

The Multidimensional Business Value of Information Systems Interoperability

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ABSTRACT

The creation of complete scientific foundations in the IS interoperability domain necessitates not only the development of mature and widely applicable interoperability architectures, methods and standards, but also the systematic investigation of the business value they generate. This chapter initially analyses the theoretical foundations of the multi-dimensional business value of IS interoperability, and then reviews the quite limited empirical literature on it. Next it presents an empirical study of the business value generated by the adoption of three main types of IS interoperability standards: industry-specific, proprietary and XML-horizontal ones. It 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 three types of IS interoperability standards increase considerably the positive impact of firm's ICT infrastructure on two important performance dimensions: business processes performance and innovation. However, the effects of these three types of standards differ significantly: the adoption of industry-specific IS interoperability standards has the highest positive impacts, while proprietary and XML-horizontal ones have similar lower impacts. Furthermore, it is concluded that the industry-specific and the proprietary interoperability standards also have positive impacts even at the level of firm's financial performance.

INTRODUCTION

The creation of complete scientific foundations in the information systems (IS) interoperability domain necessitates not only the development of mature and widely applicable interoperability architectures, methods and standards, but also the systematic investigation of the business value they generate (Legner & Lebreton, 2007; Lampathaki et al., 2012; Jardim-Goncalves et al., 2012). Since big investments are made for the development of various interoperability technologies, and then for their implementation at firm level, it is necessary to study the resulting business benefits and value. This is going to be quite 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. Furthermore, it will assist firms in maximizing the value they derive from these investments.

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 highly beneficial. In this direction there has been theoretical literature analyzing the business value of IS interoperability, however there is limited empirical literature on it, as explained in more detail later in the following section. 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. Therefore more empirical research is required concerning all the dimensions of the business value that IS interoperability generates, in order to assess their importance and magnitude in ‘real life’ and also identify ways of increasing them.

This chapter initially analyses the theoretical foundations of the multi-dimensional business value of IS interoperability, based on a review of relevant theoretical literature, and also of literature in the area of business networks, and then reviews the limited empirical literature in this area. Next it presents an empirical study of the effects of adopting three different types of IS interoperability standards on:

- a) the impact of firm’s information and communication technologies (ICT) infrastructure on two important performance dimensions: business processes performance and innovation,
- b) and on firm’s financial performance.

It is 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. In particular, this empirical study is focusing on three main types of IS interoperability standards (Nurmilaakso, 2008a, 2008b; Lampathaki et al., 2009):

- The industry-specific (or vertical) 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. As a typical example we can mention the health sector specific standards published and maintained by organizations like the Clinical Data Interchange Standards Consortium (CDISC) (see <http://www.cdisc.org/>). Such industry-specific standards usually are ‘tailored’ to meet the needs of the firms of the specific sector, so they have exactly the whole needed “depth and breadth”: they include all the range of the required documents and elements of them, and at the same time they do not carry additional elements that would serve neighbouring or even irrelevant domains.

- The proprietary standards, which are typically created and maintained by large and strong firms, who can impose such de-facto specifications for business documents’ exchange to their own customers, suppliers or business partners. Such interconnection standards are still very popular in several sectors, e.g. in the large, multinational supermarket chains for accepting electronic invoices from myriads of small and medium suppliers. As a typical example we can mention the TESCO electronic invoicing specifications (see Tesco Invoice Delivery Service at <http://tesco.gxs.co.uk>). They usually have extensive depth and breadth, but fulfill mainly the needs of (i.e. include mainly the documents and elements required by) the strong creator firm.

- The XML-horizontal standards, which are mainly open cross-sectoral (horizontal) specifications of business documents’ interchange formats, aiming to be used by firms of all sectors, which have been based on the XML (eXtensible Markup Language). Typical examples of such standards are the Universal Business Language (UBL) specifications (providing a library of standard XML specifications for the most frequently used business documents to be used in general procurement and transport contexts – see https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ubl), or the eXtensible Business Reporting Language (XBRL) (supporting financial information exchange – see <http://www.xbrl.org>). They are broad enough to cover many important aspects of the documents that need to be exchanged among firms, but due to their horizontal nature they 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 (2006) 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 disjoint.

Our study is structured in seven sections. In the next section the theoretical foundations of the business value of IS interoperability are analysed, while in the following section the limited relevant empirical literature is reviewed. Then the research hypotheses of our empirical study are developed. The data and method of the study are described in the next section, followed by the results. In the final section the conclusions are summarized.

THEORETICAL FOUNDATIONS

There has been some theoretical literature analysing and discussing various dimensions of business value generated by IS interoperability. The most important of them is definitely a report titled 'Unleashing the Potential of the European Knowledge Economy – Value Proposition for Enterprise Interoperability' (Li et al., 2008), which has been written by a high level Informal Study Group (ISG) launched by the European Commission. It concludes that IS interoperability has the potential to improve efficiency dramatically, which has been the main focus in the past, and additionally it 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 this new dimension of the 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, & Cruz-Machado, 2009; Grilo&Jardim-Goncalves, 2010).

Previously Choi and Whinston (2000) had argued that IS interoperability is highly important for maximizing the potential benefits of computing and digital networking technologies. In particular, they argue that 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. Also, 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 allows gaining big efficiencies in managing multi-partner transactions, in which multiple trades occur among numerous participants who are very often dispersed geographically. Furthermore, it can significantly improve efficiency in product design, manufacturing and distribution, and at the same time increase customers' choices and satisfaction. 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 highly important requirements. The same paper identifies three main functions of IS interoperability that 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).

IS interoperability constitutes a valuable infrastructure, which facilitates and supports various advanced and highly beneficial business practices, making them less costly and more easy and quick to implement and beneficial. One of them is definitely the Electronic Data Interchange (EDI) (Jimenez-Martinez & Polo-Redondo, 2004), 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. Another beneficial business practice that can be facilitated and supported by IS interoperability is Collaborative Planning, Forecasting and Replenishment (CPFR) (Dudek & Stadtler, 2007; Stadtler, 2009), defined as the combination of data and the intelligence of multiple trading partners across the supply chain in order to improve planning and fulfilment of customer demand, which can provide important benefits, especially in cases of goods and services characterised by unstable demand. Similarly, Vendor-Managed Inventory (VMI) (Kuk, 2004), defined as a new approach to inventory management, in which the supplier assumes the responsibility of tracking and replenishing firm's inventory, can also be facilitated and supported by IS interoperability of the involved firms, and lead to customers' service improvements and at the same time inventory cost reductions. It should be emphasized that the extent of exploiting the above capabilities finally determines the extent of value generation from IS interoperability.

Furthermore, it should be strongly emphasized that interoperability of firm's IS can 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 centers, 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 & Johanson, 1992; Hakansson & Snehota, 1995).

Business networks have become of critical importance in the modern economy (Rycroft, 2007; Busquets, 2010; Zeng et al., 2010), so 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 & 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.

Furthermore, business networks facilitate learning through transfer of knowledge among participating firms, so they act as 'conduits' for moving and processing knowledge, and increasingly become the 'locus' of combination of diverse knowledge and complementary resources, creation of novel knowledge and innovation at a network level, rather than within the firms of the network. Extensive previous research in the innovation domain has shed light on the increasing importance of business networks for innovation activity in the last decade (Cumbers, 2003; Dewick & Miozzo, 2004; Mancinelli & Mazzanti, 2009; Zeng et al., 2010; Huizingh, 2011; Salavisa et al., 2012). It has revealed that there has been a fundamental change in the way firms design and implement innovation; while previously this has been viewed as a predominantly internal task, in the last decade it increasingly becomes a more 'open' and collaborative process based on interactions among different firms. Interorganizational mainly cross-sectoral networks, which facilitate the flows of information, knowledge and resources have emerged as a highly effective strategy.

Therefore firm's business performance today depends critically on its participation in multiple business networks, having 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 & Snehota, 1995; Baraldi & Nadin, 2006): 'activity links' (i.e. mutual adaptations in their activities), 'resource ties' (i.e., technical connections and mutual orientations of their physical and organisational resources) and 'actor bonds' (i.e. social interactions between individuals and organisational units of cooperating firms). These require extensive exchanges of information, both 'structured' and 'unstructured', with cooperating firms in multiple networks; the exchange of the former (structured information) can be significantly facilitated by IS interoperability.

EMPIRICAL LITERATURE

However, the business value of IS interoperability has been only to a very limited extent empirically investigated, so it has not been sufficiently examined to what extent the abovementioned expectations of the relevant theoretical literature are realised; only a very small number of empirical studies have been conducted concerning IS interoperability business value, and all of them are based on small datasets.

Boh, Xu, & 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 has concluded 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, & 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.

We remark that these few empirical studies do not investigate the multiple dimensions of the business value generated by IS interoperability, i.e. its impacts on various aspects of firm's operation and performance, do not examine its effect on firm's innovation activity, and also do not examine and compare these effects for different types of standards. Our study contributes to filling this empirical research gap, by investigating the effects of the three main types of IS interoperability standards on several business performance variables (both 'final' and 'intermediate' ones, as explained in the following section), based on a large dataset collected from 14065 European firms.

RESEARCH HYPOTHESES

Since business performance depends on a large number of 'internal' and 'external' variables (associated with the internal resources and organization of the firm, and its external environment respectively), our first two research hypotheses concern the effect of adopting IS interoperability standards on two 'intermediate' business performance variables (impact of firm's ICT infrastructure on business processes performance and innovation), while our third research hypothesis concerns a 'final' business performance variable (financial performance). Previous IS literature has emphasized that ICT affects positively firms' business performance mainly through two mechanisms: by increasing the performance of their business processes, and by driving and facilitating innovations in their business processes and in their products and services (e.g. Brynjolfsson & Hitt, 2000; Brynjolfsson & Saunders, 2010); so for this reason we have focused our first two research hypotheses on the effects of IS interoperability on these two mechanisms.

In particular, as mentioned previously, IS interoperability 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. 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 (Wu & Chang, 2011). Also, these data can be oriented towards supporting and enhancing coordination and collaboration, for instance data on stock levels, production plans and sales forecasts, or on common projects, supporting various highly efficient business practices (Choi & Whinston, 2000). Furthermore, IS interoperability standards can facilitate the participation in business networks, the exploitation of physical resources of other firms, the achievement of economies of scale, resulting finally in important operational benefits (Kajikawa et al., 2010; Baraldi & Nadin, 2006). The above will increase the impact of firm's ICT infrastructure on the performance of its business processes. Therefore our first research hypothesis is:

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

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' and collaborative, based on extensive interactions with business partners, customers and suppliers (Zeng et al., 2010; Huizingh, 2011); among them should be exchanged initially ideas and then structured documents (e.g. with designs of new products). The latter flows can be greatly facilitated and supported by IS interoperability. Furthermore, IS interoperability can be of critical importance for the quick and low cost production, marketing and distribution of the designed innovative products, through a close cooperation with multiple suppliers, sub-contractors, wholesalers and retailers, and exchange of various electronic documents with them. Also, as mentioned previously, 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 (Baraldi & Nadin, 2006; Kajikawa et al., 2010; Salavisa et al., 2012), and at the same time allow gaining access to small niche markets for selling to them wider ranges of products (Li et al., 2008). Therefore our second research hypothesis is:

H2: The adoption of IS interoperability standards increases the impact of firm's ICT infrastructure on its innovation activity

Finally, as the adoption of IS interoperability standards will increase the business benefits provided by firm's ICT infrastructure concerning both its business processes performance and its innovation activity, we expect that it will finally affect positively its financial performance. So our third research hypothesis is:

H3: The adoption of IS interoperability standards has positive impact on firm's financial performance

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 Watch (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, standards and practices, the impacts of ICT use, and also the 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 the Appendix we can see the questions we used from the above questionnaire for this study.

In order to test research hypotheses 1 and 2, using the above data we estimated the following regression models M1 and M2, having as dependent variables the main variables of these hypotheses: the impact of firm's ICT infrastructure on business processes performance (ICT_BPRO) and on innovation activity (ICT_INNO); as main independent variables they have the adoption of the three types of standards examined in this study, the industry-specific standards (IND_ST), the proprietary standards (PRO_ST) and the XML-horizontal standards (XMLHOR_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):

$$\text{ICT_BPRO} = b_0 + b_1 * \text{IND_ST} + b_2 * \text{PRO_ST} + b_3 * \text{XMLHOR_ST} + b_4 * \text{INT_IS} + b_5 * \text{ESAL_IS} \quad (\text{M1})$$

$$\text{ICT_INNO} = b_0 + b_1 * \text{IND_ST} + b_2 * \text{PRO_ST} + b_3 * \text{XMLHOR_ST} + b_4 * \text{INT_IS} + b_5 * \text{ESAL_IS} \quad (\text{M2})$$

The impact of ICT on business processes performance (ICT_BPRO) was measured as 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 respectively. 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 et al., 2004; Sanders, 2007; Kearns

&Sabherwal, 2007). The impact of ICT on firm's innovation activity (ICT_INNO) was measured as 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 & Meroño-Cerdan, 2008).

Our main independent variables are three dichotomous items (IND_ST, PRO_ST and XMLHOR_ST) assessing whether the firm uses industry-specific standards, proprietary standards and XML-horizontal standards respectively in order to exchange data with its customers and suppliers. Furthermore, taking into account that the impact of firm's ICT infrastructure on business performance depends critically on the degree of its development, i.e. the extent of using IS for supporting firm's internal processes and for interacting with the external environment (i.e. lower extent of ICT use for these purposes results in lower ICT impact on business performance), we have also included two additional independent variables; they correspond to the two most widely used types of IS: the intra-organizational/internal and the e-sales ones. The first variable was the degree of development of firm's internal IS (INT_IS), which was measured as the average of 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 Document Management (EDM) system, Enterprise Resource Planning (ERP) system, 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 & Meroño-Cerdan, 2008; Brews & Tucci, 2004). The second additional variable was the degree of development of e-sales IS (ESAL_IS), which was measured as the average of four items (ESAL_IS1 to ESAL_IS6 – see Appendix) assessing whether the firm uses IS for the four main stages of sale's lifecycle: 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 & Meroño-Cerdan, 2008; Brews & Tucci, 2004; Hashim, Murphy & 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 above-mentioned ten sectors covered by our survey nine sectoral dummies (while one sector was used as a reference group).

Similarly, in order to test research hypothesis 3 we estimated the following regression model M3, having as dependent variable the main variable of this hypothesis: firm's financial performance (FINP); it has the same independent variables with the above M1 and M2 models (the adoption of the three examined types of standards and the degree of development of firm's internal and e-sales IS), and also an additional one concerning firm's human capital (HCAP), which is widely recognised as an important determinant of its financial performance (Arvanitis & Loukis, 2009):

$$FINP = b_0 + b_1 * IND_ST + b_2 * PRO_ST + b_3 * XMLHOR_ST + b_4 * INT_IS + b_5 * ESAL_IS + B_6 * HCAP (M3)$$

Financial business performance (FINP) was measured as the average of three items (FPIN1, FINP2 and FPIN3 – see Appendix) assessing whether firm's turnover, marketshare and productivity increased, stayed roughly the same or decreased in the last financial year in comparison with the previous one. Finally firm's human capital (HCAP) was quantified through the percentage share of firm's employees having a college or university degree (see Appendix). Such items have been used extensively in previous empirical management research for measuring financial business performance and human capital respectively (Martinez-Lorente et al., 2004; Hyvonen, 2007; Koellinger, 2008). For the estimation of this M3 model the data from the 834 Hospital Activities sector (S10) were not used, because of missing data for some financial performance items.

RESULTS

Effects on Business Impact of ICT Infrastructure

In Table 1 we can see the results of the estimation of the M1 and M2 regression models—for each model we can see the standardized coefficients of the independent variables, which allow a comparison of their effects on the dependent variable. We remark that in both models the standardized coefficients for all the three examined types of IS interoperability standards (variables IND_ST, PRO_ST and XMLHOR_ST) are positive and statistically significant. This indicates that the adoption of industry-specific, or proprietary or XML-horizontal standards for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners) increases the positive impact of firm's ICT infrastructure on the performance of its business processes (dependent variable ICT_BPRO) and on its innovation activity (dependent variable ICT_INNO). Therefore our first two research hypotheses H1 and H2 are supported for all three examined types of IS interoperability standards. These results provide a strong empirical evidence of the multi-dimensional business value generated by IS interoperability, with respect to both business processes performance and innovation activity. Also, we can see that in both models the standardized coefficients of the degree of development of firm's internal IS (variable INT_IS) and e-sales IS (variable ESAL_IS) are positive and statistically significant as well, as expected. 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 business processes performance and innovation, and this necessitates the inclusion of sectoral dummies in such regressions.

	ICT_BPRO	ICT_INNO
IND_ST	0.156***	0.119 ***
PRO_ST	0.039***	0.043 ***
XMLHOR_ST	0.038***	0.103 ***
INT_IS	0.219***	0.173 ***
ESAL_IS	0.074***	0.176 ***
DUM_1	-0.063***	-0.036 ***
DUM_2	-0.076***	-0.032 ***
DUM_3	-0.026***	-0.029 ***
DUM_4	-0.011	0.020 **
DUM_5	-0.009	0.029***
DUM_6	0.003	-0.030 ***
DUM_7	-0.014	-0.068 ***
DUM_9	0.017*	0.117 ***
DUM_10	-0.015*	0.023 ***

Table 1. Estimated regression models of the impact of firm's ICT infrastructure on business processes performance and innovation.

It is interesting to compare between the effects of these three types of IS interoperability standards by examining the corresponding standardized coefficients of these two regression models in the above Table 1 – we can also see them below in Figure 1 normalised as percentages of the corresponding standardized coefficients of the degree of internal IS development in the three models. We remark that the effects of these three types of standards differ significantly. In particular, we can see that the adoption of industry-specific standards leads to the highest increase of the impact of ICT infrastructure on business processes performance and innovation: the corresponding standardized coefficients in the two models (0.156 and 0.119) are higher than the ones of the proprietary standards (0.039, 0.043 respectively) and the XML-horizontal ones (0.038, 0.103 respectively). This is because, as

mentioned in the Introduction, industry-specific standards have the following two important characteristics:

i) They have exactly the whole needed “depth and breadth”: they cover almost all the electronic documents exchanged between a firm in the industry and its suppliers, customers, sales channels, business partners, etc. (such as orders, invoices, payments, returns, product designs, production plans, demands, etc.), and also for each of them include the whole range of required elements, but do not include additional data elements (Nurmilaakso 2008; 2008; Lampathaki et al., 2009).

ii) They also have 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, the proprietary standards usually have extensive ‘depth and breadth’, but cover mainly the needs (documents and elements) of the strong creator firm. Also, they are characterized by much lower levels of applicability, as such a standard can be used for establishing IS interoperability only with the creator firm and a relatively small number of firms that adopt it. For these reasons the adoption of proprietary standards leads to lower increase of the impact of firm’s ICT infrastructure on business processes performance and innovation than the industrial ones.

Finally, the XML-horizontal standards, as mentioned in the Introduction, are mainly cross-sectoral (horizontal) at the time when the data of this study were collected, so they are characterized by higher levels of applicability, since they can be used for exchanging electronically business documents with firms not only of the same industry, but also of other industries as well. However, they lack the needed depth and breadth for representing sector-specific characteristics and information elements, as they have been developed with a ‘least common denominator’ logic, so they cover mainly business documents and elements of them that are common across sectors, and do not provide a ‘perfect match’ with needs. For these reasons the adoption of XML-horizontal standards results in a lower increase of the impact of firm’s ICT infrastructure on the business processes performance and innovation in comparison with the industrial standards. However, the difference between the effects of these two types of standards (industry-specific and XML-horizontal ones) is much smaller with respect to innovation, since according to previous innovation literature (e.g. Castellacci, 2008) important innovations require extensive interactions and therefore information exchange among firms of different sectors, and XML-horizontal standards can greatly facilitate and support this.

Figure 1. Normalised effects of independent variables in the ICT_BPRO (M1), ICT_INNO (M2) and FINP (M3) models as percentages of the effects of internal IS (INT_IS).

It is interesting to compare the magnitudes of the above effects of these three types of IS interoperability standards with the corresponding effects of the degree of development of internal and e-sales IS using Table 1 and Figure 1. We remark that the effect of the industry-specific standards in the first business processes performance model is 71% ($=0.156/0.219$) and in the innovation model it is 69% ($=0.119/0.173$) of the effect of the degree of development of the internal IS, which is regarded as the fundamental determinant of the business impact of ICT. Therefore the effects of adopting industry-specific standards on the impacts of firm’s ICT infrastructure on business processes performance and on innovation seem to be quite strong, about two thirds of the corresponding ones of the degree of development of the internal IS. For the proprietary and the XML-horizontal standards the above percentages are lower: 18% and 25% respectively for the former, and 17% and 60% respectively for the latter.

We can make a similar comparison with the effects of e-sales IS. We remark that the effect of industry-specific standards in the first business processes performance model is 211% ($=0.156/0.074$) and in the innovation model 68% ($=0.119/0.176$). Therefore the effects of adopting industry-specific standards on the impact of firm’s ICT infrastructure on business

processes performance (innovation) is more than double (two thirds of) the one of the degree of development of e-sales IS. For the proprietary standards and the XML-horizontal standards the above percentages are lower: 53% and 24% respectively for the former, and 51% and 58% respectively for the latter.

Effects on Financial Performance

In the following Table 2 we can see the results of the estimation of the M3 regression model.

	FINP
IND_ST	0.069 ***
PRO_ST	0.028 ***
XMLHOR_ST	0.005
INT_IS	0.100 ***
ESAL_IS	0.082 ***
HCAP	0.058 ***
DUM_1	-0.017
DUM_2	-0.122 ***
DUM_3	-0.019 *
DUM_4	-0.052 ***
DUM_5	-0.042 ***
DUM_6	-0.001
DUM_7	-0.007
DUM_8	-0.024 *

Table 2. Estimated regression model of firm's financial performance.

We remark that the standardised coefficients of the industry-specific and the proprietary standards (variables IND_ST and PRO_ST) are positive and statistically significant, while the standardised coefficient of the XML-horizontal standards (variable XMLHOR_ST) is positive as well, but much smaller and statistically non-significant. Therefore we can conclude that the adoption of industry-specific or proprietary standards for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners) has positive impacts even at the level of firm's financial performance. Therefore our third research hypothesis H3 is partially supported (only for two of the three examined types of IS interoperability standards). Also, we remark that the standardised 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 (variable HCAP), are positive and statistically significant as well, as expected.

A comparison of the magnitudes of the standardised coefficients of the independent variables (using Table 2 and Figure 1) shows that the degree of development of the internal IS has the strongest effect on financial performance (standardised coefficient 0.100), followed by the degree of development of the e-sales IS (0.082), and then the adoption of industrial standards (0.069) and the human capital (0.058), while much weaker is the effect of the adoption of proprietary standards (0.028). These results provide additional empirical evidence of the high business value that IS interoperability generates: the adoption of industry-specific standards has a strong impact even at the level of financial performance, which is 69% ($=0.069/0.100$) of the effect of the degree of development of the internal IS, and 84% ($=0.069/0.082$) of the effect of the degree of development of the e-sales IS (so it is comparable with the effects of the main ICT-related determinants of firm's financial performance). The adoption of proprietary IS interoperability standards has also statistically significant impact at the level of financial performance, but of lower magnitude, about 40% ($=0.028/0.069$) of the effect of the industry-specific standards; this is probably due to the lower applicability of the proprietary standards in comparison with the industry-specific standards, as the former can be used for establishing IS interoperability only with the strong creator firm and the small number of

adopting firms. On the contrary, the adoption of XML-horizontal IS interoperability standards does not have statistically significant impact at the level of financial performance; this probably happens because they cover mainly business documents and elements of them that are common across sectors, having been developed with a 'least common denominator' logic, so they do not fulfil important industry-specific requirements.

CONCLUSIONS

The progress towards a scientific maturity of the information systems (IS) interoperability domain and the creation of complete scientific foundations of it will require balanced research both at the technological and the business level: it necessitates both the development of mature and widely applicable interoperability architectures, methods and standards, and at the same time the systematic investigation of the business value they generate. This chapter makes a contribution in this direction. Initially it analyses the theoretical foundations of the multi-dimensional business value of IS interoperability: they include i) previous theoretical literature discussing various possible contributions of IS interoperability to different aspects of business performance, and also ii) previous literature in the area of business networks, as IS interoperability can be an important facilitator of this increasingly important element of modern economy. Then, the quite limited empirical literature on IS interoperability business value is reviewed.

Furthermore, we contribute to filling this research gap by presenting an empirical study of the business value generated by the adoption of three fundamental types of IS interoperability standards: industry-specific, proprietary and XML-horizontal ones. We examine their effect on several business performance variables, both 'intermediate' and 'final' ones. In particular, as intermediate performance variables we have used the impacts of firm's ICT infrastructure on its business processes performance and innovation, while as final business performance variable we have used firm's financial performance. This empirical study has been based on a large dataset collected from 14065 European firms (from 25 countries and 10 sectors) through the e-Business Market 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 of IS interoperability standards adopted. In particular, it has been concluded that the adoption of all these three types of standards for establishing IS interoperability with cooperating firms (e.g. customers, suppliers, business partners) increase the positive impact of firm's ICT infrastructure on the performance of its business processes and its innovation activity. 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 proprietary standards and XML-horizontal ones have similar lower impacts. Furthermore, it has been concluded that the industry-specific and the proprietary interoperability standards have positive impacts even at the level of firm's financial performance. All the above effects of the industry-specific IS interoperability standards are quite strong, having a level of about two thirds of the corresponding effects of the degree of development of internal IS (regarded as the main determinant of business benefits from ICT).

The findings of our study have interesting implications for IS research and management. It provides theoretical foundations and also an empirical framework for future empirical research on the business value of various IS interoperability architectures, methods and standards. 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 firm's IS (as it happened with most of the previous research in this area), but also their interoperability with the ones of other cooperating 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 seems to generate; this emphasis should be similar to the one placed on the development of the functionality of various types of firm's IS. 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), such as the industry-specific standards.

Further empirical research is required on the business value that IS interoperability generates, examining from this viewpoint various existing and emerging IS interoperability architectures, 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 (both ‘internal’ and ‘external’ ones) and the mediators of the effects of the adoption of various IS interoperability architectures, methods and standards on various dimensions of business performance.

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KEY TERMS & DEFINITIONS

Information Systems (IS) Interoperability: The ability of two or more IS or components to exchange information and to use the information that has been exchanged.

Industry-specific standards: Standards created mainly 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.

Proprietary standards: Standards typically created and maintained by large and strong firms, which impose de-facto specifications for business documents' exchange with their own customers, suppliers or business partners.

XML-horizontal standards: Standards based on the XML (eXtensible Markup Language), used for open cross-sectoral (horizontal) specifications of business documents' interchange formats to be used by firms of all sectors (though recently many industrial standards, and also some proprietary ones, have been ported to XML as well).

Red Ocean Strategies: Strategies based on competition through lower prices in existing established products and services or marginal innovations in them.

Blue Ocean Strategies: Strategies aiming to make the competition irrelevant by creating new market spaces, termed as 'blue ocean', through the introduction of radical innovations in the products, services and processes.

Business Networks: Structures comprising different and heterogeneous organizations (e.g. firms having different resources and capabilities, suppliers, customers, universities, research centers, etc.), having various types of relationships among them and also economic and social exchanges, which aim at the design, production and marketing of complex products and services.

APPENDIX

Survey questions used for measuring each variable

Variable	Items
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?
Financial performance (FINP)	FINP1: Has the turnover of your company increased, decreased or stayed roughly the same when comparing the last financial year with the year before?
	FINP2: Has the share of your company in its most significant market increased, decreased, or remained the same over the past 12 months?
	FINP3: Has the productivity of your company increased, decreased or stayed roughly the same when comparing the last financial year with the year before?
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?
XML-horizontal standards adoption (XMLHOR_ST)	Do you use XML-based 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 EDM (Enterprise Document Management) system?
	INT_IS3: Do you use an ERP (Enterprise Resource Planning) system?
	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
E-Sales IS degree of development (ESAL_IS)	INT_IS6: to manage capacity or inventories?
	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?