Drivers and impacts of R&D adoption on transport and logistics services

Antonio Hidalgo1, Vicente López2 and José Albors3

1Dept. Business Administration. Universidad Politécnica de Madrid, c/José Gutiérrez Abascal, 2. 28006 Madrid, Spain. ahidalgo@etsit.upm.es
2Dept. Business Administration. Universidad Politécnica de Madrid, c/José Gutiérrez Abascal, 2. 28006 Madrid, Spain. vlopez@etsii.upm.es
3Dep. Business Administration. Universidad Politécnica de Valencia, c/Camino de Vera s/n. 46022 Valencia, Spain. jalbors@omp.upv.es

Actually, technologies and applications in industries are changing via business restructuring, new business models, new knowledge and supply chains. So R&D is not focused primarily on manufacturing industry as it used to be, but on different kinds of industries as logistics and transport (TLS). Nevertheless, the characteristics of the TLS industry determine the introduction of specific R&D solutions accordingly to sectors operations. The objective of this paper is to describe the R&D opportunities in the TLS industry and how managers use them to make their businesses more innovative and efficient. Using the Structure-Conduct-Performance (SCP) model the paper identifies the links between R&D adoption and innovation dynamics. Relating the findings, on the driver’s side there are three points that are worth mentioning: increasing market competition, the relationships of firms interacting with each other and the availability and quality of complementary assets such as employee skills and IT know-how. On the impacts’ side, firms advanced in terms of implementing R&D solutions are more likely to implement organizational changes. Finally, a set of recommendations on how to further improve the continuous innovation in the TLS industry is presented.

1. Introduction

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. For example, the transport sector in Europe plays a significant role in the economic development: it currently generates 7% of Gross Domestic Product (GDP) and for around 5% of employment in the European Union. On the other hand, the global logistics industry is estimated at 13.8% of the global EU GDP.

Actually, technologies and applications in industries are changing via business restructuring, new business models, new knowledge and supply chains. So R&D is not focused primarily on manufacturing industry as it used to be, but on different kinds of industries (knowledge industries and also -inter alia- logistics and transport and related industries). Nevertheless, the characteristics of the TLS industry determine the introduction of specific R&D solutions accordingly to sectors operations. These solutions may be classified into three categories (Garrido et al., 2007): i) identification technologies, ii) data communications technologies, and (iii) data management technologies.

In what concerns the identification technologies, firms may appeal to Radio Frequency Identification (RFID) that facilitates logistics information collection and exchange. As regards data communications technologies, firms may appeal to the adoption of internal computer networks composed of multiple connected computers that communicate over a wired (LAN) or wireless (WLAN) medium to share data and other resources. Nowadays, as regards the data management technologies, the firms usually deal with a large amount of data which means that data collection and exchange are critical for transport and logistics information management and control. These technologies are oriented to develop specific software applications for knowledge management to help companies organising information, for example, implementing technologies for inter-modal transportation management system or intelligent transport
system, while more advanced technologies could be oriented to manage cargo handling and fleet control system. In this area could be considered the new applications based on open source software (OSS) like the Modern Warehouse Management Systems (WMS) that operates quite a number of different interfaces, consider restricted storage strategies, and minimize transport routes and times.

Good quality in data acquisition can help TLS firms deliver customers' goods more accurately and efficiently 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 (Bowersox and Daugherty, 1995; Lewis and Talayevsky, 1997).

The main area of innovation that has been of significant discussion in TLS industry is based on information and communication technologies (ICT) which have the capacity to impact organizational structure, firm strategy, operational procedures and buyer-supplier relationships (Williams et al., 1997). The swift development of these technologies (identification, communication, and management technologies) as well as the declining prices for its use has considerably enhanced its diffusion during the last few years. As a consequence, its impact on productivity has become a broadly discussed topic in management sciences and several studies found empirical evidence for positive productivity effects of ICT at the firm level (Brynjolfsson and Hitt, 1996; Licht and Moch, 1999; Greenan and Mairesse, 2000).

Nevertheless, its adoption can improve the efficiency of firms (Cash and Konsynski, 1985), create an integrated approach linking transport modes in innovative ways, improve the quality of their services and, thus, increase organizational flexibility and competitiveness (Patterson et al., 2003).

The objective of this paper is to describe the R&D opportunities in the TLS industry and how companies (managers) use them to make their businesses more innovative and efficient. The analysis is organized as follows. In section 2, it is brought a descriptive assessment of the state-of-play of R&D solutions in the TLS industry. It focused on the diffusion of R&D-based applications, and on how they are used by companies, both for internal processes and for exchanges with other organisations or consumers. Sections 3 and 4 provide a complementary analytical perspective to identify the drivers and impacts of R&D adoption by TLS firms. Finally, section 5 concludes with some comments on the implications of the findings and some recommendations on how to improve the actual scenario of R&D adoption in the TLS industry.

2. State-of-play of R&D solutions in the TLS industry

2.1 Data collection

The sample studied is comprised of a total of 1097 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 eight countries (seven European countries -France, Germany, Italy, Poland, Spain, Sweden and United Kingdom- and USA) 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), United Kingdom (136) and USA (100).

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.
2.2 Implications of RFID technology

In practice, although the RFID technology is not new, the applications are very much at an exploratory stage. In the transport industry, RFID systems have the inherent capacity to assist in vehicle identification, tracking and tracing and thereby enhance both economic efficiency and security. RFID systems are playing a role in increasing load factors and hence reducing empty running. They have the potential to make better use of the infrastructure, help increase use of alternative modes, enhance enforcement and facilitate road charging.

In logistics applications, RFID enables service providers to better track and trace consignments on the different legs of transport processes. For example, intercontinental container shipping provides a good example for the value of reliable tracking and tracing: very often more than 20 different companies need to cooperate in transport of one single container. Railway operators suffer from poor monitoring of their wagons, which are spread across the rail network. By tagging not only packages and consignments but also transport units and vehicles with RFID technology, the asset management of these transport operators can be improved.

Results from the survey show a very limited use of RFID technologies yet (Figure 1). Only 2% of firms (23 from a total of 1097 surveyed firms), accounting for 13% of the sector's employment, have declared that they do use this technology. By sub-sector, about 6% of the logistics firms, 1% of passenger transport firms and 1% of the freight transport companies said they used RFID. The highest percentage of those firms (77%) said that they use RFID technologies to manage goods, products and services in-house. Only large firms show the higher adoption of RFID technologies (24%). Nevertheless, if the typical innovation life-cycle applies to RFID technology, a possible scenario for the TLS industry is that the technology will be adopted by medium-sized and smaller companies once it has proven successful in larger firms, and when the technology has matured and become more affordable to SMEs.

```
<table>
<thead>
<tr>
<th>% of companies using RFID by sub-sector</th>
<th>RFID application areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&amp;L - total (EU-7)</td>
<td>to support the order of goods</td>
</tr>
<tr>
<td>Passenger trans.</td>
<td>to manage products inhouse</td>
</tr>
<tr>
<td>Freight transport</td>
<td>to support customer service</td>
</tr>
<tr>
<td>Logistics</td>
<td>to manage the value chain</td>
</tr>
</tbody>
</table>

Data are weighted by employment (firms representing x% of employment in the sector).
Base: all companies.
```

Figure 1. RFID implementation in TLS

2.3 Data communications technologies

Current R&D solutions provide new possibilities for networks, the distribution of information and the design of business logic. The accessibility and the endless opportunities to creatively use the Internet has brought many implications to the organisations core business processes to generate enormous benefits in terms of performance as well as provide greater value-added products and services (Porter and Stern, 2001).

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. Low-cost access to the Web and the dissemination of e-business technologies provide firms with a tool to satisfy customer demand by using traditional services in conjunction with growing information-based services. Firms can automate existing processes and dramatically reduce cycle times throughout the supply chain. They can enhance communication, collaboration, and cooperation between knowledge teams (including virtual teams) using intranet technologies as well as between the organisation and
members of its external constituent organisations using extranet technologies. Moreover, firms may link their electronic systems to those of their suppliers, distributors, and dealers in powerful inter-organisational network to support effective supply chain management objectives, including integrated production life cycle planning. Key findings regarding the adoption of communication technologies in the TLS industry are summarised below:

1. Internet access is therefore fundamental for enterprises to start benefiting from the information society. For most EU Member States and USA Internet adoption is approaching saturation point. In line with this tendency, in the present study, nearly all companies (97%) which use computers in the TLS industry are connected to Internet. Only among passenger transport firms, a minority of 5% responded that they have not Internet connection. By share of employment, firms representing 99% of the sector workforce are connected to Internet (Table 1).

2. On the path to the adoption of these technologies, 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 TLS industry 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.

<table>
<thead>
<tr>
<th>Companies with Internet access</th>
<th>Companies whose Internet access has a bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 144 kbit/s</td>
</tr>
<tr>
<td>Weighting</td>
<td>Empl. %</td>
</tr>
<tr>
<td>Sectors</td>
<td></td>
</tr>
<tr>
<td>Passenger transport</td>
<td>99</td>
</tr>
<tr>
<td>Freight transport</td>
<td>98</td>
</tr>
<tr>
<td>Logistics</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1. Internet access and bandwidth in TLS

3. 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 only reaches 22% of the firms (Table 2), although it is already used by about a half of the large-sized firms, and even one third of the small companies. As it can be seen, the use of ICT to connect computers internally to a company network increases with company size.

4. 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). In this context, intranet and extranet 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%).

<table>
<thead>
<tr>
<th>Weighting</th>
<th>LAN</th>
<th>WLAN</th>
<th>Intranet</th>
<th>Extranet</th>
<th>Remote access</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Empl. %</td>
<td>Firms %</td>
<td>Empl. %</td>
<td>Firms %</td>
<td>Empl. %</td>
</tr>
<tr>
<td>Sectors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger transport</td>
<td>75</td>
<td>50</td>
<td>39</td>
<td>22</td>
<td>52</td>
</tr>
<tr>
<td>Freight transport</td>
<td>43</td>
<td>22</td>
<td>17</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Logistics</td>
<td>75</td>
<td>27</td>
<td>30</td>
<td>7</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 2. Networks and protocols used in TLS
5. Remote access means that employees can access data from the company's computer system remotely (i.e. 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%).

2.4 Software systems for internal process integration

Specific software applications for knowledge management are intended to help companies organising information that is relevant for employees in a way that they can easily retrieve and use it. To add intelligence and automation to the business process, TLS companies began deploying ERP applications that could handle customer information, material planning forecasts and pricing information. These systems could now automatically initialize a procurement process and rely on the EDI system for the message exchange. As shown in table 3, the use of ERP systems in the TLS industry is notably low (6%), compared, for example, to other sectors as chemicals, steel, plastics, rubber or furniture (45%). Yet, there is still a considerable gap in ERP adoption between small firms on the one hand (14%) and the medium-sized (23%) and large firms (41%) on the other. Outsourcing of these services could be a viable alternative. Thus, this is then one of the main challenges for further expanding B2B e-business activity, because if a business partner does not have an ERP system, the exchange of data in standardised electronic format is hardly possible.

Supply chain management (SCM) software can help companies from the TLS industry to match supply and demand through integrated and collaborative interaction tools. SCM provides an oversight of the flows of products/materials, information and finances, as they move in a process from supplier to manufacturer, to wholesaler, to retailer or to consumer. SCM coordinates and integrates these flows both within and among companies. However, as can be seen from table 3, in the TLS industry only 6% of firms representing about 21% of employment have an SCM system. The use of SCM systems is clearly a domain of the large firms: while only about 6-8% of SMEs have adopted a SCM system, about 36% of large firms did so.

About a fifth of firms (representing about 44% of sector employment) in the TLS industry reported the use of software solutions or internet-based services for e-procurement (software application to manage the placing or receipt of orders). This shows that there is a gap between the percentage of companies placing at least some orders online (41%) and those that use special software for this (20%). It can be assumed that companies without such software place orders mainly through websites or extranets of suppliers, which does not require any special e-procurement system. The digital back-office integration of procurement related processes (all the way from ordering to the receipt of goods/services) is probably not in advanced state in these cases. It is interesting to observe that the percentage of firms with special ICT systems for e-procurement is more than three times (20%) than those firms with an ERP system (6%).

<table>
<thead>
<tr>
<th>Weighting</th>
<th>ERP system</th>
<th>SCM system</th>
<th>e-Procurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Empl. %</td>
<td>Firms %</td>
<td>Empl. %</td>
</tr>
<tr>
<td>Sectors</td>
<td>21</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>Passenger trans.</td>
<td>16</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Freight transport</td>
<td>17</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>Logistics</td>
<td>30</td>
<td>4</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 3. Use of e-Business software systems in TLS

2.5 Specific R&D solutions

The characteristics of the TLS industry have determined the adoption of specific technologies accordingly to sectors operations. These technologies can be grouped in the following systems: maintenance management system, cargo handling technologies, fleet control system, intermodal transportation management system, and intelligent transport system. The findings of the survey (Table 4) shows that less used technologies are the intermodal transportation management system (4%), the cargo handling technology (5%) and the intelligent transport system (7%). More advanced systems for cargo handling
and fleet control are mostly used by mid-sized and large companies in the freight transport and logistics sectors.

The survey also shows that many companies have developed a proprietary solution based on open source software (OSS) which permits users to use, change, and improve the software, and to redistribute it in modified or unmodified form. The availability of the source code supports a high innovation grade, next to more efficient maintenance of the software which will result in a more effective effort by ICT experts. The cost is very low, but it has to take into account the learning curve and the cost of deployment and also the potential impact on the rest of the software that they are expected to integrate with.

<table>
<thead>
<tr>
<th></th>
<th>Maintenance management system</th>
<th>Cargo handling technology</th>
<th>Fleet control system</th>
<th>Intermodal transportation management system</th>
<th>Intelligent transport system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting</td>
<td>Empl. %</td>
<td>Firms %</td>
<td>Empl. %</td>
<td>Firms %</td>
<td>Empl. %</td>
</tr>
<tr>
<td>Sectors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger trans.</td>
<td>32</td>
<td>15</td>
<td>16</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>Freight transport</td>
<td>29</td>
<td>18</td>
<td>3</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Logistics</td>
<td>32</td>
<td>13</td>
<td>18</td>
<td>4</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 4. Use of specific R&D solutions in TLS

3. Drivers and impacts of R&D adoption. Analytical perspective

Economic literature suggests that the adoption and diffusion of R&D solutions among firms in the economy at large is a striking example of the possible dynamics of technological change and economic development (Acemoglu, 2002; Carayannis and Turner, 2006). 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 analysis, an extended Structure-Conduct-Performance (SCP) paradigm was used as a conceptual framework for the identification of R&D adoptions. 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 is 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). 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 R&D adoption at the firm level through the contrast of different hypotheses.

The SCP model and the bi-directional relationships of its elements are represented in figure 2.
3.1 Hypotheses

Increasing competence in the market is an important factor that drives the adoption of new technologies and innovation (Dawe, 1994), 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 (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 belief was that ICT was to eliminate the limitations of location and enable firms to expand regardless of geographical locations (Cairncross, 1997). Actually, ICT offers firms 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 R&D solutions.**

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 Scott, 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 R&D investments (Rush et al., 2007). In other words, firms that combine high levels of R&D adoptions 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 R&D-enabled innovations.**

R&D 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 (Gomes and Park, 1997). The benefits of information integration with the help of ICT solutions 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; 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:

**H3. Firms that use ICT applications to exchange information with business partners are more likely to introduce R&D-enabled innovations.**

R&D 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. 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). This leads to the following hypothesis:

**H4. R&D adoption will affect organisational changes positively.**

### 4. Methodology and results

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 R&D solutions 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 5).

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing competence</td>
<td>0.633*</td>
<td>0.257</td>
</tr>
<tr>
<td>Less than 249 employees</td>
<td>-3.637**</td>
<td>0.471</td>
</tr>
</tbody>
</table>

**Model diagnostics**

N = 932; R-squared = 0.10

Note: OLS regression.* Significance 95%, ** Significance 99%

**Table 5. Effect of market competence and the intensity of R&D adoption**
An analysis of the results leads to the conclusion that increasing market competence drives R&D adoption and the hypotheses 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 R&D solutions (firms that have more than 249 employees).

Hypothesis 2

In order to focus the analysis only on R&D-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 R&D-enabled innovation and the share of ICT practitioners and employees with a university degree, a probit regression was run (Table 6).

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 R&D-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 R&D-driven innovative process depends on the availability and quality of complementary assets.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>% employees with higher university degree</td>
<td>0.005*</td>
<td>0.002</td>
</tr>
<tr>
<td>ICT practitioners</td>
<td>0.920**</td>
<td>0.117</td>
</tr>
<tr>
<td>Less than 249 employees</td>
<td>-0.014</td>
<td>0.230</td>
</tr>
</tbody>
</table>

Model diagnostics

N = 845; R-squared = 0.09

Note: Probit estimates. * Significance 95%, ** Significance 99%

Table 6. Effect of employee skills on R&D-enabled innovation

Hypothesis 3

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 R&D-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 R&D-enabled innovations.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of SCM</td>
<td>0.704*</td>
<td>0.139</td>
</tr>
<tr>
<td>Share information</td>
<td>0.599**</td>
<td>0.122</td>
</tr>
<tr>
<td>Less than 249 employees</td>
<td>-0.183</td>
<td>0.185</td>
</tr>
</tbody>
</table>

Model diagnostics

N = 932; R-squared = 0.09

Note: Probit estimates. * Significance 95%, ** Significance 99%

Table 7. Effect of electronic collaboration with business partners on R&D-enabled innovation
Hypothesis 4

The dependent variable controlling for organisational changes is based on firms’ 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 technologies 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, ERP, SCM, CRM and the use of the Internet to buy and sell goods.
- R&D 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 R&D-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 R&D applications use and, in particular, ICT-skilled employees are the major drivers of organisational changes. This, together with the previous result, indicates that skills, software and hardware have different implications for companies’ conduct and performance. Whereas hardware is a necessary condition for an efficient R&D adoption, 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>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure index</td>
<td>0.000</td>
<td>0.002</td>
</tr>
<tr>
<td>Software index</td>
<td>0.362*</td>
<td>0.060</td>
</tr>
<tr>
<td>ICT practitioners</td>
<td>0.571*</td>
<td>0.195</td>
</tr>
<tr>
<td>% of employees with higher university degree</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td>Less than 249 employees</td>
<td>-0.312</td>
<td>0.338</td>
</tr>
</tbody>
</table>

Model diagnostics

N = 651; R-squared = 0.05

Note: Ordered logit estimates. * Significance 99%

Table 8. Effect of R&D adoption on organizational change

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. R&D solutions in the area of ICT have major potential influences on the mobility of people and goods, and also a potentially important enabler of change in social and organisational practices, thus affecting the demand for transport in spatial and temporal terms.

The continuous improvement of R&D applications in the TLS industry has allowed companies to embrace opportunities to substitute manual processes by electronic exchanges, thus optimising the flow of information in and between companies, taking advantages of the increased diffusion of e-business software systems. This translates into more intensive and advanced electronic business practices, and a greater potential for exploiting cost-saving opportunities. Nevertheless, the perceived importance of e-business is clear for large-size companies, but not for small companies.
The analysis allows identifying the driving forces of R&D adoption 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 R&D adoption. 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 adoption of R&D applications supporting inter-firm collaboration. Close relationships facilitate investments in specific technologies. Third, the success of the R&D-driven innovative process depends on the availability and quality of complementary assets such as employee skills and ICT know-how.

On the impacts’ side, companies advanced in terms of R&D adoption are more likely to implement organisational changes. A detailed analysis shows that the intensity of R&D applications (specific software) and ICT-skilled employees 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.

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.* 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. 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 is an important barrier to e-business diffusion. Policy measures may include, as appropriate, active dialogue with industry on challenges in formation of value networks and other potential barriers 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.

6. References


Garrido, S., Ferreira, J., Leitão, J. (2007): The role of logistics’ information and communication technologies in promoting competitive advantages of the firm, University of Beira Interior, Munich Personal RePEc Archive.


