of our study are described, and in section 5 the results are presented and discussed. In the final section 6 we summarize our conclusions and propose future research directions.

2 BACKGROUND

2.1 ICT and Innovation

It is widely recognized that the ICT have a great potential not only to improve the efficiency of established business processes of firms, through which their usual products and services are produced, but also to facilitate and drive important innovations in their business processes, and also in their products and services. There has been extensive theoretical literature analyzing the innovation potential of ICT (Hammer, 1990; Orlikowski, 1992; Hammer & Champy, 1993; Davenport, 1993; Bresnahan & Trajtenberg, 1995; Brynjolfsson and Hitt, 2000; Orlikowski, 2000; Bresnahan *et al.*, 2002; Champy, 2002; Avgerou, 2003; Lyytinen and Newman, 2008; Brynjolfsson and Saunders, 2010; Brynjolfsson, 2011). This literature argues that most of the existing work practices, business processes and product/services of firms have been developed in the pre-ICT era, so they have been influenced and shaped to a large extent by the dominant manual mode of work, and the high costs of information processing and transfer at that times. Therefore the extensive capabilities offered by the new computerized mode of work, and the dramatic decrease of information processing and transfer costs, can lead to big innovations in work practices and business processes. Moreover, ICT can contribute to high beneficial transformations of existing processes by changing the geographic allocation of tasks, leading in some cases to more centralization and in some others to more decentralization, according to the specific characteristics and needs of each task. ICT can support radical improvements of business processes through their potential to facilitate the flow of information between globally distributed processes and ensure the availability of consistent information all over the firm. Also, they can be very useful for simplifying business process, reducing considerably the number of their activities, and for achieving cross-functional process level optimization rather than departmental level optimization. Economic literature argues that ICT are quite different than the other technologies used by firms: they are 'general purpose technologies' (Bresnahan and Trajtenberg, 1995), being characterized by high pervasiveness, flexibility and adaptability, so that they can be used in many different ways and for many different purposes in various sectors of the economy, opening up important opportunities for innovations in business processes, products and services of firms. Furthermore, ICT can directly drive ICT-based innovations in firms' products and services, and even their business models (Tapscot *et al.*, 2000; Brynjolfsson and Saunders, 2010). It can enable new products and services, and also higher variety and personalization of existing products and services, which would not be operationally and economically feasible without ICT. Beyond the above direct ICT-based innovation, ICT can also indirectly impact positively on firm's innovation activity, through its potential to increase the productivity of firms' research and development (R&D) and innovation creation processes (Kleis *et al.*, 2012). ICT can significantly help improving the collection, management and exchange of innovation-related knowledge, and can enable researchers distributed in different research centres, and also personnel from different functions and disciplines of the firm, to easily and rapidly share knowledge assets.

However there has been much less empirical literature concerning the effect of ICT on innovation, aiming to examine to what extent the high expectations of the above theoretical literature are realized (Han and Ravichandran, 2006; Hempell and Zwick, 2008; Engelstätter, 2012; Kleis *et al.*, 2012; Engelstätter and Sarbu, 2013). Han and Ravichandran (2006) examined the relationship between IT investment and firm innovation outcome based on data for 450 US manufacturing firms; their findings reveal that IT investment did not have a direct effect on innovation outcomes measured by patent counts, but the interaction between ICT investment and R&D expenditure positively affected innovation. Hempell and Zwick (2008), using data from 4.500 German firms from service and manufacturing sectors, concluded that ICT investment and share of employees working mainly on a computer have a positive impact on functional flexibility (measured through the numbers of employees working in teams, workgroups and quality circles) and through it on product and process innovation, while they also have a direct effect on both kinds of innovation as well. Engelstätter (2012) examined the relationship between three types of enterprise software offering different types of functionality – Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM) – and firms' innovation performance. His study based on data from 1.454 German firms. The results showed that (a) the likelihood of introducing process innovations is correlated positively with SCM systems, while the likelihood of introducing product innovations correlated with the use of CRM ones,

and also that (b) the number of process innovations a firm realized is correlated positively with ERP systems, whereas the number of product innovations is correlated with the use of SCM ones. Kleis *et al.*, (2012), analysing data from 201 large U.S. manufacturing firms over the period 1987 to 1997 including a total of 1.829 observations, examined the relationships between IT, innovation activity and innovation output. They concluded that IT and R&D both are positive and statistically significant as far as the innovation production is concerned. In general, ICT Capital has a positive effect on patents output (which is used as a product innovation measure), and especially on the more 'incremental' (i.e. less radical) ones. Engelstätter and Sarbu (2013) in their research investigated the relationship between the use of sector-specific standardized/packaged enterprise software and customized enterprise software on service innovation (the research based on 335 German firms from ICT and knowledge – intensive service sectors and the data collected during the period 2007 – 2009). The results showed that primarily customized enterprise software contributes to innovation.

The above limited empirical research in this area tends to view ICT as a single and unidimensional entity, and operationalizes it through too simple measures, such as firm's ICT investment (total or per employee), share of employees using computers, or the functionality provided, etc. However, firm's ICT is a multi-dimensional entity (having many hard/technical and soft/non-technical dimensions), and this previous empirical research has not examined the effects of various dimensions/characteristics of firm's ICT on its innovation performance; such research would be quite useful for firms, as it would provide them guidance as to which dimensions/characteristics of ICT should be developed in order to maximize the innovation drive provided. Our study contributes to filling this research gap, focusing on the interoperability dimension of firm's ICT infrastructure, and examining its impact on innovation.

2.2 IS Interoperability

IS Interoperability is defined by IEEE as the 'ability of two or more systems or components to exchange information and to use the information that has been exchanged' (IEEE, 1990). It is widely recognised in both academic and practitioners' communities that the establishment of interoperability of firm's IS with the ones of other trading partners (e.g. customers, suppliers, business allies) can generate considerable business value. So, through most of the research that has been conducted on IS interoperability has a technological perspective, there has been some research on the business value of it (Choi and Whiston, 2000; Grilo *et al.*, 2007; Lebreton and Legner, 2007; Li *et al.*, 2008; Grilo *et al.*, 2009; Grilo and Jardim-Goncalves, 2010); most of it is theoretical, and focuses mainly on the efficiency related benefits it can provide to firms, however it mentions important possible innovation related benefits that can be generated as well.

Choi and Whinston (2000) argue that IS interoperability is fundamental in order make full exploitation of their potential of ICT. In particular, it allows firms to communicate, exchange information, deliver products and services in real time, and this results in significant business benefits. Also, it can significantly improve efficiency in new product design, manufacturing and distribution, and at the same time increase customers' choices and satisfaction. The same paper stresses that the business value generated by interoperability is not limited to efficiency gains, as it can be a fundamental driver and enabler of important collaborative innovations. It also enables the personalization of offerings and the composition at a low cost of new complex products/services by combining and bundling complementary products/services from many different suppliers who are active in traditionally separated markets. Grilo *et al.*, (2007) state that firms tend increasingly be active in many different countries and cooperate with various geographically dispersed suppliers and customers; also they gradually change the way they innovate and produce, taking advantage much more than in the past of information and knowledge of their supplier, customer and distribution chains; establishing IS Interoperability, firms will be able to change the way they produce and innovate, they will increase productivity and flexibility, achieving higher levels of integration of their internal value chain and of the external supply chains in which they participate. Lebreton and Legner (2007) propose an IS interoperability impact assessment model, which includes the main types of value expected to be generated by interoperability. They are divided into two main categories: operational and strategic ones (with some of the latter being associated with innovation support). The operational value includes reduction of some important types of transaction costs (defined as 'friction costs' at firm's boundaries due to relationships with other firms): the connectivity costs (=

costs for setting up or improving business relationships), the coordination costs (= costs for the execution of the transactions) and monitoring costs (= costs for ensuring the correct completion of the transactions); also it includes higher transaction completion speed and more transaction visibility/transparency. The strategic value is associated with the relationships with customers (more contacts and intimacy, personalization of products/services, extension of products/services portfolio by forming innovative networks of value creation and bundling core competencies from many different firms (possibly from different geographic regions and industries)) and the suppliers (more contacts and intimacy, increase of buyers' power, more outsourcing due to reduction of transaction costs), and also with the achievement of operational excellence (improvements in assets utilization, productivity and agility). An Informal Study Group (ISG) launched by the European Commission to investigate the value proposition of enterprise interoperability in their final report (Li *et al.*, 2008) conclude that it has a great potential to increase the performance of firm's business processes, to support deeper cooperation with other firms and to stimulate new value creation through innovation. They stress that IS interoperability can be an important driver of collaborative development of significant value innovation through inter-firm 'value networks' (defined as webs of relationships that generate tangible and intangible value through complex dynamic exchanges between two or more individuals, groups or firms). Grilo *et al.*, (2009) and Grilo and Jardim-Goncalves (2010) analyse the value proposition of IS interoperability in the architectural, engineering and construction sector, and develop a model for measuring the impact of interoperability at the enterprise level, which includes four important dimensions of it: value level (efficiency, differentiation, value innovation), interaction type (communication, coordination, cooperation, collaboration, channel enrichment), breadth of impact (intra-company, hub-spokes dyads, business networks, ecosystems, industry, cross-industry), and geographic range (local, regional, national, European, global). We remark that all these four dimensions include elements associated with products/services and processes innovation.

IS interoperability reduces the effort, cost and time required for developing inter-organizational IS connecting firms with their customers, suppliers and business partners, and for integrating their IS, so they facilitate and increase activity in this direction; this, according to previous relevant literature (Mukhopadhyay and Kekre, 2002; Yi *et al.*, 2005; Malhotra *et al.*, 2007), leads to important both operational benefits (lower transaction and transaction costs, due to reduced need for clerical work, higher data accuracy, shorter response times and inventory costs savings) and strategic benefits (closer collaboration with customers, suppliers and business partners, higher knowledge exchange with them, learning about customers' needs and problems, and also market trends and competition, development of new products/services and improved business processes). Some of the latter are strongly associated with innovation in processes and in products/services. Furthermore, IS interoperability can similarly facilitate and support many innovative highly beneficial business practices, making them easier and less costly, such as electronic data interchange (Jimenez-Martinez and Polo-Redondo, 2004; Robey *et al.*, 2008), collaborative planning, forecasting and replenishment (Alemany *et al.*, 2011; Dudek and Stadtler, 2007; Stadtler, 2009), vendor-managed inventory (Achabal *et al.*, 2000; Kuk, 2004; Myers *et al.*, 2000), open innovation (Chesbrough, 2003; Chesbrough and Crowther, 2006; Huizingh, 2011), participation in value networks and digital business ecosystems (Barlow and Li, 2005; Busquets, 2010; Nachira, 2007) and development of new business models (Tapscott *et al.*, 2000; Tavlaki and Loukis, 2005; Timmers, 1998); therefore the interoperability of IS facilitates and fosters highly beneficial activity in the above directions.

However, limited empirical research has been conducted concerning the business value of IS interoperability (Mouzakitis *et al.*, 2009; Zu *et al.*, 2014). The study of Mouzakitis *et al.* (2009) investigates empirically the effect of five layers of interoperability (network, data, application, process and business) on the required effort for B2B IS integration; it is based on a dataset collected from 239 Greek firms which had successfully completed at least one B2B IS integration project. It concludes that IS interoperability at the data, process and business levels is significantly associated negatively with integration effort. Zu *et al.*, (2014) investigate empirically the effect of the extent of deployment and integration in business processes of the RosettaNet industry-specific standard on the operational and strategic benefits that adopting firms obtain, using a dataset collected from 186 Chinese firms. It concludes that the extent of integration of this standard has positive effects on both the operational and the strategic benefits, while the extent of deployment has positive effect only on the strategic benefits.

Therefore, the above quite limited empirical research is not dealing with the effects of firm's IS interoperability on its innovation activity; our study contributes to filling this research gap.

3 RESEARCH HYPOTHESES

Our first research hypothesis concerns the effect of IS interoperability on process innovation. As mentioned in the previous section, the adoption of IS interoperability standards allows the seamless and direct electronic execution and completion of transactions with suppliers, customers and business partners, through the electronic exchange of quotations, orders, shipment notes, invoices, payment notes, and other business documents, without the need of developing and maintaining intermediate conversion programs; we expect that this can lead to changes in the firms' business process associated with such external transactions, resulting in transformations of them and efficiency gains. IS interoperability can lead to more intensive information exchange with suppliers, customers and business partners, resulting initially in better understanding of each other's practices, processes, needs and problems, and then in beneficial 'mutual adaptations' of work practices and business processes (Malhotra *et al.*, 2007). Furthermore, as mentioned in the previous section, IS interoperability can facilitate and support advanced cooperative business practices, such as collaborative planning, forecasting and replenishment (Stadtler, 2009), and vendor-managed inventory (Kuk, 2004), leading to significant innovations in the corresponding processes. Also, according to Lebreton and Legner (2007) IS interoperability reduces transaction costs (= costs of transacting and cooperating with other firms), so it can lead to more outsourcing of firm's activities, which will substantially affect firm's processes. For the above reasons we expect that the adoption of IS interoperability standards in firms' ICT infrastructures for exchanging data with cooperating firms (suppliers, business partners, customers) will have a positive effect on firms' process innovation; thus our first research hypothesis is:

Hypothesis 1: The adoption of IS interoperability standards has a positive effect on process innovation

Our second research hypothesis concerns the effect of IS interoperability on product/service innovation. The establishment of IS interoperability with existing and potential customers, suppliers and business partners can be very useful for the collaborative conception, design and implementation of new products/services, or the improvement of existing ones. Firms' innovation processes (previously 'closed' within firm's boundaries) become increasingly 'open', involving to a significant extent customers, suppliers and business partners (see literature on open innovation, e.g. Huizingh, 2011); this necessitates the exchange initially of ideas and then of structured documents (e.g. with designs of new products, and later with demand and production plans), which can be greatly facilitated and supported by the interoperability of their IS. As mentioned above, IS interoperability can lead to intensification of information exchange with suppliers, customers and business partners, which can also resulting in sharing of knowledge, and also in synthetic creation of new knowledge, concerning new market trends and needs, business opportunities and technologies, competition movements, etc. (Malhotra *et al.*, 2007), fostering product/service innovation. Furthermore, the adoption of IS interoperability standards can also improve efficiency in new products' design, manufacturing and distribution, and also in extending their personalisation, increasing customers' choices and satisfaction (Choi and Whinston, 2000). In general, the adoption of IS interoperability standards enables the innovative personalization of offerings and the composition of new complex products/services by combining and bundling complementary products/services from many different suppliers, who are active in traditionally separated markets. Also, IS interoperability facilitates the participation in business networks, which have been recognized as important sources of innovation, as they enable extensive sharing of diverse sources of knowledge, combination of them and creation of innovative products and services (Zeng *et al.*, 2010; Salavisa *et al.*, 2012). For the above reasons we expect that the adoption of IS interoperability standards in firms' ICT infrastructures for exchanging data with cooperating firms (suppliers, business partners, customers) will have a positive effect on firms' product/service innovation, so the second research hypothesis is:

Hypothesis 2: The adoption of IS interoperability standards has a positive effect on product/services innovation

4 DATA AND METHOD

For this empirical study we used a large dataset collected in the 'e-Business Survey 2006', conducted by the European e-Business Market W@tch (www.ebusiness-watch.org), an observatory organization supported by the European Commission. The objective of this survey was to assess the extent of adoption and use of various types of ICT infrastructures, applications, standards and practices, the impacts of ICT use, and also the extent of innovation in the firms of the member states of European Union, the acceding and candidate countries and also the countries of the European Economic Area (EEA). It was conducted computer-aided telephone interview (CATI) technologies, and included 14.065 telephone interviews with decision-makers of firms from 29 countries from the above areas. The target population of this survey included all firms of the above countries, which are active in one of the following ten important economy sectors: Food and Beverages (SECT 1), Footwear (SECT 2), Pulp and Paper (SECT 3), ICT Manufacturing (SECT 4), Consumer Electronics (SECT 5), Shipbuilding and Repair (SECT 6), Construction (SECT 7), Tourism (SECT 8), Telecommunication Services (SECT 9) and Hospital Activities (SECT 10). A stratified sample by company size and sector was randomly selected from this population, including a 10% share of large firms (with 250+ employees), a 30% share of medium sized firms (with 50-249 employees), a 25% share of small firms (with 10-49 employees), while the remaining 35% were micro firms (with less than 10 employees).

Using the above data, the following four innovation models were estimated in order to test our research hypotheses:

INNOVPD = b0 + b1*INTEROP + b2*INT_IS +b3*E_SALES+ b4*COMP + b5*R&D + b6*HCAP + b7*D_ MED + b8*D_ LARGE+ b9*D_SECT (1)

INNOVPC = b0 + b1*INTEROP + b2*INT_IS +b3*E_SALES+ b4*COMP + b5*R&D + b6*HCAP + b7*D_ MED + b8*D_ LARGE+ b9*D_SECT (2)

INNOVPD = b0 + b1*IND_ST + b2*XMLHOR_ST + b3*PRO_ST + b4*INT_IS +b5*E_SALES+ b6*COMP + b7*R&D + b8*HCAP + b9*D_ MED + b10*D_ LARGE+ b11*D_SECT (3)

INNOVPC = b0 + b1*IND_ST + b2*XMLHOR_ST + b3*PRO_ST + b4*INT_IS +b5*E_SALES + b6*COMP + b7*R&D + b8*HCAP + b9*D_ MED + b10*D_ LARGE + b11*D_SECT (4)

For measuring innovation performance (dependent variables) we have used two binary (Yes/No) variables (INNOVPD, INNOVPC). These two variables assess whether the firm has introduced product/service innovations and process innovations respectively in the last three years, and have been used by many researchers in the past (e.g. Kessler, 2003; Novelli *et al.*, 2006; Arvanitis, 2008; Soto-Acosta *et al.*, 2009).

With respect to the independent variables, in the first two models (1) and (2) we have included a composite firm's IS interoperability index, which has been calculated as the average of three dichotomous variables assessing whether the firm uses industry – specific standards, XML – horizontal standards and proprietary standards respectively in order to exchange data with its customers, suppliers and business partners (IND_ST, XMLHOR_ST and PRO_ST). In the other two models (3) and (4) we included all these three dichotomous variables, in order to examine and compare the individual effects of these three types of standards.

We also included for comparison reasons one of the ICT variables/dimensions used as independent variable in previous empirical research on the effect of ICT on innovation (see section 2.1), the functionality provided by the IS, measured through the degree of the functional development of firms' internal and e-Sales IS. The degree of development of the functionality of firm's ICT infrastructure, i.e. the extent of support it provides for firm's internal processes and also for its interaction with the external environment, is widely recognized as the main determinant of the ICT business value generated for the firm (more important than the hardware that firm's ICT infrastructure includes, used also as independent variable in some previous empirical studies on the effect of ICT on innovation). We used two such variables, which correspond to the two most widely used types of IS: the intra-organizational/internal and the e-Sales ones. The first of them was the degree of functional development of firm's internal IS (INT_IS), which was calculated as the average of four items assessing whether or not the firm has four

important types of enterprise IS Enterprise Resource Planning (ERP) system, Customer Relationships Management (CRM) system, Supply Chain Management (SCM) system and Internal Collaboration system (variables INT_IS1 – INT_IS4, see Appendix). Such items have been used extensively in previous empirical IS research for measuring internal IS (Brews and Tucci, 2004; Koellinger, 2008; Soto-Acosta and Meroño-Cerdan, 2008). The second variable was the degree of functional development of e-Sales IS (E_SALES), which was measured through four items, assessing whether the firm uses IS for the four main stages of the lifecycle of a sale: for publishing offers to customers, answering calls for proposals or tenders, receiving orders from customers and enabling customers to pay online (variables E_SALES1 – E_SALES4, see Appendix). These items have also extensive previous literature support (Soto-Acosta and Meroño-Cerdan, 2008; Brews and Tucci, 2004; Hashim *et al.*, 2007).

Furthermore, we have used some additional independent variables corresponding to some 'traditional' factors affecting innovation according to previous relevant research (Cohen, 1995; Vinding, 2006; Arvanitis, 2008): competition (COMP) and existence of R&D department (R&D); also a human capital variable (HCAP), equal to the percentage share of firm's employees having a University or College degree; and finally, firm size: using the number of employees in full-time equivalents as a measure of firm size, we formed two dummy variables from it: one for medium-sized firms (D_MED for firms with 50 to 249 employees) and a second one for large firms (D_LARGE for firms with more than 250 employees), while small firms (with less than 50 employees) were used as a reference group.

In order to control for other sector-specific factors affecting our two dependent variables (product/service innovation and process innovation), we also included for the abovementioned ten sectors covered by our survey nine sectoral dummies (SECT1 – 9), while one sector was used as a reference group.

5 RESULTS

The above four models have been estimated using LOGIT estimation, which is the most appropriate estimation method, according to the relevant econometric literature (e.g. Gujarati, 2008), if the dependent variable is binary. The estimates are shown in the following tables 1 and 2. For each independent variable the exp(b) is shown, which is equal to the increase of the odds ratio of each dependent variable if the corresponding independent variable increases by one unit; statistically significant coefficients having significance levels lower than 10%, are shown in bold.

	Process Innovation	**Product/Service Innovation**
Interoperability	**3.463*** **	**2.489*** **
Internal IS	**4.734*** **	**2.836*** **
e-Sales IS	**2.120*** **	**2.298*** **
Competition	**1.516*** **	**1.588*** **
R&D	**1.463*** **	**2.019*** **
Human Capital	1.114	**1.416*** **
Medium-sized firms	**1.336*** **	.955
Large firms	**1.242*** **	.909
SECT 1	1.011	**1.919*** **
SECT 2	**.729*** **	**1.581*** **
SECT 3	.978	1.074
SECT 4	**.755*** **	**1.246** **
SECT 5	**.810***	**1.512*** **
SECT 6	**.604** **	**.506*** **
SECT 7	**.596*** **	**.552*** **
SECT 8	**.710*** **	.983
SECT 9	.930	**1.300*** **

Constant	**.177*** **	**.185*** **
N	14065	14065
Cox & Snell R^2	.154	.159
Nagelkerke R^2	.215	.215

Table 1. Innovation models with the composite IS interoperability index

	Process Innovation	**Product/Service Innovation**
Industry – specific standards	**1.599*** **	**1.426*** **
XML – horizontal standards	**1.650*** **	**1.437*** **
Proprietary standards	**1.323*** **	**1.207*** **
Internal IS	**4.745*** **	**2.848*** **
e-Sales IS	**2.137*** **	**2.315*** **
Competition	**1.511*** **	**1.583*** **
R&D	**1.456*** **	**2.011*** **
Human Capital	1.110	**1.412*** **
Medium-sized firms	**1.326*** **	.949
Large firms	**1.232*** **	.904
SECT 1	1.013	**1.920*** **
SECT 2	**.733*** **	**1.587*** **
SECT 3	.981	1.076
SECT 4	**.755*** **	**1.246** **
SECT 5	.813	**1.516*** **
SECT 6	**.609** **	**.510*** **
SECT 7	**.596*** **	**.551*** **
SECT 8	**.712*** **	.985
SECT 9	.927	**1.298*** **
Constant	**.175*** **	**.184*** **
N	14065	14065
Cox & Snell R^2	.155	.160
Nagelkerke R^2	.215	.216

Table 2. Innovation models with the three individual standards' adoption variables

In Table 1 we can see that in both models the exp(b) of the composite IS interoperability variable is statistically significant, and also higher than one (3.463 and 2.489 respectively), which means that the corresponding b coefficients are positive. The same happens in both models of Table 2 with the three individual dichotomous concerning the adoption of the three examined types of IS interoperability standards (industry-specific, XML-horizontal and proprietary). Therefore we can conclude that the adoption of IS interoperability in general, and also of each of these three types of standards, in firms' ICT infrastructures for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners), all have positive effects on both process and product/service innovation. So both our research hypotheses are supported.

Furthermore, we can see that in all four models the effects of the degree of functional development of firm's internal IS and e-Sales IS on process and product/service innovation are statistically significant and positive as well, as expected. We also remark that the former has much stronger positive effect on process innovation than in product/service innovation (exp(b) are 4.734 and 2.836 respectively in Table 1, and 4.745 and 2.848 in Table 2), while the latter has similar effects on both process innovation and product/service innovation.

Proceeding to the examination of the results for the other independent variables concerning the examined traditional innovation factors, we can see that the existence of an R&D department in a firm and the

competition have both statistically significant positive effects on process and product/service innovation. On the contrary the human capital has statistically significant positive effect on product/service innovation, but not on process innovation (which indicates that highly educated human resources are especially important for product/service innovation, but less important for process innovation). Also, we can see that size has a positive impact only on process innovation (which indicates that firm size plays an important role when it comes to reorganizing business processes, as larger firms have more complex and inflexible processes, so process innovation can be more beneficial for them than for the smaller firms). Finally, we remark that many of the coefficients of the sectoral dummies are statistically significant, which indicates that there are sector-specific factors that affect the innovation activity, and this necessitates the inclusion of sectoral dummies in such regressions.

It is interesting also to compare the effects of IS interoperability on innovation with the ones of the other independent variables used in the models of Tables 1 and 2, by examining the corresponding coefficients. As far as the process innovation is concerned, from the first model of Table 1 we remark that the degree of functional development of the internal IS have the strongest impact on it (4.734) followed by the overall degree of interoperability development (3.463) and the degree of development of e-Sales IS (2.120). Then two examined traditional innovation factors follow: competition (1.516) and R&D (1.463). These indicate that the degree of development of interoperability of firm's IS has a very strong positive impact on process innovation, which is a lower than the impact of the internal IS, but higher than the impacts of the e-Sales IS, and important traditional innovation factors (R&D, competition). As far as the product/service innovation is concerned, from the second model of Table 1 we remark that the degree of functional development of the internal IS has the strongest impact (2.836) on it again, followed by the overall degree of interoperability development (2.489) and the degree of functional development of e-Sales IS (2.298); then three 'traditional' innovation determinants follow: R&D (2.019), competition (1.588) and human capital (1.416). The above comparison indicates that the degree of development of the interoperability of firm's IS has a very strong positive impact on product/service innovation as well, which is a little lower than the impact of the internal IS, but is higher than the impacts of the e-Sales IS and important traditional innovation factors (R&D, competition, human capital); this is quite interesting if we take into account that the functionality of firm's internal and e-Sales IS are widely recognized as the main determinants of the extent of ICT business benefits and value at firm level.

Finally, from the models of Table 2 we can compare the effects of adopting these three types of IS interoperability standards on innovation, by examining the corresponding coefficients. With respect to process innovation: from the first model of Table 2 we remark that the adoption of XML – horizontal standards and the adoption of industry – specific standards have the strongest effects of similar magnitude (1.650 and 1.599 respectively), and the effect of the adoption of proprietary standards is weaker (1.323). Similar are the conclusions with respect to product/service innovation from the second model we remark that again the adoption of XML – horizontal standards and the adoption of industry – specific standards have the strongest effects of similar magnitude (1.437 and 1.426 respectively), while the corresponding effect of the adoption of proprietary standards is weaker (1.207). These conclusions indicate that the impact of IS interoperability on firm's innovation activity depends on the type of adopted standards: the adoption of XML – horizontal and industry – specific standards has stronger positive impact on firms' innovation activity than the adoption of the proprietary ones. This is probably because the first two types of IS interoperability standards are characterized by much wider applicability than the third. In particular, as mentioned in the Introduction, XML – horizontal standards are characterized by the widest applicability, as they can be used for exchanging electronically many business documents with a very large number of firms from many different industries; the industry – specific standards are characterized by wide applicability as well (though lower than the XML – horizontal), as they can be used for exchanging electronically many different business documents with a large number of firms from the particular industry (e.g. suppliers, customers, business partners). On the contrary the proprietary standards have much lower applicability, as they can be used for exchanging business documents with a much smaller number of firms (usually the strong creator firm and its business network). This wider applicability of the XML – horizontal and industry – specific standards leads to more opportunities for information and knowledge exchange, for transaction business processes transformation and streamlining, for facilitating and supporting advanced business practices (such as

vendor-managed inventory, collaborative planning, forecasting and replenishment, etc.), and also participation in business networks and digital business ecosystems, resulting finally in stronger innovation drive.

6 CONCLUSIONS

In the previous sections of this paper has been presented an empirical investigation of the effect of IS interoperability (meant as compliance with various types of relevant standards) on firm's process and product/service innovation. Also, the individual effects of the adoption of three different fundamental types of IS interoperability have been examined and compared. Finally, the above effects have been compared with the ones of the degree of functional development of firm's internal IS and e-Sales IS (widely recognized as the main determinants of ICT business benefits and value at firm level). Our empirical study has been based on a large dataset from 14.065 European firms (from 25 countries and 10 sectors) collected through the e-Business W@tch Survey of the European Commission, which has been used for estimating process and product/service innovation models.

It has been concluded that IS interoperability has a strong impact on firm's both process and product/service innovation. This impact is weaker than the corresponding impact of the degree of functional development of firm's internal IS, but stronger than the ones of the degree of functional development of firm's e-Sales internal IS and several 'traditional' innovation determinants (R&D, competition, human capital). The adoption of IS interoperability standards can promote process and product/service innovation by facilitating and supporting communication and data/knowledge exchange with firm's customers, suppliers and business allies. Also, IS interoperability can be highly supportive and useful for the collaborative conception, design and implementation of product innovations, which is quite important given the growing trend towards 'open innovation'; it facilitates the participation in business networks and digital business ecosystems, which are important sources of innovation in modern economy. At the same time, the adoption of these IS Interoperability standards also leads to important innovation in firms' business processes, as it facilitates and supports the electronic exchange of various business documents, such as quotations, orders, shipment notes, invoices and payment notes, and also various advanced cooperative business practices, such as collaborative planning, forecasting and replenishment, and vendor-managed inventory. Another interesting conclusion has been that the positive impact of IS interoperability on innovation depends on the type of the adopted standards: we have found that the impact of the industry – specific and the XML – horizontal standards is stronger than the impact of the proprietary standards, as the former are characterised by much wider applicability than the latter.

Further empirical research is required on the effect of IS interoperability on innovation, examining various existing IS interoperability architectures, frameworks, methods and standards, and also various types of innovation (both incremental and radical). Also, it would be useful to investigate mediators and moderators of the relationship between IS interoperability and innovation, in order to provide guidance for maximizing the positive impact of the former on the latter.

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Appendix

Survey questions used:

Variable	**Items**
INNOVPD	During the past 12 months, has your company launched any new or substantially improved products or services?
INNOVPC	During the past 12 months, has your company introduced any new or significantly improved internal processes, for example for producing or supplying goods and services?
Industry – specific standards adoption (IND_ST)	Do you use industry-specific standards for exchanging data with buyers and suppliers?
XML – Horizontal standards adoption (XML-HOR_ST)	Do you use XML-based standards for exchanging data with buyers and suppliers?
Proprietary standards adoption (PRO_ST)	Do you use proprietary standards for exchanging data with buyers and suppliers?
Internal IS degree of development (INT_IS)	Does your company use any of the following systems or applications for managing information in your company?
	INT_IS1: An ERP system, that is Enterprise Resource Planning System?
	INT_IS2: An SCM system, that is a Supply Chain Management System
	INT_IS3: A CRM system, that is a specific software suite for customer relationship management?
	INT_IS4: Does your company use online applications OTHER THAN e-MAIL, for example special software, to share documents between colleagues or to perform collaborative work in an online environment?

E-Sales IS degree of development (ESAL_IS)	Which of the following marketing or sales related processes does your company support by specific IT solutions? Do you use IT solutions for ... [item]?
	ESAL_IS1: Publishing offers to customers
	ESAL_IS2: Answering calls for proposals or tenders
	ESAL_IS3: Receiving orders from customers
	ESAL_IS4: Enabling customers to pay online for ordered products or services
Competition (COMP)	To what extent do you think that competition in your sector has increased or decreased due to ICT? Has competition significantly increased, somewhat increased, or rather decreased?
R&D (R&D)	How many employees are primarily conducting research and development in your company?
Human Capital (HCAP)	What is the percentage share of firm's employees with a University or a College degree?