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DRIVERS AND IMPACTS OF ICT ADOPTION ON TRANSPORT AND LOGISTICS SERVICES. AN EUROPEAN PERSPECTIVE.

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Abstract: The availability of high quality transport and logistics services (TLS) is of paramount importance for growth and competitiveness of an economy. The objective of this paper is to describe how companies in this industry use ICT for conducting business and to assess the impact of this development for firms and for the industry as a whole. Using the Structure-Conduct-Performance (SCP) model and the bi-directional relationships of its elements, the paper identifies the links between ICT adoption and market structure, innovation dynamics and firm performance. A set of recommendations on how to further improve the actual scenario of e-business in the TLS industry is also presented.

Keywords: ICT, e-business, transport, logistics, innovation.

1. Introduction

Today, business organizations face a more complex and competitive environment than ever before (Srinivasan et al., 1994; Porter and Stern, 2001). As trade barriers crumble and less developed countries enter the competitive marketplace, firms now confront a greater number of competitors able to introduce new products and services faster and cheaper (Garten, 1998). Furthermore, as consumers have become more discriminating and demanding (Ellinger et al., 1997), product life cycles have been shortened, forcing firms to contract time to commercialization (Lovelace et al., 2001) and provide higher levels of customer service and customized products. Consequently, most firms have entered into a high–competitive marketplace characterized by an increase in competition, uncertainty, and complexity (Merrifield, 2000).

In this business environment, innovation of organizational processes is a major business challenge (Tornatzky and Fleischer, 1990) and critical for firms success (Veliyath and Fitzgerald, 2000). If in the past firms focused on reducing costs and improving quality to gain a competitive advantage, today companies must be able to innovate at the global frontier and create and commercialize a stream of new products

and processes that shift the technology frontier (Porter and Stern, 2001). One area of innovation that has been the focus of significant discussion is information and communication technologies (ICT) adoption which have the capacity to impact organizational structure, firm strategy, operational procedures and buyer-supplier relationships (Williams et al., 1997).

The swift development of ICT as well as the declining prices for its use has considerably enhanced its diffusion during the last few years. As a consequence, the impact of ICT on productivity has become a broadly discussed topic in management sciences and several studies find empirical evidence for positive productivity effects of ICT at the firm level (Lichtenberg, 1995; Brynjolfsson and Hitt, 1996; Licht and Moch, 1999; Greenan and Mairesse, 2000). Nevertheless, ICT adoption may increase organizational flexibility and competitiveness (Patterson et al., 2003).

Transport and logistics services (TLS) are recognized as key components of a successful economy, enabling the movement of goods, services and people as efficiently as possible. These should arrive in time at the right destination and retain the right quantities and quality, while respecting the level of service selected for the process (Bowersox and Calantone, 1998). ICT systems are critical for managing TLS firms (Bowersox and Daugherty, 1995; Lewis and Talayevsky, 1997; Williams et al., 1997) because they need to manage information effectively and to integrate several activities including inbound and outbound transportation, distribution, warehousing, and fleet management, in order to streamline the physical product flows of their customers.

The ICT are important since they make available the right information, at the right time and at the right place. This popular logistical paradigm, which most often refers to physical goods, is shown to have equal relevance in the management of information (Introna, 1991; Lee et al., 1997; Levary, 2000). Using e-business technologies, the TLS companies can improve their efficiency and productivity (Cash and Konsynski, 1985), create an integrated approach linking transport modes in innovative ways and, thus, improve the quality of their services (Patterson et al., 2003).

The objective of this paper is to describe how companies in the TLS industry use ICT for conducting business and to assess the impact of this development for firms and for the industry as a whole. The paper is organized as follows. In section 2, it is brought a descriptive assessment focused on the ICT existing infrastructure, the diffusion of ICT-based applications, and on how they are used by companies in the European TLS industry. In section 3, the conceptual framework for the analysis of drivers and impacts of ICT adoption is discussed, and the main theoretical hypothesis are implemented focussing on the critical role of ICT for innovation in the TLS industry in three different dimensions: innovation dynamics, market structure, and firm performance. Section 4 provides the methodology and presents the relevant empirical results. Section 5 concludes with some comments on the implications of the findings and some recommendations on how to improve the actual scenario of e-business in the TLS industry.

2. A brief description of ICT on TLS in Europe

In the European Union, the abolition of frontiers has resulted in the establishment of a just-in-time or revolving stock production system. The transport sector generates 7% of European Union gross domestic product (GDP) and for around 5% of employment. Nevertheless, the challenge is to find solutions for freight and passengers

that are economically viable and that also promote sustainable growth, fuel economy, the reduction of emissions, safe and healthy lifestyles and social inclusion.

Road transport services account for 1.6% of the EU GDP and give jobs to 4.3 million people. The whole economy and society depends heavily on efficient road transport: 44% of the goods are moved by trucks (compared with 41% for short sea shipping, 10% for rail and 4% for inland waterways) and 85% of the persons are moved by cars, buses or coaches (compared with 5% by air and 6% by railways). Between 1970 and 2005 the share of the goods market carried by rail in EU-15 fell from 20% to 8% (down from 283 billion tonnes per kilometre to 241 billion). Passenger transport by rail also declined less dramatically: in 1970, the modal share of rail was 10.2% and fell to 6.3% in 2005 in the EU-15 (European Commission, 2007).

Logistics is the process of planning, implementing and controlling the movement of people, raw materials, half-finished products and finished goods. These should arrive in time at the right destination and retain the right quantities and quality, while respecting the level of service selected for the process. The global logistics industry is estimated at roughly 5.4 trillion euro, or 13.8% of the global EU GDP.

Over the last few years, firms operating in the transport and logistics sector have made significant progress in their adoption of new technologies, particularly those linked to the Internet and e-business. Using these technologies, TLS companies improve their productivity, create an integrated approach linking transport modes in innovative ways and, thus, improve the quality of their services. Key findings regarding use and access to ICT in the TLS are summarised below.

Internet access is therefore fundamental for enterprises to start benefiting from the information society. For most EU Member States Internet adoption is approaching saturation point. Overall, for the EU in 2005, 91% of enterprises with 10 or more persons employed had internet access. In line with this tendency, in the present study, nearly all companies (97%) which use computers in the transport and logistics sectors are connected to Internet. Only among passenger transport firms, a minority of 5% responded that they have no Internet connection. By share of employment, firms representing 99% of the sector workforce are connected to Internet (Table 1).

Table 1 - Internet access and bandwidth in the TLS

ICT	Companies with Internet Access		Companies whose Internet access has a bandwidth					
			< 144 kbit/s		> 144 kbit/s – 2 Mbit/s		>2 Mbit/s	
Weighting	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %
Sectors	**99**	**97**	**8**	**17**	**51**	**52**	**41**	**31**
Passenger transport	99	95	9	20	41	50	50	30
Freight transport	98	97	9	17	58	53	33	30
Logistics	100	100	6	14	46	51	48	35

On the path to the adoption of e-business, connectivity is the first step and also a precondition for all potential benefits of the use of computer networks. The tendency of the firms in the sectors is to have a higher broadband connection. Only 17% of the companies (representing 8% of the sectors workforce) still use an Internet access up to

144 kbit/s, while a half of the firms have bandwidth connection ranging from 144 kbit/s to 2 Mbit/s, and near a third have more than 2 Mbit/s bandwidth connections.

The adoption of internal computer networks is a critical step towards the computer integration of business processes. Such integration potentially streamlines and boosts the efficiency and productivity of the firm. In the TLS industry a half of all firms (75% for the logistics) representing 75% of employees operate a LAN. However, the deployment of WLAN technology only reach 22% of the firms, although it is already used by about a half of the large-sized firms, and even one third of the small companies (Table 2).

The size and scalability of any computer network are determined both by the physical medium of communication and by the software controlling the communication (i.e. the protocols). An Intranet is a specific application of the internal computer network which serves as a communication tool within the enterprise, and an Extranet can be viewed as part of a company's Intranet that is extended to users outside the company. As such, both can be regarded as a next step in the use of the internal computer network as e-business. Around one quarter of the TLS firms uses an Intranet and, again, it depends on the company size, ranging from a relative small 23% for micro-sized firms to a high 77% for large firms. Only a few firms in the industry use an Extranet (6%), most been used by large-sized firms (42%).

Remote access means that employees can access data from the company's computer system remotely, e.g. when working from home or travelling. In the TLS industry, 24% of firms (comprising about half of the sector's employment) enable remote access. This indicator is quite common among large firms (74%) and medium-sized ones (57%); however, is not yet widely used by small firms (23%).

Table 2 - Networks and protocols used in the TLS

ICT	Companies									
	LAN		WLAN		Intranet		Extranet		Remote access	
Weighting	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %
Sectors	**75**	**50**	**39**	**22**	**52**	**24**	**24**	**6**	**49**	**24**
Passenger trans.		43		22		17		5		21
Freight transport		44		20		25		5		26
Logistics		75		27		30		7		21

The characteristics of the TLS industry have determined the introduction of specific ICT technologies accordingly to sectors operations. However, some conclusions could be made from the presented data: one tenth of the TLS firms use a fleet control system, the rate of adoption depending again on firm’s size. The less used technologies are the intermodal transportation management system (4%), a cargo handling technology (5%) and an Intelligent Transport System (7%). More advanced systems, for example for cargo handling and fleet control, are mostly used by mid-sized and large companies in the freight transport and logistics sectors (Table 3).

Summarizing, the existing ICT infrastructure and e-business software systems analysed in this study led the TLS sector to a situation in which only a quarter of firms have not introduced any e-business activity in their normal operations. On the other hand, 10% of companies carry out most of their business processes in the e-business mode, while almost another quarter do so with a good deal of their processes, and 42% use e-business with some of their business operations. In a general view, it can be

concluded that 3 of 4 companies in the TLS industry use e-business in one way or another to realise their business activity.

Table 3 - Use of specific ICT solutions for TLS

ICT	Companies									
	Maintenance management system		**Cargo handling technology**		**Fleet control system**		**Intermodal transportation management system**		**ITS**	
Weighting	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %
Sectors	**32**	**15**	**16**	**5**	**29**	**10**	**12**	**4**	**16**	**7**
Passenger trans.	29	18	3	0	24	3	1	0	10	2
Freight transport	32	13	18	4	26	9	10	6	18	10
Logistics	28	20	24	8	39	17	24	2	17	1

3. Theoretical approach and hypothesis

Economic literature suggests that the adoption and diffusion of ICT technologies among firms in the economy at large is a striking example of the possible dynamics of technological change and economic development (Breshnahan and Trajtenberg, 1995; Helpman and Trajtenberg, 1998; Acemoglu, 2002; Carayannis and Turner, 2006). ICT are essentially enabling technologies that facilitate innovations in the application sectors. For example, computers have contributed to automate back-office operation, and network applications increasingly help to coordinate and integrate processes between firms.

The investment in ICT is most intensive and most dynamic in services (OECD, 2000). In earlier studies on innovation, the service sector has been characterized as a mere applier of technological innovations developed in the manufacturing sector (Pavitt, 1984). However, more recent empirical studies confirm a more active role of the service sector in the process of technological change (Sirilli and Evangelista, 1998). Therefore, differences in technological opportunities, appropriability conditions, and cumulativeness of innovative capabilities may lead to differences in the innovation paths between firms in the service sector.

The authors suggest that adoption and diffusion of new technologies can be spurred by many different drivers and can have far-reaching consequences or impacts. For this study, an extended Structure-Conduct-Performance (SCP) paradigm was used as a conceptual framework for the analysis of ICT impacts. Developed by Mason (1939) and Bain (1951), the paradigm states that firm and industry performance is determined by the conduct of buyers and sellers, which is a function of the market structure.

The term structure goes beyond market structure characteristics of the original concept. The main features are related to the number and size of firms, the number and preferences of customers, and the level of ease of market entry. Further industry structure characteristics are related to products and production factors: the degree of product differentiation, the degree of vertical integration of production (i.e. the technologies available to the firms and the level of competence), and the workforce composition and the demand for labour, most importantly with regard to knowledge and skills (Scherer, 1980; Sampler, 1998).

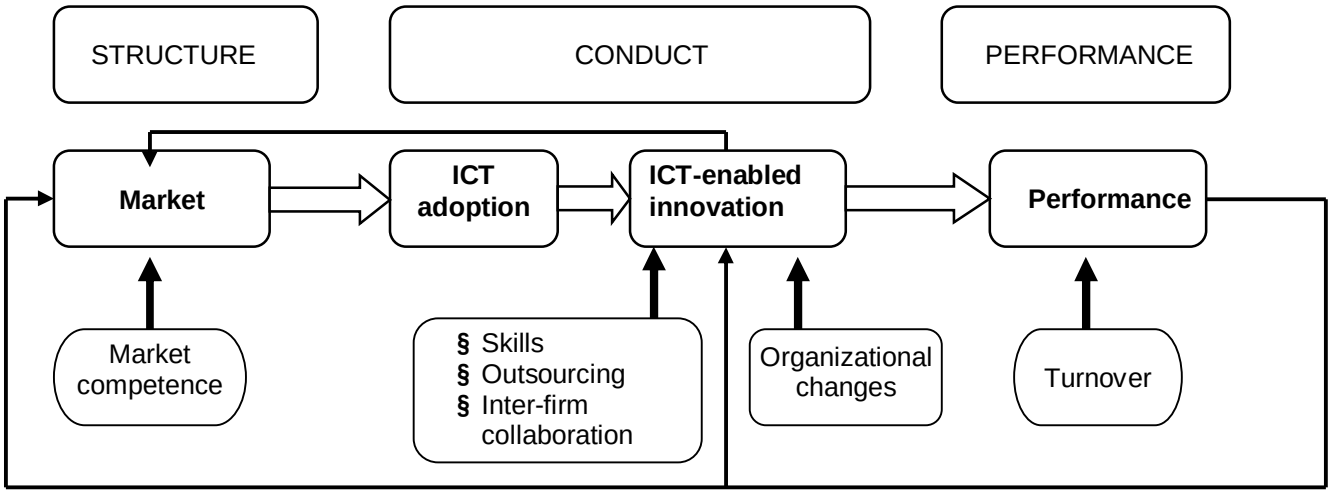
These industry structure components influence a firm's conduct. The conduct aspects most important are production strategies, particularly with regard to inter-firm collaboration (Baker, 1992), as well as outsourcing and organizational change (McAfee, 2006). Finally, a firm's performance is assumed to be the outcome of its conduct. Successful innovations improve firm performance by, for example, reducing production cost, increasing productivity, improving product quality or enabling it to enter new markets (Jones et al., 2001; Gera and Gu, 2004).

In contrast to the standard SCP paradigm, the flow of causality is in fact not one-directional (Fauchart and Keilbach, 2002; Nepelski, 2003). As an example of feedback between performance and industry structure, successful and innovative companies are more likely to grow and increase their market share at the expense of less progressive firms, which transforms the market structure. There may also be feedbacks between conduct and industry structure: for example, depending on the innovation type (i.e. product or process innovation, ICT enabled or not), innovations influence the choice of products manufactured and a firm's cost structure. Innovations may also change the incentives to perform activities in-house versus outsourcing them and, consequently, may influence the demand for labour and its composition. It may also further shape the relationships with suppliers and customers, for example with regard to collaboration intensity.

Thus, in the following discussion it is assumed that firm performance may have a feedback effect on both firm conduct and industry structure, and conduct may have a feedback on structure. This conceptualisation allows for an enhanced economic approach that studies the drivers and impacts of ICT and ICT-enabled innovations at the firm and sector level.

The SCP model and the bi-directional relationships of its elements are represented in figure 1. The model allows us to identify firm and industry dimensions that can be considered as relevant for the adoption and diffusion of ICT, in particular by analysing links between ICT adoption and market structure, innovation dynamics, and firm performance. For each of the links to be analysed, a number of hypotheses are proposed.

Figure 1 - Conceptual framework for the analysis of drivers and impact of ICT adoption



3.1. ICT and market structure

Increasing competence in the market is an important factor that drives the adoption of new technologies and innovation (Dawe, 1994; Nepelski, 2003), as companies search for new opportunities to cut costs by improving process efficiency or develop new products. Firms want to escape competition by innovating and this can be done by securing a monopoly position, which might stem from a successful innovation protected from imitating by means of a patent, a trademark, or a copyright. Furthermore, just by being the first in the market, a firm may secure an unchallenged position by building up the necessary capacity to enjoy substantial economies of scale, or strategic know-how (Tsai, 2001; Eriksson and Chetty, 2003).

Historically, distance to market and transportation cost limited the number of customers a firm could reach. At the beginning of the Internet era, a common believe was that ICT and e-commerce were to eliminate the limitations of location and enable firms to expand regardless of geographical locations (Cairncross, 1997). Actually, ICT offers existing firm possibilities to expand their market reach enabling companies to cross boundaries (Johnston and Vitale, 1988), which consequently increase the competence. These "new competence" entails flexible response, customization, networking, and new forms of inter-firm organization (clustering), rather than classic price competition dominated by vertically-integrated firms (Best, 1990). Based on the foregoing, the following hypothesis can be stated:

H1. *Increasing competence in the market is a driver for the adoption of ICT.*

As pointed out by Cohen and Levinthal (1990), the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. They argue that this absorptive capacity is largely a function of the level of prior related knowledge and skills. First, the absorptive capacity accumulated in a particular area in one period will permit a more efficient accumulation in the next. Second, experienced firms will be able to better predict the nature and commercial potential advances in an uncertain environment.

Absorptive capacity arises from a long process of investment and accumulation of knowledge through which the firm obtains the so-called technological stock (Tsai, 2001). The capacity of firms to internalize technological knowledge becomes a crucial dimension of competition and turns into a critical determinant of their future performance (Lanctot and Swan, 2000). Thus, in order to develop marketable products or feasible production processes, a firm needs to build up its knowledge stock and expertise, i.e. complementary assets. The most obvious example of investments in complementary assets include investments in software, training and organisational transformations that accompany ICT investments (Stock et al., 2001). In other words, firms that combine high levels of ICT and high levels of worker skills have better firm innovation performance. Based on this evidence, the second hypothesis to be tested is:

H2. *Firms characterised by a higher share of ICT practitioners and employees with a university degree are more likely to conduct ICT-enabled innovations.*

3.2. ICT and innovation dynamics

The growing diffusion of ICT in all areas of business is a major enabler of technological change, innovation and thus economic development (Clemons and Row, 1991; Williams et al., 1997). ICT-driven innovation activity is central to the subsequent effects of ICT economic impact. This section tries to analyse in what degree specific factors are linked with ICT-enabled innovation in the TLS industry and whether

companies which conduct ICT-enabled innovation are likely to exhibit superior performance.

Following transaction cost theory, decreasing costs of search, evaluation and monitoring of suppliers should lead to a shift away from firms and toward markets as a form of organising economic activity (Coase, 1937; Williamson, 1985). Consequently, the expectations regarding the potential of ICT as technologies introducing innovative ways of doing business, re-shaping firm boundaries, and changing the constellations of value chains were enormous (Johnston and Lawrence, 1988; Milgrom and Roberts, 1990; Fulk and DeSanctis, 1995). The availability of powerful and cheap ICT increases the attractiveness of markets (Malone et al., 1987; Lucking-Reiley and Spulber, 2001) and have spurred firms to focus on their core competences and to reduce their dependency on hierarchy, while outsourcing increasing amounts of business activities and services (Erber and Sayed-Ahmed, 2005). Thus, we propose the following hypothesis:

H3. *ICT adoption by firms will be influenced positively by the degree of outsourcing capacity.*

ICT has a direct impact on process innovation in an organisational setting by facilitating inter-organisational links (Lee, 2000). ICT-enabled inter-organisational integration and collaboration enhance the innovation capabilities of companies by providing opportunities for shared learning, transfer of technical knowledge and resource exchange (Kogut, 1988; Gomes and Park, 1997). The benefits of information integration with the help of ICT are related to the optimisation of the value chain, the creation of communication infrastructures facilitating production networks or enabling partners to align the incentives of multiple players by creating joint business units or teams managing the same tasks (Lambert et al., 1998; Stank et al., 1999; McAfee, 2006).

Rather than e-commerce, it is the use of electronic networks that leads to a higher probability of firms collaborating in innovative activities and increases the amount of collaborative relations they have (European Commission, 2004). The use of e-collaboration tools, such as SCM or other applications to share information, is critical to share data with business partners (Truman, 2000). Hence, the following hypothesis to be tested is:

H4. *Firms that use ICT applications to exchange information with business partners are more likely to introduce ICT-enabled innovations.*

ICT adoption may impact on a company's organisation, i.e. the structure and the relationships between departments within a firm. Organisational changes may relate to a rearrangement of functions, workflows and importance of departments and employees working in them (Doherty and King, 1998; Pianta, 2004). The reorganization of production and distribution around ICT has enables the adoption of new processes, procedures, and organizational structures, which in turn, have led to sustainable gains in productivity, quality, and responsiveness (Brynjolfsson and Hitt, 1996; Litan and Rivlin, 2000).

ICT transformed the process of replicating business innovations across organisations (Brynjolfsson et al., 2006). Traditionally, deploying business innovation on a larger scale took time and required considerable involvement of resources and employees. Today, ICT allows companies to embed business innovations and then

implement them across the organisation at a much smaller cost than before without compromising on quality (Stoneman and Kwon, 1996).

The copy-exactly strategy is particularly beneficial if the initial understanding of the process is low, the lifecycle is short and the process is difficult to improve (Terwiesch and Wu, 2004). This is true for manufacturing industries with rapidly changing production technologies and intensive technological competition. In such industries the speed of adoption of new production processes plays a decisive role for remaining at the cutting edge. On the other hand, tools, such as email, knowledge management systems, wikis or instant messaging, considerably improve the process of innovation in knowledge-intensive and service-oriented sectors with informal, unstructured and spontaneous type of work, such as banking (McAfee, 2006). ICT facilitates firms' innovativeness by propagating innovations that are less structured than business processes. This leads to the following hypothesis:

H5. *ICT use will affect organisational changes positively.*

3.3. ICT and firm performance

The effects of ICT on corporate performance are not clear because not all studies have demonstrated clear payoffs from ICT investments (Chan, 2000; Kohli and Devaraj, 2003). In addition, the results vary depending on how performance and ICT payoffs are measured and analysed. For example, one empirical study finds positive impacts of ICT investments on productivity, but not on profits (Brynjolfsson and Hitt, 1996). Meanwhile, other studies did not find positive effects of ICT capital on productivity, while ICT labour positively contributed to output and profitability (Prasad and Harker, 1997).

These somewhat ambiguous results of the impact of ICT on corporate performance can be explained if one drops the assumption that there is a direct link between ICT investments and corporate performance. The key to understanding the impacts of ICT on performance is to view ICT as an enabler of innovation (Koellinger, 2006). Indeed, Clayton and Waldron (2003), in a study on e-commerce adoption and business impact, found that businesses maintaining higher levels of new and improved product sales relative to turnover achieve above sector average rates of sales growth, i.e. they increase market share. The effect is present in both manufacturing and service sectors. Hence, the last hypothesis to be tested is:

H6. *ICT-enabled innovations will affect the firm's performance positively.*

4. METHODOLOGY AND RESULTS

4.1. Data collection

The sample studied is comprised of a total of 997 firms belonging to the following business activities: land/road and rail transport (NACE Rev. 2, 49.1, 49.2, 49.3, and 49.4) and logistics sectors of warehousing and storage, cargo handling and other transportation support activities (NACE Rev. 2, 52.10, 52.24, and 52.29) to the extent that these sectors interact with transport activities.

The survey was carried out during 2007 in seven European countries (France, Germany, Italy, Poland, Spain, Sweden and United Kingdom) and was financed by the European Commission through the e-Business W@tch Programme. The firms were drawn locally based on official statistical records and widely recognised business directories such as Dun&Bradstreet or Heins and Partner Business Pool. The description

of the sample per country is the following: France (150), Germany (130), Italy (124), Poland (141), Spain (128), Sweden (188) and United Kingdom (136).

The technique employed was a telephone survey. Pilot telephone interviews prior to the regular fieldwork were conducted with about 10 companies in each country, in order to test the questionnaire (structure, comprehensibility of questions, average interview length). In the interviews, not all questions were asked to all companies. We use filter questions to make the interview more efficient, for example, questions on the type of Internet access used were only asked to those companies that had replied to have Internet access. Thus, the question whether a company has Internet access served as a filter for follow-up questions.

The rate of response was very high (93.5%) because in the voluntary telephone survey, in order to achieve the total targeted interviews, was necessary to contact more companies than just the number equal to the target. With regard to the indicators included in the questionnaire, a dichotomous response is applied for respondents.

4.2. Results obtained

To test the hypothesis established in the theoretical model different regressions were run depending on the critical variables in each case. This method of regression is used to estimate a model using the minimum number of non-superfluous and at the same time significant variables (Guillén, 1992).

Hypothesis 1

The dependent variable accounting for the intensity of the ICT usage is a set of answers to the questions regarding the Internet connection type (less than 144 kbit per second, between 144 kbit and 2 megabit per second, or more than 2 megabit per second), the use of LAN, WLAN, WWW, Intranet, Extranet, ERP, SCM, CRM, the use of the Internet to sell and buy goods, and employing IT practitioners (one score for each positive answer). Thus, the variable can take values between “0” and “13”. The independent variable indicates whether the competence in a firm’s market increased in the last 12 months or not and takes a value “1” or “0” respectively. In addition, the regression includes dummy variables controlling for firm size and country of origin. To analyse the relationship between market competence and ICT adoption intensity, an ordinary least-squares regression was run (Table 4).

Table 4 - Effect of market competence and the intensity of ICT use

Independent variable	Coefficient	Standard Error
Increasing competence	0.633*	0.257
Less than 249 employees	-3.637**	0.471
Model diagnostics		
N = 932; R-squared = 0.10		
Note: OLS regression. The table does not report the country coefficients * Significance 95%, ** Significance 99%		

An analysis of the results leads to the conclusion that increasing market competence drives ICT usage. The hypothesised relevance of increasing market competition for the intensity of ICT adoption was confirmed. In other words, more intense competition forces companies to use innovative technologies to cut costs and look for more innovative ways of conducting business. Moreover, firm size is an

advantage because appears to have a considerably strong effect on the adoption of ICT (firms that have more than 249 employees).

Hypothesis 2

In order to focus the analysis only on ICT-enabled innovations, a dummy variable was constructed out of companies' answers to the questions on whether their product or service innovations introduced by a company in the last 12 months were directly related or enabled by information or communication technology. It takes a value of "1" if any product or process innovations were directly related to or enabled by ICT and "0" otherwise.

The main explanatory variable is the share of employees with a higher university degree. To additionally account for the effect of internal capacity on innovation, a variable controlling for the presence of ICT practitioners was added. This should control for the effect of ICT-specific skills on a company's innovative potential. Furthermore, the model includes also variables controlling for firm size and country of origin. Except for the variable on the share of educated employees, all independent variables are dummy variables, taking a value of "1" if a specific characteristic is identified, and "0" otherwise. To analyse the relationship between ICT-enabled innovation and the share of ICT practitioners and employees with a university degree, a probit regression was run (Table 5).

An analysis of the results leads to the following conclusions: changes in share of employees with a higher university degree positively affect the likelihood of conducting ICT-enabled innovations. Similarly, employing IT practitioners significantly increases firm's propensity to use ICT to develop new products and services. This finding provides further evidence that the success of the ICT-driven innovative process depends on the availability and quality of complementary assets.

Table 5 - Effect of employee skills on ICT-enabled innovation

Independent variable	Coefficient	Standard Error
% of employees with higher university degree	0.005*	0.002
ICT practitioners	0.920**	0.117
Less than 249 employees	-0.014	0.230
Model diagnostics		
N = 845; R-squared = 0.09		
Note: Probit estimates. The table does not report the country coefficients. * Significance 95%, ** Significance 99%		

Hypothesis 3

The dependent variable can take a value "1" if a company outsourced any of its business activities in the last 12 months, or "0" if it did not. The explanatory variable controlling for a company's ICT endowment level is an index composed of answers to the questions regarding the Internet connection type (less than 144 kbit per second, between 144 kbit and 2 megabit per second, or more than 2 megabit per second), the use of LAN, WLAN, WWW, Intranet, Extranet, ERM, SCM, CRM, the use of the Internet to sell and buy goods and employing IT practitioners (one score for each positive answer). Thus, the variable can take values between "0" and "13". In addition, the regression includes dummy variables controlling for firm size and country of origin. To

analyse the relationship between outsourcing and ICT adoption, a probit regression was run (Table 6).

An analysis of the results leads to the following conclusion: the ICT intensity increases the propensity to outsource business activities. The more advanced a company is in terms of ICT use, the more likely it is to have outsourced some business activities in the last 12 months. This provides support to the hypothesis that ICT enables companies to redefine their make-or-buy decisions and to outsource business activities that were previously done in-house.

Table 6 - Effect of intensity of ICT use and outsourcing

Independent variable	Coefficient	Standard Error
ICT adoption	0.059*	0.017
Less than 249 employees	0.050	0.237
Model diagnostics		
N = 932; R-squared = 0.051		
Note: Probit estimates. The table does not report the country coefficients. * Significance 99%		

Hypothesis 4

Again, the analysis focuses only on ICT-enabled innovations. Independent variables control is related to the use of SCM systems and sharing information on inventory levels or production plans electronically with business partners. The regression includes also variables controlling for firm size and country of origin. All independent variables are dummy variables, taking a value of "1" if a specific characteristic is identified, and "0" otherwise. To analyse the relationship between ICT-enabled innovation and the use of electronic data and information exchange between business partners, a probit regression was run (Table 7).

An analysis of the results leads to the following conclusions: the use of applications and practices supporting the electronic exchange of information between companies (e-Collaboration tools) positively affect the likelihood of conducting ICT-enabled innovations.

Table 7 - Effect of electronic collaboration with business partners on ICT-enabled innovation

Independent variable	Coefficient	Standard Error
Use of SCM	0.704*	0.139
Share information	0.599**	0.122
Less than 249 employees	-0.183	0.185
Model diagnostics		
N = 932; R-squared = 0.09		
Note: Probit estimates. The table does not report the country coefficients. * Significance 95%, ** Significance 99%		

Hypothesis 5

The dependent variable controlling for organisational changes is based on companies' answers to the questions of whether they introduced changes in corporate strategy, management techniques, organisational structure and marketing concepts. For

each positive answer a firm scores one point. Consequently, the dependent variable takes a value between "0", if a company did not carry out any of the listed changes, and "4" if it undertook all of them. In order to account for various effects of different ICT components on organisations, explanatory variables include:

- Hardware index that comprises of hardware components used by a firm and includes the share of employees with an Internet access at their workplace, Internet connection capacity and the use of LAN, Intranet and Extranet.
- Software index that comprises of software applications used by a firm. The index includes the following applications: a software application to manage the placing or receipt of orders, ERM, SCM, CRM and the use of the Internet to buy and sell goods.
- ICT human capital variable that controls for the presence of ICT practitioners.

In addition, the regression includes dummy variables controlling for the percentage of employees with a higher university degree, firm size and country of origin. To analyse the relationship between ICT-enabled innovation and the organisational change, an ordered logit regression was run (Table 8).

An analysis of the results leads to ICT hardware has little importance for organisational change. Hardware endowment, measured in terms of network infrastructure usage and Internet access, does not increase the likelihood of introducing organisational changes. On the contrary, software use and ICT practitioners drive organisational changes. The intensity of ICT applications use and, in particular, ICT-skilled employees is the major drivers of organisational changes.

This, together with the previous result, indicates that ICT skills, software and hardware have different implications for companies' conduct and performance. Whereas hardware is a necessary condition for an efficient ICT use, it is not a sufficient condition for business transformation. These are rather human skills combined with innovative software that enable firms to rearrange their operations, functions and workflows, i.e. find innovative ways of doing business. Hardware infrastructure, in contrast, is already a commodity that does not offer companies any potential to create a competitive advantage.

Table 8 - Effect of ICT use and organizational change

Independent variable	Coefficient	Standard Error
Infrastructure index	0.000	0.002
Software index	0.362*	0.060
ICT practitioners	0.571*	0.195
% of employees with higher university degree	0.003	0.004
Less than 249 employees	-0.312	0.338
Model diagnostics		
N = 651; R-squared = 0.05		
Note: Ordered logit estimates. The table does not report the country coefficients. * Significance 99%		

Hypothesis 6

The analysis focuses only on whether and how ICT-enabled innovations affect firms' performance. The dependent variable is a dummy variable that takes a value "1"

if a firm reported a sales increase in the last 12 months or "0" otherwise. Explanatory variables control for the introduction of any ICT-enabled innovations in the same time period, firm size and country of origin. All independent variables are dummy variables, taking a value of "1" if a specific characteristic is identified, and "0" otherwise. To analyse the relationship between a firm's performance change and ICT-enabled innovation activity, a probit regression was run (Table 9).

An analysis of the results leads to ICT-enabled output is positively related with performance increase. Firms with a higher incidence of ICT-enabled innovation activity are more likely to report a performance increase (i.e. to have experienced a sales growth). Although performance increase was used as dependant variable, this should not be read as a simple formula for success as there are possible confounding factors such as growth of a company in general. A similar result might also have been obtained by exchanging the dependent and independent variables, in the sense that successful companies (i.e. firms experiencing performance growth) are more innovative. In any case, the results indicate that the dynamics of business growth and innovativeness are strongly linked, possibly reinforcing each other.

Table 9 - Effect of ICT-enabled innovation activity on performance increase

Independent variable	Coefficient	Standard Error
ICT enabled innovation	0.300*	0.095
Less than 249 employees	-0.128	0.184
Model diagnostics		
N = 932; R-squared = 0.07		
Note: Probit estimates. The table does not report the country coefficients. * Significance 99%		

5. CONCLUSIONS

Due to the high turnover and number of jobs in the TLS industry and its interrelation with almost all other economy sectors, any improvements to the competitiveness and effectiveness of transport and logistics companies will have a positive impact on other industries. Over the last few years firms operating in the TLS sector have made significant progress in their adoption of new technologies, particularly those linked to ICT and e-business. In Europe, ICT and e-business activities deployment has thus become increasingly important for the TLS industry and about 75% of companies use e-business in one way or another to realise their business activity.

The analysis allows identifying the driving forces of ICT and its impact on selected business dimensions. On the driver's side, there are three points that are worth mentioning. First, increasing market competition is one of the driving forces behind ICT usage. In other words, more intense competition make companies use innovative technologies in order to cut costs and look for more innovative ways of conducting business. This, in turn, enables them to withstand the effect of increasing rivalry. Second, the relationships of companies interacting with each other play an important role in the diffusion of ICT applications supporting inter-firm collaboration. Close relationships facilitate investments in specific technologies. Third, the success of the ICT-driven innovative process depends on the availability and quality of complementary assets such as employee skills and ICT know-how.

On the impacts' side, the following issues draw one's attention. First, companies advanced in terms of ICT usage are more likely to have outsourced business activities.

This provides support to the hypothesis that ICT enables firms to redefine their make-or-buy decisions. However, a detailed analysis shows that the intensity of ICT applications use and ICT-skilled employees that are the major drivers of organisational changes. Hardware infrastructure, in contrast, is already a commodity that does not offer companies any potential to create a competitive advantage. Second, ICT usage has a positive impact on company performance, i.e. firms that introduced ICT-enabled innovations were more likely to have experienced a sales growth and increase market share.

On the basis of evidence from this study, the following issues have been identified as particularly relevant for policy making:

(i) *Improving ICT skills and managerial understanding and skills for e-business.* ICT usage and high levels of employee's skills complement each other, leading to skill-biased technological change and an advantage for TLS firms with highly skilled employees in adopting and using ICT. The picture that emerges from the survey is that ICT skills are a decisive issue, especially among SMEs, notably at the managerial level, i.e. how to use e-business to support a company's strategy. Training programmes need to be more focused on managerial understanding and skills for e-business, such as how to effectively integrate e-business processes into existing business models and strategies to change organisational structures.

(ii) *Promoting efforts towards ICT-enabled innovation.* The implementation of new ICT and complementary investments can lead to innovations, and innovations are positively associated with sales growth. In other words, innovative firms are more likely to grow. The empirical evidence presented in this study corresponds with the theoretical predictions that suggest that ICT and innovation are positively associated with performance at the firm level. Policy makers should envisage the creation of lead programmes in fields of excellence such as logistics and transport.

(iii) *Developing standards for e-business, facilitating the process of interoperability*. The importance of standards as a means of reducing transaction cost and increasing competitiveness has been identified as an important barrier to e-business diffusion. Policy measures should allow for temporal and business considerations in a competitive marketplace and may include, as appropriate, active dialogue with industry on challenges in formation of value networks and other potential barriers to implementation of interoperability as well as maintaining an agenda of priority identification, target-setting and monitored progress of interoperability in respect of an evolving priority list of functional digital enablers of ICT innovation and uptake.

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