BUSINESS VALUE OF INFORMATION SYSTEMS INTEROPERABILITY – AN EMPIRICAL STUDY BASED ON BALANCED SCORECARD

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Abstract

It is widely believed that the establishment of interoperability of firm's IS with the ones of other cooperating firms (e.g. customers, suppliers, business partners) can generate significant business value. However, this has been only to a very limited extent empirically investigated. This paper contributes to filling this research gap by presenting an empirical study of the effect of IS interoperability on the four business performance dimensions/ perspectives proposed by the Balanced Scorecard approach (financial, internal business processes, customers, learning and innovation). In particular, we examine the effects of adopting three different fundamental types of IS interoperability standards differing in the level of detail and applicability: XML, industry-specific standards and proprietary standards. Our study is based on a large dataset from 14065 European firms (from 25 countries and 10 sectors) collected through the e-Business Watch Survey of the European Commission. It is concluded that all these three examined types of IS interoperability standards increase considerably the positive impact of firm's IS on the above four business performance perspectives/dimensions; however, their effects differ significantly. The adoption of industry-specific interoperability standards has the highest positive impact, while proprietary and XML standards have similar lower impacts. These conclusions provide valuable empirical evidence of the multidimensional business value generated by IS interoperability and its strong dependence on the type of IS interoperability standards adopted.

Keywords: business value, balanced scorecard, interoperability, standards, XML

1 Introduction

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 highly beneficial both operationally and strategically. It is widely believed, both among practitioners and academics, that the establishment of interoperability of firm's information systems (IS) with the ones of other cooperating firms (e.g. customers, suppliers, business partners) can generate considerable business value. Simlarly, at the economy and society level IS interoperability is regarded as a fundamental pre-condition for the development of an advanced digital economy and society in the European Union in the recent 'Digital Agenda for Europe' of the European Commission (European Commission, 2010a), and also as a factor of critical importance for the success of 'Europe 2020' strategy for smart, sustainable and inclusive growth (European Commission, 2010b). In the same direction a high level 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 IS interoperability 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. In the same report it is

emphasized that today, due to the increasing globalization of the economy, firms have to be active, compete and cooperate in many countries, and participate in international networks, and this increases further the need for and the value of interoperable IS.

However, the above beliefs and expectations concerning the business value that IS interoperability creates has been only to a very limited extent investigated empirically. As explained in more detail in the following section, only a very small number of empirical studies have been conducted on IS interoperability business value, all of them based on very small datasets. The above report (Li et al., 2008) notes that there is a lack of evidence of the value and impact of IS interoperability, which has negative impact on its adoption by firms, and especially by SMEs, and finally recommends that it is necessary to conduct more research in this direction. Therefore more empirical research is required about the various dimensions of business value that IS interoperability creates, in order to assess their magnitude, gain a better understanding of their generation mechanisms and find ways to increase them.

This paper contributes to filling this research gap. Its contribution is threefold:

a) It adds to the quite limited empirical literature on the business value of IS interoperability by presenting an empirical study of the effect of IS interoperability on business performance, which is based on a large dataset collected from 14065 European firms (from 25 countries and 10 sectors) collected through the e-Business Watch Survey of the European Commission.

b) It examines this effect not only with respect to the financial performance, but with respect to the four business performance perspectives proposed by the well established Balanced Scorecard approach (financial, customers, internal business process, learning and innovation perspectives) (Kaplan and Norton 1992; 1996a; 1996b; Creamer and Freund, 2010), which has been repeatedly used in empirical IS studies in the past (Martinsons, Davison and Tse, 1999; Milis and Mercken, 2004; Chand et al., 2005; Wu and Chang, 2011), based on the arguments and recommendations of Grilo et al. (2007).

c) It examines and compares the effects of adopting three different fundamental types of IS interoperability standards, which differ significantly in the level of detail and applicability: XML (low detail – high applicability), industry-specific standards (high detail – high applicability) and proprietary standards (high detail – low applicability) (Nurmilaakso, 2008; 2008; Lampathaki et al., 2009).

We believe that the findings of this study are useful to the rapidly growing community of researchers, practitioners, and also consulting and ICT companies, working in the area of IS interoperability. Furthermore, they are useful to standardization bodies and to government organizations of various layers which design and implement strategies for the development of digital economy and society in their constituencies. Finally, our findings are useful to individual firms formulating their IS interoperability strategies.

Our paper is structured in six sections. In the following section 2 the background of this study is presented, while in section 3 the research hypotheses are developed. The data and method of the study are described in section 4, and the results are presented and discussed in section 5. Finally in section 6 the conclusions are summarized and future research directions are proposed.

2 Background

Previous literature has identified and discussed various dimensions of business value generated by IS interoperability; it is worth reviewing in more detail some representative studies conducted in this direction. Choi and Whinston (2000) argues that IS interoperability is higly important for maximizing the potential benefits of computing and digital networking technologies. It is the key enabler of a new generation of advanced and highly beneficial business practices, such as supply chain management, logistics management, knowledge

management, online retailing and auction markets. IS interoperability allows market participants to communicate, exchange information, deliver and use products and services in real time, and this results in significant business benefits. It is of critical importance in the modern economy, which is characterized by more intensive interactions and exchanges among firms and consumers occurring constantly, in real time, throughout the value chain, and with an increasing number of business partners. It allows gaining big efficiencies in managing multi-partner transactions, in which multiple trades occur among numerous participants who are very often dispersed geographically. In general it can significantly improve efficiency in product design, manufacturing and distribution, and at the same time increase customers' choices and satisfaction. But the business value that interoperability generates is not limited to efficiency gains, since it can be a fundamental driver and enabler of important innovations; it enables the personalization of offerings to customers and the composition at a low cost of new complex products/services by bundling complementary products/services from many different suppliers who are active in traditionally separated markets. Grilo et al. (2007) argue that firms today increasingly tend to be active in several countries, so they have to cooperate with more and geographically dispersed suppliers and customers; also, they have to change the way they innovate and produce, to increase productivity and flexibility, to achieve higher levels of integration of their internal value chain and of the supply chains in which they participate, and to exploit better the information rich supplier and distribution chain. Establishing IS interoperability with trading partners is of critical importance for meeting the above requirements that characterize modern economy. The same paper identifies three main functions of IS interoperability which generate significant business value: informational function (exchange of information of various complexity levels), transactional function (electronic execution of the whole life-cycles of various types of transactions) and collaboration function (collaborative products/services design and development). Due to this multi-dimensional value generated by IS interoperability it is finally concluded that a Balanced Scorecard approach should be adopted for measuring this value.

The value proposition of IS interoperability is further elaborated in the abovementioned report 'Unleashing the Potential of the European Knowledge Economy – Value Proposition for Enterprise Interoperability' Li et al. (2008) written by a high level Informal Study Group (ISG) launched by the European Commission. It is concluded that IS interoperability has the potential to improve efficiency dramatically, which has been the main focus in the past, but additionally can also drive the collaborative development of significant value innovation by 'value networks', defined (based on Allee (2002)) as 'webs of relationships that generate tangible and intangible value through complex dynamic exchanges between two or more individuals, groups, or organizations'. In this direction it defines the new value proposition of IS interoperability as "Value innovation derived from new forms of open collaboration and channels targeting new, global and highly customized niches, and grounded in interoperable complex ecosystems, connecting end-users, producers, suppliers, software vendors, telecommunication companies, public bodies and citizens; empowering employees; and sustaining stronger economic growth". 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 ("selling less of more products", according to Anderson (2006), which means producing a wider range of products and gaining greater access to small niche markets for selling these products). While the first interaction types support mainly 'red ocean strategies' the last ones support and facilitate 'blue ocean strategies' (using the terminology

introduced by Kim and Mauborgne (2005): firms pursuing 'blue ocean strategies' do not aim to out-perform the competition in the existing market, but to create new market space or a "blue ocean", making the competition irrelevant, by introducing radical innovations in the products, services and processes; on the contrary firms pursuing 'red ocean strategies' compete through lower prices or marginal innovations). Also, according to this framework the scope of exploitation of IS interoperability can vary considerably, and is a significant determinant of the magnitude of the business value generated. So it can be used only for achieving internal information integration (i.e. for making interoperable the applications of different organizational units of the firm), or have a wider scope and use it for supporting specific dyadic business relationships, a hub-spokes structure, or even business networks; widening the scope of exploitation will result in more business value. The above EIVP framework has already been successfully used for analyzing IS interoperability in the Architecture, Engineering and Construction (AEC) sector (Grilo, Jardim-Goncalves and Cruz-Machado, 2009; Grilo and Jardim-Goncalves, 2010).

However, despite the above high expectations of this literature, the business value of IS interoperability has been only to a very limited extent investigated empirically; only a very small number of empirical studies have been conducted concerning IS interoperability business value, and all of them are based on very small datasets. 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 industries, e.g. semiconductor manufacturing, telecommunications, etc.), and its integration in firm's processes, on the operational and strategic benefits that adopting firms obtain; it is based on dataset collected from 62 firms from China, Japan, Malaysia, Singapore and Taiwan. It was concluded that the extent of integration and deployment of this standard have 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 levels of interoperability (network, data, process, application and business interoperability) on the required B2B integration effort; it is based on a dataset collected from 239 Greek firms which had successfully completed at least one B2B integration project in a predefined time period. It was concluded that interoperability at the data, process and business levels is negatively associated with integration effort. The present study focuses on data interoperability, and examines the effects of three different types of standards that can be used for this purpose on the four business performance dimensions proposed by the well established Balanced Scorecard approach, based on a large dataset collected from 14065 European firms.

3 Research Hypotheses

Our first research hypothesis concerns the effect of adopting IS interoperability standards on firm's business processes. These standards allow the easy and low cost exchange of various types of data between the firm and its customers, suppliers and business partners (Li et al., 2008), without the need of developing complex data conversion programs. As mentioned in previous section 2, these data can be at the informational or transactional mode (using the terminology introduced by Grilo et al. (2007)), and concern both descriptions of products and services at various levels of detail, and also quotations, orders, shipments, receipts, invoices, payments and returns, leading to process efficiency. Also, data can be exchanged that support and enhance coordination and collaboration, for instance data on stock levels, production plans and sales forecasts, or on common projects, and lead to highly efficient business practices (Choi and Whinston, 2000)). The above will increase the impact of firm's ICT infrastructure on the performance of business processes. Therefore our first research hypothesis is:

H1: The adoption of IS interoperability standards increases the impact of ICT on the business processes performance

The adoption of IS interoperability standards is also expected to increase the value offered by a firm to its customers. It allows the electronic execution of customers' transactions through the electronic exchange of quotations, orders, shipment notes, invoices and payment notes, which will reduce their transaction costs and at the same time will increase the speed of delivery to them of our products and services (Li et al., 2008). At the same time it reduces the cost of the personalization of products and services offered to customers according to their specialized needs and tastes, and the composition of complex products/services by bundling complementary products/services from many different suppliers (Choi and Whinston, 2000)). In general IS interoperability supports a more intensive interaction between a firm and its customers, so that collaborative 'value co-creation' (Vargo, Maglio and Archpru Akaka, 2008) can take place. Therefore our second research hypothesis is:

H2: The adoption of IS interoperability standards increases the impact of ICT on the value offered to customers

Furthermore, the establishment of IS interoperability with existing and potential customers, suppliers and business partners that these standards enable can be very useful for the design and implementation of innovations. Today the innovation process becomes increasingly 'open', involving to a significant extent firm's customers, suppliers and business partners (Chesbrough, 2003; Huizingh, 2011); among them should be exchanged initially ideas and then structured documents (e.g. with designs of new products). As mentioned in section 2, IS interoperability can drive the collaborative development of significant value innovation by 'value networks', and at the same time allow gaining access to small niche markets for selling to them wider ranges of products (Li et al., 2008). Inter-organizational and cross-sectoral networks, which facilitate the accelerated flows of information, resources and trust necessary to develop and diffuse innovation have become of critical importance in modern economy (Allee, 2002; Zeng, Xie and Tam, 2010); the above flows can be greatly supported by IS interoperability. Therefore our third research hypothesis is:

H3: The adoption of IS interoperability standards increases the impact of ICT on firm's innovation activity

Finally, as the adoption of IS interoperability standards is expected – as mentioned above - to increase the impact of firm's ICT infrastructure on the performance of business processes, the value offered to customers and the innovation activity, we expect that it will increase the impact of firm's ICT infrastructure on its financial performance. Therefore our fourth research hypothesis is:

H4: The adoption of IS interoperability standards increases the impact of ICT on financial performance

4 Data and Method

For this 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 established observatory organization supported by the DG Enterprise and Industry of the European Commission. This survey aimed to assess the extent of adoption and use of various types of ICT infrastructures, applications and practices, the impacts of ICT use, and also innovation in the member states of European Union, acceding and candidate countries and also 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 the Appendix we can see the questions we used from the above questionnaire for this study.

In order to test the research hypotheses developed in section 3, for each of the four perspectives of business performance proposed by the Balanced Scorecard approach (financial, customers, internal business process, learning and innovation), using the above data we estimated one regression model with the specification shown below, having as dependent variable the impact of ICT on this perspective of business performance (ICT_BP):

ICT_BP = bo + b1*XML + b2*IND_ST + b3*PRO_ST + b4*INT_IS + b5*ESAL_IS

and having as independent variables the adoption of the XML standard (XML), industry-specific standards (IND_ST) and proprietary standards (PRO_ST), and also the degree of development of firm's internal IS (that support its internal processes) (INT_IS) and e-sales IS (ESAL_IS). Positive and statistically significant coefficients b1, b2 and b3 will indicate that the adoption of XML, industry-specific standards and proprietary standards respectively increase the impact of ICT on business performance.

With regard to the dependent variables, the impact of ICT on financial business performance (ICT_F INP) was measured through the average of two items (ICT_FPIN1 and ICT_FPIN2, see Appendix) assessing whether ICT had positive influence, no influence or negative influence on firm's revenue growth and productivity respectively. The impact of ICT on the value offered to the customers (ICT_CUSV) was measured through the average of two items (ICT_CUSV1 and ICT_CUSV2, see Appendix) assessing whether ICT had positive influence, no influence or negative influence on the quality of firm's products and services, and on quality of customer service respectively. The impact of ICT on business processes performance (ICT_BPRO) was measured through the average of two items (ICT_BPRO1 and ICT_BPRO2, see Appendix) assessing whether ICT had positive influence, no influence or negative influence on the efficiency of business processes and on internal work organization. Such items assessing the perceived influence of ICT on various aspects of business performance have been extensively used in previous empirical IS research (Martinez-Lorente, Sanchez-Rogriguez and Dewhurst 2004; Sanders, 2007; Kearns and Sabherwal, 2007). Finally the impact of ICT on firm's innovation activity (ICT_INNO) was measured through the average of two items (ICT_INNO1 and ICT_INNO2, see Appendix) assessing whether the firm had introduced in the last 12 months any ICT-based product/service or process innovation. These items have also extensive previous literature support (Koellinger 2008; Soto-Acosta and Meroño-Cerdan, 2008).

Our main independent variables were three dichotomous items (XML, IND_ST, PRO_ST, see Appendix) assessing whether the firm uses the XML standard, industry-specific standards and proprietary standards respectively in order to exchange data with its customers and suppliers. These three items concern three different fundamental types of IS interoperability standards, which differ considerably in two important aspects: the level of detail and applicability. The first of these standards is the Extensible Markup Language (XML), which defines the syntax of the exchanged electronic documents, and constitutes a 'meta-language' for supporting such an exchange, but does not cover their semantics (Nurmilaakso, 2008; Lampathaki et al., 2009); so it is an IS interoperability standard characterized by low level of detail, which needs additional definitions at the semantic level in order to achieve a useful and effective data exchange. For this reason based on it have been developed several more detailed mainly industry-specific standards (e.g. RosettaNet for high-tech industries, CIDX for the chemical industry, MISMO for the mortgage industry), and also proprietary ones, which define the particular data elements of the exchanged electronic documents and their semantics (meanings) as well; many of them are based on XML adding to it semantic level definitions.

The above three types of standards differ not only in the level of detail, but also in the level of applicability, i.e. in the extent of possible application for establishing IS interoperability with other firms. A proprietary standard can be used for establishing IS interoperability only with a small number of firms adopting it, so it is characterized by low applicability; on the contrary XML and industry-specific standards can be used for establishing IS interoperability with much bigger numbers of firms, so they applicability level is much higher.

Taking into account that the impact of ICT on business performance depends critically on the extent of using IS for supporting firm's internal processes and also its interaction with the external environment (i.e. lower extent of ICT use for these purposes results in lower impact on business performance), we have also included two additional independent variables corresponding 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 (INT_IS1 to INT_IS6, see Appendix) 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. Such items have been used extensively in previous empirical IS research for measuring internal IS use (Koellinger, 2008; Soto-Acosta and Meroño-Cerdan, 2008; Brews and Tucci, 2004). The second was the degree of development of e-sales IS (ESAL_IS), which was measured through four items (ESAL_IS1 to ESAL_IS6, see Appendix) 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. These items have also extensive previous literature support (Soto-Acosta and Meroño-Cerdan, 2008; Brews and Tucci, 2004; Hashim, Murphy and Law, 2007).

Finally, in order to control for other sector-specific factors affecting the impact of ICT on business performance, 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

In Table 1 we can see the results of the estimation of the above four regression models, having as dependent variables the impacts of ICT on the four business performance perspectives proposed by the Balanced Scorecard approach: financial performance (ICT_FINP), value offered to customers (ICT_CUSV), performance of business processes (ICT_BPRO) and innovation (ICT_INNO); for each model we can see the standardized coefficients of the independent variables, which allow a comparison of the effects of them on the dependent variable.

We remark that in all four models the standardized coefficients for all the three examined types of IS interoperability standards (variables XML, IND_ST and PRO_ST) are positive and statistically significant. At the same time in all models the standardized coefficients of the extent of using IS for supporting internal processes (variable INT_IS) and for conducting sales electronically (variable ESAL_IS) are positive and statistically significant as well. Therefore we can conclude that the adoption of XML, industry-specific standards or proprietary standards for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners) all increase the positive impact of ICT on the financial performance of the firm, the value offered to the customers, the performance of its business processes and the innovation activity of the firm. So all four research hypotheses H1 to H4 are supported for all the three examined types of IS interoperability standards. These

results provide a strong empirical evidence of the multi-dimensional business value generated by IS interoperability, based on a large dataset.

	ICT_FINP	ICT_CUSV	ICT_BPRO	ICT_INNO
XML	0.044 ***	0.030 ***	0.038***	0.103 ***
IND_ST	0.165 ***	0.158 ***	0.156***	0.119 ***
PRO_ST	0.037 ***	0.035 ***	0.039***	0.043 ***
INT_IS	0.145 ***	0.142 ***	0.219***	0.173 ***
ESAL_IS	0.122 ***	0.124 ***	0.074***	0.176 ***
DUM_1	-0.118 ***	-0.062 ***	-0.063***	-0.036 ***
DUM_2	-0.098 ***	-0.052 ***	-0.076***	-0.032 ***
DUM_3	-0.080 ***	-0.043 ***	-0.026***	-0.029 ***
DUM_4	-0.031 ***	-0.016 *	-0.011	0.020 **
DUM_5	0.006	0.016 *	-0.009	0.029***
DUM_6	-0.029 ***	-0.018**	0.003	-0.030 ***
DUM_7	-0.074 ***	-0.071***	-0.014	-0.068 ***
DUM_9	0.037	0.041***	0.017*	0.117 ***
DUM_10	-0.069 ***	-0.024***	-0.015*	0.023 ***
* denotes statistical significance at the 10% level; ** denotes statistical significance at the 5% level; *** denotes statistical significance at the 1% level.				

Table 1. *Estimated regression models of the contributions of ICT to financial performance, customers' value, business processes performance and innovation.*

It is also interesting to compare between the effects of these three IS interoperability standards using the corresponding standardized coefficients of the above regression models. We remark that these effects differ significantly. In particular, we can see that the adoption of industry-specific standards leads to the highest increase of the impact of ICT on all the examined dimensions of business performance: the corresponding standardized coefficients in the four models (0.165, 0.158, 0.156 and 0.119) are much higher than the ones for XML (0.044, 0.030, 0.038, 0.103 respectively) and proprietary standards (0.037, 0.035, 0.039, 0.043 respectively). This is because industry specific standards are characterized by:

i) High level of detail, as they define the particular data elements of many electronic documents exchanged between a firm and its suppliers, customers, sales channels, business partners, etc. (such as orders, invoices, payments, returns, product designs, production plans, demands, etc.) and their semantics (meanings) (Nurmilaakso 2008; 2008; Lampathaki et al., 2009), so they enable a fully automated exchange of numerous such electronic documents; this significantly reduces costs, improves efficiency and fosters and drives innovation.

ii) High level of applicability, as they are usually adopted by most of the firms belonging to the particular industry (e.g. suppliers, competitors, customers, sales channels, etc.), so they can be used for establishing IS interoperability with most of the firms we have transactions and cooperation with.

On the contrary XML is characterized by high level of applicability (as many firms and software products increasingly adopt XML), but lower level of detail (as it is a 'meta-language' that defines only the syntax of exchanged electronic documents, but not the data elements of them and their semantics), so it needs to be complemented with more structural

and semantic definitions to be agreed between the trading partners; for these reasons it generates a lower increase of the impact of ICT on business performance. The opposite holds for the proprietary standards, which are characterized by high level of detail (as they usually define the data elements of the exchanged electronic documents and their semantics), but lower level of applicability (as such a standard can be used for establishing IS interoperability only with a small number of firms adopting it).

Furthermore, it is interesting to compare the magnitudes of the effects of the above three IS interoperability standards on business performance with the corresponding effects of the degree of development of internal and e-sales IS. We remark that the effect of industry-specific standards in the financial performance model it is 114% (=0.165/0.145) of the effect of the degree of development of the internal IS, which is regarded as the fundamental determinant of the impact of ICT on business performance; the corresponding percentages in the other three models are 111% in the customers' value model, 71% in the business processes performance model and 69% in the innovation model. This indicates that the adoption of industry-specific standards for establishing IS interoperability with cooperating firms has in general similar levels of effects on business performance with the degree of development of internal IS. Therefore the business value of firm's internal ICT infrastructure can be roughly doubled if we adopt industry-specific standards for establishing its interoperability with the ones of other cooperating firms.

We can make a similar comparison with the effects of e-sales IS. We remark that the effect of industry-specific standards in the financial performance model is 135% (=0.165/0.122) of the effect of the degree of development of the e-sales IS, which is regarded as another highly important and value generating type of IS increasingly used by firms; the corresponding percentages in the other three models are 127% in the customers' value model, 211% in the business processes performance model and 68% in the innovation model. This indicates that the adoption of industry-specific standards for establishing IS interoperability with cooperating firms has stronger effects on business performance (with the only exception of innovation performance) than the degree of development of e-sales IS.

Finally, we remark that most of the coefficients of the sectoral dummies are statistically significant, which indicates that there are sector-specific factors that affect the impact of ICT on the examined dimensions business performance, and this necessitates the inclusion of sectoral dummies in such regressions.

6 Conclusions

Previous research has identified and discussed various dimensions of business value generated by IS interoperability, however empirical investigation of them has been quite limited. In the previous sections has been presented an empirical investigation of the business value generated by the adoption of IS interoperability standards along the four business performance dimensions proposed by the well established Balanced Scorecard approach (financial, internal business processes, customers, learning and innovation). It has been based on a large dataset collected from 14065 European firms (from 25 countries and 10 sectors) through the e-Business Watch Survey of the European Commission. The results provide empirical evidence of the multidimensional business value generated by IS interoperability, its big magnitude and its strong dependence on the type (level of detail and applicability) of IS interoperability standards adopted.

In particular, it has been concluded that the adoption of XML, industry-specific standards or proprietary standards for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners) all increase the positive impact of ICT on the financial performance of the firm, the value offered to the customers, the performance of its business processes and the innovation activity of the firm. Furthermore, it has been found that the effects of the above three types of standards differ significantly: the adoption of industry-

specific IS interoperability standards has the highest impact on business performance, while XML and proprietary standards have similar lower impacts; this is because industry-specific standards are characterized by high levels of detail and applicability. Another interesting finding is that these effects of the industry-specific IS interoperability standards are quite strong, being of similar magnitude with the corresponding effects the degree of development of internal IS, and of higher magnitude than the corresponding effects of the degree of development of e-sales IS.

The findings of our study have interesting implications for IS research and management. It provides a framework for future empirical research on the business value of various standards, forms and levels of IS interoperability based on the well established Balanced Scorecard approach. Also, the strength of the effects of adopting such standards indicates that future research on IS business value should take into account not only the degree of development of various types of IS, but also the level of interoperability as well of firm's ICT infrastructures with the ones of other firms. 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 interoperability generates; this emphasis should be similar to the one placed on the development of internal IS functionality. In order to maximize this business value IS managers should adopt standards characterized by high level of detail (so they can enable a fully automated exchange of numerous such electronic documents) and wide applicability (so they can be used for establishing IS interoperability with a large number of firms they have transactions and cooperation with).

Further empirical research is required on the business value that IS interoperability generates, examining various standards, forms and levels of IS interoperability. It is important to investigate empirically the business value not only of the 'technical' interoperability, but also on the 'organizational' interoperability as well, and their complementarities. Also, it is necessary to understand the mediators of the relation between the adoption of IS interoperability standards and various dimensions of business performance.

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Appendix

Survey questions used for measuring each variable.

Variable	Items
Impact of ICT on financial performance (ICT_FINP)	ICT_FINP1: Has ICT had a positive, negative or no influence on revenue growth?
	ICT_FP2: Has ICT had a positive, negative or no influence on the productivity of your company?
Impact of ICT on value offered to customers (ICT_CUSV)	ICT_CUSV1: Has ICT had a positive, negative or no influence on quality of your products and services?
	ICT_CUSV2: Has ICT had a positive, negative or no influence on quality of customer service?
Impact of ICT on business processes performance (ICT_BPRO)	ICT_BPRO1: Has ICT had a positive, negative or no influence on internal work organisation quality of customer service?
	ICT_BPRO2: Has ICT had a positive, negative or no influence on the productivity of your company?
Impact of ICT on innovation (ICT_INNO)	ICT_INNO1: During the past 12 months have you launched any new or substantially improved product or services directly related to or enabled by information or communication technology?
	ICT_INNO2: During the past 12 months have you introduced any new or substantially improved internal processes directly related to or enabled by information or communication technology?
XML Adoption (XML)	Do you use XML for exchanging data with buyers and suppliers?
Industry-specific standards adoption (IND_ST)	Do you use industry-specific standards agreed between you and your business partners for exchanging data with them?
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