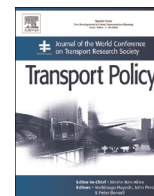




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Innovation in the European transport sector: A review

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ABSTRACT

This article reviews innovation of the European transport industries. It combines a quantitative analysis of the R&D investment of manufacturers of transport equipment, transport service providers and the constructors of transport infrastructure for the years 2008 and 2011 with a qualitative assessment of their incentives to innovate. The latter takes into account sector-specific innovation systems, their distinct market environments and the products and services produced. The findings show that, although the transport sector as a whole is the largest industrial R&D investor in the EU, there are important differences in the level of innovation activities carried out by the highly heterogeneous sub-sectors. These differences seem to be of systemic nature: they are found consistently in the quantitative analysis and the theoretical considerations. The result is highly policy-relevant as it indicates that policies targeting innovation in transport need to take into account the specific innovation capacities of the various sub-sectors.

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1. Introduction

The European transport sector is to reduce its emissions of greenhouse gases by 60% compared to its 1990 levels, strongly reduce its oil dependency, and limit the growth of congestion; these objectives are to be achieved without curbing mobility (European Commission, 2011). Innovative solutions, comprising new technologies, suitable infrastructures and organisational improvements, are one important means in implementing these goals. At the same time, successful innovations can help the European transport industry in maintaining its global competitiveness. To this end, the European Commission published a communication that serves as a starting point for the preparation of a strategic framework for transport research, innovation and deployment (European Commission, 2012).

In order to identify where there is a need for public interventions to stimulate, steer or complement the transport sector's innovation activities, the sector's capacities and incentives to innovate need to be reviewed. Such a review needs to be undertaken at the level of the various transport sub-sectors in order to account for the high heterogeneity of the transport sector in terms of

modes, technologies, customers, infrastructure and services, which are likely to lead to very different research activities across them.

The present paper undertakes such a review. In order to derive robust conclusions, it combines a qualitative review of factors influencing the level of innovation activities in industry with a quantitative analysis of R&D investments. For every sub-sector, a hypothesis on the propensity to invest in research and innovation is formulated, based on factors such as market size, the nature of different transport-related goods and the competition intensity (Section 2). The quantitative analysis of the corporate R&D investments of EU-based transport industries for the years 2008 and 2011 is introduced in Section 3. The outcome of that quantitative analysis is then (Section 4) compared with the initial expectations about the innovation propensity. Conclusions are presented in Section 5.

2. Hypothesis

2.1. Theoretical considerations

We expect to find a wide discrepancy in the R&D intensity of the various transport subsectors due to the very different nature of their market environment, the goods and/or services they produce, their innovation system and other external factors such as regulations.

Transport companies innovate in order to increase the range

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¹ The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

and improve the quality of goods and services – and with this to ultimately increase market shares and enter into new markets – and to simultaneously add flexibility and reduce costs in the production processes. On the other hand, most barriers identified by transport companies are of financial nature, such as lack of funds or high costs of innovation, and market related, with e.g. the dominance of established companies or uncertainties in the demand for innovative goods hampering innovation (as shown by the results of the Community Innovation Survey CIS 2010).

The degree to which different companies in the transport sub-sectors engage in R&D activities is largely determined by the expected returns on R&D investment and the possibility to gain an advantage over its competitors. These depend on a number of factors, which are likely to vary substantially across different transport companies.

Firm size is considered one of the factors positively influencing a company's propensity and capacity to invest in R&D (Schumpeter, 1942; Galbraith, 1952). This relationship has generally been confirmed in empirical studies (see Cohen, 2010 for an overview), even though a recent study questions it for the energy industry (Costa-Campi et al., 2014). Larger firms can more easily spread the costs of R&D; higher sales volumes imply that the benefit from R&D investments is usually greater. At the same time, larger companies are considered to have easier access to financing. Eventually, they may be in a better position to market their innovation and therefore earn benefits from their R&D investments.²

Market size influences the profitability of the R&D investment, and therefore has an immediate impact on innovation effects ('demand-pull', Schmockler, 1966). The expected market for the innovative product – linked to turnover times of equipment and the level of appreciation of innovation by the consumer as well as regulation – and the possibility to capitalise on the innovation, in comparison to the capital intensiveness of the innovation, ultimately determines the potential return of innovation activities. In particular, heterogeneous goods in which innovation may be a 'selling factor' will trigger more innovation efforts from the manufacturer than goods that compete merely over the price, even though process innovations are also important in the latter case in order to reduce production costs. Consumers' appreciation of innovative products, such as through their improved functionality, environmental and symbolic attributes help the adoption of innovative products (Noppers et al., 2014). Long turnover times and a small market size tend to be adverse to innovation as they result in a lower demand for (novel) products and hence potentially longer payback times for the innovators. For the diesel engine efficiency market, Bonilla et al. (2014) found that the propensity of European and Japanese firms to be innovative is positively related with the market size.

The market structure may create further incentives or disincentives to innovate. Aghion et al. (2005) found that the relationship between product market competition (expressed by a Lerner index) and innovation (measured by patents) takes the shape of an inverted U, where certain competition levels benefit the innovation activity of economic sectors and others (monopoly or very high levels of competition) hinder their innovation potential. This confirmed the inverted U-shape relation between R&D intensity and concentration described earlier by Scherer (1967).³

² For a deepened introduction on demand, appropriability and technological opportunity and the 'Profiting from Innovation Framework' we refer to Teece (2010).

³ In his extensive review of empirical studies on innovation, Cohen (2010) referring to studies by Sutton (1998), Cohen and Levin (1989) and others, questions that market structure is an independent important driver of innovation; moreover, innovation may influence market structure. However, making reference to Gilbert (2006), this does not imply that the market structure does not matter for

ITF (2010) sketched such an inverted U-curve for the transport sector and showed that, for example, both the more monopolistic structure of public transport and the strong competition of trucking would result in lower innovation efforts, whereas the competition regime of car manufacturing would support efforts in innovation.

According to the Porter hypothesis (Porter and van der Linde, 1995), environmental regulations are another driver for environmental-related technological innovations. Environmental regulations usually create a market for new products, whose growth and size is comparably predictable. Since regulations and standards are particularly high for some transport sectors, they may stimulate innovation in areas that otherwise would be targeted less. This has a direct effect on the competitiveness and may promote the creation of lead markets in countries where the regulations are implemented first (Beise and Rennings, 2003). Several studies demonstrate that environmental regulations and standards raise the innovation efforts of firms (OECD, 2011; Bonilla et al., 2014).

Oltra and Saint Jean (2009) show on the basis of a patent analysis that environmental innovations can best be explained by the simultaneous consideration of technological regimes, demand condition regimes and public policy. Carlsson and Stankiewicz (1991) further describe a technological innovation system through the interaction of three elements in a specific technological area, namely actors, networks and institutions. Hence, also these elements need to be taken into account here, which, however, will only be done briefly due to their complexity. We refer to Köhler et al. (2013) and Wiesenthal et al. (2011) for a more comprehensive analysis of EU transport innovation systems.

Even though the present analysis is restricted to civil innovations, knowledge inflows from defence-driven innovation efforts need to be acknowledged, in particular since in many cases the same actors are involved in both civil and military research activities.

2.2. Expected innovation efforts in diverse transport sectors

In the following, we will estimate the innovation propensity of the various transport sub-sectors that we would expect when applying qualitatively the criteria of the factors mentioned above and their resulting impact on innovation efforts.

The car manufacturing industry sector can be described as a monopolistically competitive industry with large-scale companies involved (ITF, 2010). Here, innovative products serve as one criterion for the company's branding and are one of the 'selling factors' of vehicles, since users are not only price sensitive, but attach importance to car performance and customisation. In addition, the sector is exposed to increasingly stringent environmental regulation, which is largely being met through technological improvements. In consequence, innovative products contribute significantly to the turnover of the industry, accounting for 43% of the total (see Fig. 1). At the same time, however, the industry needs to reduce costs and increase productivity. Process innovations are crucial for aligning these objectives. One example for this is the introduction of a platform strategy or the development of engine families to be used by many different models, brands of the same group or even across manufacturers, in order to enable economies of scale despite the backdrop of segment and body-style proliferation. Hence, innovation in the automotive sector is characterised by a strong focus on the core competencies and the constant interplay of product and process innovation (Rhys, 2005; quoted in Sofka et al., 2008). Thus, the automotive

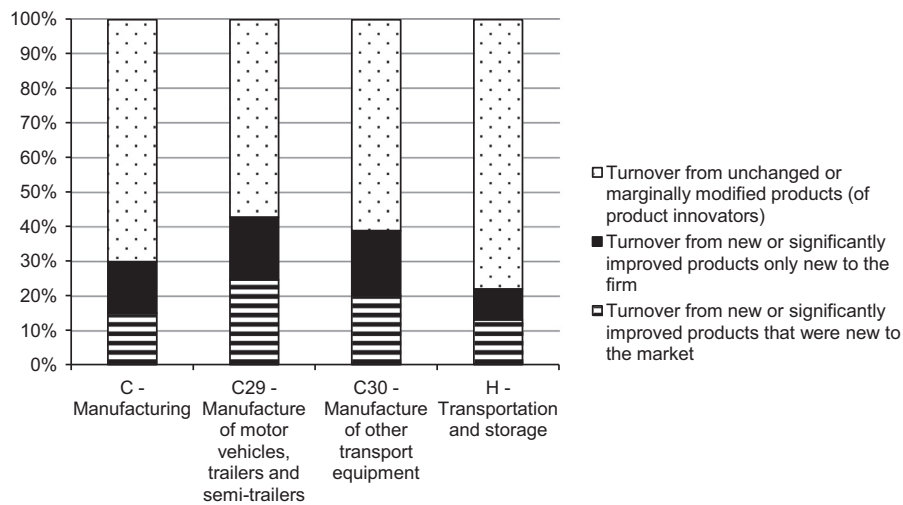


Fig. 1. Contribution of innovative products (new to the market; new to the firm) to the turnover of companies in transport-related sectors. Data source: Eurostat CIS survey 2010 (based on NACE R2 sectors).

sector has a high incentive for innovating, and can leverage on large markets to recover costs.

Within the automotive industry, manufacturers of commercial vehicles are exposed to a higher level of cost pressure than car manufacturers, as road freight transport companies follow a rational economic logic when acquiring new equipment and are not easily convinced to use innovative technologies unless they reduce their overall costs. In parallel, they are also exposed to a smaller and more volatile market base (the commercial vehicle market is especially sensitive to changes of the economic growth rate). Both of this would result in innovation efforts that are still considerable, but below that of car manufacturers.

The automotive industry is characterised by a strong innovation system with a very strong 'vertical' knowledge flow between component suppliers and vehicle manufacturers (Köhler et al., 2013). Suppliers carry out around 75% of the vehicle production (IHS Global Insight, 2009), with large tier 1 suppliers showing responsibility for engineering, pre-assembling, logistics and co-ordination of upstream suppliers in order to deliver complete functional units to the car manufacturers (Christensen, 2011; European Commission, 2009). Hence, one can expect that within the automotive sector, the component suppliers are the most research-intensive actors.

Competition levels in the aviation industry are elevated (Hollanders et al., 2008), even if the aircraft manufacturing industry is dominated by a very few large airframe and engine manufacturers, who all compete in a global market. The Airbus Group, Boeing, Dassault, Finmeccanica (Alenia Aeronautica), Bombardier and Embraer are the main airframe manufacturers, with Russian and Chinese manufacturers mainly active in their internal markets. Rolls-Royce, General Electric and Pratt & Whitney are the main manufacturers of turbofan engines for large civilian aircraft. There are also a few major helicopter manufacturers, with both Boeing (Hughes) and Airbus Helicopters (formerly Eurocopter) being major manufacturers together with Finmeccanica (AgustaWestland) in the EU. Innovation constitutes a selling factor for the aviation production industry, in particular concerning efficiency due to the very elevated relevance of fuel cost for the airline revenues; therefore, innovative products contribute to almost 40% of the total turnover of the manufacturers of other transport equipment, which include aviation (see Fig. 1). In addition, the industry is exposed to exceptionally strong safety and security requirements and increasing pressure to reduce its environmental impacts. The high interlinkage and mutual knowledge flows

between civil and military aircraft developments is another important characteristic of this sector. We therefore expect a high importance of innovation in the aviation sector.

In the rail supply industry, competition is elevated despite the rather limited number of players and the relatively small market size, in comparison with road modes. The main manufacturers in Europe are Alstom and Siemens, with Bombardier in Canada, GE from the US and Hitachi from Japan competing. Railway vehicles have a typical lifetime of 30–35 years (Bombardier, 2010), while signalling and control systems have a similar lifetime. These factors make the market for new locomotives and rolling stock small and the development of major technological changes very difficult. Innovation is further hampered by the particularly high innovation costs in this industry. To enter into the market there is a very complex process of acceptance – homologation – of both new trains and control systems. Considering the smaller market and the entry barriers, we expect moderate innovation activities.

The waterborne sector in the EU is limited to mainly specialist products and military production; production of low-value vessels is undertaken outside of the EU. Key industrial actors include shipyards like Fincantieri, IHC Merwede and the Marine Systems section of ThyssenKrupp, as well as marine equipment manufacturers like MAN Diesel & Turbo, Wärtsilä, and Rolls-Royce Marine. With the relatively small market of vessels produced, the opportunities for the recovery of investments targeting innovations are limited. However, especially for the EU-based shipbuilding industry, which is world leader in the export of military vessels (European Commission, 2009), the knowledge transfer from military innovations is likely to be important.

For most of the providers of transport services, and here in particular for freight transport services (trucking, postal service, etc.), competition levels are very high. Low entry and exit barriers in road freight, as well as a competition that is essentially based on the price of the service offered, result in many small companies and a limited number of rather large firms operating at small margins and allow for a limited capacity to cover fixed costs and finance innovation. The economic downturn has further increased the competition pressures between companies. As transport services mainly differ through price, innovative products contribute only little to the total turnover of the sector (about 20%; CIS 2010). Hence, transport companies focus largely on reducing their costs and have lower incentives to invest in R&D.

The construction sector is exposed to a high level of competition, in particular for small contractors, since the selection of

Table 1
Expected innovation propensity of transport sectors.

Factors considered	Are the sub-sectoral characteristics for each of the factors beneficial for engaging in innovation?							
	Automotive			Civil aeronautics	Waterborne	Rail	Transport service providers	Infrastructure construction
	Car manufacturers	Component suppliers	Commercial vehicles manufacturers					
Nature of the goods ^a	++	++	+	+	+	-	-	-
Size of companies	++	+	++	++	+	+	-	0
Market size	++	++	+	+	-	+	-	-
Competition level	++	++	-	++	+	+	-	-
Strong innovation system	++	++	++	++	+	+	0	0
Regulations and standards	++	++	++	++	++	++	0	0
Expected innovation efforts^b	++	++	+	++	+	+	0	0

Symbols refer to: 0 no impact on innovation; – creates a disincentive to engage in innovation activities; + creates an incentive for innovation in the sector; and ++ creates a strong incentive.

^a Homogeneous versus heterogeneous goods.

^b Based on the hypothesis described earlier and the characteristics of each transport sector.

designers and constructors is largely based on tendered prices (Egan, 1998). In parallel, competition among large general contractors and among specialty firms has been identified as oligopolistic (OECD, 2008; Girmscheid and Brockmann, 2006). Thus, we expect a limited innovation performance of the construction industry.

In the following table (Table 1) we combine the factors that are considered influential for a company's engagement in innovation activities (listed in the first column) with the above characterisation of transport sub-sectors. In a qualitative manner, we try to roughly estimate what the relevant characteristics of the sub-sectors would mean for its incentives to engage in innovation activities. The bottom column provides an aggregate estimation of the degree of R&D activities that we would expect to find in each of the transport sub-sectors. These expectations will then be compared with the results of the quantitative assessment of R&D intensities (Section 4).

3. Measuring the R&D investment at a company level

3.1. Approach

The Industrial R&D Investment Scoreboard (JRC-DG RTD, 2009, 2010, 2012) forms the starting point for the analysis of corporate R&D investments in this work. It is prepared from companies' annual audited reports and accounts, following the ICB classification. Companies are allocated to the country of their registered office.

Instead of following the ICB classification of that database, we undertake an assessment on the basis of individual companies. This approach allows us to assess all relevant transport sub-sectors; moreover research from companies in the supply chain that are allocated to non-transport ICB classes can be included. For companies that are only partially active in the transport field, the non-transport related R&D investments are approximated and removed from the total. In more detail this bottom-up approach follows five steps (see Wiesenthal et al., 2012):

Step 1: The identification of key industrial players by transport sub-sector, namely automotive industry (manufacturers of passenger cars and of commercial vehicles, component suppliers), civil aeronautics/aviation (manufacturer of aircrafts and component supplier for civil purposes), shipbuilders and

marine equipment manufacturers, rail manufacturers and component suppliers, companies that construct and maintain transport infrastructures and transport service providers (logistics and freight transport service providers, passenger transport service providers as well as the providers of infrastructure such as harbours).⁴

Step 2: R&D investments for the companies are taken from the EU Industrial R&D Investment Scoreboard and – when needed – further complemented by information obtained through a systematic research of annual reports. Out of the initial list of 250 companies identified in step 1, the R&D investment could be identified for 163. In order to enable a comparison of the R&D investments between the years 2008 and 2011, the sample had to be identical for both years. To this end, we had to exclude a few of these companies that were no longer operating in 2011, further reducing the sample base to 142 companies.

Step 3: Removal of non-transport related R&D. While many of the companies identified operate in the transport sector only, a number of large companies also have substantial activities in non-transport sectors. This is the case in particular for large supranational companies such as Robert Bosch, Siemens, Alstom, etc. For those players, assumptions had to be made on the parts of their overall R&D activity that are directed towards transport where this could not directly be derived from official sources.

Step 4: Several companies are active in more than one transport mode or sub-sector. For these players, an allocation of the R&D investments by mode has been performed.

Step 5: The summing up of the individual companies' R&D investments by sub-sector.

The results of this analysis are compared with other sources to the extent possible. In particular, we provide results from the Eurostat/OECD BERD (Business enterprise sector's R&D expenditure) database, which contains data on the business enterprise sector's expenditure in R&D for different socio-economic objectives following the NACE classification. It further breaks down the R&D

⁴ In a previous work (Wiesenthal et al., 2011), an effort was made to single out the R&D intensity related to the Intelligent Transport Systems. However, since ITS is more a group of technologies rather than a sector, and because of the fact that many of the other actors mentioned above are likely to dedicate important parts of their R&D to ITS applications (Juliussen and Robinson, 2010), ITS is not singled out in the present work.

expenditures by sources of funds, i.e. business enterprise sector (BES), government sector (GOV), higher education sector (HES), private non-profit sector (PNO) and abroad (ABR).

However, these databases are not directly comparable due to differences in the sectoral classifications (i.e. NACE vs ICB), and in particular due to different geographical allocation schemes. The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed (Azagra Caro and Grablowitz, 2008). BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of financing.

3.2. Uncertainties

An assessment based on a limited number of companies bears the risk of systematically under-estimating the actual research efforts. Even more so, the reduction of the companies analysed to those that are active in both years of the assessment may lead to an under-estimation of the aggregate R&D investments. However, the comparison of the 2008 R&D investment of the sample base with 163 companies (Wiesenthal et al., 2011) with the results of the present analysis shows a very limited difference of –2%. Secondly, the removal of non-transport-related R&D investment and the allocation of R&D investments to sub-sectors is often estimated on the basis of indirect proxy indicators, thereby introducing uncertainty.

An assessment of the R&D and economic performance of key industries in the automotive sector (AEA, 2012) showed that in the scoreboard data automotive suppliers are under-represented. Our bottom-up approach can, however, compensate this partially and includes a larger list of suppliers, in particular comprising the large ones.

Knowledge spillovers into the transport sector cannot be fully captured, such as progress in research on materials (e.g. lightweight composite materials), informatics (Intelligent Transport Systems) or with the energy sector.⁵ There are important knowledge inflows from research funded by military funds, in particular in aeronautics but also the waterborne sector. Similarly, major consumers of transport services, in particular large retail companies, are likely to spend a part of their R&D investments for the improvement of the supply chain logistics. There are also important spillover effects between and within modes that cannot be quantified in this study; for example, the rail industry benefits from truck engine research.

4. Results and discussion

The EU-based transport industry invested €38.2 billion in transport-related R&D in 2008 and €₂₀₀₈ 42.8 billion in 2011 (Table 2; in constant prices 2008), making it the largest industrial R&D investor in the EU. This figure hides a very high divergence in R&D investment levels (see Fig. 2) and in the R&D intensity – i.e. the R&D investments in relation to the net sales – of the various transport sub-sectors.

Transport R&D investments are clearly dominated by the spending of the automotive industry, which amounted to €₂₀₀₈ 34.8 billion in 2011. Compared to the year 2008, R&D investments increased by 11%, yet at a slower pace than the net sales, resulting in a slight decrease in the R&D intensity from 5.2% to 4.8%. In line

Table 2

R&D investments of EU-based transport-related companies in 2008 and 2011 (at constant prices, 2008).

Investments	2008 (M€ ₂₀₀₈)	2011 (M€ ₂₀₀₈)
Automotive	31,298	34,846
Car manufacturers	17,607	19,844
Commercial vehicles manufacturers	3,488	4,158
Component suppliers	10,203	10,844
Civil Aviation	4,563	5,579
Waterborne	598	603
Rail	873	874
Infrastructure	198	207
Transport services providers	713	644
Transport Sector	38,243	42,753

with the concentration of vehicle manufacturing in a few large firms, also R&D investments are strongly concentrated on a limited number of actors, with 12 players accounting for almost 90% of the total in 2008 and 80% of the total in 2011.

Within the automotive sector, car manufacturers are the largest investors in R&D with €₂₀₀₈ 19.8 billion in the year 2011 (R&D intensity of 4.8%), much above the investment levels of manufacturers of commercial vehicles (€₂₀₀₈ 4.2 billion; intensity of 4.0%) and automotive suppliers (€₂₀₀₈ 10.8 billion). The R&D intensity of suppliers is the largest of the automotive subsectors, reaching 5.8% in 2008 and 5.1% in 2011, which underlines their importance in the innovation chain and their propensity to innovate. Compared to the year 2008, all three segments of the automotive industry increased their R&D investments in 2011; however, R&D intensities slightly decreased except in the commercial vehicles segment.

These figures are well in line with results of other studies. The European Automobile Manufacturers' Association (ACEA) and the European Council for Automotive R&D (EUCAR) reported that 'the fifteen ACEA members together spend over €26 billion every year on R&D, or about 5% of their turnover'.⁶ The European Association of Automotive Suppliers (CLEPA, 2009) stated that automotive suppliers in Europe present an annual R&D spending of €12 billion. According to BERD, the overall R&D expenditure of the automotive industry (BES funds) accounted to €21.4 billion in 2008 (even though a direct comparison is not possible as explained in Section 3).

Manufacturers of civil aeronautics equipment are the second largest R&D investing transport sector, and the one having by far the highest R&D intensity (7.8% in 2008 and 6.5% in 2011), which confirms the hypothesised innovation propensity of this sector formulated in Section 2.2. The aggregated R&D investments to civil aeronautics of the 19 largest EU-based companies including Airbus Group, Finmeccanica, Rolls Royce, Safran amounted to €4.6 billion in 2008 and €₂₀₀₈ 5.6 billion in 2011. Our result is backed by figures that can be derived from the Aerospace and Defence Industries Association of Europe (ASD, 2009), according to which the self-funded R&D investments of the EU civil aeronautics industry was around €5.5 billion in 2008. The increase of 22% between 2008 and 2011 is in line with the rise found between the ASD (2012) figures for 2011 with the ones for 2008 (ASD, 2009). The Eurostat BERD (BES funds) under the NACE R1 category DM353 'Manufacture of aircraft and spacecraft' give a total of €4.8 billion for 2008.

The major EU-based waterborne transport equipment manufacturing industries invested around €₂₀₀₈ 600 million in R&D in both 2008 and 2011, with their R&D intensity increasing from 3.3%

⁵ Research done by fuel suppliers is not considered here as oil companies are parts of the energy sector; their R&D investments in terms of alternative motor fuels was analysed in Wiesenthal et al. (2009).

⁶ From the ACEA website and EUCAR (2010). See also EUCAR (2009, 2008) and ACEA (2009) for further information on automotive R&D.

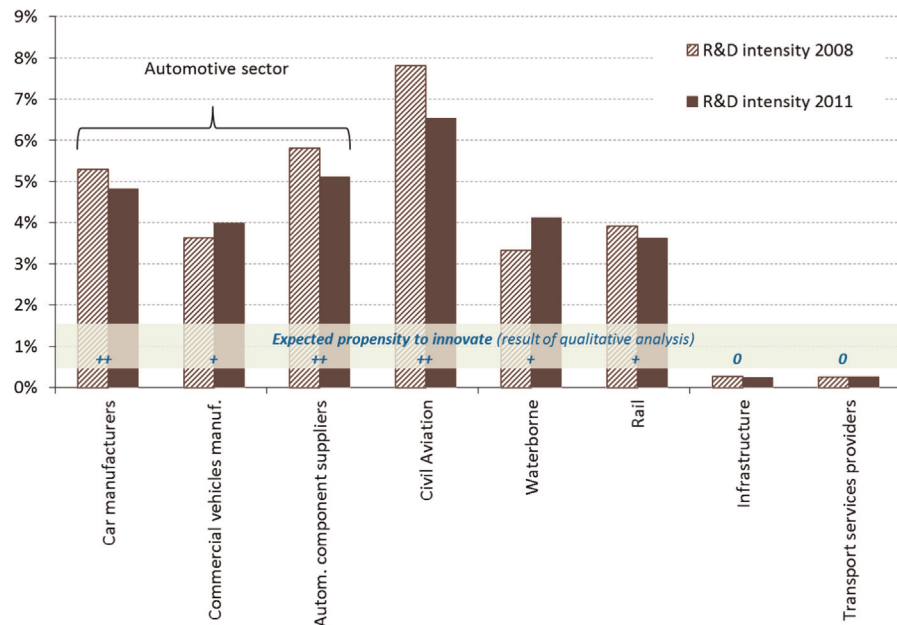


Fig. 2. R&D intensities of EU-based transport-related companies in 2008 and 2011, and expected innovation propensity.

to 4.1%, which corresponds to a moderate propensity to innovate. For 2008, the 14 EU companies assessed in this sector have been further classified into shipyards (€106 million invested; R&D intensity of 1.6%) and marine equipment manufacturers (€492 million). The R&D intensities found in the present assessment related to EU shipbuilders and equipment manufacturers are supported by the analysis undertaken by *Ecorys* (2009; p.132). However, even if the main EU-based firms of this domain have been analysed, this figure is probably an underestimation of the real picture since a number of smaller companies are not covered.

The aggregated R&D investments that covers the 15 largest EU-based rail equipment manufacturers and suppliers leads to an estimate of around €₂₀₀₈ 873 million spent in R&D in 2008 and 2011, with an R&D intensity of 3.9% and 3.6% respectively. This result is in line to an analysis reporting an R&D investment of €1 billion of the rail supply industry (*European Commission*, 2010).

The category 'transport service providers' includes companies involved in industrial transportation such as Deutsche Post, TNT Post Danmark, companies involved in the provision of passenger transport services, including railway operators like Deutsche Bahn, public transport operators like Veolia Transport and RATP, airlines such as Lufthansa, and the providers of infrastructure services like harbours and highway operators. The aggregated R&D investments of this sector amounted to more than € 700 million in 2008.⁷ For the same set of companies, the R&D investments for 2011 decreased to €₂₀₀₈ 644 million in line with their net sales, resulting in a stable R&D intensity (0.3%).

It should be noted that the limited R&D intensity of transport service companies does not capture the innovation in areas that fall outside those captured by our quantitative assessment. An important part of the sector's innovation stems from the purchase of innovations from other industrial sub-sectors through the acquisition of advanced machinery, software and other equipment, instead of the financing of research activities (CIS 2010 survey). In the case of logistics, which is a prominent area in the field of transport services, this is well illustrated by the increasing adoption of a number of ICT-based innovations such as Computerised

Vehicle Routing and Scheduling, vehicle tracking systems, and radio frequency identification. Moreover, the sector reacts to changing market and regulatory environment using non-technological innovations such as fleet and freight management or public transport travel information (*Hyard*, 2013; *van den Bergh et al.*, 2007), which cannot as easily be measured by R&D investments.

R&D investments in transport infrastructure construction reached some €200 million in 2008 and €₂₀₀₈ 207 billion in 2011. This is the result of an analysis of the R&D investments of 12 EU-based firms that are considered as key players in this domain and form part of the Europe's 100 construction companies listed in *Deloitte* (2009). The rather limited performance of the construction sector with respect to innovation (R&D intensity of 0.3%) is confirmed by other studies, either carried out for specific countries like the UK (e.g. *NESTA*, 2007), or looking at the construction sector in more general terms (*OECD*, 2009). In particular in the construction industry, however, a R&D-related indicator captures innovation activities only very partially. As the construction industry is dominated by heuristics, in which past experiences and tacit knowledge are important in project executions (*Maqsood et al.*, 2006), knowledge management, the organisational structure and human resources are other factors that strongly impact on the success of innovation (*Gambatese and Hallowell*, 2011).

5. Conclusions

The results of the quantitative bottom-up assessment of companies' R&D investments performed in this paper for two years – 2008 and 2011 – are fully in line with the expectations concerning their innovation efforts that were derived from the assessment of relevant factors. This underlines that the very high variation in the research-affinity of different transport sub-sectors is of structural nature and strongly linked to their market environment and innovation system.

This finding is highly-policy relevant, in particular considering the need for additional innovation in the transport sector (*European Commission*, 2011, 2012). Although a first glance at the elevated R&D investments of the European transport industry may come to the conclusion that the sector is research-intensive and is therefore not in need of any public intervention, a closer look by

⁷ Company-based data was complemented with information from *European Commission* (2010) and *Webers et al.* (2010).

sub-sector reveals the high dissimilarity of innovation efforts across sub-sectors, which are of systemic nature. Whereas manufacturers of cars and airplanes demonstrate elevated R&D intensities, transport service providers and companies involved in the construction of transport infrastructure have limited R&D intensities, which can well be explained by their different market environments and knowledge creation processes. The analysis points to the fact that especially actors that are well positioned to pursue cross-modal innovations and improvements in the supply-chain, such as service companies or builders of infrastructure, have a low incentive to invest in R&D, which could imply that the potential of this type of innovation cannot fully be exploited by industry alone.

Finally our results show that all transport sectors, except the service providers, increased their R&D investments during the years of the economic downturn, following a general increase of net sales. However net sales have increased at a higher pace than R&D investments, resulting in a decrease of R&D intensities for many sectors. This different dynamics may indicate that R&D programmes have a longer term perspective that does not exactly respond to the shorter term fluctuations of sales within a company.

There are, however, a number of limitations in the analysis which require a further assessment. Firstly, the bottom-up analysis performed here may lead to a (slight) underestimation of the R&D investments of the sector due to limited number of companies assessed. Secondly, the level of R&D investments does not provide any indication on the nature of the innovation carried out. It may be argued that despite the large research activities, radical innovations are not fully exploited by car manufacturers (Zapata and Nieuwenhuis, 2010; Wiesenthal et al., 2011). Finally, R&D investments cannot fully capture non-technological innovations and the exploitation of tacit knowledge, which can be relevant in particular for service providers and construction companies.

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