

THE EFFECTS OF INFORMATION SYSTEMS INTEROPERABILITY ON BUSINESS PERFORMANCE

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Abstract

Extensive investments are made for the development of various types of information systems (IS) interoperability technologies, and also for their implementation at firm level. This necessitates the systematic study of the business value that IS interoperability technologies generate. However, quite limited empirical research has been conducted on this. Our study contributes to filling this research gap by presenting an empirical study of the effect of the adoption of three types of IS interoperability standards (industry-specific, XML-horizontal and proprietary ones) on the business benefits firms gain from their information and communication technologies (ICT) infrastructures. It is 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. For all these three types of IS interoperability standards it has been concluded that their adoption for establishing IS interoperability with cooperating firms (suppliers, business partners, customers) increases the business benefits gained from firm's ICT infrastructure, both the cost reduction and the sales growth related ones. A comparison among these three types of IS interoperability standards shows that their positive effects on the ICT business benefits differ, with the industry-specific standards having the strongest effects, which are of similar magnitude with the ones of the degree of development of firm's internal IS (widely recognized as the main determinants of these benefits). Furthermore, we have found that the adoption of industry-specific standards is particularly important for realizing sales growth related benefits from firm's ICT infrastructure.

Keywords: Information systems (IS), Information and Communication Technologies (ICT), Interoperability, Standards, Business Performance, Business Benefits

1 INTRODUCTION

Extensive investments are made for the development of various information systems (IS) interoperability technologies, and also for their implementation at firm level. This necessitates the systematic, both theoretical and empirical, study of the business value that IS interoperability technologies generate. IS Interoperability, 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), has been regarded for long time as quite beneficial for firms, offering to them high levels of business benefits. The European Commission, both in the 'Digital Agenda for Europe' and in the 'Europe 2020' strategy, place strong emphasis on the importance of IS interoperability as a fundamental pre-condition for the development of an advanced digital economy and society in the European Union, and as a factor of critical importance for the success of its future strategies for smart,

sustainable and inclusive growth (European Commission, 2010a and 2010b). There has been considerable theoretical literature analyzing the business value of IS interoperability (briefly reviewed in section 2.1). However, there is limited empirical literature on it, since only a very small number of empirical studies have been conducted concerning the business value of IS interoperability, and all of them are based on small datasets (they are briefly reviewed in section 2.2).

This paper contributes to filling this research gap. It presents an empirical study of the effects of the adoption of three different fundamental types of IS interoperability standards for exchanging data with cooperating firms (suppliers, business partners, customers) on the business benefits a firm gains from its information and communication technologies (ICT) infrastructure. In particular, in our study we examine the abovementioned effects of the following three types of IS interoperability standards (Nurmilaakso 2008a and 2008b; Lampathaki et al., 2009):

- The 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. 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 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. 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 have been developed with a ‘least common denominator’ logic, i.e. they include mainly elements that are common across sectors. It should be mentioned that recently, due to the fast adoption of XML, many industrial 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, so XML-based standards were mainly horizontal, therefore the three types of standards we examine in this empirical study were then disjoint.
- The proprietary standards, which are typically created and maintained by large and 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 strong creator firm.

Furthermore, we proceed to a comparison between the effects of these three types of IS interoperability standards on the business benefits gained from firm’s ICT infrastructure, in order to understand to what extent IS interoperability business value depends on the type and the particular characteristics of the adopted interoperability standards. Finally, in order to make a ‘realistic’ assessment of the magnitude of these effects, we compare them with the corresponding effects of the degree of development of firm’s internal and e-sales IS, which are widely recognized as the main determinants of ICT business benefits and value at firm level.

Our 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 its results will be useful for providing guidance to the technological IS interoperability research, in order to focus on the most valuable directions, and also to the individual firms for making more informed decisions concerning their IS interoperability related investments, taking into account not only technical, but also business value factors as well.

Our paper consists of six sections. The following section 2 outlines the background of our study (previous theoretical and empirical literature on the business value of IS interoperability), while in section 3 the research hypotheses of our study are formulated. Then in section 4 the data and method of our study are described, and in section 5 results are presented and discussed. In the final section 6 we summarize our conclusions and propose future research directions.

2 BACKGROUND

2.1 Theoretical Literature

There has been considerable theoretical literature on the business value of IS interoperability, which has identified and discussed various kinds of business benefits it offers. Choi and Whinston (2000) argue that IS interoperability is highly important for maximizing the potential benefits of computing and digital networking technologies. In particular, they argue that it can significantly improve efficiency in product design, manufacturing and distribution, and at the same time lead to increased customers' choices and satisfaction. Also, IS interoperability allows market participants to communicate, exchange information, deliver and use products and services in real time, and these can result in significant business benefits.

It is widely recognised that IS interoperability can greatly facilitate and reduce the cost of electronic data interchange (EDI) (Jimenez-Martinez and Polo-Redondo, 2004; Chatterjee and Ravichandran, 2004; Robey et al., 2008), which allows the electronic exchange of various types of structured business documents with customers, sales channels, suppliers, business partners, etc. (e.g. quotations, orders, shipment notes, invoices, payment notes), resulting in significant operational and strategic benefits. Grilo et al. (2007) identify three main business value generating functions of IS interoperability: the informational function (capabilities for exchanging information of various complexity levels), the transactional function (capabilities for electronic execution of the whole life-cycles of various types of transactions) and the collaboration function (capabilities for collaborative products/services design and development).

Lebreton and Legner (2007), summarizing relevant research conducted as part of the ATHENA ('Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Application') European project, argue that IS interoperability has significant both operational and strategic impacts. With respect to the former they argue that it leads to reduction of cost and time of the three main stages of business transactions: connection, coordination and monitoring. Concerning the strategic impacts they argue that since IS interoperability reduces significantly transaction costs, it can lead to structural changes of firms and higher degree of outsourcing tasks (i.e. production of some parts) to external contractors so that they can focus on their core competencies. Also, it can increase the flexibility and responsiveness of firm's ICT infrastructure, leading to significant improvements of firm's 'agility', defined as its ability to respond to environmental changes (e.g. to new market conditions) (Sengupta and Masini, 2005). Finally, interoperability allows more and better contact with customers, and also facilitates more personalisation of products and services offered to them, leading in increased 'customer intimacy'.

The value proposition of IS interoperability is examined and elaborated in a relevant report) authored by a high level Informal Study Group (ISG) launched by the European Commission titled 'Unleashing the Potential of the European Knowledge Economy – Value Proposition for Enterprise Interoperability' (Li et al., 2008). It concludes that IS interoperability has the potential to improve efficiency dramatically, which has been the main focus in the past, and at the same time it can also facilitate and drive the collaborative development of significant value innovation through 'value networks'. The same report proposes an 'Enterprise Interoperability Value Framework' (EIVP), which identifies five types of interaction among firms that can be supported and enhanced by interoperability: communication (exchange of information), coordination (alignment of activities for mutual benefit, avoiding gaps and overlaps, in order to achieve efficiency gains), cooperation (obtaining mutual benefits by sharing or partitioning work, or by establishing supply chain visibility, where manufacturers and distributors allow each other's visibility of stocks, sales and production plans in order to optimize value chain stocks), collaboration (an engagement to work together in order to achieve results and innovative solutions that the participants would be unable to accomplish alone) and channel (producing a wider range of products and gaining greater access to small niche markets for selling these products).

Furthermore, IS interoperability can facilitate and support innovative highly beneficial advanced cooperative business practices, making them easier and reducing their implementation cost and time,

such as collaborative planning, forecasting and replenishment (Stadtler, 2009), vendor-managed inventory (Kuk, 2004), resulting in significant business benefits. The adoption of IS interoperability standards leads to common data definitions with supply chain partners, which enable firms to develop the 'higher-order capabilities' of supply chain process integration (= integration of its physical, financial and information flows with its supply chain), leading to the generation of significant and sustainable performance gains with respect to operational efficiency, customers relations and finally sales revenues (Rai et al., 2006). Furthermore, it enables the gradual development of highly sophisticated 'interfirm IT capabilities', which help in the co creation of greater relational value (Rai et al., 2012).

The interoperability of firm's IS can also facilitate, support and reduce the cost and time required for its participation in 'business networks', defined as structures comprising different and heterogeneous organizations (e.g. firms having different resources and capabilities, suppliers, customers, universities, research centres, etc.), having various types of relationships among them and also economic and social exchanges, which aim at the design, production, marketing and distribution of mainly complex products and services (Hakansson and Johanson, 1992; Hakansson and Snehota, 1995). Business networks in the modern economy have become of critical importance (Rycroft, 2007; Busquets, 2010; Zeng et al., 2010), and the competition in many industries tends to be more among business networks than among individual firms. The participation of a firm in business networks offers significant business benefits (Kodama, 2005; Baraldi and Nadin, 2006; Kajikawa et al., 2010; Zeng et al., 2010): access to complementary resources and capabilities, new markets and technologies, diverse knowledge, and also opportunities to achieve economies of scale, to focus on their core competencies, to share the costs and risks of their activities, and to coordinate them in order to cope with market and technological complexities that characterise modern economy. For these reasons firm's business performance today depends critically on its participation in multiple business networks, which might have variable compositions, objectives and time-horizons (some of them having long term orientation, while some others having shorter term orientations, focusing mainly on the exploitation of individual business opportunities), and this can be greatly facilitated and supported by IS interoperability. The relationships among firms as part of such networks necessitate specific actions at three layers (Hakansson and Snehota, 1995; Baraldi and Nadin, 2006): 'activity links' (i.e. mutual adaptations in their activities), 'resource ties' (i.e., technical connections and mutual orientations of their physical and organizational resources) and 'actor bonds' (i.e. social interactions between individuals and organizational units of cooperating firms). All these types of actions necessitate extensive exchanges of information, both 'structured' and 'unstructured', with cooperating firms; the exchange of the former (structured information) can be greatly facilitated by IS interoperability.

2.2 Empirical Literature

However, despite the above theoretical literature, there has been quite limited empirical investigation of the business value of IS interoperability.

Boh, Xu and Soh (2008) investigate empirically the effects of the extent of deployment of a single industry-specific standard (the RosettaNet, a standard aiming to facilitate B2B electronic transaction in high-tech electronic industries), and its integration in firm's processes, on the operational and strategic benefits that adopting firms obtain from it; it is based on dataset collected from 62 firms from China, Japan, Malaysia, Singapore and Taiwan. They conclude that the extent of integration and deployment of this standard have both similar positive effects on the strategic benefits obtained, while the former is the main determinant of the operational benefits.

Mouzakitis, Sourouni and Askounis (2009) investigate empirically the effect of five different interoperability levels (network, data, process, application and business level interoperability) on the required B2B integration effort with suppliers, customers and business partners; it is based on a dataset collected from 239 Greek firms that had successfully completed at least one B2B integration project in a predefined time period. They conclude that interoperability at the data, process and business level is negatively associated with integration effort.

Our study contributes to filling this empirical research gap, by investigating the effects of three different types of IS interoperability standards on the benefits generated by firm's ICT infrastructure, based on a large dataset collected from 14.065 European firms.

3 RESEARCH HYPOTHESES

Based on the above theoretical literature outlined in 2.1, we expect that the adoption of IS interoperability standards for exchanging data with cooperating firms (suppliers, business partners, customers) will reduce the corresponding transaction costs and generates significant operational benefits. It allows the electronic exchange of important business documents (e.g. quotations, orders, shipment notes, invoices, payment notes), and this results in lower needs for administrative personnel, less paperwork, less errors, faster payments/improved cash-flow, avoidance of production stoppages resulting from lack of raw material, reduction of purchasing/sales cycles (ordering, delivery and invoice), and also of stock levels (Jimenez-Martinez and Polo-Redondo, 2004; Robey et al., 2008). This reduction in the costs of transacting with other firms can also lead to outsourcing tasks more on non-core tasks (i.e. production of some parts) to external specialised contractors, and focusing on core competencies, and this can further reduce costs (Lebreton and Legner, 2007). Also, as mentioned in 2.1 IS interoperability facilitates and supports advanced cooperative business practices, such as collaborative planning, forecasting and replenishment, vendor-managed inventory, etc., which can also result in further efficiencies and cost reduction. Furthermore, IS interoperability standards can facilitate and support the participation in business networks, and this enables the exploitation of physical resources of other firms, the achievement of economies of scale, resulting finally in important cost reductions and in general operational benefits (Kajikawa et al., 2010; Baraldi and Nadin, 2006). 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 increase the cost reduction related business benefits firms gain from their ICT infrastructures, so our first research hypothesis is:

H1: The adoption of IS interoperability standards has a positive effect on the cost reduction related business benefits firms gain from their ICT infrastructures.

Since IS interoperability with customers allows the easy and low cost electronic execution and completion of transactions with them, through the electronic exchange of quotations, orders, shipment notes, invoices and payment notes, we expect that this will improve the quality of customer service and increase their satisfaction. In general, the easy and low cost electronic exchange of important business documents that IS interoperability enables with all cooperating firms, such as suppliers, customers and business partners, will improve the whole cooperation with them, and this will contribute positively to the improvement of important customer service components, such as order cycle time reduction, product availability, and distribution correctness and flexibility. Also, IS interoperability allows the easy, quick and low cost composition of new and/or personalised products and services, by combining products and services of other firms, and this increases customers' choices and satisfaction. In general, it can significantly improve efficiency in new product design, manufacturing and distribution, in collaboration with suppliers, customers and business partners (Li et al., 2008). Additionally, it will facilitate and support the participation in business networks that design and produce complex innovative products and services (Zeng et al., 2010). All these will lead to sales revenue growth. 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 increase the cost reduction related business benefits firms gain from their ICT infrastructures, so our first research hypothesis is:

H2: The adoption of IS interoperability standards has a positive effect on the sales growth related business benefits firms gain from their ICT infrastructures.

Initially IS were viewed mainly as tools for cost reduction, while subsequently firms started to view them as tools for increasing sales revenue as well. Therefore the business benefits generated by firms' ICT infrastructures include in general both cost reduction related benefits and sales growth related

ones. So for the reasons mentioned in the above two research hypotheses we expect that the adoption of IS interoperability standards will increase the business benefits gained from firms' ICT infrastructures, thus our third research hypotheses is:

H3: The adoption of IS interoperability standards has a positive effect on the business benefits firms gain from their ICT infrastructures.

4 DATA AND METHOD

For the present empirical study we used a large dataset collected in the 'e-Business Survey 2006', which was 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 member states of European Union, the acceding and candidate countries and also the countries of the European Economic Area (EEA). It was based on 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 selected highly important economy sectors: Food and Beverages (S1), Footwear (S2), Pulp and Paper (S3), ICT Manufacturing (S4), Consumer Electronics (S5), Shipbuilding and Repair (S6), Construction (S7), Tourism (S8), Telecommunication Services (S9) and Hospital Activities (S10). 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).

In order to test our research hypotheses we estimated three regression models having the specifications shown below:

$$\text{ICT_BEN} = b_0 + b_1 \cdot \text{IND_ST} + b_2 \cdot \text{XMLHOR_ST} + b_3 \cdot \text{PRO_ST} + b_4 \cdot \text{INT_IS} + b_5 \cdot \text{ESAL_IS} + b_6 \cdot \text{HCAP} \quad (1)$$

$$\text{ICT_BEN_COST} = b_0 + b_1 \cdot \text{IND_ST} + b_2 \cdot \text{XMLHOR_ST} + b_3 \cdot \text{PRO_ST} + b_4 \cdot \text{INT_IS} + b_5 \cdot \text{ESAL_IS} + b_6 \cdot \text{HCAP} \quad (2)$$

$$\text{ICT_BEN_SALES} = b_0 + b_1 \cdot \text{IND_ST} + b_2 \cdot \text{XMLHOR_ST} + b_3 \cdot \text{PRO_ST} + b_4 \cdot \text{INT_IS} + b_5 \cdot \text{ESAL_IS} + b_6 \cdot \text{HCAP} \quad (3)$$

having as dependent variable the ICT business benefits (ICT_BEN), the cost reduction related ICT business benefits (ICT_BEN_COST) and the sales growth related ICT business benefits (ICT_BEN_SALES) respectively. The first (ICTBEN) was measured through the average of seven items, which assess whether firm's ICT infrastructure had positive influence, no influence or negative influence on revenue growth, efficiency of business processes, internal work organization, procurement cost, quality of products and services, customer service and productivity (ICTBEN1 – ICTBEN7, see Appendix). The second dependent variable (ICT_BEN_COST) was measured through the average of four of the above items, which concern cost reduction related ICT benefits, assessing whether firm's ICT infrastructure had positive influence, no influence or negative influence on the efficiency of business processes, internal work organization, procurement cost and productivity (ICTBEN2, ICTBEN3, ICTBEN4, ICTBEN7). The final dependent variable (ICT_BEN_SALES) was measured through the average of the remaining three of the above items, which concern sales growth related benefits, assessing whether firm's ICT infrastructure had positive influence, no influence or negative influence on revenue growth, quality of products and services and productivity of the company (ICTBEN1, ICTBEN5, ICTBEN6). Previous empirical IS research extensively used such items assessing the perceived influence of ICT on various aspects of business performance (Martinez-Lorente et al., 2004; Sanders, 2007; Kearns and Sabherwal, 2007).

As independent variables have been used three dichotomous items (IND_ST, XMLHOR_ST and PRO_ST) 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.

Furthermore, taking into account that the business benefits generated by firm's ICT infrastructure depend critically on the degree of its development, i.e. the extent of using IS for supporting firm's internal processes and also its interaction with the external environment, we have also included two such independent variables. They 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 development of firm's internal IS (INT_IS), which was measured through six items assessing whether the firm has: a) a basic internal infrastructure: the Intranet, and also b) five important applications supporting fundamental internal functions: Enterprise Resource Planning (ERP) system, accounting software, software for tracking working hours or production time, capacity or inventories management software and software for sharing documents between colleagues or performing collaborative work in an online environment (INT_IS1 - INT_IS6, see Appendix). Such items have been used extensively in previous empirical IS research for measuring internal IS use (Brews and Tucci, 2004; Koellinger, 2008; Soto-Acosta and Meroño-Cerdan, 2008;). The second additional independent variable was the degree of development of e-sales IS (ESAL_IS), 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 (ESAL_IS1 - ESAL_IS4, see Appendix). These items have also extensive previous literature support (Soto-Acosta and Meroño-Cerdan, 2008; Brews and Tucci, 2004; Hashim, Murphy and Law, 2007).

We also included an additional independent variable for firm's human capital (HCAP), which is widely recognized as an important precondition for the successful exploitation of new technologies and the generation of benefits from them (Vinding, 2006; Arvanitis and Loukis, 2009); it was quantified through the percentage share of firm's employees having a college or university degree. Finally, in order to control for other sector-specific factors affecting our two dependent variables, we also included for the abovementioned ten sectors covered by our survey nine sectoral dummies (while one sector was used as a reference group).

5 RESULTS

The results of the estimation of the three regression models (1), (2) and (3) specified in the previous section are shown below in Table 1 (for all independent variables we can see the corresponding standardized coefficients, which allow comparisons between their effects on the dependent variable). We remark that in all three models the standardized coefficients for all the three examined types of IS interoperability standards (variables IND_ST, XMLHOR_ST and PRO_ST) are positive and statistically significant. Therefore we can conclude that the adoption of industry-specific, or XML-horizontal or proprietary standards in firms' ICT infrastructures for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners) increases the business benefits that these infrastructures generate, both the cost reduction and the sales growth related ones. The adoption of these IS interoperability standards leads to reductions of firms' operating costs, by enabling electronic interchange of important business documents (e.g. quotations, orders, shipment notes, invoices, payment notes), and at the same time facilitating and supporting advanced cooperative business practices, such as collaborative planning, forecasting and replenishment, vendor-managed inventory, etc., and also participation in business networks. At the same time the adoption of these IS interoperability standards also leads to increase of sales revenue, by enabling improvement of customers' service, allowing the easy and low cost composition of new and/or personalised products and services by combining products and services of other firms, and also facilitating and supporting the design and production of complex innovative products and services through business networks. So all our three research hypotheses H1, H2 and H3 are supported for all three examined types of IS interoperability standards.

Furthermore, we can see that in all three models the standardized coefficients of the degree of development of firm's internal IS (variable INT_IS) and e-sales IS (variable ESAL_IS), and also of the human capital (HCAP), are positive and statistically significant as well, as expected. 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 business benefits generated by ICT from firms, and this necessitates the inclusion of sectoral dummies in such regressions.

	ICT_BEN	ICT_BEN_COST	ICT_BEN_SALES
IND_ST	0.175***	0.164***	0.158***
XMLHOR_ST	0.044***	0.042***	0.038***
PRO_ST	0.041***	0.041***	0.033***
INT_IS	0.188***	0.200***	0.138***
EXT_IS	0.118***	0.090***	0.131***
HCAP	0.086***	0.070***	0.091***
DUM_1	-0.009	-0.030**	0.020
DUM_2	-0.013	-0.032***	0.014
DUM_3	0.015	0.001	0.030**
DUM_4	0.053***	0.045***	0.054***
DUM_5	0.056***	0.038***	0.068***
DUM_6	0.010	0.012	0.006
DUM_7	0.042***	0.037***	0.041***
DUM_8	0.092***	0.053***	0.124***
DUM_9	0.092***	0.060***	0.115***

Table 1. Estimated models for ICT business benefits, cost reduction related ICT business benefits and sales growth related ICT business benefits

The above three regression models also allow us to compare the effects of these three types of IS interoperability standards on the ICT business benefits by examining the corresponding standardized coefficients. We remark that in all three models the standardised coefficient of the industry-specific standards (0.175 in the ICT_BEN model, 0.164 in the ICT_BEN_COST model, 0.158 in the ICT_BEN_SALES model) is much higher than the ones of the XML-horizontal standards (0.044, 0.042 and 0.038 respectively) and the proprietary standards (0.041, 0.041, 0.033 respectively). Therefore the adoption of industry-specific standards leads to much higher increase of the benefits generated by firm's ICT infrastructure than the adoption of the other two examined types of standards (XML-horizontal standards and proprietary standards). This is probably because, as mentioned in the introduction, the industry-specific standards have all the required "depth and breadth" for the specific industry, covering the whole range of documents and elements required for the data exchange needs of the industry. At the same time the industry-specific standards are characterized by high level of applicability, as they can be used for exchanging electronically many different business documents with most of the firms we have transaction and cooperation with (our suppliers, customers, business partners). On the contrary, the proprietary standards have extensive depth and breadth, but include mainly the documents and elements required by the strong creator firm, and also are characterized with much lower applicability (they can be used for exchanging business documents with the creator firm, and also with the smaller number of firms adopting such a standard). The opposite happens with the XML-horizontal standards: they are characterized by high applicability (as they can be used for exchanging business documents with a very large number of firms from many different industries), but they lack the needed depth for representing important sector-specific characteristics and information elements, as they have been developed with a 'least common denominator' logic (they include mainly elements that are common across sectors).

Finally, in order to make a 'realistic' assessment of the magnitude of effects of these IS interoperability standards, we compared them with the corresponding effects of the degree of

development of firm's internal and e-sales IS, which are widely recognized as the main determinants of the extent of ICT business benefits and value at firm level. We first focus on the ICT business benefits model (second column of Table 1). We remark that the degree of development of internal IS and the adoption of industry-specific have the strongest effects on the generation of ICT business benefits, which are of similar magnitude (standardised coefficients 0.188 and 0.175 respectively). Lower is the effect of the degree of development of e-sales IS (0.118), followed by the effects of the human capital (0.086) and then the adoption of XML-horizontal standards (0.044) and proprietary standards (0.041). Therefore the effects of adopting industry-specific standards on the benefits generated by firm's ICT infrastructure seem to be quite strong, of similar magnitude with the one of the degree of development of the internal IS (regarded as the main determinant of the ICT benefits), and about 50% ($0.175/0.118=1.48$) higher than the effect of the degree of development of the e-sales IS. The effects of adopting XML-horizontal and proprietary standards are much lower, about one fifth each of the corresponding effect of the degree of development of the internal IS (for the XML-horizontal standards $0.044/0.188=23.4\%$, and for the proprietary standards $0.041/0.188=21.8\%$).

We then examine similarly the other two models of the cost reduction related ICT business benefits (third column of Table 1) and of the sales growth related ICT business benefits (fourth column of Table 1), and we can identify an important difference between them. In the former we remark that the effect of the degree of development of firm's internal IS on the cost reduction related ICT business benefits is higher than the one of the adoption of industry-specific interoperability standards (standardised coefficients 0.200 and 0.164 respectively), followed by the effects of the degree of development of e-sales IS (0.090), the human capital (0.070) and the adoption of XML-horizontal and proprietary standards (0.042 and 0.041 respectively). On the contrary in the latter we remark that the effect of the adoption of industry-specific interoperability standards on the sales growth related ICT business benefits is higher than the one of the degree of development of firm's internal IS (standardised coefficients 0.158 and 0.138 respectively), which has similar effects with the degree of development of e-sales IS (0.131), followed by the human capital (0.091) and the adoption of XML-horizontal and proprietary standards (0.038 and 0.033 respectively). Therefore the adoption of industry-specific interoperability standards for exchanging data with cooperating firms (suppliers, business partners, customers) is particularly important for realizing sales growth related benefits from firm's ICT infrastructures.

Our findings are in general in agreement with the ones of the limited empirical literature on the business value of IS interoperability (reviewed in 2.2), which found evidence for some kind of business value generated by the adoption of IS interoperability standards (however using small datasets): positive impacts of the extent of deployment of a single industry-specific standard (RosettaNet) on the operational and strategic benefits that adopting firms obtain from it (Boh, Xu and Soh, 2008), or negative impacts of IS interoperability at the data, process and business level on the required B2B integration effort (Mouzakitis, Sourouni and Askounis, 2009). However, our study adds to this limited empirical literature by examining and comparing the effects of three different types of IS interoperability standards on the benefits that firms gain from their ICT infrastructures, distinguishing between cost benefit related ICT benefits and sales growth related ICT benefits; also by proceeding to a 'realistic' assessment of the magnitude of the above effects comparing them with the corresponding effects of the degree of development of firm's internal and e-sales IS, which are widely recognized as the main determinants of the extent of ICT business benefits and value at firm level (all these being empirically investigated based on a large dataset from 14.065 European firms).

6 CONCLUSIONS

The extensive investments made for the development of various IS interoperability technologies, and then for their implementation at firm level, necessitate the systematic study of the business value they generate. In this direction there has been some theoretical literature, but only quite limited empirical research. This paper contributes to filling this important research gap, presenting an empirical study of the effects of the adoption of three fundamental types of IS interoperability standards (industry-specific, XML-horizontal and proprietary ones) on the benefits firms gain from their ICT

infrastructures, and also distinguishing between cost reduction related benefits and sales growth related benefits.

For all these three types of IS interoperability standards it has been concluded that their adoption for establishing IS interoperability with the ones of cooperating firms increases the business benefits generated by firms' ICT infrastructures. However, the magnitudes of the positive effects of these three types of standards on ICT benefits differ considerably. The industry-specific IS interoperability standards have the strongest effects, since they are characterized on one hand by high applicability (they can be used for exchanging many different types of business documents with most of the firms we are cooperating with), and on the other hand by high depth and breadth (they cover all the special data exchange requirements – both documents and elements of them – of the particular industry). Finally, we have found that the magnitudes of these effects of the industry-specific standards on the ICT benefits are high, of similar magnitude with the ones of the degree of development of firm's internal IS (regarded as the main determinant of the extent of ICT benefits), and also higher than the ones of e-sales IS. The adoption of these industry-specific standards is particularly important for realizing sales growth related benefits from firm's ICT infrastructure. Our results provide empirical evidence, based on a large dataset, of the business value generated by IS interoperability, its big magnitude and its strong dependence on the type of IS interoperability standards adopted.

The findings of our study have interesting implications for IS research and management. The strength of the effects of adopting such standards on the benefits gained from ICT indicates that future research on IS business value should take into account not only factors concerning the degree of development of various types of firm's IS, but also factors concerning their level of interoperability with the IS of other firms. Our study provides a useful framework for future research on this. With respect to IS management practice, our conclusions indicate that it is necessary to place strong emphasis on establishing interoperability of firm's IS with the ones of other cooperating firms, due to the high business value that this interoperability generates; this emphasis should be similar to the one placed on the development of the functionality of firm's IS. However, in order to maximize this business value IS managers should adopt standards characterized by wide applicability (so that they can be used for establishing IS interoperability with a large number of other firms) and also sufficient "depth and breadth" (so that they enable a fully automated exchange of numerous electronic business documents including all required elements).

Further empirical research is required on the business value that IS interoperability generates, examining various existing and emerging IS interoperability architectures, frameworks, methods and standards. Also, it is necessary to extend this research towards other 'interoperability layers', and investigate empirically the business value not only of the 'technical' interoperability, but also of the 'organizational' interoperability as well, and their complementarities. Finally, it is necessary to identify and understand the moderators and the mediators of the effects of the adoption of various IS interoperability architectures, frameworks, methods and standards on various dimensions of business performance.

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Appendix

Survey questions used for measuring each variable:

Variable	Items
ICT Benefit (ICT_BEN)	ICTBEN1: Has ICT had a positive, negative or no influence on sales revenue growth?
	ICTBEN2: Has ICT had a positive, negative or no influence on the efficiency of business processes?
	ICTBEN3: Has ICT had a positive, negative or no influence on internal work organization?
	ICTBEN4: Has ICT had a positive, negative or no influence on procurement cost?
	ICTBEN5: Has ICT had a positive, negative or no influence on quality of products and services?
	ICTBEN6: Has ICT had a positive, negative or no influence on customer service?
	ICTBEN7: Has ICT had a positive, negative or no influence on productivity?
Industry-specific standards adoption (IND_ST)	Do you use industry-specific standards for exchanging data with buyers and suppliers?
XML-horizontal standards adoption (XMLHOR_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)	INT_IS1: Do you use an Intranet?
	INT_IS2: Do you use an ERP system (that is Enterprise Resource Planning System)?

	INT_IS3: Do you use accounting software (other than a spreadsheet)?
	Do you use online applications other than e-mail ... ?
	INT_IS4: to share documents between colleagues or to perform collaborative work in an online environment
	INT_IS5: to track working hours or production time
	INT_IS6: to manage capacity or inventories?
E-Sales IS degree of development (ESAL_IS)	Do you use IT solutions for...?
	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
Human Capital (HCAP)	What is the percentage share of firm's employees with a college or university degree?