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Enterprise Systems Adoption and Firm Performance in Europe: The Role of Innovation

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Abstract:
Despite the ubiquitous proliferation and importance of Enterprise Systems (ES), little research exists on their post-implementation impact on firm performance, especially in Europe. This paper provides representative, large-sample evidence on the differential effects of different ES types on performance of European enterprises. It also highlights the mediating role of innovation in the process of value creation from ES investments. Empirical data on the adoption of Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM), Knowledge Management System (KMS), and Document Management System (DMS) is used to investigate the effects on product and process innovation, revenue, productivity and market share growth, and profitability. The data covers 29 sectors in 29 countries over a 5-year period. The results show that all ES categories significantly increase the likelihood of product and process innovation. Most of ES categories affect revenue, productivity and market share growth positively. Particularly, more domainspecific and simpler system types lead to stronger positive effects. ERP systems decrease the profitability likelihood of the firm, whereas other ES categories do not show any significant effect. The findings also imply that innovation acts as a full or partial mediator in the process of value creation of ES implementations. The direct effect of enterprise software on firm performance disappears or significantly diminishes when the indirect effects through product and process innovation are explicitly accounted for. The paper highlights future areas of research.

Keywords: Enterprise Systems; ERP; SCM; CRM; KMS; DMS; IT Adoption; Post-implementation Phase; IT Business Value; Innovation; Firm Performance; Europe.

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Enterprise Systems Adoption and Firm Performance in Europe:

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1. INTRODUCTION

Enterprise Systems (ES) are large-scale, integrated, cross-functional, and data-centric application software that provide service to all or a group of organizational subunits. Enterprise systems consist of different categories, such as ERP (Enterprise Resource Planning), SCM (Supply Chain Management), CRM (Customer Relationship Management), KMS (Knowledge Management System), and DMS (Document Management System). Since 1990s firms have invested heavily in these systems such that the worldwide enterprise software market amounted to about $230 billion in 2008 and is estimated to reach around $315 billion by 2012 (Gartner 2008).

Numerous reports of successful ES projects with considerable operational and strategic benefits exist (Murphy and Simon 2002; Shang and Seddon 2002; Davenport 2000). Equally important, the failure of ES investments has been frequently acknowledged in the literature, ranging from 40 to 75 percent of implemented projects (Hong and Kim 2002; Liang et al. 2007; Scheer and Habermann 2000). The implementation of an enterprise system can go beyond the boundaries of a single department or even the whole organization and involves tremendous risks and uncertainties and a worrying level of

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complexity that should be managed (Davenport 1998; Huang et al. 2004; Rettig 2007; Sumner 2000). Moreover, ES initiatives are generally among the most lengthy and expensive Information Technology (IT) projects of companies nowadays (Markus et al. 2000; O'Leary 2000; Scott and Vessey 2002). While the average installation costs about $15 million, large organizations end up spending hundreds of millions of dollars on ES software (Rettig 2007).

The above characteristics of enterprise systems implementations make the systematic and rigorous assessment of their business value particularly important for corporate decision-makers. In this respect, the long-term, post-implementation assessment of ES software is of great import. Enterprise systems lead to diverse effects throughout their lifecycle (Gattiker and Goodhue 2005; Markus and Tanis 2000; Nicolaou and Bhattacharya 2006; Rajagopal 2002; Ross and Vitale 2000). Enterprise systems take a long time to be implemented and further to be customized and are largely used over a span of several years. Prior evidence suggests that enterprise systems benefits accrue over periods of time as opposed to one-time windfall gains and that a time-lag of few years is necessary before ES adopters begin to demonstrate positive differential performance in comparison to their non-adopting peers (Liu et al. 2008; Nicolaou 2004a, 2004b). Moreover, the success or failure of early stages (i.e. the implementation or shakedown phase) does not necessarily relate to the performance effects of later stages (i.e. the post-implementation or acceptance phase) (Bajwa et al. 2004; Chou and Chang 2008; Häkkinen and Hilmola 2008; Liang et al. 2007).

This paper analyzes *whether* and *how* the adoption of enterprise applications affects performance of companies after these systems are used for a sufficiently large period of time. The existing body of the empirical literature usually focuses on a single type of enterprise software (and mainly ERP) and uses case studies or, to a lesser degree, surveyed data from a limited number of (mainly US) sectors (e.g. Hendricks et al. 2007; Hitt et al. 2002; McAfee 2002). The literature on the innovation and performance impacts of other enterprise system types than ERP is either scarce or absent. Furthermore, most of existing literature focuses on immediate or short-term as opposed to long-term effects of ES (Esteves and Pastor 2001; Yu 2005). This paper differs from previous studies in four aspects. First, it provides large-sample, economy-wide evidence of the firm-level performance effects of ES adoption across the major industries of European countries. Second, it enables cross-system comparison by analyzing the differential effects of different enterprise systems on various innovation and performance measures of the firm. Third, it concentrates on the post-implementation stage of ES applications, rather than their selection, implementation, announcement or shakedown phase. Fourth, it differentiates between the direct and indirect effects of enterprise systems on firm performance and identifies product and process innovation as important mediating factors.

The present study enhances our understanding of what aspects of firm performance are influenced by different types of enterprise systems and through what mechanisms. The findings show that all ES types, which were examined, significantly increase the likelihood of product and process innovation. In addition, most of ES categories exhibit significantly positive impact on revenue, productivity and market share growth. In contrast, none of ES types significantly increase the odds of being profitable, while ERP systems even decrease the odds. The analysis further reveals that innovation plays a significant mediating role in linking ES adoption to firm performance. The direct effect of enterprise software on firm performance for most of ES categories completely disappears when the indirect effect through product and process innovation is explicitly accounted for.

We proceed by reviewing the literature in the next section to gain knowledge on the benefits, costs and effects of enterprise systems. Section three explicates a conceptual model to link ES adoption to firm performance. Three hypotheses are derived on the basis of this model and the reviewed literature. The next section describes the sample data. Section five discusses the econometric model used to test the hypotheses and explores the relevant operationalization issues. Estimation results are presented and discussed in section six. We finally conclude the paper and provide recommendations for future research.

2. BENEFITS, COSTS AND EFFECTS OF ENTERPRISE SYSTEMS

2.1. Enterprise System Types

The literature on critical success factors and organizational change management of enterprise systems identify factors that influence the quality and success of ES implementations (Al-Mashari et al 2003; Markus et al. 2000; Motwani et al. 2005; Nah et al. 2001). On the basis of the existing literature, we distinguish between two classes of enterprise systems. These classes differ by the extent of the organization that is (fundamentally) affected by installation of the system. Implementation of some enterprise systems requires a wide range of organizational units to be involved/changed, for these systems to provide full functionality according to their design specification. ERP systems, for instance, cannot effectively function unless the information, transactions, and functions of different domains of the organization, such as procurement, production, marketing and sales, distribution, finance, and human resource management are integrated through a shared data store (Davenport 1998; Willcocks and Sykes 2000). Similarly, SCM applications can best fulfill their functional promises by coordinating and streamlining the activities related to movement and storage of raw materials, work-in-progress inventory, and finished goods throughout the whole supply chain of the company (Liu et al. 2005; Lummus and Vokurka 1999). KMS software is also productive when the information and knowledge assets of the organization are all collected, organized, combined, processed, and shared (Alavi and Leidner 2001; King and Marks Jr. 2008). We categorize these enterprise systems whose implementation involves and affects a broad spectrum of organizational entities as *organization-wide systems.*

The other class of enterprise systems is more confined to a limited number of organizational units. These systems are typically simpler and easier-to-use and are not necessarily implemented throughout the whole organization. For example, CRM systems are used to gather, track, and analyze a company's contacts and relationships with its current or prospective customers (Boulding et al. 2005). The Marketing and Sales department of the company is usually the organizational unit that is directly involved in and affected by a CRM installation. In fact, for a functional CRM system, all the separate firm departments are not necessarily integrated. DMS applications can be installed for separate departments and do not need full organizational integration as well (Knowles 1995; Laserfiche 2007). A DMS is a computerized system to collaboratively create, edit, archive, and publish electronic documents of a single or multiple domains of an organization with similar documentation processes and requirements. We categorize these enterprise systems whose implementation narrows to a limited array of organizational entities as *domain-specific systems*.

2.2. Benefits and Costs of Enterprise Systems

Numerous benefits and costs have been attributed to enterprise systems in the literature. The benefits of enterprise software can be grouped into four categories (e.g. Botta-Genoulaz and Millet 2005; Botta-Genoulaz et al. 2005; Davenport 2000; Rikhardsson and Kræmmergaard 2006; Shang and Seddon 2002; Uwizeyemungu and Raymond 2009):

(1) *Information reach and richness*: enterprise systems make new, improved, more accurate, and otherwise inaccessible information available to different organizational units; this results in better governance and control of the firm, improved planning and coordination of activities, more informed decisions, and faster response times.

(2) *Process automation and integration:* business processes of the firm are changed and further streamlined according to built-in best practices of the enterprise software; this results in administrative savings through eliminating manual, repetitive procedures and operational savings through more efficient and aligned business processes.

(3) *Information systems maintenance and modification:* an enterprise software in the form of a central and integrated IT system instead of several loosely-coupled subsystems and separate business applications results in reduction of information systems costs through economies of scale and scope.

(4) *Organizational competence and effectiveness:* through different mechanisms, enterprise systems adoption leads to among others, organizational learning, employee empowerment, business agility, service quality, and customer satisfaction, which can be further translated to growth and competitive advantage of the firm.

The benefits of enterprise systems go together with certain costs and restrictions (e.g. Davenport 1998; Kremers and Van Dissel 2000; Robey et al. 2002; Soh et al. 2000). In addition to spending in software, hardware, training, maintenance, and consultancy services, the costs and restrictions of enterprise systems can be categorized into four groups:

(1) *Structural rigidities and misfits:* the built-in, generic best practices in the enterprise software might not optimally suit the particular, local requirements of the implementing organization.

(2) *Data standardization and organizational change:* the initial technological investment and later organizational change required for standardizing data and processes might result in various restraints and resistances by employees; changing workers' visions and attitudes towards technology also adds to the challenge.

(3) *Error- and change-escalating effects:* the tight coupling and interaction of IT components in the form of a unified, centralized enterprise system makes it hard to change or adjust a single subsystem without affecting others; an error or breakdown in one subunit quickly propagates throughout the whole system.

(4) *System size and complexity:* the huge size combined with high degree of complexity makes it complicated and time-consuming to learn, understand, configure, test and use enterprise software.

Complex organization-wide systems have more potential to generate business value and competitive gains. However, the extra benefit comes at the cost of more considerable risks, structural rigidities, organizational changes and error-escalating effects (Huang et al. 2004; Rettig 2007; Scott and Vessey 2002; Sumner 2000). In contrast, domain-specific applications are relatively smaller, simpler, cheaper and easier to implement, optimize, and use and therefore expected to exhibit higher probabilities of successful implementation.

2.3. Performance Effects of Enterprise Systems

Two streams of research can be distinguished. First, the IT Business Value literature investigates information technology effects at different levels of analysis. The earlier studies are equivocal in pronouncing the business value of IT, with a number of them reporting negative, neutral or mixed effects (Byrd and Marshall 1997; Hitt and Brynjolfsson 1996), while the majority of the more recent studies confirm a significant positive impact (Bardhan et al. 2006; Bartel et al. 2007; Bharadwaj 2000). The second strand of the literature focuses on performance impact of enterprise systems as a specialized subclass of information technologies (Hendricks et al. 2007; Hitt et al. 2002). The existing empirical literature largely consists of trade articles, (collection of) case studies, field experiments, and (self-reported) industry surveys, mostly from the US (e.g. Akkermans et al. 2003; Kohli and Hoadley 2006; Mabert et al. 2001 and relevant references therein; McAfee 2002; Uwizeyemungu and Raymond 2009). These studies are useful by offering meaningful and concrete lessons for implementation strategies but lack a certain generalization of their results that is achievable through rigorous and representative empirical analyses.

The existing empirical studies based on objective data are equivocal about the performance effects of different types of enterprise systems. A number of studies report negative impacts during the implementation process or one to two years after ERP systems go live (known as shakedown, shakeout or brake-in phase) and only positive effects after two to three years of continued use (known as onward, upward or acceptance phase) (Hitt et al. 2002; Liu et al. 2008; Nicolaou 2004a). Several studies also report insignificant differences in profitability or financial performance between ERP-adopters and non-adopters (Poston and Grabski 2001; Wieder et al. 2006). On the contrary, a considerable group of the literature observes profound positive impacts of ERP adoption on order lead time (Cotteleer and Bendoly 2006), on profitability (Hendricks et al. 2007), on return on assets, return on investment and asset turnover (Hunton et al. 2003) or on information response time and order cycle (Mabert et al. 2000).

Although the majority of the existing literature on enterprise systems focuses on ERP[1] and uses US data, there are a handful of studies on other ES types and based on non-US data. Here, a distinction shall be made between two branches of the literature. The first group treats SCM, CRM and KMS concepts as a corporate policy, management practice or organizational capability (e.g. Li et al. 2006; Massey et al. 2002; Coltman 2007; Ryals 2005). The second group explicitly focuses on SCM, CRM, and/or KMS as IT-based enterprise systems.

Dehning et al. (2007) investigate the financial benefits of SCM systems in 123 US manufacturing firms and report improvements in gross margin, inventory turnover, market share, return on sales, and general administrative expenses. Similarly, Hendricks et al. (2007) use a sample of 140 SCM implementations in the US and show that, on average, SCM adopters experience positive stock returns and improvement in profitability in comparison to their industry peers. Shin (2006), using a production function approach and a dataset of 525 Korean SMEs, finds that SCM adoption raises SMEs'

[1] It is partly because ERP has been introduced into business earlier than most of the other enterprise applications and can act as a platform for implementing them (Ragowsky and Somers, 2002).

productivity, especially in the manufacturing sector. Wieder et al. (2006) rely on a sample of 102 Australian firms to conclude that SCM software, when jointly used with ERP, results in higher performance at the level of internal business processes.

Hendricks et al. (2007) analyze a sample of 80 CRM implementations in the US and find no evidence for improvement in stock returns or profitability for firms invested in CRM. Using 21 responses from an exploratory survey conducted in the UK financial services sector, Karakostas et al. (2005) report limited benefits from IT-enabled CRM tools in terms of operational saving and absolutely no effect on internal processes. Feng et al. (2004) setup a pair-wise design and find that KMS-adopting firms significantly reduce administrative costs, improve productivity and gain competitive advantage over their non-adopting peers, especially in the second year after implementing the knowledge management system. In a similar study, Feng and Chen (2007) report that KMS adoption pays off in profitability, particularly in manufacturing firms.

2.4. Innovation Effects of Enterprise Systems

The literature adopts two opposing views with regard to the innovation contribution of enterprise systems. Enterprise systems can impede but also stimulate innovation. One view deals with the inherent rigidities and complexities of enterprise systems and thus advocates the impeding effects. Enterprise applications can impose structural and procedural constraints, as they bring and install with themselves a set of generic, pre-programmed and fixed or hard-to-customize routines and procedures in the organization, which might fit the information needs, internal structures and specific idiosyncrasies of some organizations but misfit those of others (Kremers and Van Dissel 2000; Soh et al. 2000). In this view, enterprise systems are understood as constraining systems with inherent rigidity, inertia, and resistance to change (Davenport 2000). The tight coupling and cross-departmental integration of, especially organization-wide, enterprise systems make them highly complex, vulnerable to change and difficult to understand/manipulate and thereby hamper innovation (Gattiker and Goodhue 2000; Robey et al. 2002).

The other view focuses on information reach and richness promoted by these systems and therefore acknowledges an enabling role. Enterprise systems are enablers of innovation and change as information and knowledge are essential elements in the innovation processes of the firm (Leonard-Barton 1995). Enterprise systems enhance the access to and flow of timely and accurate information and relevant ideas internally and externally. This accelerates the problem solvings and decision makings involved in any innovation process. Furthermore, enterprise applications have the potential to significantly enhance the knowledge capabilities of the firm through increasing its absorptive capacity[2] (Kim 1998; Sirvardhana and Pawlowski 2007) and providing opportunities to acquire new knowledge[3] (Ko et al. 2005; Lee and Lee 2000; Volkoff et al. 2004).

3. CONCEPTUAL MODEL AND HYPOTHESES

The conceptual model focuses on the post-implementation phase of enterprise systems. Among other researchers, Botta-Genoulaz et al. (2005) and Uwizeyemungu and Raymond (2009) emphasize on post-implementation assessment of ES business value as one of the important directions of future research on enterprise systems. This is essential as previous research reports that long-run benefits of enterprise systems can be completely different from their immediate after-effects (Nicolaou 2004a; Nicolaou and Bhattacharya 2006). In constructing the conceptual model, two notions are relevant: *the facilitating or supportive role of ES* and *the enabling or innovative role of ES*. As far as the first notion is concerned, IT in general and ES in particular can directly support and facilitate the status quo, i.e. current situation, in the firm. This includes increasing the efficiency/productivity of current workflows, automating existing business processes, facilitating present information routines and communication channels, and

[2] The efforts and interactions of organizational members to observe and resolve problems during the implementation and customization of an enterprise system significantly increase the absorptive capacity of the organization.
[3] The business knowledge pre-embedded in the architecture and reference model of the software as well as the expertise of consultants and advisors participating in system installation and maintenance are important sources of new knowledge.

supporting available product portfolios and service offerings of the firm. With regard to the second notion, IT and especially ES can substantially change the status quo and enable new or significantly modified practices, routines, processes, methods, channels, services, and/or products. The enabling role yields new processes, services and/or products and thus indirectly affects firm performance through these innovations. These two notions lead us to construct the model displayed in Figure 1.

INSERT FIGURE 1 ABOUT HERE

As shown in Figure 1, enterprise systems affect firm performance through two different paths. The upper path is the direct path without any intervening element in between. The lower indirect path, though, goes through innovation as the mediating factor. The central component of the model relates to firm-, market-, and country-specific characteristics that moderate the relationships in the model. This means that the effect of enterprise systems on corporate performance can differ from one firm to another, depending on the firm's resources and capabilities (e.g. the skills level or infrastructure of the firm), market and industry conditions (e.g. concentration of the market or knowledge-intensity of the sector), and country characteristics (e.g. the regulatory regime or intellectual property rights of the country). Below, different constructs and relationships in the model are substantiated in more details, leading us to formulate three research hypotheses.

3.1. The Relationship between Enterprise Systems Adoption and Innovativeness[4]

Innovation is a knowledge-intensive organizational process (Adamides and Karacapilidis 2006), where information and knowledge are the key determinants of success (Brown and Eisenhardt 1995). Innovation is a process where creative and knowledgeable people and communities frame problems and then search, select, and combine information to enhance their understanding and resolve the problems (Teece 2001; Von Hippel 1994). In an innovation process, for optimal decision making and problem solving, all the relevant information, ideas, and insights should be considered and all the

[4] The terms "innovativeness" and "innovation" are used interchangeably in the literature as well as this paper.

obstacles and constraints shall be identified from all the relevant (distributed) sources and stakeholders. The required knowledge for the innovation process exists either inside or outside the boundaries of the firm. If the knowledge is available internally, it must become visible to everyone through gathering and codifying it at a central, accessible location; this way, the important information does not remain trapped in isolated minds, documents or applications. If the required knowledge is not available internally, it must be collected, structured, and processed through external sources (such as suppliers, customers, universities, and consultants). In this respect, enterprise systems facilitate information flow and communication among the diverse set of actors and teams involved in an innovation process. They help the corporation be more innovative as they aggregate, organize and integrate data, from internal and external sources, and process it into useful information (Richards and Jones 2008). Even more, they support transformation of information into organizational knowledge (O'Leary 2000).

The adoption of enterprise systems does not only come with benefits but also at certain costs. The hindering effects of enterprise software with respect to innovation can be summarized into two groups: (1) the inherent rigidity and inflexibility of enterprise systems due to their built-in business process models, which might not suit every single organization (Davenport 2000; Soh et al. 2000) and (2) the difficult task of customizing these systems due to their high level of integration and complexity, which impedes their users' understanding, learning and change capability (Robey et al. 2002; Rettig 2007).

The benefits can be expected to outweigh the costs in the long run as a firm uses its enterprise application for a lengthy enough period of time.[5] In fact, we expect to face a *system lifecycle effect* as the main obstacles are primarily experienced during the implementation and early post-implementation (or shakedown) of the enterprise system, lasting for as long as 2-3 years (or, in some instances, more) (Hitt et al. 2002; Hunton et al. 2003; Liu et al. 2008; Markus et al. 2000; Poston and Grabski 2001; Rajagopal 2002). Afterwards, we expect that the positive effects become dominant. By the time we

[5] The existing research indicates that for an average ES application this time period is about two years (Hendricks et al. 2007; Mabert et al. 2000; McAfee, 1999; Nicolaou 2004a; O'Leary, 2000; Umble and Umble, 2002).

reach the so-called post-implementation phase of enterprise applications, the firm should have learned from its own or others' history and be more comfortable using and adapting the software to its own specific needs and thereby more benefits are likely after additional experience with the system (Scott and Vessey 2000; Shang and Seddon 2000); employees should have received the required trainings/incentives and have accepted and institutionalized the system as an inevitable part of their routine day-to-day business activities (Peterson et al. 2001); software flaws should have been adequately detected and removed and cross-functional coordination/integration has been probably realized (Nicolaou 2004a). In this respect, the recent empirical research shows that the performance contribution of ES implementations improves once time since adoption increases (e.g. Krasnikov et al. 2009; Wieder et al. 2006).

The internal, sectoral and national context in which the innovation process happens, consisting of among others workforce quality/education, organizational infrastructure, knowledge-intensity of the sector, and the national innovation system of the country, are also important elements in determining and shaping the outcomes of innovation (Damanpour 1991; Scott and Bruce 1994; Subramanian and Nilakanta 1996). The above discussion leads us to hypothesize that:

Hypothesis 1: The continued adoption of enterprise systems enhances innovativeness of the firm as measured by product and process innovation, controlling for contextual factors.

3.2. The Relationship between Innovation and Firm Performance

The link between innovation and firm performance has been the subject of some past studies (e.g. Koellinger 2008). Product innovation corresponds to the generation of a new production function (Beath et al. 1987). If demand for the new product exists in the market, sales can be expected to increase. Even if the new product substitutes an existing product of the firm, premium prices can be charged and sales growth is achievable, providing the new product is substantially differentiated from the existing offerings of the firm (Shaked and Sutton 1982). The above mechanism is conceivable for both physical goods and intangible services. Process innovation corresponds to the outward shift of an existing production function (Dasgupta and Stiglitz 1980). This can be translated to productivity increase (Ghosal and Nair-Reichert 2009) as more output can be generated using the same amount of inputs or the same amount of output with less inputs. This productivity gain can be captured in lower production costs of the process output(s). The resulting cost saving can be further transformed to lower prices. Assuming that the price elasticity of buyers is high enough to substantially react to the price difference, ceteris paribus, process innovation can lead to more revenues for the firm.

Although economic theory predicts that innovating firms will experience output growth and are more likely to survive in the market (Audretsch 1995), the ability of the firm to appropriate above-normal profits from its innovative sales and increase its market share is contingent on several, mostly external, contextual factors (Geroski et al. 1993; Levin et al. 1987; Stoneman and Kwon 1996). The firm is able to outperform its competitors and capture private rents until the moment that the innovation becomes technologically obsolete as the taste of buyers or market standards change over time or the (direct or indirect) competition copies the innovation (and its associated complementary assets) or introduces a better, cheaper or more novel product to the market (Teece 1986; 2006). Therefore, to sustain the payoffs, the innovator should put its effort to prohibit any sort of imitation or technology transfer. This is the appropriability problem (Geroski 1995) and depends on a number of factors. Some factors are internal to the firm such as its strategy towards forming strategic alliances with rivals, adopting diverse protective mechanisms (e.g. patenting, secrecy, and complementary service bundling) or timing of innovation, i.e. first-mover advantages (Harabi 1994). Other factors are exogenous and normally beyond the control of the firm (Melville et al. 2004) and include market concentration, type of rivalry, knowledge intensity of the industry, rate of obsolescence of the technology, intellectual property rights and regulatory regime of the country (see Roberts 1999 and relevant references therein). To capture the above effects, the conceptual model incorporates contextual characteristics as moderators of the links among ES adoption, innovation and firm performance.

The discussion in section 3.1 and 3.2 brings us to the following hypothesis:

Hypothesis 2: The continued adoption of enterprise systems enhances performance of the firm as measured by revenue growth, productivity growth, market share growth, and profitability via product and process innovation, controlling for contextual factors.

3.3. The Direct Relationship between Enterprise Systems Adoption and Firm Performance

The direct effects of enterprise systems on firm performance are observable when they facilitate or support current processes, routines, work policies and product/service offerings of the firm to make them more efficient, without promoting radically new ways of doing or coordinating things or introducing fundamentally new products or services. For example, an ERP system results in administrative and operational saving by eliminating manual, repetitive tasks of data entry and reporting (e.g. Davenport 2000; Gupta and Kohli 2006). This can be translated to lower variable costs of production and thereafter to lower prices and hence higher sales if demand is price-elastic. Similarly, a SCM application leads to lower inventory levels and order processing times (Liu et al. 2005; Lummus and Vokurka 1999) which can again manifest in the form of lower production costs and higher revenues. KMS and DMS software result in internal efficiencies through facilitating knowledge sharing and document searching (King and Marks Jr. 2008) and thus promote productivity and growth.[6]

Contextual factors play an important role in moderating the direct link between ES adoption and firm performance as well. Internal efficiencies after installing an enterprise system are made ineffective in terms of price-cutting and growth promotion if other competing firms in the marketplace replicate these

[6] These systems might result in some inefficiencies in the short run, as employees ought to spend some of their productive time to codify their otherwise tacit knowledge and keep the software updated. However, in the long run, collective productivity gains will be observed due to higher and faster accessibility of knowledge and information throughout the organization.

efficiencies through installing similar systems or adopting feasible alternatives. The discussion here leads to:

Hypothesis 3: The continued adoption of enterprise systems enhances performance of the firm as measured by revenue growth, productivity growth, market share growth, and profitability directly (by improving the efficiency of current practices and policies), controlling for contextual factors.

4. DATA AND DESCRIPTIVE STATISTICS

4.1. Data

The data in this study originates from the *Decision-maker Surveys* in years 2003, 2005, 2006, and 2007 (two surveys), executed by e-Business Market W@tch and sponsored by the Enterprise and Industry Directorate General of the European Commission. The objective of e-Business Market W@tch is to monitor the adoption and asses the impact of IT and e-Business practices in Europe by providing scientifically reliable, methodologically consistent, and internationally comparative empirical data of European enterprises in diverse sectors. For comparison purposes, the 2007 surveys are extended with a considerable number of US establishments. The surveys are conducted at the enterprise-level[7], from random, representative samples of the respective industry sector populations in each country. The surveys use a mix of CATI (computer-assisted telephone interview) method and face-to-face interviews. The target decision-maker in the enterprise is normally the person responsible for IT within the company, typically the IT manager or chief technology/information officer. Alternatively, in small enterprises without a separate IT unit, the managing director or the owner is interviewed.[8]

The 2003 survey includes 10315 enterprises in 25 countries and 22 sectors[9], the 2005 survey 5218 enterprises in 7 countries and 14 sectors, and the 2006 survey 14065 enterprises in 29 countries and 12 sectors. The 2007 survey was conducted in four separate sub-projects, two of which are relevant to this

[7] Defined as a business organization of one or more establishments that is comprised as one legal unit.
[8] Visit: http://www.ebusiness-watch.org/ for further methodological details on e-Business W@tch Decision-maker Surveys.
[9] A sector is defined at 2-digit level (NACE rev. 1.1).

study: Manufacturing (MFG) and Retail, Transport & Logistics (RTL). The MFG survey covers a sum of 1821 enterprises in 8 countries and 5 sectors and the RTL survey 2023 enterprises in again 8 countries but only 4 sectors. If one pools all the datasets, [10] there are in total 33442 enterprises in 29 distinct European countries (EU-27 plus Norway and Turkey) and 29 different sectors (Manufacturing {NACE codes: 15, 17, 18, 19, 20, 21, 22, 24, 25, 17, 29, 30, 31, 32, 34, 35, and 36}; Construction {NACE code 45}; Services {NACE codes: 50, 52, 55, 60, 62, 63, 64, 72, 74, 85, and 92}). Before constructing the pooled dataset, the individual annual surveys were carefully cleaned and checked for internal consistency. That means that all the logical or systematic inconsistencies as well as entry or typo errors were detected (by means of computer programs) and manually removed from the dataset after carefully observing the survey responses one by one. Table 1 shows the distribution of enterprise observations in each sector-country group in the pooled version of the dataset.[11]

INSERT TABLE 1 ABOUT HERE

We deal with 448 unique markets (sector-country pairs) with an average of 75 firms in each group. Large countries of Europe represented in the sample, namely Germany, France, United Kingdom, Italy, Spain, and Poland comprise more than half of the observations. The remaining countries constitute between 0.34% (Cyprus) and 5.30% (Czech Republic) of the sample. The manufacturing sector, covering almost all the important low- and high-tech industries, amounts to 48% of the sample. The services sector, making up 41% of the sample, covers almost all the important service industries except for banking, insurance/pension and financial intermediation (NACE 65-67). The construction sector represents the remaining 11% of the sample.

[10] Since enterprise unique identifiers are not available, constructing a panel data through linking the datasets is not possible; a pooled dataset is the only viable option for conducting a longitudinal analysis at the firm-level to benefit from the time dimension of the data.

[11] Due to space constraints, only the pooled version of the data and its descriptive statistics are presented; descriptives of the individual datasets are available upon request.

To asses the representativeness of the sample, we compared the sample characteristics with those of the National Accounts data for the available countries.[12] Two criteria were considered important: (1) the relative distribution of different sectors (in terms of the number of enterprises) in the surveyed countries, and (2) the relative distribution of different enterprise size classes in the sampled sectors. The comparisons corroborate the idea that the sample can be assumed to be a good representation of the underlying population in the respective countries, though, for those sectors of the economy which are relatively heavier and more advanced users of IT and e-Business.[13]

4.2. Descriptive Statistics

Table 2 gives the descriptive statistics of the relevant variables.

INSERT TABLE 2 ABOUT HERE

Forty-four percent of the firms in the sample have introduced at least an innovative product or service to the market in the annual period they were surveyed, while less than 40% of them have had an internal process innovation in the same period. About half of the firms have experienced sales growth when comparing the financial year prior to the survey with the year before. More than half of them have experienced productivity increase while less than 45% have had market share growth in their primary market(s). More than 83% of the sampled firms have been profitable in the past year (with reference to when they were surveyed).[14] These promising performance indicators partly reflect the expansionary, upgoing business cycle in the period of analysis (2003-2007).

[12] The control data is supplied by Eurostat (available at: http://epp.eurostat.ec.europa.eu/portal/page/portal; last access: 11 Sep. 2009). The correlation tables and accompanying tests are not presented due to space constraints but accessible upon request.
[13] The Financial sector is an exception, whereas it is an intensive user of IT but non-represented in our sample due to the decision of e-Business W@tch to cover it in another separate survey. Our sample is also not a good representation of Agriculture/Forestry, Fishery, Mining, Energy, and Public supplies with relatively low levels of IT usage. Moreover, among the different size classes, large enterprises (with more than 249 employees) are slightly under-represented in the sample.
[14] As expected, the output measures are not independent. The Pearson correlation coefficients reveal the highest correlations among the growth indicators: revenue growth and productivity growth (0.61) and revenue growth and market share growth (0.56). The lowest correlations exist between innovation measures and profitability: process innovation and profitability (0.05) and product innovation and profitability (0.07). The complete correlation table is accessible on request.

The average firm in the sample has about 134 employees, of which about a quarter has at least a college or university degree and about one-tenth is primarily engaged in R&D activities. The standard deviation of these variables indicates a rather large spread of their values around their mean and thereby high heterogeneity among the sampled firms in these respects. Eighteen percent of the sampled companies actively compete in international markets; sixty-nine and twenty-nine percent belong to Western and Eastern Europe respectively.[15] Around 18% of the firms have a market share of up to 5% and 23% a market share of more than 25% with the rest lying somewhere in between. When it comes to IT infrastructure, 71% of the enterprises have access to some sort of broadband internet with an average of 30% (i.e. less than one-third) of their employees connected to high-speed internet at their workplace. The standard deviation of this variable confirms that it is wide-ranging around its average point among the surveyed companies. Overall, 19% of the sampled firms are mature in adopting e-Business technologies or conducting e-Business processes, which shows that there is plenty of room for improvements in this area in Europe.

With respect to the variables of main interest, i.e. enterprise systems, two-fifth of the sampled enterprises is using at least one type of ES software by 2007. ERP and DMS are the most commonly used applications, with an average adoption rate of 1 out of 5 enterprises, followed by CRM, KMS, and SCM; this can be partly explained by the fact that ERP usually acts as a common platform for installing CRM and SCM applications and that many companies prefer a less complex system of information management like DMS to a sophisticated one like KMS. [16] Moreover, CRM, KMS, and SCM systems are relatively new compared to ERP and DMS.

[15] Cyprus, Malta, and Turkey were not classified in either Western or Eastern Europe.
[16] In our sample, about half of the firms with a CRM or SCM system also have an ERP installed. About half of the firms which decided to implement an information management system have only opted for DMS while only less than 30% of them have gone for KMS.

The average IT budget (incorporating hardware, software, services and personnel) as percentage of the company total costs and turnover is 7.78% and 1.51% respectively.[17] The available macro data (Eurostat 2009) indicates a comparable trend of IT expenditure (as percentage of GDP) in most of the sampled countries, although the average for the whole European Union (EU-27) for the sub-period 2004-2006 is higher, i.e. 2.70%. The average share of IT practitioners (responsible for implementation and maintenance of IT infrastructure and computer networks) as a percentage of corporate employees (in absolute terms) is 8.85%. An important notion is that the surveyed firms in our sample, on average, are using ERP, SCM, CRM, and KMS systems in their daily business for 66, 48, 42, and 44 months respectively, by the time they were questioned.[18,19] Comparing these numbers with the available observations in the literature, which imply an average of 17-21 months for full installation and a comparable or shorter period for optimization of ES applications (Hendricks et al. 2007; Mabert et al. 2000; McAfee 1999; O'Leary 2000; Umble and Umble 2002), indicates that the average firm in our sample has already passed the implementation, customization and adaption phases of enterprise systems and is likely in a diffusion, routinization or institutionalization stage where it is capable of utilizing the installed applications effectively and productively (Rajagopal 2002).

Finally, the comparison of ES adoption rates over time and in different enterprise size classes and industrial sectors in Europe yields interesting results. Figure 2 shows an overall growing trend of ES adoption in Europe in the period 2003-2007. The most considerable growth for all the ES types under consideration is seen from year 2003 to 2005. From 2005 to 2007, the ES market in Europe seems to be more stable. Over this period, ERP adoption has hardly experienced any growth, while SCM and CRM utilization have grown modestly.

[17] The budgetary data is not presented in Table 2 as this information is not available for the whole period of analysis but only for some years of the survey.
[18] Taking into account the adoption frequency of different enterprise systems in the sample, these figures can be translated into a weighted average of more than 52 months (or about 4.5 years) as an overall ES maturity indicator.
[19] The medians are 54, 38, 30, and 35 months and the percentiles with less than one year of adoption are 7%, 13%, 15%, and 14% for ERP, SCM, CRM and KMS respectively. The minimum of adoption duration for all the ES categories is one month and the maximum more than 167 months.

INSERT FIGURE 2 ABOUT HERE

Figure 3 clearly indicates that large enterprises (with more than 249 employees) use ES software of any type significantly more than their medium and small counterparts.[20] This can be partly attributed to availability of investment capital and other organizational resources, which are necessary for implementing and maintaining these systems, in large corporations. Moreover, ES applications typically imply substantial organizational changes and governance implications, which make them impractical or unjustified for rather smaller organizations with lower levels of structural complexity and information need.

INSERT FIGURE 3 ABOUT HERE

Figure 4 shows that the construction sector (with a relatively lower degree of technology adoption, innovation, and skilled labor) generally adopts enterprise systems less than the manufacturing and services sectors. Between the manufacturing and services, ERP and SCM are more common to manufacturing firms while CRM, KMS and DMS to services companies. This can be explained by the nature of core business functions, internal processes and final products of these two broad sector categories. In the manufacturing, the core activities of the corporate value chain include procurement, inbound logistics, and operations to transform the physical inputs into finished goods (Porter 1985). In the services, supply chain management, materials handling and physical operations are of a lesser significance, while marketing/sales, after-sales services, and customer relationships are more important due to the more intangible character of the final products. Furthermore, services firms are usually more knowledge-intensive than their manufacturing counterparts.

INSERT FIGURE 4 ABOUT HERE

5. ECONOMETRIC MODEL, OPERATIONALIZATION AND REGRESSION METHOD

[20] One-way ANOVA was used to test the significance of the differences. The test results are available on request.

5.1. Model Specifications

The following general logistic model is used to relate enterprise systems adoption to firm-level innovativeness.

$$\ln\left[\frac{p(Innovation_{i,j}=1)}{1-p(Innovation_{i,j}=1)}\right]=\alpha_0+\bar{\alpha}_1\overline{ES}_{i,j}+\alpha_2 Size_{i,j}+\alpha_3 Education_{i,j}+\alpha_4 Internet_{i,j}+\alpha_5 eBusiness_{i,j}+$$
$$\sum Market_{i,j}+\sum Time_{i,j}+u_j+\varepsilon_{i,j} \qquad (1)$$

where *i* and *j* refer to the firm and the market in which the firm operates respectively and u_j and $\varepsilon_{i,j}$ specify unobserved market- and firm-specific effects.

A similar estimating equation is used to model the total (including both the direct and indirect) effects of enterprise systems adoption on firm performance.

$$\ln\left[\frac{p(Performance_{i,j}=1)}{1-p(Performance_{i,j}=1)}\right]=\beta_0+\bar{\beta}_1\overline{ES}_{i,j}+\beta_2 Size_{i,j}+\beta_3 Education_{i,j}+\beta_4 Internet_{i,j}+\beta_5 eBusiness_{i,j}+$$
$$\sum Market_{i,j}+\sum Time_{i,j}+u_j+\varepsilon_{i,j} \qquad (2)$$

The dependent variable in the above estimation models is the log odds of a measure of innovativeness or performance. We distinguish between two innovation types: product innovation and process innovation. We also deal with four performance indicators: revenue growth, productivity growth, market share growth, and profitability. These are among the key measures of firm performance as recommended by, among others, Chand et al. (2005) and March and Sutton (1997).

In this study, we differentiate between the direct (or facilitating) and indirect (or enabling) effects of enterprise systems on firm performance. Innovation is predicted to act as a mediator in transmitting the indirect effects. Robust and systematic identification of indirect effects, especially when the mediation factor is dichotomous, presents conceptual and practical difficulties in nonlinear models such as logit (Li et. al 2007; MacKinnon 2007; Van der Laan and Petersen 2004). Among the available path-analytic methods, we employ the following 3-step approach to yield easy-to-interpret results (Baron and Kenny 1986; Cohen et al. 2003; Hair et al. 2006: 867-868):

1. First, model (2) above is used to estimate the total (i.e. the qualitative sum of the direct and indirect) effect of enterprise systems on firm performance. [21]

2. We then develop model (3) below where two innovation dummies are included as additional predictors of firm performance. This model extracts and only estimates the direct effect of enterprise systems on firm performance.

$$\ln\left[\frac{p(Performance_{i,j}=1)}{1-p(Performance_{i,j}=1)}\right]=\gamma_0+\bar{\gamma}_1\overline{ES}_{i,j}+\bar{\gamma}_2\overline{Innovation}_{i,j}+\gamma_3 Size_{i,j}+\gamma_4 Education_{i,j}+\gamma_5 Internet_{i,j}+\gamma_6 eBusiness_{i,j}+ \sum Market_{i,j}+\sum Time_{i,j}+u_j+\varepsilon_{i,j} \quad (3)$$

3. At last, we compare the estimation results of model (2) and (3). If the relationship between ES adoption and firm performance remains significant and unchanged once innovation is included in the model, then mediation (and, consequently, the indirect effect) is not supported. If the relationship reduces but still remains significant, then *partial mediation* is supported. If the relationship is reduced to a point where it is not significant anymore, then *full mediation* is verified.

5.2. Construction of Variables

Table 3 summarizes the output measures in models (1)-(3) and their definitions. These dichotomous variables take a value of 1 if the firm exhibits a certain characteristic and 0 otherwise. In other words, if the corresponding response is "yes" or indicates a positive change (i.e. "increased") the measure is coded 1 and 0 otherwise. "Don't Know [DK]", "Refused to Say", and "Not Applicable [NA]" responses are recoded as missing.

INSERT TABLE 3 ABOUT HERE

[21] A simple arithmetic summation does not give a precise estimate as we work with log-linear models.

The qualitative output measures used in this research have two advantages. The first one is that they provide information on the changes and dynamics of the performance measures. Information on the (absolute) level of turnover, productivity, market share, or profit of the firm per se would not reveal insights about the comparative performance improvements (due to ES adoption) as tracking these levels over time is not possible in a pooled dataset. Second, in contrast to common input-based indicators, such as R&D intensity, or indirect, output-oriented measures (such as patent counts), the qualitative innovation measures employed in this study imply explicit, actual innovative output of the firm rather than an innovation-related activity (which may or may not finally lead to an innovative output).

The set of explanatory variables in models (1)-(3) consists of both the ES adoption variables and the observed control variables. Table 4 summarizes the relevant covariates and describes their source question(s) in the survey.

INSERT TABLE 4 ABOUT HERE

$\overline{ES}_{i,j}$ is a vector of system variables that takes two versions.[22] The basic specification only includes a dummy variable tracking if the firm uses enterprise systems (of any type). The comprehensive specification extends this overall indicator into a set of five dummies referring to ERP, SCM, CRM, KMS and DMS adoption separately. We include the natural log number of employees ($Size_{i,j}$) to control for size and hence economies-of-scale effects. Larger firms are more likely to have introduced innovations due to higher availability of financial and knowledge resources. The logarithmic form is used to reduce the effect of skewness, as the number of employees is right-skewed. Percentage of higher-educated employees ($Education_{i,j}$) is a measure of general skills- and knowledge-level, or shortly, professionalism of the workforce, which matters to both innovation and business performance

[22] For the sake of robustness check, we ran four versions of each model. Two versions (with a single dummy or dummies for all application types) are presented in this paper. The other two models (with dummies for only organization-wide or domain-specific systems) yielded comparable results in terms of the sign and significance of the estimates.

of the firm (Damanpour 1991; Scott and Bruce 1994; Subramanian and Nilakanta 1996). Investments in IT, in general, and ES software, in particular, are associated with the availability as well as the share of labor that is highly educated and skilled (Brynjolfsson and Hitt 2002; Chun 2003). Bartel and Lichtenberg (1987) also argue that better educated workers have a comparative advantage in learning-to-use, implementing and using new technologies and innovating as they assimilate and transform new ideas and perspectives more readily. As a result, exclusion of this variable from the model would result in an upward bias in estimating the ES effects.

IT infrastructure is the next influential factor. High internet penetration and strong IT infrastructure in the workplace lead many companies to rethink their business practices and encourage them to utilize e-Business applications (Mendelson 1999; Zhu 2004). Among infrastructure variables, broadband internet connectivity enhances innovation (Van Leeuwen et al. 2009). Internet-enabled employees are also more productive, ceteris paribus, as (fast) internet allows them to promptly obtain and share information through internal and external sources (SCB 2008). Moreover, the broadband intensity of the firm is considered as a good predictor of how advanced its IT infrastructure and how large its IT capital stock is (Eurostat 2008). To capture the effect, we use $Internet_{i,j}$ as a dummy variable to indicate if the firm uses any type of broadband internet. Finally, it is questionable to compare the effect of ES adoption on firm performance in firms with divergent degrees of engagement in (or reliance on) e-Business. We therefore use $eBusiness_{i,j}$ as a binary variable to distinguish firms with a significant part of their business processes being conducted electronically from those with only minor or none involvement in e-Business. If ES adoption is associated with more e-Business use in general and e-Business adoption affects firm performance positively, then omitting this explanatory variable would result in upward-biased estimates of the ES variables.

In models (1)-(3), we also control for market effects through market share measures. Firms enjoying large market shares have more market power, benefit from premium prices and private profits (for instance, through monopolistic behavior), have access to more funds and protective mechanisms, and are more likely to engage in innovative activities (e.g. Blundell et al. 1999). Thereby, we include a set of four dummies for different market share classes, as explained in Table 4. Lastly, we correct for economy-wide transitory shocks to performance by including a dummy variable for each survey year.[23]

5.3. Regression Method: Conditional Fixed-effects Logit

We employ conditional fixed-effects logit for qualitative outcomes to estimate the models explained earlier (Chamberlain 1980). This method is required to generate consistent results, taking into account the nature of our data. Correction is needed for unobserved heterogeneity including firm-, sector-, and country-specific effects in order to attain unbiased estimates. Firm-specific effects (and omitted-variables bias) are controlled for as far as relevant firm-level regressors are included in the model. Further control is not feasible as repeated firm observations cannot be identified in our dataset. However, sector- and country-specific effects can be better accounted for since repeated observations over different sectors and countries can be well traced in the dataset. The economic and regulatory conditions of each industry sector differ from one country to another. Besides, the economic and structural conditions of different sectors within a single country vary greatly. However, the conditions of one sector in a single country can be assumed to be reasonably comparable for all firms operating in that sector and rather stable over time. Therefore, a sector-country group or market is the preferred economic unit for eliminating exogenous fixed effects.

[23] We also ran regressions with a number of additional explanatory variables to check for the sensitivity of the results with respect to alternative specifications and to increase the overall fit of the model. In one version, we included "the share of employees directly engaging in research and development activities" as an extra quality measure of the corporate human capital. In another attempt, we replaced $Internet_{i,j}$ with "the share of employees with broadband internet access at their workplace" as an alternative, continuous indicator of fast internet connectivity. Finally, we estimated the models with an additional market-related control that indicates if the firm competes in international markets or not. Including additional explanatory variables did not improve the overall fit of the model significantly. In all the cases, comparable results were gained in terms of the sign and significance of all the estimates. Due to smaller sample size of these variations (caused by more missing values) and thereby reduced representativeness of the estimation sample, we decided to stick to the basic specification with the original set of independent variables explained in the text. Non-reported results are accessible upon request.

We opt for modeling the relationship between observable characteristics and performance outcomes of the firm in an error component model with separate controls for firm- and market-specific effects, i.e. models (1)-(3). We further opt for using a conditional variation of logit for estimating the effects of interest. Our choice of specification model and regression method is based on three reasons. First, maximization of the fixed-effects likelihood function can generate inconsistent estimations if there is a considerable large number of matched case-control groups with a rather small number of observations per group relative to the sample size (Chamberlain 1980). Second, contrary to an unconditional fixed-effects model (with only firm-specific but not market-specific effects), the error components in model (1)-(3) relax the assumptions that market effects are independent of observed and unobserved firm effects (i.e. $E\left[u_j \mid \bar{x}_{i,j}\right] \neq 0$ and $E\left[u_j \mid \varepsilon_{i,j}\right] \neq 0$). These assumptions are generally unrealistic, as market and country characteristics have certain effects on formation, development and decline of firms as well as their characteristics that are shaped over time (e.g. Dunne et al. 1988; 1989). Third, adding separate industry and country dummies into the regression model (i.e. DV method) is not the preferred approach to control for sector- and country-specific heterogeneity as: (1) the DV method implies that a sector, although different from other sectors, is identical in all countries, while sectors expose diverse structural and economic characteristics in different countries; and (2) this method would confound sampling and real effects, due to the heterogeneous coverage of industries among the sampled countries (Koellinger 2008).[24]

6. REGRESSION RESULTS AND DISCUSSION

6.1. The Impact of Enterprise Systems Adoption on Firm Innovativeness

Table 5 reports the regression results for model (1) (see arrow 1 in Figure 1).

INSERT TABLE 5 ABOUT HERE

[24] We observe data for a number of industry sectors in different countries but it is not necessarily the case that all sectors are covered in each country. See Table 1 for the distribution of markets in our sample.

As shown in Table 5, the adoption of enterprise systems increases the likelihood of being product and process innovator by 77.6% and 102.5% respectively.[25] The impact of enterprise applications on process innovation is stronger as ES adoption entails various process changes in the organization and provides vast process information that can be later used for process innovation. All five types of ES software under assessment are significantly and positively associated with product and process innovation. Comparatively, CRM exhibits the largest impact on both types of corporate innovation, followed by KMS for product and SCM for process innovation. This is inline with the argument that more specialized systems, especially the external ones, are more difficult to implement but once implemented properly are more effective (Aral et al. 2006; Shin 2006). Moreover, this highlights the very crucial role of customers (as lead users) in innovation processes of the firm as emphasized by Von Hippel (1988; 2005). On the basis of the findings, we can not reject *Hypothesis 1* for any of the ES types we studied.

The results also suggest that larger firms have more access to the required resources and expertise to innovative and thus are more likely to be (product and process) innovator. A one-percent increase in the number of employees results in 13.5% and 21.6% increase in the odds of being product and process innovator respectively. A one-percentage point increase in the share of employees with a university degree leads to 0.4% to 0.7% growth in the odds of being innovator as well. As expected, broadband connectivity (as a major component of the firm IT infrastructure) and e-Business maturity do matter for innovation.

6.2. The Overall Impact of Enterprise Systems Adoption on Firm Performance

The dependent variable in model (2) is the log odds of experiencing revenue, productivity or market share growth or being profitable. Table 6 reports the estimation results.

[25] For all the regressions, we also calculated the Average Marginal Effects in addition to Odds Ratios. Because the results are perfectly comparable and yield similar conclusions, we stick to the more common representation, i.e. the Odds Ratio.

INSERT TABLE 6 ABOUT HERE

Ceteris paribus, adopting enterprise systems goes together with more sales, productivity, and market share but not with profitability. Distinguishing between different types of ES applications, CRM has the largest total impact on revenues and productivity and KMS on market share. CRM-adopting enterprises are 28.8 and 22.4 percent more likely than their non-adopting peers to show revenue and productivity growth respectively. This finding strongly corroborates the positive evidence provided by numerous researchers in the field, although it contradicts with a number of previous studies (Hendricks et al. 2007; Karakostas et al. 2005) which report insignificant contribution of CRM systems to firm performance. CRM software are showed to play an important role in effectively contacting/targeting customers, gathering data on their ideas and needs, and providing them with accustomed after-sales services (Ahearne et al. 2007; Bligh and Turk 2004). A customer-centric shift in the company culture and structure leads to better brand recognition and customer acquisition, satisfaction and retention and thus more sales (and productivity) (Karakostas et al. 2005; Mithas et al. 2005). Furthermore, CRM compared to a system like ERP is more domain-specific (as it affects a smaller part of the enterprise) and less complex and thus its installation as well as customization is easier, faster and more likely to be successful (Rettig 2007).

The likelihood of market share growth, ceteris paribus, is 34.2% and 19.5% higher for KMS-and DMS-adopters. This finding endorses previous studies that report the competitive advantage of KMS-adopters over their non-adopting peers (e.g. Feng and Chen 2007) and highlights the important role of organizational learning and knowledge management in the contemporary firm (Al-mashari et al. 2002). It also supports the idea that knowledge-oriented systems are more important to market share of the firm than process-oriented systems.[26] The strong influence of knowledge-oriented systems on market

[26] In this respect, ERP, SCM and CRM can be considered as *process-oriented systems*, as they affect and integrate business processes of an organization in the first place. KMS and DMS can be understood as *knowledge-oriented systems*, as they affect and integrate knowledge assets of an organization above all.

share can also be explained by the fact that these systems, in the long-term, create additional added value and demand for customers through substantial product/service quality improvements and customer satisfaction (e.g. Ofek and Sarvary 2001).

In addition to CRM and KMS, ERP and DMS also exhibit significant positive impact on revenue growth. Except for ERP, all the ES applications studied significantly improve productivity and market share of the firm. Some surprising findings are that SCM and KMS do not significantly enhance the likelihood of revenue growth (regression 6). The effect of ERP adoption on productivity and market share growth is also insignificant (regression 8 and 10). Sales and productivity are respectively influenced by ERP and SCM systems at only 10% significance level (regression 6 and 8). This suggests that European enterprises have not managed to effectively utilize their ERP, SCM and to some extent KMS investments, which can be attributed to more sophisticated and extensive nature of these systems compared to simpler and smaller counterparts such as CRM and DMS. Organization-wide systems involve and affect a larger number of parties/domains inside or outside the organization and thus entail more organizational changes after implementation. On the contrary, domain-specific applications require lower degrees of cross-functional integration and process standardization and create/modify fewer inter-departmental dependencies and therefore are more likely to be implemented successfully and become fruitful (at least in the short- or medium-term after adoption). Recent market research upholds this argument as well (Gartner 2009a; 2009b).[27]

Another surprising finding relates to the ambiguous relationship between enterprise systems adoption and profitability. Adopting an enterprise system per se does not make the firm more likely to be in the group of profitable firms (regression 11). A closer look reveals that, everything else held constant, ERP adoption might be disadvantageous for firm profitability while other system types are not related to profitability at all; ERP-adopters are 22.9% less likely to be profitable (regression 12). This finding

[27] Gartner reports that the CRM applications generating the most interest in 2009 are often implemented as discrete, departmental and channel-specific projects, rather than as part of a larger transformation program of the whole organization.

substantiates a number of past studies (Poston and Grabski 2001; Wieder et al. 2006). Two possible explanations for these non-positive results can be put forward. First, due to their complex and expansive nature, enterprise systems might require a much larger investment time-lag (than the average time span of 52 months observable in our sample) after full implementation in order to be properly embedded in the organization. Only after this time-lag, they might reveal substantial benefits that cancel out the huge initial investment costs (and hence result in a net positive effect). Second, in contrast to a common expectation, on average, the main stakeholders of ES projects (i.e. software vendors, consultants, and the adopting organizations), after about two decades, have not yet seemingly reached a high level of maturity and expertise in implementing enterprise systems, adapting them to a particular organization, reengineering the necessary business processes, and utilizing these systems effectively. In this case, the very complex and intertwined nature of enterprise systems might hinder understanding, learning-to-use and modifying them by the management and employees to readily fit them to the profit-making objectives of the firm (see e.g. Rettig 2007).[28, 29]

With respect to control variables, larger firms tend to be more likely to exhibit increasing turnover and productivity, growth in their market and profitability (due to economy-of-scale effect and price setting power). The share of higher-educated employees is positively related to higher odds of revenue, productivity and market share growth but not (short-term) profitability. Access to high-speed internet and advance in e-Business practices increase the probability of the enterprise to be in the group of firms experiencing revenue, productivity, or market share improvement. This can be attributed to the fact that broadband-enabled employees tend to be more productive and IT-induced processes to be more efficient (Eurostat 2008; SCB 2008). The positive effects of infrastructure interconnectivity and e-

[28] This suggests a shallow *learning curve* of progress in the mastery of enterprise systems.

[29] From a contingency theory perspective, two more explanations are conceivable as well. First, the required critical success factors for ES implementations might have been absent or not advanced enough in our sampled firms. Failing to provide these factors in the right time would generate suboptimal returns. Second, the average firm in the sample might have failed to effectively protect the strategic advantages of enterprise systems from being imitated by the competition. The firm is then only able to yield temporary excess returns at best, lasting as long as replication occurs.

Business maturity on firm profitability are weaker. Still, firms with high-speed internet access at their workplace and those with a significant part of their processes conducted electronically (i.e. mature in e-Business adoption) are 15.7 and 28.9 percent more likely to be profitable.

6.3. The Direct versus Indirect Impact of Enterprise Systems Adoption on Firm Performance

Model (3) is used to disentangle the direct and indirect effects of enterprise systems adoption on firm performance (compare arrow 2 and 3 in Figure 1). Table 7 reports the estimation results.

INSERT TABLE 7 ABOUT HERE

Product and process innovation lead to higher performance. [30] Being innovative boosts the chance of being a better performer irrespective of the performance measure considered. Being innovative goes together with higher possibility of a positive profit as well by 21.1% to 22.2%. When comparing the results in Table 7 with those in Table 6, the most interesting finding is that the estimates of almost all ES variables lose their significance when innovation is explicitly included in the model. This means that innovation variables pick up almost all the effects of ES variables on firm performance. The two exceptions here are the effects of CRM on revenue growth and KMS on market share growth, which preserve their significance (regression 13 and 15); even in these cases, the effects are diminished. Adoption of a CRM or KMS system increases the probability of turnover or market share growth by 28.8% or 34.2% respectively, which are reduced to 16.3% and 27.0% when only the direct impact of these systems is considered.[31]The findings in Table 6 and 7 indicate that *Hypothesis 2* can not be rejected for most of ES application types and performance measures under investigation, except for profitability. As far as firm profitability is concerned, *Hypothesis 2* is rejected for all ES categories

[30] Comparatively, product innovation is more important than process innovation to revenue and market share growth, while process innovation is more influential to productivity growth. The effect on profitability is comparable for both product and process innovation.
[31] Running the Wald Test in a simultaneous Seemingly Unrelated Regression (SUR) model also confirms that the ES estimates in model (2) and (3) differ significantly (at 1%). The test results are available upon request.

even at 10% significance level. Furthermore, our observations lead us to reject *Hypothesis 3* for almost all ES types and performance measures studied, except for the two incidents noted above.

Following the 3-step approach explained earlier in section 5.1, we conclude that innovation plays the role of a *full mediation* factor in mediating the positive impact of several types of enterprise systems on firm performance. In some instances, though, the role of innovation is reduced to *partial mediation*. Put it differently, the findings corroborate the idea that the enabling role of enterprise systems represents a very substantial part of their performance impact and that their facilitating role only accounts for a minor (and mainly statistically insignificant) part. This finding perfectly matches the argument put forward by McAfee and Brynjolfsson (2008) that companies make a competitive difference and lead their rivals through investing in IT (and especially ES) if they can use the technology to come up with new and better ways of doing and making things. In their view, innovating with the help of technology is the next critical step and management challenge after deploying technology in order to survive and thrive in the current competitive environment: “Deploy, innovate, and propagate” (McAfee and Brynjolfsson 2008: 103).

CRM and KMS effects on revenue and market share growth are somewhat distinctive when it comes to the extent of mediation through innovation. CRM systems exhibit significant direct effects on corporate sales. This can be attributed to the very important and explicit role of CRM systems to support existing sales and marketing practices of the firm through better targeting/communicating customers and increasing sales force efficiency (e.g. Dong and Zhu 2008; Richards and Jones 2008 and relevant references therein). KMS systems reveal significant direct effects on market share. This highlights the important role of these systems in supporting the knowledge assets of the company and increasing the efficiency of existing knowledge sharing processes (Alavi and Leidner 2001; Ofek and Sarvary 2001). The direct role of information and knowledge in gaining and sustaining competitive advantage (e.g. Ofek and Sarvary 2001; Porter and Millar 1985; Vives 1990) explains the considerable (direct and indirect) impact of KMS systems on market share as well.

6.4. Direction of Causality

Because the data at our disposal is of a cross-sectional character, endogeneity problem (as a result of simultaneity) may arise once modeling the relationship between ES adoption and firm performance.[32] With models (1)-(3), we suggested that causality runs from independent ES variables to dependent performance indicators (and not the other way around). Our inference is based on the following three arguments:

(1) There are a number of theoretical and empirical academic studies that explicitly deal with this causality issue and indeed support the interpretation of causality from ES adoption to firm performance (e.g. Byrd and Marshall 1997; Melville et al. 2004; Pare´ et al. 2008). Especially, Aral et al. (2006) explicitly focus on the causality issue between ES adoption and performance improvements and document strong empirical evidence (and theoretical explanation) for the fact that the use of enterprise systems actually causes performance gains rather than strong performance inspiring or driving the purchase or adoption of enterprise IT systems.

(2) An important assumption of causality is that the cause precedes the effect temporally. This means that the cause must have occurred at an earlier point in time than the effect. A careful look at the survey design and the dependent and main independent variables used in this study reveals that the dependent variables capture a phenomenon (i.e. change in performance or occurrence of innovation) within the past year of the survey while the explanatory ES adoption variables deal with an incident (i.e. adoption of an enterprise system) much further back in time

[32] Cross-sectional techniques for casual inference from observational data (such as traditional matching, potential outcomes, propensity score, and regression discontinuity) have serious data/measurement limitations (Mithas and Krishnan 2009; Winship and Morgan 1999). Working with a panel dataset does not resolve the causality issue per se, but only allows for more options and specific techniques to explicitly test for causality (Winship and Sobel 2004).

(on average between 3.5 and 5.5 years, depending on the system type). The system adoption is then an ongoing course of action prior to observation of the output changes. This built-in time-lag discards the assumption of causality running from firm performance to ES adoption to a great extent.

(3) To partially investigate the reverse causality issue, we conducted two series of tests: MANOVA/ANOVA and 3SLS/2SLS. The results of these tests also support our argument on the direction of causality. We had access to two particular questions in the surveys asking whether or not any of the firm's product or process innovations are directly related to or enabled by IT (and not necessarily ES).[33] The MANOVA test indicates that the adopters of enterprise systems are significantly more likely to jointly exhibit IT-enabled product and process innovations. Similar conclusions are drawn whether individual ES types or a combination of them are used to model the joint variation of the dependent (innovation) variables. The ANOVA tests lead to comparable results when the effects of enterprise systems adoption on IT-enabled innovation are separately considered for product and process innovation. Alternatively, we estimated a simultaneous system where we estimate an additional equation that allows for the systems adoption to depend on output measures, in addition to make the innovation and performance indicators dependent on ES adoption. When we estimate the system of equations by 3SLS or 2SLS, we find that the reverse causality is statistically insignificant (in case of any of the output measures). This means that we could not find any significant impact of our output measures on the decision to adopt enterprise systems; the

[33] These questions are different from those used to construct our innovation measures in this study. They explicitly ask the respondent about IT-enabled innovation while the dependent variables in model (1) are based on questions asking about innovativeness of the firm in general. To increase the validity of our research findings (see Straub 1989; Straub et al. 2004) we did not use these questions to build our outcome variables. However, they can be perfectly used for testing causality as they explicitly establish the direction of causality for the respondent. If deploying enterprise systems boosts the possibility and probability of innovating for the firm, then, ceteris paribus, we expect to find a disproportional share of firms having IT-enabled innovation(s) across subsamples with and without ES adoption. This is exactly what we examine through the MANOVA and ANOVA tests.

inverse relationship was though found to be significant (for all the output measures). Appendix A presents more details on the test results.

7. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

7.1. Conclusions

This paper investigates *whether* and *how* enterprise systems affect innovativeness and performance of the firm. It contributes to the debate on the performance payoff of enterprise systems by providing new evidence (to answer the "what" question) and insights (to answer the "how" question). We use a representative pooled dataset of 33,442 enterprises across 29 European countries (EU-27 plus Norway and Turkey) and 29 sectors (covering all the major non-financial economic activities) over a 5-year period (2003-2007). Six measures of organizational performance (i.e. product and process innovation, revenue, productivity and market share growth and profitability) in a conditional fixed-effects logit model are analyzed.

Four major and two minor conclusions can be drawn based on the research results. First, with regard to the innovation effects, the findings support a significant contribution of ES adoption to product and more strongly to process innovation for all the application types studied. As a consequence, this research can be considered as an attempt to mitigate the argument on the hampering effects of enterprise systems with respect to innovation. Second, as to the performance effects of ES adoption, the analysis reveals that almost all enterprise applications significantly contribute to corporate sales, productivity and market share. However, no ES software is found to be supportive to profitability likelihood of the firm, which makes profit a critical measure of performance that requires special attention when it comes to assessing the business value of enterprise systems. Third, this research sheds light on the important mediating role of innovation in the ES value creation process of the firm. Enterprise systems are found to significantly contribute to organizational performance insofar as they enable the adopting firm to substantially change/improve its internal production processes and/or introduce new products/services to the market. In other words, those systems that only facilitate the existing business processes and product portfolios of the firm without leading to innovations seem not to generate significant performance improvements. This result gives weight to the necessity of innovating with enterprise systems when optimum outcomes are sought for. As to the fourth major conclusion, the findings reflect the fact that discrete, departmental applications that are less complex and easier to understand/use such as CRM and DMS are, on average, more beneficial to firm performance compared to expansive and sophisticated counterparts such as ERP, SCM, and KMS that mandate radical organizational changes and affect the whole structure of the firm.[34, 35] Domain-specific, in contrast to organization-wide, applications only influence a (few) specific units of the firm, are easier to learn and integrate into the daily works of employees and have shorter payback periods and, therefore, are more likely to result in a successful implementation.

Concerning the minor conclusions of the research, we find that ERP systems, as the most common type of ES software in business, are on average ineffective in boosting the productivity and market share of the firm; their impact on corporate revenue, too, is only weakly significant. This finding supports the hampering view about ERP software that is mainly attributed to their structural inflexibility, technical complexity, gigantic size and complicated interactions with other organizational entities, which make the complete implementation of an ERP system a nightmare for corporate officers. ERP packages are purchased with the hope to make firm operations simplified, while in reality they seem to make things even more complicated. Finally, our observations support us to conclude that educated workforce, broadband accessibility, and e-business processes are (very) strong determinants of organizational innovation and performance.

[34] In our study, domain-specific systems are found to be the only group of applications with a significantly positive impact on all the output measures under investigation (except for profitability). As far as our analysis is concerned, this conclusion is valid for European corporations with an average of 3-5 years since their first use of ES software in daily business.

[35] This conclusion supports Rettig's argument that ES software has introduced so many complex, difficult technical and business issues that just making it to the finish line with one's shirt on can be considered a win. "Is enterprise software just too complex to deliver on its promises?" she further questions (Rettig 2007, pp. 25).

7.2. Limitations of the Research and Recommendations for Future Research

The pooled data at our disposal is limited in the sense that it does not allow for other panel data techniques or dynamic specifications, which would provide the opportunity to better control for unobserved firm-specific heterogeneities and to deal with the causality issue more explicitly. In a panel setting, quantitative measures of output would be more desirable as they contain a greater amount of information about the performance of the firm. Before and after (i.e. within-firm) comparisons can also be conducted in certain panel datasets, resulting in greater understanding of the adoption pattern of ES at the firm level. In connection to this issue, future research should concentrate on the longer-term performance effects of enterprise systems that would lead us to better understand and appraise the ultimate value of ES and the extent of time-lags between costs incurred and benefits accrued.

Additionally, we have not really conducted a cross-sectoral or -country analysis, as we aimed at the overall, economy-wide effects of enterprise systems in Europe. However, such analyses can be very illuminating by unraveling the considerable differences among different sectors and countries with regards to how they use and create value from information technology in general and enterprise systems in particular. Finally, more research should be devoted to analyzing the critical success factors that ultimately make a specific ES project a success or a failure. For example, future research needs to search for and clarify complementarities between enterprise systems and certain organizational characteristics and practices. In this respect, synergies among different types of enterprise systems, especially when they are jointly adopted, shall be studied as well.

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FIGURES/TABLES

Figure 1: Conceptual Model of Relationships among Enterprise Systems, Innovation and Firm Performance

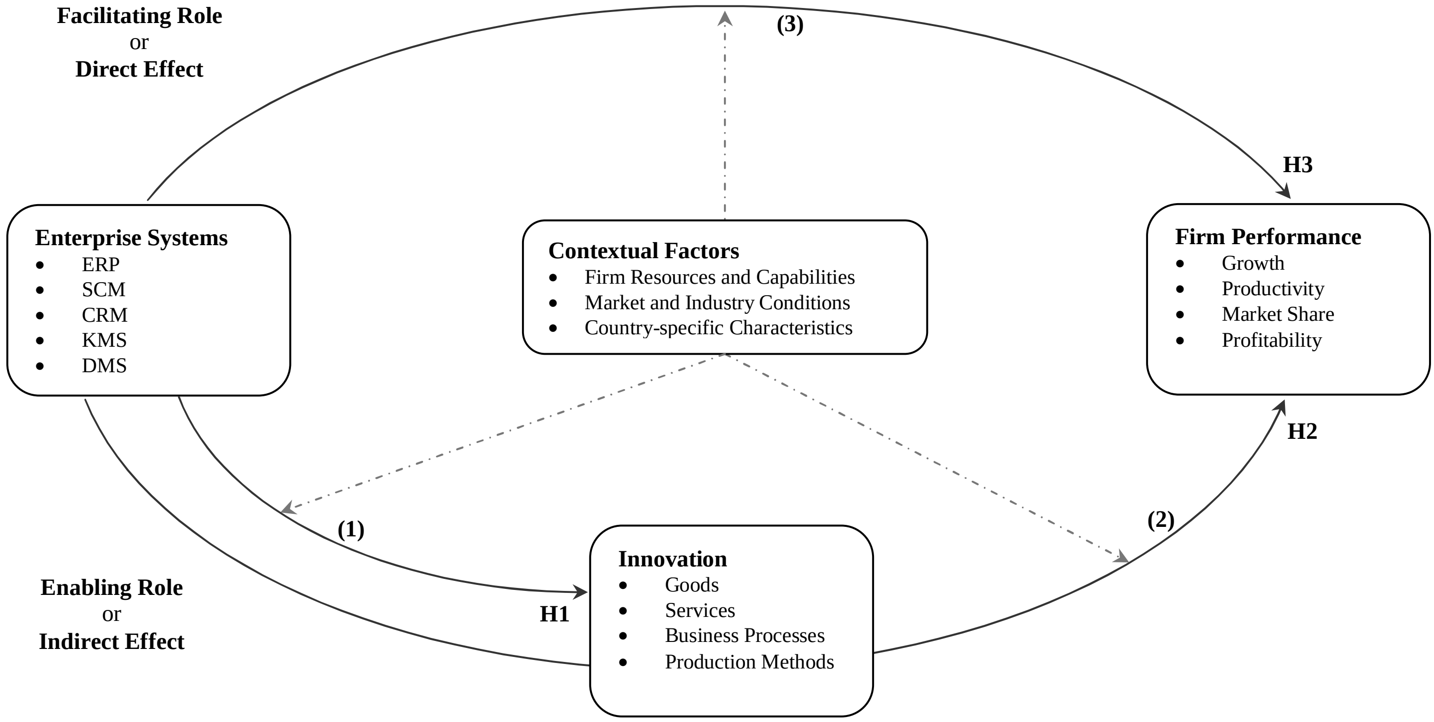

Table 1: Composition of Enterprise Observations in the Pooled Dataset (% of Sample Total)

Country / Sector	Manufacturing (%)	Construction (%)	Services (%)	% Sample
Austria	0.68	0.36	1.06	2.09
Belgium	0.78	0.30	1.02	2.10
Bulgaria	0.48	0.36	0.36	1.20
Cyprus	0.15	0.24	0.43	0.82
Czech Republic	3.28	0.48	1.62	5.38
Denmark	0.39	0.30	1.11	1.80
Estonia	0.68	0.45	1.26	2.39
Finland	1.50	0.42	1.01	2.92
France	4.87	0.69	3.58	9.13
Germany	5.33	0.62	3.37	9.31
Greece	1.21	0.53	0.68	2.41
Hungary	1.55	0.45	1.02	3.03
Ireland	0.48	0.36	0.99	1.83
Italy	5.42	0.61	3.16	9.20
Latvia	0.46	0.39	0.89	1.74
Lithuania	0.31	0.36	0.71	1.38
Luxembourg	0.00	0.19	0.16	0.35
Malta	0.00	0.10	0.36	0.45
Netherlands	0.88	0.16	1.07	2.10
Norway	0.23	0.55	0.72	1.50
Poland	4.69	0.59	3.23	8.52
Portugal	0.94	0.00	1.17	2.11
Romania	0.39	0.36	0.57	1.32
Slovakia	0.53	0.38	0.91	1.82
Slovenia	0.36	0.50	1.15	2.01
Spain	5.20	0.64	3.32	9.16
Sweden	1.71	0.00	2.04	3.76
Turkey	0.52	0.22	0.45	1.20
United Kingdom	4.84	0.62	3.51	8.98
Total	48.00	11.06	40.94	100.00

- *Manufacturing sector* includes: Foods and beverages (NACE 15), Textile, apparel, footwear and leather products (17, 18 & 19), Wood, wood products and furniture (20& 36), Publishing, printing and pulp/paper products (21 & 22), Chemicals, chemical products, pharmaceuticals, rubber and plastics (24 & 25), Metals, metal products and machinery/ equipment manufacturing (27 & 29), ICT manufacturing, consumer electronics, electrical machinery and office equipment (30, 31 & 32), and Automotive/transport equipment manufacturing and aerospace industries (34 & 35).

- *Construction sector* includes: Construction (NACE 45).

-*Services sector* includes: Retail and Wholesale (NACE 50 & 52), Tourism, hotels and recreational/cultural activities (55, 62, 63 & 92), Transport and logistics (60 & 63), ICT services and telecommunications (64 & 72), Business services (74), and Health, hospital and social services (85).

Table 2: Descriptive Statistics of the Variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Innovation					
Product/Service Innovation	29681	.444	.497	0	1
Internal Process Innovation	29705	.393	.488	0	1
Firm Performance					
Revenue Growth	30064	.511	.500	0	1
Productivity Growth	12464	.533	.499	0	1
Market share Growth	15819	.447	.497	0	1
Profitability	11182	.837	.369	0	1
Firm & Market Characteristics					
# of Employees	32529	133.787	850.874	1	60000
% Higher Education	27909	26.058	30.724	0	100
% R&D Employees	14876	11.032	22.228	0	100
International Competition	22846	.176	.380	0	1
Western Europe*	33442	.687	.464	0	1
Eastern Europe**	33442	.288	.453	0	1
Manufacturing	33442	.479	.500	0	1
Services	33442	.409	.492	0	1
Construction	33442	.112	.316	0	1
Market Share $\in$ [0,5]	33442	.178	.383	0	1
Market Share $\in$ (5,10]	33442	.051	.221	0	1
Market Share $\in$ (10,25]	33442	.068	.251	0	1
Market Share $\in$ (25,100]	33442	.229	.420	0	1
IT Infrastructure & Enterprise Systems					
Broadband Internet	31346	.711	.453	0	1
% Internet-enabled Employees	22232	29.757	38.889	0	100
e-Business Maturity	32844	.190	.393	0	1
Enterprise Resource Planning	31711	.200	.400	0	1
Supply Chain Management	31698	.111	.314	0	1
Customer Relationship Management	31798	.141	.348	0	1
Knowledge Management System	27355	.112	.315	0	1
Document Management System	20005	.192	.394	0	1
Enterprise System *(of any type)*	30463	.398	.489	0	1

**Western Europe* includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden, and United Kingdom.

***Eastern Europe* includes: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia.

Figure 2: Development of the Mean Values of ES Adoption Rate in Europe over the Period 2003-2007

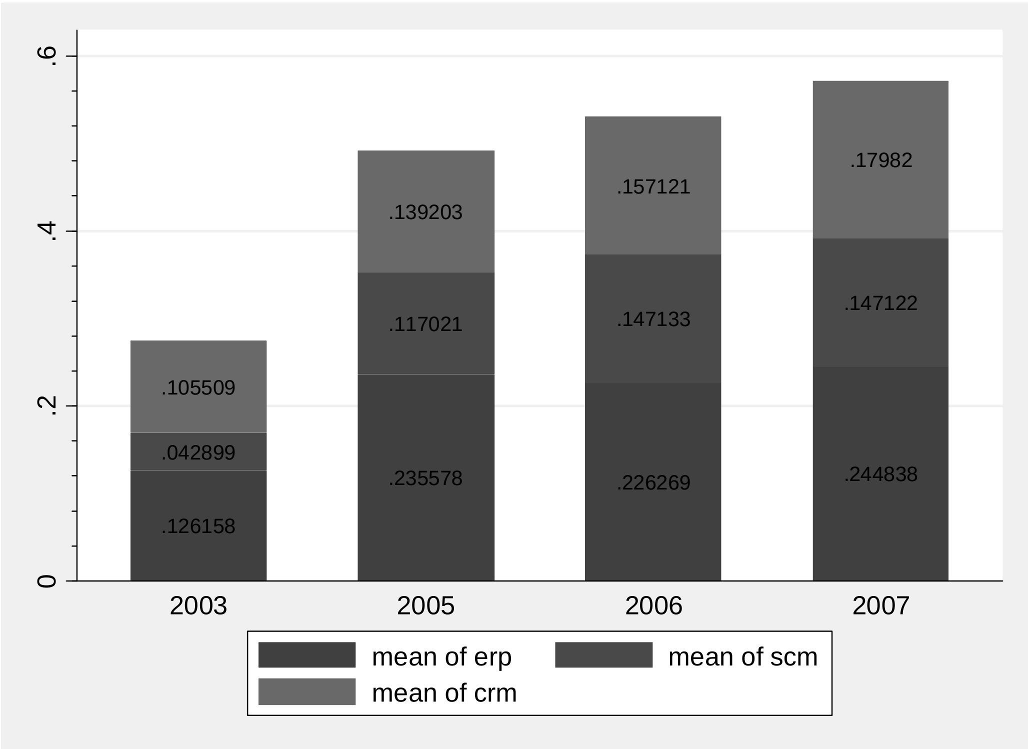

Figure 3: Mean Values of ES Adoption Rate in Different Enterprise Size Classes in Europe

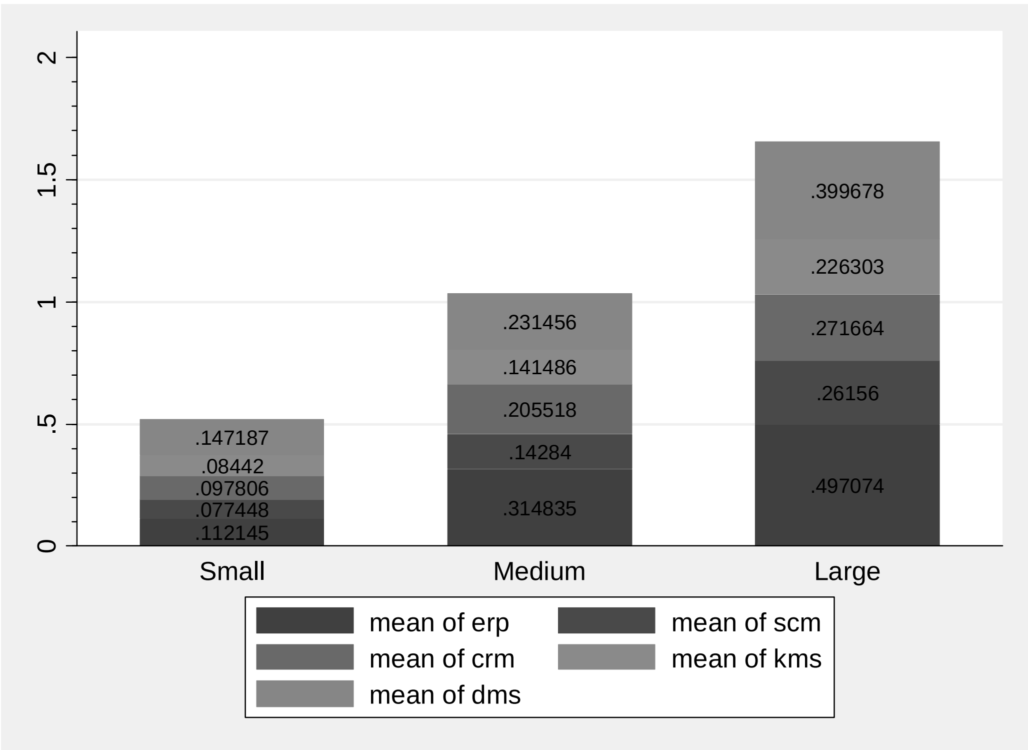

Figure 4: Mean Values of ES Adoption Rate in Different Sectors of the Economy in Europe

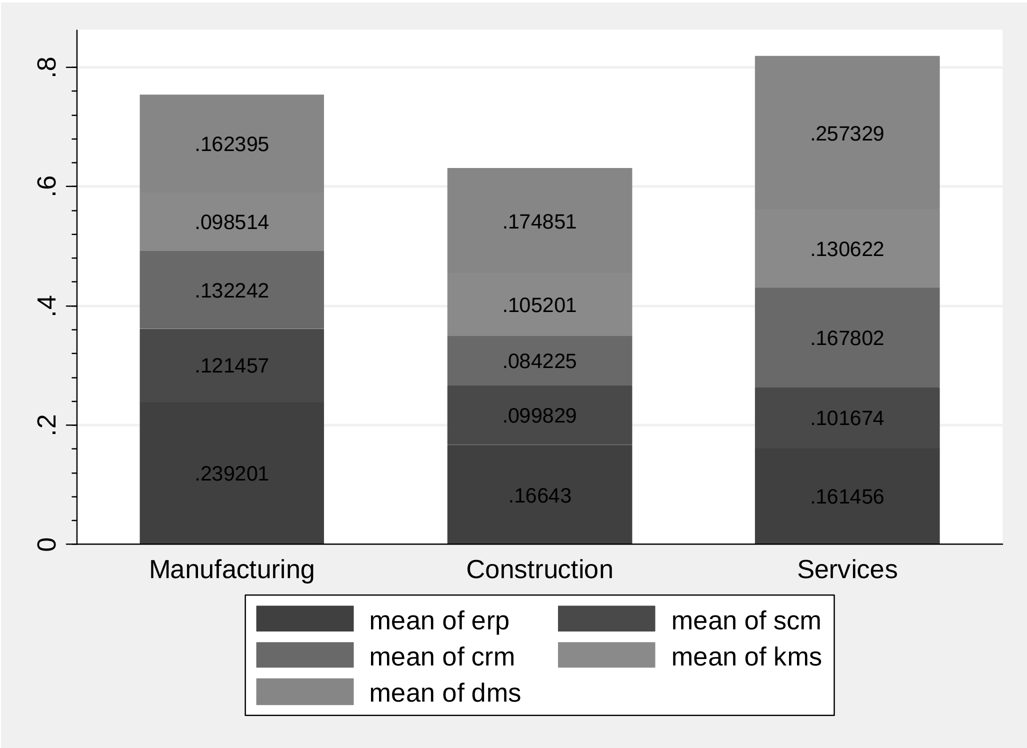

Table 3: Measures of Firm Innovativeness and Performance and their Source Questions in the Survey

Dependent Variable	Type	Relevant Question from the Survey to Construct the Variable
Innovativeness		
Product Innovation	Dummy	• During the past 12 months, has your company launched any new or substantially improved product or services? (*yes/ no/ DK, refused or NA)**
Process Innovation	Dummy	• During the past 12 months, has your company introduced any new or significantly improved internal processes, for example for producing or supplying goods or services? (*yes/ no/ DK, refused or NA)*
Performance		
Revenue Growth	Dummy	• Has the turnover of your company changed when comparing the last financial year with the year before? *(increased/ decreased/ stayed roughly the same/ DK/ NA)*
Productivity Enhancement	Dummy	• Has the productivity of your company changed when comparing the last financial year with the year before? *(increased/ decreased/ stayed roughly the same/ DK)*
Market Share Increase	Dummy	• Has the share of your company in its most significant market changed over the past 12 months? *(increased/ decreased/ remained roughly the same/ DK/ NA)*
Profitability	Dummy	• Has your company been profitable over the past 12 months? *(yes/ no/ DK, refused or NA)*

*DK: Don't Know; NA: Not Applicable

Table 4: Independent Variables and their Source Questions in the Survey

Independent Variable	Type	Relevant Question(s) from the Survey to Construct the Variable
		Enterprise Systems
ERP	Dummy	• Does your company use an ERP (i.e. Enterprise Resource Planning) system?* *(yes/ no/ don't know what this is/ DK)*
SCM	Dummy	• Does your company use a SCM (i.e. Supply Chain Management) system?* *(yes/ no/ don't know what this is/ DK)*
CRM	Dummy	• Does your company use a CRM (i.e. Customer Relationship Management) system?* *(yes/ no/ don't know what this is/ DK)*
KMS	Dummy	• Does your company use a KMS (i.e. Knowledge Management System) system?* *(yes/ no/ don't know what this is/ DK)*
DMS	Dummy	• Does your company use a DMS (i.e. Document Management System) system?* *(yes/ no/ don't know what this is/ DK)*
		Control Variables
# of Employees	Continuous	• How many employees does your company have in total, including yourself? *(numerical value/ DK/ no answer)*
% Highly-educated Employees	Continuous	• What is the estimated percentage share of employees with a college or university degree in your company? *(numerical value/ DK/ no answer)*
Broadband Internet	Dummy	• Does your company have access to broadband internet, i.e. via DSL/ADSL/SDSL, Cable, direct Fibre/Fixed connection, Wireless connection, or other Broadband connections? *(yes/ no/ DK)***
e-Business Maturity	Dummy	• According to the overall experience of your company, would you say that e-business constitutes a significant part of the way your company operates today, or some part or none at all? *(significant part/ some part/ none at all/ DK)**** *or* • Would you say that most of your business processes are conducted electronically as e-business, a good deal of them, some, or none? *(most/ a good deal/ some/ none/ DK)*
Market Share	Set of Dummies	• How large is the market share of your company in its primary, most significant market? *(0-5%/ 5%-10%/ 10%-25%/ 25-100%/ DK)*

DK: Don't Know; NA: Not Applicable

* The ES questions are accompanied by short descriptions about what the system is and what it is used for.

** Depending on the year of the survey, all or a combination of different connection types has been questioned.

*** Depending on the year of the survey, one of these two questions has been asked in the interview questionnaire.

Table 5: Regression Results for Assessing the Effect of ES Adoption on Firm Innovativeness

Regression	1	2	3	4
	Product Innovation (Model 1)		Process Innovation (Model 1)	
	Odds Ratio (Standard Error)			
ES	1.776*** (.060)	---	2.025*** (.070)	---
ERP	---	1.275*** (.069)	---	1.328*** (.072)
SCM	---	1.231*** (.077)	---	1.522*** (.096)
CRM	---	1.783*** (.105)	---	1.691*** (.099)
KMS	---	1.298*** (.082)	---	1.423*** (.090)
DMS	---	1.287*** (.076)	---	1.477*** (.088)
ln(Employees)	1.136*** (.011)	1.135*** (.015)	1.270*** (.013)	1.216*** (.017)
%Higher Education	1.007*** (.001)	1.006*** (.001)	1.005*** (.001)	1.004*** (.001)
Broadband Internet	1.250*** (.048)	1.266*** (.063)	1.529*** (.061)	1.519*** (.081)
e-Business Maturity	1.790*** (.071)	1.826*** (.094)	1.857*** (.073)	1.916*** (.099)
Market Share controls	Yes	Yes	Yes	Yes
Time controls	Yes	Yes	Yes	Yes
Model Diagnostics				
Observations	22666	13712	22703	13731
Groups	256	189	257	190
Ave. Obs./Group	88.5	72.6	88.3	72.3
Log-likelihood	-13215	-7764	-12658	-7307
Model Significance	0.000	0.000	0.000	0.000

*, **, and *** indicate significance at 90%, 95%, and 99% confidence level respectively. Fixed-effects logit, conditioned on market-specific effects, is used. Estimates are shown in Odds Ratios (OR = exp(b)). Standard Errors have also been transformed according to OR presentation. Groups indicate sector-country pairs.

Table 6: Regression Results for Assessing the Total Effect of ES Adoption on Firm Performance

Regression	5	6	7	8	9	10	11	12
	Revenue Growth (Model 2)		Productivity Growth (Model 2)		Market Share Growth (Model 2)		Profitability (Model 2)	
	Odds Ratio (Standard Error)							
ES	1.239*** (.042)	---	1.340*** (.064)	---	1.267*** (.054)	---	0.973 (.078)	---
ERP	---	1.107* (.060)	---	1.099 (.072)	---	1.025 (.067)	---	0.771* (.110)
SCM	---	1.069 (.067)	---	1.148* (.083)	---	1.177** (.085)	---	1.113 (.218)
CRM	---	1.288*** (.076)	---	1.224*** (.085)	---	1.126* (.077)	---	1.202 (.212)
KMS	---	1.003 (.063)	---	1.197** (.090)	---	1.342*** (.098)	---	0.928 (.167)
DMS	---	1.131** (.066)	---	1.156** (.080)	---	1.195*** (.082)	---	1.071 (.176)
ln(Employees)	1.145*** (.012)	1.150*** (.016)	1.179*** (.018)	1.178*** (.020)	1.075*** (.015)	1.069*** (.018)	1.065*** (.022)	1.125*** (.039)
%Higher Education	1.004*** (.001)	1.004*** (.001)	1.005*** (.001)	1.005*** (.001)	1.004*** (.001)	1.003*** (.001)	1.001 (.001)	1.002 (.002)
Broadband Internet	1.261*** (.047)	1.238*** (.059)	1.276*** (.071)	1.280*** (.074)	1.292*** (.069)	1.282*** (.076)	1.157** (.085)	1.257* (.150)
e-Business Maturity	1.445*** (.058)	1.433*** (.074)	1.672*** (.097)	1.627*** (.100)	1.565*** (.077)	1.634*** (.098)	1.289*** (.126)	1.251 (.184)
Market Share controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Model Diagnostics								
Observations	21337	13049	9799	9126	12212	8963	8610	3557
Groups	256	190	160	160	194	159	143	62
Ave. Obs./Group	83.3	68.7	61.2	57.0	62.9	56.4	60.2	57.4
Log-likelihood	-13130	-7968	-5946	-5514	-7505	-5408	-3287	-1262
Model Significance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*, **, and *** indicate significance at 90%, 95%, and 99% confidence level respectively. Fixed-effects logit, conditioned on market-specific effects, is used. Estimates are shown in Odds Ratios (OR = exp(b)). Standard Errors have also been transformed according to OR presentation. Groups indicate sector-country pairs.

Table 7: Regression Results for Assessing the Direct Effect of ES Adoption on Firm Performance

Regression	13	14	15	16
	Revenue Growth (Model 3)	**Productivity Growth (Model 3)**	**Market Share Growth (Model 3)**	**Profitability (Model 3)**
	Odds Ratio (Standard Error)			
ERP	1.047 (.058)	1.028 (.069)	0.977 (.066)	0.756* (.109)
SCM	1.006 (.064)	1.050 (.079)	1.087 (.081)	1.105 (.217)
CRM	1.163** (.071)	1.055 (.076)	0.971 (.068)	1.163 (.206)
KMS	0.959 (.061)	1.121 (.086)	1.270*** (.095)	0.899 (.162)
DMS	1.058 (.063)	1.064 (.076)	1.109 (.079)	1.038 (.172)
Product Innovation	1.585*** (.067)	1.667*** (.086)	1.811*** (.093)	1.211* (.133)
Process Innovation	1.537*** (.068)	1,783*** (.097)	1.549*** (.083)	1.222* (.136)
ln(Employees)	1.122*** (.016)	1.147*** (.020)	1.042** (.018)	1.106*** (.039)
%Higher Education	1.003*** (.001)	1.003*** (.001)	1.002** (.001)	1.001 (.002)
Broadband Internet	1.181*** (.058)	1.220*** (.072)	1.225*** (.074)	1.199 (.145)
e-Business Maturity	1.305*** (.069)	1.404*** (.089)	1.423*** (.088)	1.237 (.184)
Market Share controls	Yes	Yes	Yes	Yes
Time controls	Yes	Yes	Yes	Yes
Model Diagnostics				
Observations	12824	8960	8811	3502
Groups	190	160	159	62
Ave. Obs./Group	67.5	56.0	55.4	56.5
Log-likelihood	-7675	-5265	-5178	-1243
Model Significance	0.000	0.000	0.000	0.000

*, **, and *** indicate significance at 90%, 95%, and 99% confidence level respectively. Fixed-effects logit, conditioned on market-specific effects, is used. Estimates are shown in Odds Ratios (i.e. OR = exp(b)). Standard Errors have also been transformed according to OR presentation. Groups indicate sector-country pairs.

APPENDIX A: TESTS TO ASSESS THE DIRECTION OF CAUSALITY

(1) MANOVA/ANOVA:

Table A1: Testing for Causality through the Analysis of Variance

MANOVA *(joint IT-enabled product and process innovation)*	**Model Statistic**		**F-value**	**P-value**
Wilks' lambda	0.879		206.95	0.000
Pillai's trace	0.121		201.33	0.000
Lawley-Hotelling trace	0.136		212.58	0.000
Roy's largest root	0.130		406.37	0.000
ANOVA *(IT-enabled product innovation)*	**Sample Mean** **ES=0**	**ES=1**	**F-value**	**P-value**
ERP	0.18 (0.38)	0.31 (0.46)	447.13	0.000
SCM	0.19 (0.39)	0.32 (0.47)	298.82	0.000
CRM	0.17 (0.38)	0.41 (0.49)	1336.15	0.000
KMS	0.19 (0.39)	0.41 (0.49)	724.01	0.000
DMS	0.18 (0.39)	0.32 (0.47)	373.41	0.000
ANOVA *(IT-enabled process innovation)*	**Sample Mean** **ES=0**	**ES=1**	**F-value**	**P-value**
ERP	0.21 (0.41)	0.44 (0.50)	1323.12	0.000
SCM	0.23 (0.39)	0.45 (0.47)	810.68	0.000
CRM	0.21 (0.41)	0.49 (0.50)	1474.64	0.000
KMS	0.22 (0.41)	0.47 (0.50)	853.63	0.000
DMS	0.23 (0.42)	0.41 (0.49)	502.40	0.000

For sample means the standard deviations are reported in parentheses.

Different statistics of the MANOVA test show that the model consisting of all the ES types significantly explains the joint variation of IT-enabled product and process innovation among the sampled firms. We also attained significant results when we used individual ES types (rather than their combination) to model the effects (all p-values significant at 99%). In case of the ANOVA tests, sample means indicate the proportion of firms with IT-enabled product or process innovation in the two subgroups of adopters and non-adopters of a specific system type. The corresponding F-values indicate that the differences in sample means are statistically significant in all cases, meaning that ES adoption has indeed led to (more) innovation(s). We also conducted the Bonferroni, Scheffe, and Sidak multiple-comparison tests and found significant results at 99% for all the system types. More details are accessible upon request from the authors.

(2) **3SLS/2SLS:**

$$\begin{cases} product\_innovation = f(ES, broadband\_internet, ebusiness\_maturity, controls) \\ process\_innovation = f(ES, broadband\_internet, ebusiness\_maturity, controls) \\ revenue\_growth = f(ES, broadband\_internet, ebusiness\_maturity, controls) \\ productivity\_growth = f(ES, broadband\_internet, ebusiness\_maturity, controls) \\ marketshare\_growth = f(ES, broadband\_internet, ebusiness\_maturity, controls) \\ ES = f(product\_innovation, process\_innovation, revenue\_growth, productivity\_growth, \\ \qquad marketshare\_growth, IT\_budget, international\_competition, controls) \end{cases} \quad (4)$$

We estimate a simultaneous system of six equations using three-stage and two-stage least squares. Controls in each equation include firm size, share of higher educated employees, size of market share and sector, country and year dummies. To satisfy the order condition (necessary for model identification) two new exogenous variables are included in the ES equation. *IT_budget* (Mean: 7.862%, Std. Dev.: 18.100) measures the share of IT budget, including hardware, software, services and personnel, as percentage of the total company costs. *international_competition* (Mean: 0.174, Std. Dev.: 0.379) indicates whether or not international markets (in contrast to regional and national markets) constitute the main sales area of the firm. The following table only reports the estimates of the variables of main interest. More details on the remaining parameter estimates have not been shown in the table for the sake of simplicity and are available upon request from the authors.

Table A2: Testing for Causality through the System of Simultaneous Equations

Dependent→ / ↓Independent		**ES**	**Product Innovation**	**Process Innovation**	**Revenue Growth**	**Productivity Growth**	**Market Share Growth**
ES	*3SLS*	---	1.318*** (.289)	1.266*** (.273)	.869*** (.246)	1.079*** (.268)	1.247*** (.294)
	2SLS	---	1.318*** (.290)	1.266*** (.273)	.869*** (.246)	1.079*** (.269)	1.247*** (.295)
Product Innovation	*3SLS*	.352 (.334)	---	---	---	---	---
	2SLS	.228 (.348)	---	---	---	---	---
Process Innovation	*3SLS*	.915 (.569)	---	---	---	---	---
	2SLS	.827 (.577)	---	---	---	---	---
Revenue Growth	*3SLS*	1.058 (.859)	---	---	---	---	---
	2SLS	.829 (.924)	---	---	---	---	---
Productivity Growth	*3SLS*	.465 (.862)	---	---	---	---	---
	2SLS	.132 (.937)	---	---	---	---	---
Market Share Growth	*3SLS*	.692 (.440)	---	---	---	---	---
	2SLS	.250 (.540)	---	---	---	---	---

*** indicates significance at 99% confidence level. Three- and two-stage least squares are used for estimation of the system. Standard errors are shown in parentheses. All the equations, as indicated above, include exogenous and control variables (not shown).