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EUROPE INNOVA
Sectoral Innovation Watch

Sectoral Innovation Watch

Automotive Sector

Final sector report

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Europe INNOVA Sectoral Innovation Watch

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. A fundamental question is to what extent and why innovation performance differs across sectors. The second SIW project phase (2008-2010) aims to provide policy-makers and innovation professionals with a better understanding of current sectoral innovation dynamics across Europe

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Central to the work of the Sectoral Innovation Watch is **analysing trends in, and reporting on, innovation performance in nine sectors** (Task 1). For each of the nine sectors, the focus will be on identifying the innovative agents, innovation performance, necessary skills for innovation, and the relationship between innovation, labour productivity and skills availability.

Sector Innovation Performance: Carlos Montalvo (TNO)	
Automotive: Michael Ploder (Joanneum Research)	Knowledge Intensive Business Services: Christiane Hipp (BTU-Cottbus)
Biotechnology: Christien Enzing (Technopolis)	Space and Aeronautics: Annelieke van der Giessen (TNO)
Construction: Hannes Toivanen (VTT)	Textiles: Bernhard Dachs (AIT)
Electrical and Optical Equipment: Tijs van den Broek (TNO)	Wholesale and Retail Trade: Luis Rubalcaba (Alcala) / Hans Schaffers (Dialogic)
Food and Drinks: Govert Gijsbers (TNO)	

The **foresight of sectoral innovation challenges and opportunities** (Task 2) aims at identifying markets and technologies that may have a disruptive effect in the nine sectors in the future, as well as extracting challenges and implications for European companies and public policy.

Sector Innovation Foresight: Matthias Weber (Austrian Institute of Technology)	
Automotive: Karl Heinz Leitner (AIT)	Knowledge Intensive Business Services: Bernhard Dachs (AIT)
Biotechnology: Govert Gijsbers (TNO)	Space and Aeronautics: Felix Brandes (TNO)
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Electrical and Optical Equipment: Tijs van den Broek (TNO)	Wholesale and Retail Trade: Susanne Giesecke (AIT)
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Task 3 will **identify and analyse current and potential bottlenecks that influence sectoral innovation performance, paying special attention to the role of markets and regulations.** Specifically, the analysis will cover the importance of the different factors in the propensity of firms to innovate.

Role of markets and policy/regulation on sectoral patterns of innovation: Carlos Montalvo (TNO)	
Helena Rozeik (PRAXIS)	Klemen Koman (IER)

Task 4 concerns **five horizontal, cross-cutting, themes related to innovation**. The analyses of these horizontal themes will be fed by the insights from the sectoral innovation studies performed in the previous tasks. The **horizontal reports will also be used for organising five thematic panels** (Task 5). The purpose of these panels is to provide the Commission services with feedback on current and proposed policy initiatives.

Horizontal reports	
National specialisation and innovation performance	Fabio Montobbio (KITes) and Kay Mitusch (KIT-IWW)
Organisational innovation in services	Luis Rubalcaba (Alcala) and Christiane Hipp (BTU-Cottbus)
Emerging lead markets	Bernhard Dachs (AIT) and Hannes Toivanen (VTT)
Potential of eco-innovation	Carlos Montalvo and Fernando Diaz-Lopez (TNO)
High-growth companies	Kay Mitusch (KIT-IWW)

Contents

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Dachs, B., I. Wanzenböck, M. Weber , J. Hyvönen, H. Toivanen (2011) Lead Markets, Task 4 Horizontal Report 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2011

C. Montalvo, Diaz-Lopez, F.J. and F. Brandes (2011) ‘Potential for eco-innovation in nine sectors of the European economy’, Task 4 Horizontal Report 4, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Grupp, H., D. Fornahl, C-A-. Tran, J. Stohr, T. Schubert, F. Malerba, F. Montobbio, L. Cusmano, E. Bacchiocchi, and F. Puzone (2010) National Specialisation and Innovation Performance, Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission , March 2010

Leitner K.-H., (2010) Sectoral Innovation Foresight – Automotive Sector, Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010.

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Montalvo C., Pihor K., Ploder M. (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Automotive Sector; Task 3 Report, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, December 2011.

Ploder, M., Hartmann, C., Veres, E. and B. Bertram (2010) Sectoral Innovation Performance in the Automotive Sector, Task 1 Final Report, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, December 2010.

Executive Summary

The EU-25 automotive sector represents about 8% of total value added in the EU-25 manufacturing industry. Even though the basic parameters of cars and trucks haven't changed in the past century, the related division of labour has become increasingly complex. Export activities are evidence and indicator of the dense supply chain network in the automotive network in Europe. The suppliers have been increasingly integrated into innovation processes and questions of responsibility of innovation outcome and product liability.

Even if statistical data elides the difference between passenger cars and commercial vehicles it is of considerable relevance for innovation and market development. For example, original manufacturers of passenger cars usually deal with production lots above 100,000 cars while OEMs in the commercial and heavy vehicle segment usually produce small lots combined with a high variance in production. Product cycles which are correlated with innovation cycles in the case of passenger cars range between four and six years. Product cycles in the commercial and heavy vehicles range clearly above six years.

Motor vehicles are complex products. Innovation expenditures in the automotive sector are considerably above the average, but frequently driven outside the automotive sector, e.g. machinery and equipment, materials, electronic equipment, telematics, fuels and energy respectively information and environmental technologies.

There remain significant national differences in the structure and extent of innovation expenditures. Although new EU member countries are advancing rapidly, both on supply and demand side, a few countries (in the first place Germany) clearly dominate the sectoral economic and innovation system in Europe. The German automotive sector clearly dominates the sectoral innovation system in Europe, while the new EU member countries are advancing rapidly.

The automotive sector is dominated by enterprises belonging to a few very large enterprise groups. R&D and patent activities are highly concentrated in the automotive sector. Innovation in the automotive sector is affected by powerful supply and network structures with a decisive role being played by systems (mega) suppliers. The whole design and development process has been reorganized in the recent years as tasks are organized parallel and interactively synchronized. Beyond a new organization of innovation processes in multidisciplinary teams the direct involvement of systems and component suppliers became necessary. Based on indicators of social network analysis we can see that peripheral actors have become more strongly connected to actors in the centre since the end of the 1980s. Alternative concepts (open innovation etc.), requiring the softening of established hierarchical structures, have not been successfully to date but need to be advanced in the near future.

Both, empirical evidences and expert opinion substantiate the suspicion that the European automotive industry is currently not able to tap its full innovation potential along the value chain.

Ultra low cost vehicles are a good example of the recent need for new co-operative approaches in supply chain innovation. Eco-Innovations such as alternative powertrain concepts and their integration in totally new vehicle and mobility concepts provide a further challenge in the field of innovation. Both examples imply an increasing loss of hegemony for Western (US-American, European) OEMs and a shift (possibly relocation) of centres of innovation to emerging markets (Asia, Eastern Europe).

The automotive sector has been a job creator for a long time. Following the bursting of the ICT-bubble the share of human capital attracted from the Electronic sector has increased continuously. This appears to reflect the increasing awareness among automotive firms of the need to build up competences and knowledge in electronics, mechatronics and sensor technology. Nevertheless it is worth mentioning that the proportion of employees leaving the automotive sector for engineering and R&D-services (Nace 73, 74) considerably outnumbered the share attracted by the automotive sector (Nace 34) from engineering and R&D- services (Nace 73, 74). The relative high skill levels of European Automotive employees have to date often been seen as a locational advantage. However, the enormous attractions of Asian development are likely to witness much greater mobility of brain power and relocation of knowledge intensive activities in the future.

While innovation has for decades been driven by technological considerations, market factors are becoming even more decisive (both as potential barriers and drivers) in innovation activity. The European Union is the major markets for passenger cars and commercial vehicles. The European market is nevertheless very challenging owing to the high quality and technical standards required, as well as to the relatively low growth rates.

At the present, a considerable share of European car makers focuses almost exclusively on the European market. In contrast to Asian OEMs, the strong home market still provides the backbone of success for European automobile producers. The analysis suggests that Belgium, France, Germany, Luxemburg, and, to a lesser degree, Italy, Sweden and the UK are the countries with the best conditions for lead markets development in the automotive industry. In the long term the European automotive industry will have to target (and factor into innovation activities) new non-European customers and markets which cannot be served with established patterns of product development and innovation.

As accentuated by the SIW foresight exercise future technological development in the automotive industry will be driven by technological challenges in the field of production and storage of energy and alternative fuels as well as material sciences. Present social trends and a shift of customer preferences additionally shape technological development.

The following four scenarios have been drafted by combing the four aforementioned drivers:

Scenario 1: “Recovery and Business as Usual” is characterized by increasing income levels, incremental energy storage innovations, differentiated mobility behaviour, and an incremental increase of regulation distinguish this scenario.

Scenario 2: “Low Cost and Conventional Technology” is characterized by a combination of increasing (relatively available) income, incremental increase of capacity of energy storage, differentiation of individual mobility and an incremental increase of regulation.

Scenario 3: “Green Cars - You can have it All” may become true if relative available income will increase, breakthrough innovation with respect to energy storage are realised, the mobility behaviour becomes more differentiated and we will see a strong and quick increase of regulations.

Scenario 3: “Sustainable Revolution” is characterized by a decreasing income- levels for a longer period of time and only incremental advances in energy storage technologies, a change of mobility behaviour with a stronger use of public transport, and a strong regulation regime.

The following future innovation themes have be identified on that basis:

Development of advanced and new powertrain technologies: The main development trajectories regard technological advance of internal combustion engines, the enhanced utilization of alternative fuels such as natural gas, liquid fuels made of biomass and hydrogen, hybrid vehicles and electrified powertrains.

Development of new applications and technologies in the fields of *traffic management systems, technology-assisted driving (drive-by-wire) and new safety systems* in order to increase comfort, safety as well as efficiency of driving and mobility.

Development of *advanced production technologies* in terms of flexible manufacturing structures and new material technologies influence manufacturing systems and are important to benefit from increased vehicle performance and lower energy consumption.

The automotive sector is one of the most regulated ones in developed economies. Analyses showed that regulation played a significant and positive role for innovation in the automotive sector in the past and is expected to by a (compensating) demand-side driver for future innovation in the automotive sector. Comparing to other sectors the automotive sector proves true to be a strategically important sector for the advancement of European environment and climate policy.

Summing up major policy challenges for sectoral innovation in the automotive sector are an opening of hierarchical supply chain structures and tapping the full innovation potential along the value chain, the development of emerging growth markets outside Europe and a long term paradigmatic shift towards alternative concepts of mobility and transport.

1 Introduction

As already mentioned in the Europe INNOVA SIW-I final sector report published in May 2008, the EU-25 automotive sector represents about 8% of total value added in the EU-25 manufacturing industry.[1] However, once extensive supply relationships are taken into account, the weight of the sector rises considerably (beyond the statistical definition of the automotive sector.

The vehicle industry is both a driver and beneficiary of globalization. The automotive industry is global in its activities, but is also vulnerable to globalization and the emergence of new global competitors and increased international competition, e.g. in Asia. Larger system suppliers are trying to come to the terms with the emergence of new markets and demand side requirements.

The financial crisis of 2008 provoked a deep recession and clearly showed the vulnerability of the automotive sector. In the first half of 2009, in EU 15+ Norway, new car registrations decreased significantly. Due to higher economic growth and a larger amount of first-time car buyers, new car sales in Eastern European countries long remained on an upward trend. The commercial and heavy vehicle sector once again proved more sensitive to business fluctuations than the passenger car sector. But should this interpreted as indicator for a long term decline of one of the job and growth machines of the European economy?

The European automotive sector was already undergoing a process of restructuring before the onset of the current financial and economic crisis. The sector was in fact suffering from several problems: market saturation, consolidation, increasing fuel costs, and overcapacity.

The report presents a compilation of complementary discussions of innovation in the automotive sectors held in Tasks 1, 2, 3 and 4 of the Sector Innovation Watch (SIW-II) exercise. Thus, the following sections will provide a multidimensional picture of innovation in the automotive sector.

We will see that European automotive industry is still highly innovative, competitive and relevant for innovation in other sectors. We will also see that major challenges could require yawing from well established paths and trajectories.

Section 2 will characterize innovation in the automotive sector and discuss concentrations of economic and sectoral innovation activities across Europe.

Section 3 will discuss major carriers of innovation in the automotive sector and role and changing patterns of innovation co-operation in the sector. We will see that the value chain in the automotive sector is characterized by a high division of labour and a dense supply chain network in Europe.

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[1] Sofka,, Grimpe, Leheyda, Rammer, Schmiele (2008) Sectoral Innovation Systems in Europe: Monitoring, Analysing Trends and identifying Challenges – Automotive sector, ZEW

Section 0 will discuss future drivers of innovation in the automotive sector and summarize sector scenarios developed by the SIW foresight exercise (Task 2) and corresponding innovation themes. Section 5 is dedicated to barriers to innovation giving special reference to the role of market factors and regulation. Section 6 will supplement the preceding discussion by selected insights of horizontal analyses of sectoral innovation (Task 4) giving special reference to the role of specialization and gazelles on innovation in the automotive sector and eco-innovation opportunities and the impact of innovation on new lead markets in the case of the automotive sector. Finally section 7 will summarize some major findings and policy conclusions.

2 Patterns and performance of sectoral innovation[2]

Starting with the statistical definition of the automotive sector the following section will provide a short characterization of the sector and an overview over principal patterns and performance of innovation in the automotive sector.

2.1 Statistical definition of the sector and sector-specific indicators

The automotive sector is defined as covering the manufacture of motor vehicles, corresponding to the statistical NACE 34 sector, and divided into three subsectors (see Table 2.1).

Table 2.1 NACE classification of the automotive sector

NACE 1.1	NACE 2 (new)
34 Manufacture of motor vehicles, trailers and semi-trailers	29 Manufacture of motor vehicles, trailers and semi-trailers
34.1 Manufacture of motor vehicles	29.1 Manufacture of motor vehicles
34.2 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	29.2 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
34.3 Manufacture of parts and accessories for motor vehicles	29.3 Manufacture of parts and accessories for motor vehicles

- NACE-1.1 sector 34.1 corresponding to NACE-2 sector 29.1 contains activities in the manufacturing of motor vehicles (including cars, trucks and buses) and motor vehicle engines. Vertical integration in automotive production is very heterogeneous.
- For historical reasons NACE-1.1 sector 34.2 corresponds to NACE-2 sector 29.2 is separately present, and sums the manufacture of coachwork for motor vehicles, trailers and semi-trailers.
- The manufacture of parts and accessories for motor vehicles and engines is assigned to the subsector NACE-1.1 sector 34.3 corresponding to NACE-2 sector 29.3.

A considerable part of official statistics including complementary European databases (e.g. the Community Innovation Survey) only allows for analysis and interpretation at the NACE digit 2 level.

[2] This chapter is based on the analysis performed in Task 1 of the SIW-II. The full analysis is available in Ploder et al. (2010).

Beyond international trade statistics, currently available databases on the whole follow the NACE-classification and allow for the automotive sector to be analysed at the NACE-digit2 level.

NACE-1.1 sector 34 and NACE-2 sector 29 are adequate for delineation of the automotive sector, but insufficient for a differentiated analysis covering the technological heterogeneity of the sector. For example even at the NACE digit 3 level it simply would not be possible to differentiate the production and innovation of passenger cars production and the production and innovation of commercial vehicles. Both segments are quite different in terms of innovation processes, market rules, product life cycles and supply chain structures.

Motor vehicles are complex products. Even though the basic parameters of cars and trucks haven't changed in the past century, the related division of labour has become increasingly complex. The suppliers have been increasingly integrated into innovation processes and questions of responsibility of innovation outcome and product liability.

Moreover, different vehicles subsystems can be identified: the body, the chassis, the driveline, the electrical power subsystem and the command, control and communication subsystem. Automobiles are increasingly moving from mechanical engineering systems to systems based on electronics and electric power. (Maxton/ Wormald 2004, p.137)

Even if statistical data elides the difference between passenger cars and commercial vehicles it is of considerable relevance for innovation and market development.

2.2 Characterisation of the sectors

The automotive and the aerospace sector are the mascots of empirical investigations in supply chain networks and relations. Supply chain networks depend on vertical integration and the division of labour in an industry. In the mid 1980s, Chrysler had 3,000 suppliers and BMW 1,400 (today both have less than 500). Increasing cost-pressure, international standardization, innovation and quality management have resulted in:

- horizontal mergers on the supplier, and
- The establishment of long-term customer relationships between system supplier and OEMs.

As mentioned in Sofka et al. (2008) it is necessary to differentiate between original equipment manufacturers (OEMs), which sell products with their own brand name to the end customers, and the different levels of suppliers (tiers). OEMs integrate components and modules bought from other suppliers and usually bear the design and development responsibility for the final product. However, in the automobile and in the aerospace sector growing system complexity and shortened development times call for new rules.

Even if some brand names can be found in both the passenger car segment and the commercial and heavy vehicle segment, original equipment manufacturers face different conditions in the two markets.

For example, original manufacturers of passenger cars usually deal with production lots above 100.000 cars while OEMs in the commercial and heavy vehicle segment usually produce small lots combined with a high variance in production. Product cycles which are correlated with innovation cycles in the case of passenger cars range between four and six years. Product cycles in the commercial and heavy vehicles range clearly above six years. Extensive outsourcing strategies in to date have led a lower depth of value added for OEMs in the passenger car segment. In contrast, in the commercial vehicle segment a significance of special needs and a high variance of production are correlated with a higher depth of value added of OEMs.

So-called tier 1 level suppliers take responsibility for developing, producing and refining complete components or modules of the car. As already mentioned in Sofka et al (2008) these suppliers are critical drivers of technological innovations. What is more, they typically facilitate the OEMs assembly process through “just in time” or “just in sequence” supply which makes them an integral building block of successful process innovation in the automotive sector. In recent times a hybrid form of system suppliers has emerged: systems integrators (tier 0.5 level suppliers). While most of the automobile suppliers during the 1970s and 1980s worked as component suppliers; as usual in other areas of the machinery sector, the automobile OEMs began as a result of growing technological complexity, higher cost-pressure and (because of their greater customer-orientation) broader product portfolios sourcing out work-steps and therefore value added to system suppliers. These suppliers are capable of designing and integrating components, subassemblies and systems into modules and therefore seem to be a bridging hybrid between OEM and tier 1 level supplier. Even if some tier 1 level suppliers work for OEMs of both the passenger car and the heavy vehicle segment, the above differences also correspond to differences on the supplier side. The normally large and international supply chain networks in the passenger car segment are largely predetermined by OEMs. Supplier chain networks in the heavy vehicle segment are smaller, and compared to the passenger car segment somewhat more spatially concentrated.

While certain larger system-suppliers have established unique positions as knowledge-providers and innovation-carriers, OEMs and system suppliers (usually tier 1 level suppliers) have considerable power over smaller automotive suppliers (component suppliers). Their relatively favourable position is based on superior financial flexibility as well as their decisive position and in global production networks as well as design and innovation processes.

The evolution of automotive designs has moved toward the “platform” concept, which means that a common underbody structure is used for different chassis[3]. The platform concept is advantageous in smaller innovation cycles, since the organization and establishment of a global production networks for model differentiation is based on one basic design. Despite the resulting path dependences SMEs may still break through existing power asymmetries via innovation or create critical scope for innovations – sometimes in the form of regional clusters and networks. (Rutherford 2008)

As mentioned in Sofka et al. 2008 nanotechnology, flexible automation, electronics and fuel efficient engine alternatives are major fields of innovation on the technological side. [4]

In FP7 a successful project involving firms and automobile experts, “FURORE”, tried to define and anticipate the future of road vehicle research in order to identify key technologies and consequently the expected trajectories of innovation. The following key areas have been discussed in this context:[5]

- Fuels, their supply. alternatives (hydrogen. electric) and taxation policy
- CO_2: global warming, fossil fuel usage
- Emissions: exhaust and other sources, legislation
- Safety: occupants (in-vehicle safety), pedestrians, legislation
- Traffic Growth in volume, congestion (traffic management), policy intermodality
- Noise: vehicle, Road surface, vehicle technology vs. local measures
- Recycling: materials, future legislation.

Statistical nomenclatures are not able to distinguish adequately between different subgroups of the automotive sector adequately, e.g. passenger car and heavy duty traffic and their respective replacement cycles (less than six years and significantly more than six years respectively).

2.2.1 Innovation performance

The automotive sector contains a relatively high share of large firms and irrespective of innovation level is relatively capital intensive and exhibits a high productivity of labour. The share of innovative firms in the automotive sector is significantly higher than the average innovation-rate. Indicators of this high level of innovation and distinguishing characteristics of innovative automotive firms versus innovative non-automotive firms are:

- the considerably higher share of turnover spent on innovation expenditures

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[3] The Ford-Group internationally, and the Volkswagen-Group in Europe, were among the first to platform concept.

[4] Again the passenger car segment and the commercial or heavy vehicle segment are not identical. While the passenger car segment moves toward composite materials, innovations in metallurgy will be of higher relevance for heavy vehicles. Electronic systems in the passenger car segments are closed systems, electric systems in the commercial and heavy vehicle segment are open systems.

[5] For further particulars and a detailed discussion of future innovation issues we refer the reader to the sectoral foresight report for the automotive sector. (see: Leitner K.H. (2009) Interim Report Task2 – Sectoral Foresight – Automotive sector)

- The considerably higher share of new products, especially market novelties, with respect to total sales.

Table 2.2 Automotive industries over innovation dimensions covered by the Community Innovation Survey (CIS); only innovative firms

	Average Automotive (2)	Average Core NACE (1)	% GAP (2/1)
Share of innovative active firms	52.0%	39.4%	132.0%
Share of firms innovating in-house	51.8%	51.1%	101.4%
Innovation expenditures as a percentage of total turnover	6.3%	3.0%	210.0%
Share of total sales from new-to-market	17.3%	6.1%	283.6%
Share of total sales from new-to-firm but not new-to-market products	27.8%	6.1%	455.7%
Share of firms that use patents	26.1%	14.9%	175.2%
Share of firms that use trademarks	16.7%	17.5%	95.4%
Share of enterprises that use design registrations	19.3%	14.7%	131.3%
Ratio between total turnover and number of employees (in 1000)	329	260	119.3%
Share of firms that receive public subsidies to innovate	33.7%	21.3%	159.6%
Share of firms that introduced (enterprise based) marketing innovation	23.1%	34.1%	67.7%

Source: CIS 4, own calculations, countries included: see annex.

Considering all firms (including innovative and non innovative firms) two points need to be made:

- With respect to patents and design registrations the gap between the automotive sector and other sectors is large. Obviously mature patents are significantly more important for automotive firms than for other industries.
- The share of firms that received public subsidies is even higher for non-innovative firms in the automotive sector than in other sectors. As the CIS 4-database is not able to provide additional explanatory variables.

Table 2.3 Automotive Industries over CIS Innovation dimensions; all firms

	Average Automotive (2)	**Average Core NACE (1)**	**% GAP (2/1)**
Share of innovative active firms	52.0%	39.4%	132.0%
Share of firms innovating in-house	27.0%	19.70%	136.9%
Innovation expenditures as a percentage of total turnover	3.3%	2.20%	149.5%
Share of firms that use patents	14.9%	5.90%	253.2%
Share of firms that use trademarks	10.5%	6.80%	153.9%
Share of enterprises that use design registrations	12.6%	5.80%	216.5%
Ratio between total turnover and number of employees (in 1000)	310	229	135.4%
Share of firms that receive public subsidies to innovate	17.5%	9.20%	190.6%
Share of firms that introduced (enterprise based) marketing innovation	15.8%	13.50%	116.9%

Source: CIS 4, own calculations, countries included: see annex 1.

2.2.2 Agents for innovative activity

The automotive sector is dominated by enterprises belonging to a few very large enterprise groups. Table 2.4 gives an overview of the top thirty motor vehicle manufacturing companies and their production volume for 2008.

As these motor vehicle manufacturing companies act and produce globally, table 2.4 doesn't correspond to European or national output values. The US-American automobile industry (especially Ford and GM) began globalization of automotive technology, innovation and manufacturing, but meanwhile, nearly all European producers have also changed to a global pattern of production and development.

Table 2.4 Top thirty motor vehicle manufacturing companies by production volume 2008[6]

Rank 2008	Group	Total	Cars	Light commercial vehicles	Heavy Commercial Vehicles	Heavy Bus
1	TOYOTA	9,237,780	7,768,633	1,102,502	251,768	114,877
2	GM	8,282,803	6,015,257	2,229,833	24,842	12,871
3	VOLKSWAGEN	6,437,414	6,110,115	271,273	46,186	9,840
4	FORD	5,407,000	3,346,561	1,991,724	68,715	
5	HONDA	3,912,700	3,878,940	33,760		
6	NISSAN	3,395,065	2,788,632	463,984	134,033	8,416
7	PSA	3,325,407	2,840,884	484,523		
8	HYUNDAI	2,777,137	2,435,471	85,133	151,759	104,774
9	SUZUKI	2,623,567	2,306,435	317,132		
10	FIAT	2,524,325	1,849,200	516,164	135,658	23,303
11	RENAULT	2,417,351	2,048,422	368,929		
12	DAIMLER	2,174,299	1,380,091	330,507	395,123	68,578
13	CHRYSLER	1,893,068	529,458	1,356,610	7,000	
14	B.M.W.	1,439,918	1,439,918			
15	KIA	1,395,324	1,310,821	83,159		1,344
16	MAZDA	1,349,274	1,241,218	105,754	2,302	
17	MITSUBISHI	1,309,231	1,175,431	128,233	5,567	
18	AVTOVAZ	801,563	801,563			
19	TATA	798,265	489,742	160,966	128,169	19,388
20	FAW	637,720	637,720			
21	FUJI	616,497	552,096	64,401		
22	ISUZU	538,810		47,101	488,488	3,221
23	CHANA AUTOMOBILE	531,149	531,149			
24	DONGFENG	489,266	489,266			
25	BEIJING AUTOMOTIVE	446,680	446,680			
26	CHERY	350,560	350,560			
27	SAIC	282,003	282,003			
28	VOLVO	248,991		17,964	218,542	12,485
29	BRILLIANCE	241,553	241,553			
30	HARBIN HAFEI	226,754	226,754			

Source: OICA, July 2009

Export activities are evidence and indicator of the dense supply chain network in the automotive network in Europe. Table 2.5 illustrates the intensive cross-national linkages in the automotive sector. Despite the strength of existing national interest, the automotive sector seems to be predestined for concerted policy strategies on the European level.

[6] See the blue lines for European Original Equipment Manufacturers.

Table 2.5 Number of foreign affiliations in the automotive sector

		OWNER Country[7]												
		Belgium	Den-mark	Germany	Spain	France	Italy	Luxemburg	Netherlands	Austria	Poland	Portugal	Finland	Sweden
LOCATION of the Affiliation	Bulgaria	0	0	c[8]	0	0	c	0	0	0	0	0	0	0
	Czech Republic	2	0	60	2	9	2	1	2	4	2	0	0	0
	Estonia	0	0	0	0	0	0	0	0	0	0	0	1	1
	Spain	c	0	52	0	23	9	c	7	c	0	0	0	c
	France	3	c	46	7	0	14	5	4	3	0	0	0	7
	Italy	2	0	37	2	15	0	1	3	4	0	1	1	1
	Latvia	0	1	0	0	0	0	0	0	0	0	0	0	1
	Hungary	c	0	c	c	0	0	0	0	c	0	0	0	c
	Netherlands	0	0	4	0	c	c	0	c	c	0	0	c	3
	Austria	0	0	c	0	0	c	0	0	0	0	0	0	0
	Portugal	0	1	14	16	5	0	0	2	1	0	0	0	0
	Romania	c	0	19	0	c	7	c	c	0	0	0	0	0
	Slovenia	c	c	4	c	1	2	c	c	1	c	c	c	c
	Slovakia	0	0	20	4	3	c	0	4	c	0	0	0	0
	Finland	0	0	0	0	0	0	0	0	0	0	0	c	c
	Sweden	1	3	7	2	3	0	1	10	1	0	0	9	0

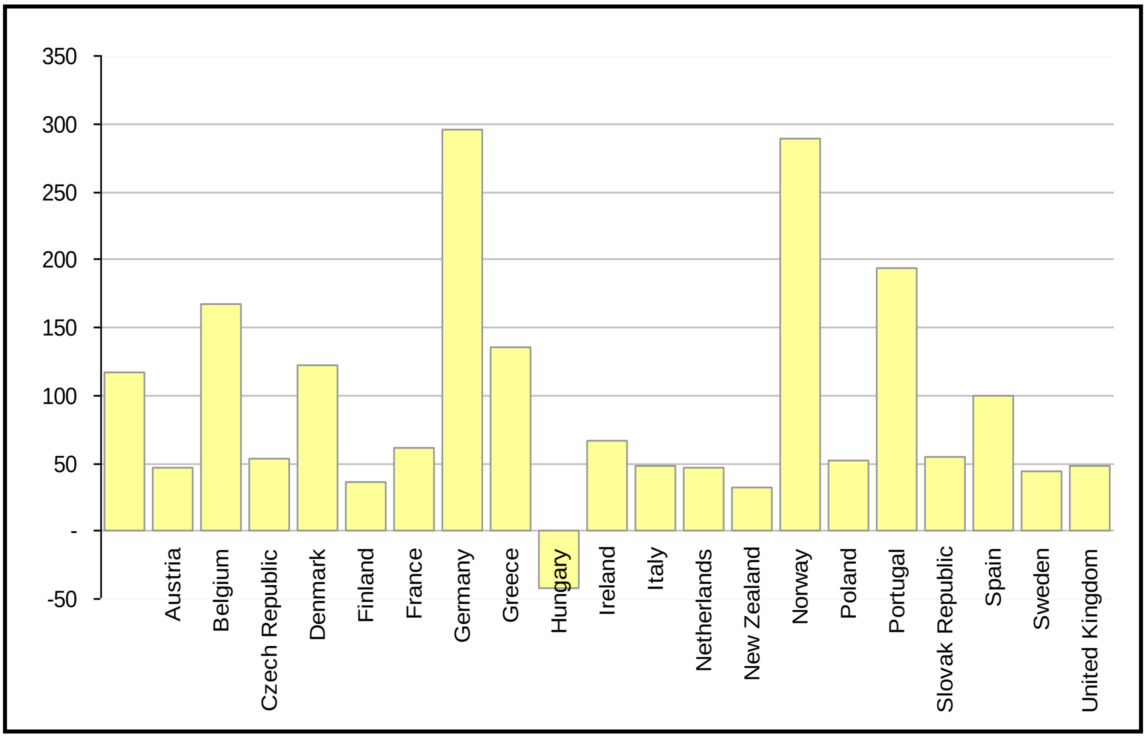
Source: Eurostat

2.2.3 National specialisation and comparative advantages in the automotive sector

In 2007, the EU-27 exported motor cars worth EUR 71.1 billion. The EU trade surplus (exports minus imports) amounted to EUR 37.5 billion. (EUROSTAT 2008). In the period between 2000 and 2007, the EU-import of motor vehicles increased (annual average of 8%) to a greater extent than exports (annual average of 6%). [9] Germany was responsible for over half (57%) of total extra-EU motor car exports and was the only member state to show a positive trade balance of noticeable size.

[7] The owner country is defined by firm-group headquarters location.
[8] “c”:= confidential; data treated as confidential owing the small number of firms.
[9] Gambini G. (2008) EU-27 trade in motor cars in 2007, in: Eurostat statistics in focus 79/2008

Figure 2-1 Relative Increase of (nominal) automotive exports between 2002 in 2006[10]



Source: Own calculations based on OECD International Trade by Commodity Statistics (ITCS).

Revealed comparative advantages (RCA) analysis is an instrument to measure the relative advantage or specialization of a country in a certain technological field. It compares the export to import relationship of automotive goods against the background of the export to import ratio of the observed country. As already mentioned in Sofka et al (2008) referring to OECD data from 2004 Germany, Spain, France, Sweden and Portugal as well as the new EU member countries, the Slovak Republic and the Czech Republic all have a comparative advantage in automotive trade in comparison with other OECD Countries. . Time series of RCA-values provide indicate a relative shift of automobile production to New EU member countries, in particular to Hungary, the Slovak Republic, Poland and the Czech Republic. While Hungary, the Slovak Republic and the Czech Republic focus on passenger cars, the increase in Poland is based on commercial vehicles.

Technological specialisation describes the sectoral profile of a country's technological portfolio, composed by patents across sectors.

[10] Export numbers as well as R&D number in this chapter are not corrected in respect of the annual inflation.

Table 2.6 Technological performance in selected sectors, 1978-2005

Sector	# patents	share	ranking
Electrical and Optical Equipment	695,239	38.91%	1
Automotive	100,378	5.62%	2
Construction	53,685	3.00%	3
Biotechnology	41,823	2.34%	4
Food & Drink	18,070	1.01%	5
Textiles	9,258	0.52%	6
Space & Aeronautics	7,891	0.44%	7

Table 2.6 illustrates the development of the sectoral technological performance between 1978 and 2005. While the technological activity in the sectors biotechnology, electrical and optical equipment and automotive considerably increases between the end of the 1970s and the end of the 1990s, the patent share in the sectors construction and textiles decreases continuously (see Appendix 2, Table XVI). Despite this, the technological performance in the sector food & drink remains quite stable. There is no clear development path in the space & aeronautics sector.

The specialisation (Relative Technological Advantage (RTA)) index can be defined as the share of a sector in a country's total patent output (over the time horizon 1978-2005) in relation with the share of this same sector over world total patent output.

General observations: at a first glance it seems that the technological competencies in the automotive sector are located in Europe. This is consistent with the evidence about the strong and persistent EU 27 specialisation in Transport Technology. The present focus, however, points at significant cross-country differences and a relative technological disadvantage of new members. Germany, France and Luxembourg are characterised by a rising specialisation in the automotive Sector.

- EU 15 countries: Germany, France and Luxembourg exhibit increasing RTA-values, indicating a rising specialisation in the automotive sector. On the other hand, Denmark, Belgium, Finland and the Netherlands have strong technological disadvantages in this sector over the entire period of investigation. Some countries like Austria, the United Kingdom, Greece, Ireland and Italy have lost their technological advantages in the 1990s.
- New Member States: most states only account for less than ten patents and show strong technological disadvantages. Only Malta has gained technological advantages in the automotive sector since the beginning of the 1990s.
- Non EU countries: China, India and the United States have strong technological disadvantages in the automotive sector. In contrast Japan is now becoming more specialised in the automotive sector after nearly two decades of under-specialisation.
- The following paragraphs will be dedicated to the relationship between technological specialisation and technological excellence (as measured by patent citations) and the role of technological specialisation for international collaborations of inventors.

Specialization and co-inventorship or innovation co-operation

Complementary to the discussion of patent citations as an indicator of specialization and knowledge flow patent data allows the analysis of direct cooperation and co-inventorship.

The present analysis follows the approach by Breschi and Lissoni (2003), who investigate the transfer of knowledge that occurs when inventors interact. A specific instance of inventors' interaction is represented by team work on patenting, which is by 'co-inventorship'.

Since this analysis focuses on the comparison at the country level, networks are related to the countries of the inventors. Hence, knowledge transfer between two countries exists, if there is co-inventorship between inventors of these countries represented by the ties of the network.

In the automotive sector, the number of inventor teams increases greatly over time. The reasons for this are manifold. First of all, the trend can be related to the strategies of multinational companies and the need to meet the demand of local consumers in different markets. Hence, the products must be adapted to the peculiarities of a certain region with the support of local specialists. Another reason lies in the re-location of production activities to regions with relative comparative cost advantages. Thus, the R&D which is located in the home country has to interact with several production sites abroad. Third, many innovations in the sector rely on the interaction of OEMs and tier firms, increasing the number of linkages.

Table 2.7 Network connections

	All		**Biotechnology**		**El. and opt. equipm.**		**Automotive**	
	94-96	00-02	94-96	00-02	94-96	00-02	94-96	00-02
EU15-EU15	6,3112.00	11,5662.71	864.34	791.15	1409.10	4200.64	378.32	10,380.05
EU15-NewEU	97.41	312.67	2.17	3.37	1.43	13.57	0.00	19.70
EU15-NonEU	2,652.24	5624.15	77.63	24.27	51.07	120.84	4.39	265.33
NewEU-NewEU	232.41	661.09	3.00	2.14	4.30	10.75	2.00	26.41
NewEU-NonEU	35.25	82.42	0.35	0.00	1.50	0.54	0.00	3.04
NonEU-NonEU	7,1618.24	11,0657.02	1,128.61	108.40	1,658.69	793.32	165.22	6362.75

Regarding the networks it can be observed that in the first period Germany plays a very important role (which is even more important than in previous networks - e.g. biotechnology). Almost all nodes which are connected to each other have a link to Germany. This situation changes in the second period. As the number of connections increases dramatically, the connections between other countries in the networks gain importance. Within the EU 15 countries the United Kingdom changes from a little connected country to a central player, in spite of decreasing specialisation. France and Germany are strongly linked to each other and many of the New Member Countries join the network.

Relating the network evolution to the specialisation, no clear relationship can be identified. On the one hand, the United Kingdom (which becomes more connected) even shows decreasing specialisation values from period one to period two. On the other hand, Germany (which is specialised in this sector) is highly connected throughout both periods.

2.3 Common set of indicators

The following paragraphs are dedicated to a basic analysis of innovation performance in the automotive sector based on available CIS 4 micro data, national R&D data (Eurostat 2009) and patent data (PATSTAT 2009).

2.3.1 Innovation input performance

CIS 4 data show that more than the half (52 %) of the firms (with more than 9 employees) in the European automotive sector confirmed undertaking innovation activities between 2002 and 2004. Germany had the highest share of innovation-active firms (76 %). 54 % of the innovative firms implemented product innovations as well as process innovations. For the most part, (52 %) the innovations were developed by the enterprise or within the enterprise group.

Although not as high as those in high-technology sectors or knowledge intensive engineering services the innovation expenditures in the automotive sector are considerably above average.

Innovative firms in the automotive sector spent 6.3 % of their turnover on innovation activities in 2004, the year of reference for the fourth Community Innovation Survey. The average automotive firms with more than 9 employees (including non-innovative firms) spent 3.3 % of its turnover on innovation activities. Innovation Processes in the automotive industry are accompanied by relatively high R&D expenditures but also relatively high investments in machinery and equipment.[11]

It appears that a considerable share of innovations arise outside the automotive sector, e.g. in machinery and equipment. Other examples for innovation drivers outside the automotive sector are the fields of materials, electronic equipment, telematics, fuels and energy respectively information, and environmental technologies.

The statistical attribution of firms to NACE-classes at the digit 3 level depends on the share of value added in different activities. The activity portfolio of individual firms is usually much more wide-ranging than that suggested by statistical data and aggregates.

- The Subsectors 34.1 (Manufacture of motor vehicles and engines) and 34.3 (Manufacture of parts and accessories for motor vehicles) represent partially overlapping segments of the core value chain for passenger cars and commercial vehicle production.

[11] The expenditures on acquisition of machinery, equipment and software as a share of total turnover in the automotive sector is 1.43%. The equivalent figure for the manufacturing sector is 1.23%.

- The subsector 34.2 comprises firms in the fields of manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers covers firms which are partially downstream of vehicle production (e.g. car cranes and elevators, superstructures for caravans, fire engines etc.) or which occupy relatively small niches.

Firms in subsector 34.1 “manufacture of motor vehicles” show the highest propensity to innovate (see Table 2.8). Although this subsector is quiet heterogeneous, the responsibility for the final vehicle and the coordination of the innovation and design process along the value chain seems to be clearly reflected in the high share of firms with product innovations, and market novelties as well as in the high share of firms cooperating on innovation.

Table 2.8 CIS automotive sub-categories and propensity to innovate

		Share of innovative active firms (“innovative firms”)	Share of firms notifying product innovations	Share of firms notifying market novelties	Share of firms notifying process innovations	Share of firms implementing new production techniques	share of firms notifying cooperation in case of innovation activities
Subsectors	34.1 Manufacture of motor vehicles	54.6%	46.5%	28.9%	20.9%	26.6%	63.1%
	34.2 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	39.4%	29.4%	17.2%	12.8%	20.5%	25.0%
	34.3 Manufacture of parts and accessories for motor vehicles	54.2%	35.3%	17.2%	16.5%	37.1%	33.9%
Firm size	Small Enterprises	39.8%	26.0%	12.5%	12.8%	21.0%	22.7%
	Medium Sized Enterprises	57.9%	40.4%	21.8%	15.5%	38.1%	36.0%
	Large Enterprises	74.3%	58.4%	34.4%	27.3%	54.4%	57.5%
Region	New EU member countries	41.9%	33.6%	19.2%	9.3%	27.0%	53.1%
	Western- Northern Europe	54.5%	41.8%	25.4%	28.0%	30.5%	41.1%
	Southern Europe	48.3%	29.8%	13.3%	10.8%	30.9%	23.6%

Source: CIS 4, own calculations, countries included: see annex.

Innovation data for subsector 34.3 “manufacture of parts and accessories of motor vehicles” seems to reflect the position of these firms as tiers production oriented suppliers, i.e. there is a high share of firms engaging in process innovation and in implementing new production techniques. There is also a relatively high share of firms cooperating on innovation activities (see tTable 2.8). Again it has to be mentioned that subsector 34.3 covers a very heterogeneous group of firms, ranging from simple work benches with little innovation, to large tier 1 level system suppliers; which are important carriers of sectoral innovation. Further analysis provides more detail.

With reference to the average of all sectors covered by the Community Innovation Survey[12] larger firms show a higher propensity to innovate than smaller ones (see Table 2.8).

Despite the incomplete nature of the survey regional differences in sub-sectoral structure are clearly evident.

Automotive firms in new EU member countries show a lower propensity to innovate. Interestingly, however, the share of firms admitting cooperation in innovation is much higher here than in Western, Northern or Southern Europe. This is probably due to the fact that automotive innovation in of new EU member countries is driven by investors (e.g. OEMs and large suppliers) from Western-Europe.

Table 2.9 Structure of innovation expenditures in selected European countries (sum = 100%)

	Intramural R&D expenditure	Extramural R&D expenditure	Expenditure on acquisition of machinery. equipment and software	Expenditure on acquisition of other external knowledge
total average	40.9%	19.1%	23.7%	2.4%
Belgium	20.7%	10.9%	66.4%	2.3%
Czech Republic	24.8%	54.3%	19.1%	1.8%
Germany	40.7%	12.2%	25.5%	2.4%
Estonia	67.2%	3.6%	29.2%	0.4%
Greece	6.9%	0.9%	92.3%	0.0%
Spain	16.8%	41.4%	27.3%	8.2%
France	51.1%	45.1%	3.3%	0.6%
Italy	52.9%	15.3%	30.3%	1.5%
Hungary	15.4%	3.7%	60.4%	20.7%
Netherlands	60.2%	22.9%	16.3%	0.6%
Poland	8.2%	5.8%	82.1%	4.3%
Portugal	24.7%	19.6%	54.6%	2.1%
Romania	11.3%	5.1%	81.0%	2.5%

Source: own calculations. Eurostat

Table 2.9 shows the structure of innovation expenditures in selected European countries. It is worth mentioning that we can identify significant national differences in the structure of innovation expenditures. While German, Italian or French firms put a relatively high weight on R&D-expenditures, investment expenditures are of a still higher significance for the automotive industry in New EU member countries. This directly reflects locational and regional patterns of the automotive innovation network in Europe.[13]

R&D data for the automotive sector are not available for all countries as illustrated in table 2.10. Based on the average of the mentioned countries it can be estimated that a share of 21% of R&D-

[12] The primary sector, the construction sector, wholesale and retail trade, tourism, the transport sector and public services are not included.

[13] The CIS 4 Database doesn't allow different types of firms (OEMs, system suppliers) to be identified.

expenditures in Europe are spend in the Automotive sector, which corroborates the role of the automotive sector for R&D and Innovation in Europe and in particular for R&D in the medium-technology sector in Europe. The EU-countries spent even more on R&D in the automobile sector than the US in the automobile industry (OECD 2008).

Table 2.10 shows the dominant role of Germany in automotive R&D in Europe and also the relatively high shares of Austria and Sweden. The new EU member countries are clearly trying to catch up.

Table 2.10 R&D-expenditures in the automotive sector (in 1000 €)

	R&D expenditures 2005	**annual increase 2003 to 2005**
Czech Rep.	913.594	24%
Germany	38.651.038	1%
Ireland	1330	10%
Greece	357.356	7%
Spain	5.485.034	12%
Italy	7855.8	6%
Hungary	361.634	21%
Netherlands	5169	4%
Austria	3.556.479	7%
Poland	439.995	27%
Portugal	462.015	18%
Romania	162.54	19%
Slovenia	242.912	8%
Sweden	8.289.953	3%
total	64.987.397	4%

Source: Own calculations, Eurostat[14]

2.3.2 Innovation output performance

The role played by patents in protecting intellectual property-rights, and as an instrument of knowledge transfer, differs significantly across sectors in Europe. From the perspective of innovation analysis patents are not an indicator of output but of throughput (Niefert 2005; Schibany, Dachs 2004). Concerning the automotive industry, patents still play an important role. Patterns of cooperation and innovation in the automotive industry have changed considerably over recent decades. (Sage 2000, Rutherford 2004, Maxton et al 2004, Heneric et al 2005) As the boundaries between OEMs and suppliers and different tiers become more and more blurred, the protection of intellectual property rights is a prerequisite for horizontal as well as multi-level cooperation in the automotive sector.

As seen from CIS 4 data, in the period 2002 to 2004, 26 % of the innovating firms in the automotive sector admitted applying patents as a result of innovation activity. Furthermore registered trademarks

[14] Numbers for France are not available for 2005

(17 % of innovating firms) and registered industrial designs (19 % of innovating firms) are also highly significant in the protection of IPRs in the automotive sector.

The significance of the various alternatives to IPR protection corresponds (at national level) to figures for intramural R&D and to R&D-intensity (R&D expenditures as a share of total turn-over) in the sector. A relatively high share of innovating firms in the automotive sector explicitly reports intramural R&D-activities.

Table 2.11 R&D and IPRs over CIS automotive sub-categories

		share of "innovative" firms notifying intramural R&D	Share of "innovative" firms that applied patents	Share of "innovative" firms that registered industrial design	Share of "innovative" firms that registered trademarks	Share of "innovative" firms that claimed copyrights
Subsectors	34.1 Manufacture of motor vehicles	78,6%	34,9%	24,0%	17,9%	3,5%
	34.2 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	58,6%	22,6%	20,4%	18,6%	1,1%
	34.3 Manufacture of parts and accessories for motor vehicles	68,7%	23,2%	17,6%	16,3%	3,0%
Firm size	Small Enterprises	59,7%	14,0%	19,4%	16,4%	1,2%
	Medium Sized Enterprises	72,4%	26,5%	14,5%	16,5%	0,7%
	Large Enterprises	76,6%	43,0%	23,8%	18,1%	8,0%
Region	New EU member countries	49,3%	7,4%	7,9%	9,6%	2,6%
	Western- Northern Europe	73,1%	40,1%	22,9%	27,3%	4,7%
	Southern Europe	66,8%	19,9%	19,3%	13,8%	1,3%

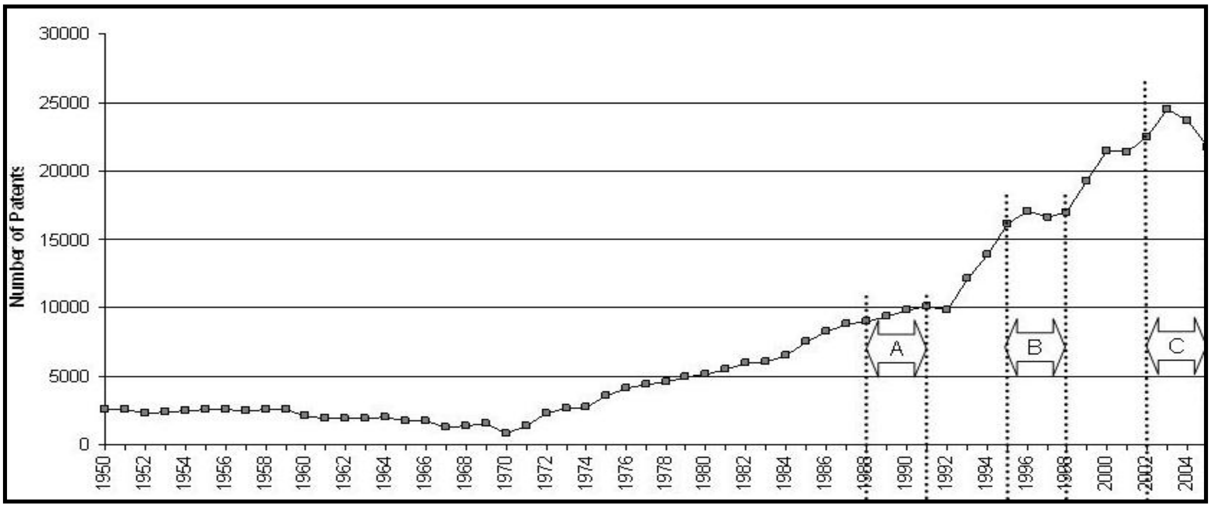
Source: CIS 4, own calculations, countries included: see annex.

CIS data also reflect the high significance of patent applications for the automotive sector and the intensive cooperation occurring within supply networks. Besides patent applications the registration of industrial design and trademarks for all subsectors is also significant. Table 2.11 shows a relatively high proportion if firms (mainly OEMs and Tier 1 system suppliers) that applied or registered intellectual property rights in Western Europe, and a considerably lower share in new EU member countries. This may partially be explained by the location of large R&D and innovation centres and IPR-strategies of large firm groups in new Western Europe. Usually their subsidiaries in new member states also save their intellectual property rights in the home countries of Western European parent companies.

Figure 2-2 shows the development of patent applications over time. To gain an insight into innovative activities at actor and country level it is useful to examine different time periods and to compare results: Period 1988 – 1991; period 1995 – 1998 and period 2002 – 2005 are all examined below.

The periods (Period 1988 – 1991; Period 1995 – 1998 and Period 2002 – 2005) have to be chosen to reflect the structural change in the automotive sector. The increase in patent activities (applications) corresponds to the increase in the number of actors over the years.

Figure 2-2 Number of patent applications for the selected application authorities (1950 – 2005)[15]



Source: DPMA. JPO. EPO. WIPO, calculations by IWW-Karlsruhe

[15] Here we used the EPO Worldwide Statistical Patent Database version October 2007. The decline of the curve in figure 2 from 2004 to 2005 is partially a result of the 18 month publication deadline for patent applications.

Table 2.12 Patent activity (weighted number of applications)[16] and relative increase of patent applications in European countries

Europe	Period (A) 1988- 1991	Period(B) 1995- 1998	Period (C) 2002- 2005	Growth-Rate A-->B	Growth-Rate A-->C	Growth-Rate B-->C
Austria	9.00	13.00	25.00	1.44	2.78	1.92
Belgium			24.00			
Switzerland		48.00	79.67			1.66
Germany	4,019.14	11,026.12	21,149.35	2.74	5.26	1.92
Denmark		4.00				
Spain		9.00	81.92			9.10
France	1,556.00	3,281.67	4,905.82	2.11	3.15	1.49
Great Britain	227.17	476.92	83.00	2.10	0.37	0.17
Ireland		7.00				
Italy		13.00	125.20			9.63
Liechten-stein		9.00	11.00			1.22
Luxembourg			22.50			
Monaco		4.00				
Netherlands	6.50	4.00	56.00	0.62	8.62	14.00
Poland			6.00			
Portugal			10.00			
Sweden	19.50	119.83	409.17	6.15	20.98	3.41
Europe	5,837.31	15,015.53	26,988.62			

Source: DPMA. EPO. WIPO

Table 2.12 shows the European countries and their weighted overall patent applications in the observed periods. In all periods the leading innovative country in the automotive sector is Germany. This corresponds closely to figures for R&D-expenditure. In period 2002- 2005 the level of patent activity is nearly the same as in Japan. France is here the second innovation driver in Europe, but its absolute activity is considerably lower than that of Germany.

It is interesting to see that developments in Great Britain and Sweden diverge considerably. In period 2002- 2005 Sweden became the third innovative power in Europe, while patent activity in Great Britain became less significant. This may have changed since 2005: BMW – as the owner of MINI and Rolls-Royce – is investing in production plants and providing new jobs. Also Nissan and Ford are strengthening their engagements in Great Britain with a training centre and an increased production (Griffiths 2008). It remains to be seen, whether the non British owners will continue to increase R&D activities and help the country to return to the innovative strength of period B.

Patent growth in Sweden increased by a factor of 20.98 from the period 1988-1991 to the period 2002- 2005. The automotive sector has a highly qualified workforce which profits from large investment in R&D. Sweden is famous for safety technology and environmental technology (Quynh-

[16] The numbers refer to the weighted number of overall patent applications. An application is weighted by the number of applications. When a filling consists of more than one applicant the patent activity must be weighted. In the case of two applicants, for example each obtains an activity figure of 0.5.

Nhu H 2008). It should be mentioned that the future of Swedish automotive technology partially depends on future arrangements with parent companies (GM, Ford) in Northern America. The strong increase in German patent activity (see table 2.12) means that patent concentration[17] in Europe rose from 0.547 in period 1988-1991 to 0.647 in period 2002-2005. While several European countries experienced positive patent growth rates, absolute patent activity in Germany remains significantly higher than in other countries examined.

In the specific case of the automotive sector, patent data seem to be an appropriate database for identifying the main innovation drivers at country and actor level, and for analysing co-patenting activities as an indicator of cooperative innovation.

[17] The concentration-measures are calculated by the Hirschman-Herfindahl-Index (HHI)

3 Carriers of innovation[18]

As already ascertained by Marin et al (2008) two dimensions related to agents and interactions are positively associated with innovation performance: international orientation of firms and interaction with suppliers. Thus, countries that have succeeded in terms of innovation have a high share of firms that co-operate with suppliers.[19] As a consequence of outsourcing a “decoupling” of product development and manufacturing has been observed. Original equipment manufacturers increasingly tried to focus on their core-competences such as product development or marketing. These trends place multinational enterprises at centre-stage: they are drivers of concentration, and weave complex production and suppliers networks. Tier 1 suppliers have been increasingly involved in development processes by OEMs and have been able to gain a unique position as knowledge providers and gatekeepers. The following sections are dedicated to the identification of leading innovation carriers, co-operation patterns on the basis of co-inventions, and system challenges of the interactive innovation along the supply chain.

3.1 Innovation carriers at the firm level

The following table shows the European firms with the highest R&D investment in Europe. Total R&D Investment for the Top10 innovation carriers in Europe was more than € 25 bn. (in 2007), more than a third of total R&D expenditures for the automotive sector in Europe (in 2006).

[18] This chapter is based on the analysis performed in Task 1 of the SIW-II. The full analysis is available in Ploder, et al. (2010).
[19] Marin A., Patel P., Paunov C. (2008) Benchmarking National Sector Specific Environments; Report Prepared for Innovation Watch/ Systematic project, funded by the European Commission

Table 3.1 Automotive innovation carriers EU industrial R&D investment scoreboard (part 1)

Company	Top1000 Rank	R&D Investment 2007	Change of R&D Investment 07/06	Aggr. Change of R&D Investment 2005-2007	Aggr. Change of Net Sales 2005-2007	Employees 2007	Aggr. Change of Employees 2005-2007	R&D/Net Sales Ratio 2007	Operating Profit 2007 in % of Net Sales	R&D per Employee 2007	Capital Expenditures 2007 in % of Net Sales	Country
		€m	%	%	%	#	%	%	%	€K	%	
Volkswagen	2	4,923.0	16.1	5.7	7.0	307,589	(1.4)	4.5	6.3	16.0	8.9	Germany
Daimler	3	4,888.0	(6.6)	(4.8)	(3.1)	357,000	(2.0)	3.8	6.8	13.7	16.0	Germany
Robert Bosch	6	3,560.0	4.8	11.0	5.0	267,562	3.9	7.7	6.9	13.3	5.7	Germany
BMW	10	3,144.0	(2.0)	3.7	8.1	97,922	(1.9)	5.6	7.1	32.1	24.5	Germany
Renault	14	2,462.0	2.6	7.9	(0.6)	133,854	0.8	6.2	7.3	18.4	8.3	France
Peugeot (PSA)	15	2,074.0	(4.6)	(1.7)	2.6	207,850	0.1	3.4	1.8	10.0	3.3	France
Fiat	17	1,741.0	9.0			179,601		3.0	5.2	9.7	5.0	Italy
Continental	32	842.1	24.2	17.3	9.7	93,895	8.4	5.1	9.9	9.0	5.1	Germany
Valeo	34	790.0	0.1	4.1	3.1	61,200	(3.1)	7.8	3.2	12.9	4.4	France
Porsche (Automobile)	36	734.1	63.7	31.9	6.2	11,444	(0.5)	10.0	80.9	64.1	15.2	Germany
ZF	38	666.0	14.0	8.3	8.0	57,372	1.7	5.3	6.7	11.6	4.6	Germany
Michelin	44	571.0	(3.4)	(0.3)	3.9	122,050	(1.2)	3.4	7.8	4.7	7.6	France
Hella	68	284.8	(0.3)	18.4	5.3	25,451	2.9	7.8	1.5	11.2	5.6	Germany
MAHLE	70	277.7	14.9		10.4	44,350	8.2	5.5	6.9	6.3	6.1	Germany
Autoliv	71	270.7	(0.5)	2.4	3.3	41,900	6.7	5.8	7.5	6.5	4.8	Sweden
Behr	77	241.0	5.2	7.3	3.5	19,448	4.6	7.1	2.5	12.4		Germany
Rheinmetall	90	179.0	5.9	5.6	5.5	19,068	0.0	4.5	6.0	9.4	4.2	Germany
Pirelli	95	173.0	1.2	0.4	(4.0)	30,780	(5.9)	2.7	7.5	5.6	4.4	Italy
Tognum	140	117.9	(4.4)			7,867		4.2	12.2	15.0	3.5	Germany
ZF Lenksysteme	143	114.2	23.6	20.6	8.2	9,830	1.7	4.4	3.7	11.6	4.6	Germany

Source: 2008 EU Industrial R&D Investment Scoreboard

Table 3.2 Automotive innovation carriers: EU Industrial R&D investment scoreboard (part 2)

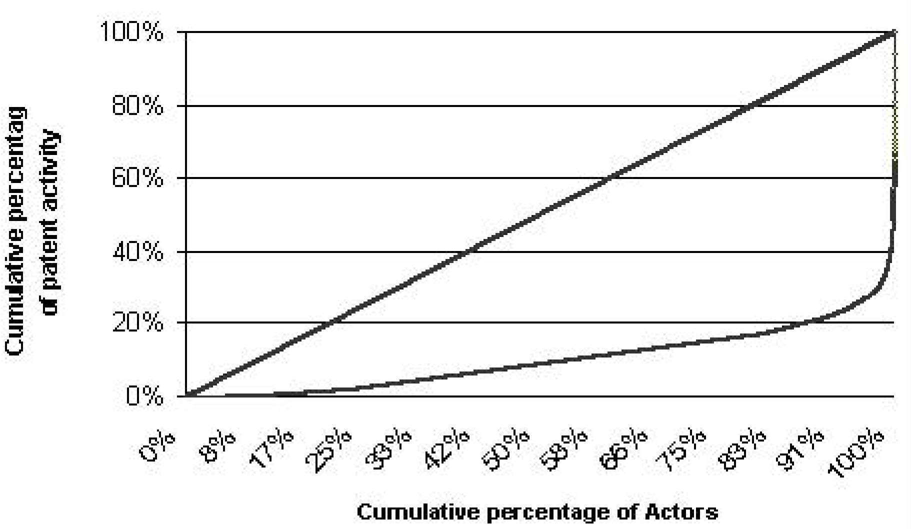
Company	Top1000 Rank	R&D Investment 2007 (€m)	Change of R&D Investment 07/06 (%)	Aggr. Change of R&D Investment 2005-2007 (%)	Aggr. Change of Net Sales 2005-2007 (%)	Employees 2007 (#)	Aggr. Change of Employees 2005-2007 (%)	R&D/Net Sales Ratio 2007 (%)	Operating Profit 2007 in % of Net Sales (%)	R&D per Employee 2007 (€K)	Capital Expenditures 2007 in % of Net Sales (%)	Country
GKN	144	113.0	10.7	(3.0)	3.6	37,735	1.0	2.1	6.2	3.0	4.5	UK
Burelle	173	95.7	(9.1)	31.8	11.8	13,834	8.9	3.4	3.1	6.9	4.4	France
IMMSI	203	71.7	7.0	22.8	17.5	7,793	5.7	3.9	6.6	9.2	2.2	Italy
Eberspaecher	206	70.2	10.6	2.2	15.3	5,477	2.3	3.1	3.5	12.8	2.5	Germany
Grammer	248	53.1	13.7	17.6	6.6	9,326	6.0	5.3	3.1	5.7	3.0	Germany
Ktm Power Sports	308	37.5	22.2	122.0	54.0	1,778	4.7	6.6	6.2	21.1	4.8	Austria
Beru	324	34.3	2.8	3.1	5.3	2,583	(1.0)	7.6	9.1	13.3	5.5	Germany
ElringKlinger	345	31.2	16.3	12.0	10.2	3,431	3.2	5.1	20.1	9.1	15.0	Germany
Haldex	356	29.4	(12.3)	(5.7)	5.5	5,518	8.5	3.5	3.7	5.3	4.8	Sweden
MGI Coutier	428	22.5	4.2	(3.0)	0.1	4,830	3.2	4.9	4.1	4.7	4.1	France
Wagon	472	19.3	61.4	8.6	13.4	6,649	7.7	2.0	(8.5)	2.9	7.7	UK
WET Automotive Systems	495	17.9	3.2	25.5	13.2	4,059		10.1	8.5	4.4	4.0	Germany
Ducati Motor	523	16.1	100.9	41.7	1.3	1,148	(0.5)	4.0	5.3	14.0	4.5	Italy
Miba	526	16.0	(13.5)	12.3	5.8	2,706	1.5	4.1	7.5	5.9	9.0	Austria
EYBL International	532	15.7	8.7	7.4	(0.9)	4,199	5.2	4.7	2.1	3.7	1.5	Austria
Carraro	538	15.3	2.1	17.1	16.6	4,036	23.5	1.9	4.8	3.8	5.2	Italy
Brembo	604	12.5	10.2	(4.3)	10.4	5,172	9.4	1.4	9.2	2.4	6.8	Italy
Nokian Tyres	628	11.5	27.8	6.2	19.4	3,462	6.8	1.1	22.7	3.3	10.7	Finland
Paragon	670	10.0	(11.7)	57.2	18.8	547	20.7	9.2	6.4	18.3	6.4	Germany
Spyker Cars	786	7.1	(20.2)	4.5	124.1	166	40.4	15.9	(106.7)	43.0	6.7	Netherlands
Torotrak	842	6.2	2.6	(3.6)	71.0	62	(13.6)	124.4	(80.0)	100.3		UK
Amtel-Vredestein	847	6.2	349.6		21.2	11,341	(22.6)	1.1	(9.5)	0.5	7.2	Netherlands
Cie Automotive	906	5.3	(16.6)	64.5	24.0	8,340	12.8	0.4	6.7	0.6	7.7	Spain
Hymer	914	5.3	(24.9)		6.7	3,097	3.7	0.6	5.6	1.7	3.0	Germany
ACH	959	4.6	(3.4)		23.4	3,130	6.5	0.6	6.7	1.5	1.9	Slovenia
Average of Top1000 Automobile Co.	-	-	4.2	4.2	3.1	-	0.4	4.6	7.0	12.8	10.0	-

Source: 2008 EU Industrial R&D Investment Scoreboard

Data from the R&D Investment Scoreboard are a valuable source for identifying those with the highest R&D inputs. Even when not all R&D and innovation activities produce patenting and co-patenting, patent data still provide a strong indicator of both throughput and output.

We must not lose sight of the fact that R&D and patent activities are highly concentrated in the automotive sector. As illustrated by the Lorenz curve for the period 2002 to 2005 it is obvious that the biggest share of the cumulated patent stock is in the hands of very few actors. This reflects the fact that the bulk of R&D expenditure is undertaken by a relatively small number of large players in Europe. In fact, the larger European automakers (OEMs) have even increased their capital spending over the past decade, e.g. for product development a new powertrain technology.

Figure 3-1 Lorenz curve of patents held in the period 2002 o 2005



Source: PATSTAT (DPMA, JPO, EPO, WIPO)

Again based on PATSTAT data, the following analysis aims to identify the main innovation carriers in the automotive sector at firm level as measured by patent activities for the periods 1988-1991, 1995-1998 and 2002-2005. The strong position of the German automotive industry is reconfirmed for all periods. A closer look at the output of the three different organization types shows that in terms of total output, the European share of the three different organization types in the basically remains constant across all three periods.

Table 3.3 Ranking of the Top10 innovation carriers as measured by patent-activities for the periods 1988-1991, 1995-1998 and 2002-2005.

Rank	Period A (1988 - 1991)			Period B (1995 - 1998)			Period C (2002 - 2005)		
	Firm	Position	Country	Firm	Position	Country	Firm	Position	Country
1	Robert Bosch GmbH	Tier 1	DE	Robert Bosch GmbH	Tier 1	DE	Daimler Chrysler AG	OEM	DE
2	Bayerische Motoren Werke AG	OEM	DE	Mercedes-Benz AG	OEM	DE	Robert Bosch GmbH	Tier 1	DE
3	Daimler-Benz AG	OEM	DE	Volkswagen AG	OEM	DE	Volkswagen AG	OEM	DE
4	Valeo	Tier 1	FR	Valeo Thermique Moteur	Tier 1	FR	Renault	OEM	FR
5	Alfred Teves GmbH	Tier 1	DE	Bayerische Motoren Werke AG	OEM	DE	Bayerische Motoren Werke AG	OEM	DE
6	Peugeot Automobiles	OEM	FR	Automobiles Peugeot	OEM	FR	ZF Friedrichshafen AG	Tier 1	DE
7	Citroen SA	OEM	FR	Siemens AG	Tier 1	DE	Peugeot Citroen Automobiles SA	OEM	FR
8	Audi AG	OEM	DE	Mannesmann AG	Tier 1	DE	Audi AG	OEM	DE
9	Renault	OEM	FR	Renault	OEM	FR	Continental AG	Tier 1	DE
10	Porsche AG	OEM	DE	ZF Friedrichshafen AG	Tier 1	DE	Valeo France	Tier 1	FR

Source: PATSTAT (DPMA, JPO, EPO, WIPO) 2002-2005

The number of Tier1 suppliers among the Top10 innovation carriers increased from period A (1988-1991) to period B (1995- 1998). This corresponds to the general picture of an increasing significance of tier level suppliers in automotive innovation activities (see section 3.3.1).

As we will see in section 3.3.1 for some of these companies specific measures of network analysis (see page 39f: “betweenness centrality”) indicate a gatekeeper-role concerning patent co-operations.

3.2 People

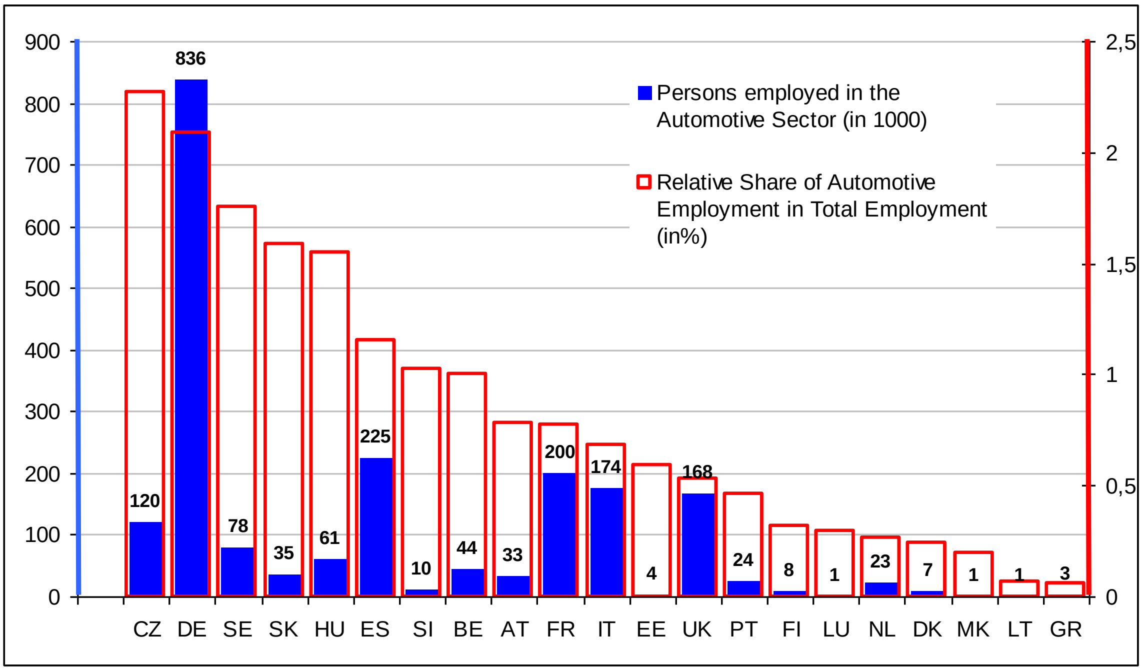
As already ascertained by Marin et al (2008) two aspects of the knowledge base are a significantly related to innovation performance. Countries with a high level of innovation performance in the automotive industry have a high share of engineers in the economy, and also have a high share of firms who engaged in training their employees.[20]

More than two million persons in Europe are employed in the automotive sector. Figure 3-2 gives an overview of the number of persons employed in the automotive sector in different European countries and the relative importance of automotive employment for national economies in Europe. The Czech Republic, Germany, Slovakia, Hungary and Spain have the highest relative share of total employment in the automotive sector. Almost 40% of European automotive employment is to be found in

[20] Marin A., Patel P., Paunov C. (2008) Benchmarking National Sector Specific Environments; Report Prepared for Innovation Watch/ Systematic project, funded by the European Commission

Germany. Apart from the dominating role of Germany the automotive industry in Europe, Figure 3-2 points to the high importance of the automotive industry for new EU member countries in the European Union.

Figure 3-2 Persons employed in the automotive sector (34) in selected European Countries (in 2007[21])



Source: EUROSTAT (nama_NACE_60_E); calculations based on national accounts

21 Data from 2006 for (persons employed) Germany; Sweden and Portugal (2007 not available)
Data from 2005 for (persons employed) Espania and Lithuania (2007 or 2006 not available)

Table 3.4 Skill levels of employees for the most common occupations in automotive industry 2006

Occupation (Profession)	ISCO	share of total automotive employment (%)	New Member Countries (NMC)				EU 15+NO				SOUTH			
			1. Low (%)	2. Medium (%)	3. High (%)	No. (#)	1. Low (%)	2. Medium (%)	3. High (%)	No. (#)	1. Low (%)	2. Medium (%)	3. High (%)	No. (#)
Assemblers	828	17	19	80	1	1,031	26	68	6	643	65	33	2	294
Physical and engineering science technicians & 0ther engineers and related professionals	311 & 214	11	2	62	36	358	6	46	49	688	19	54	27	285
Metal moulders, welders, sheet-metal workers, structural-metal preparers, and related trades workers	721	8	12	87	0	432	28	67	5	248	71	26	3	228
Metal- and mineral-products machine operators	821	7	18	82	0	248	27	68	4	349	51	40	9	201
Machinery mechanics and fitters	723	7	7	91	2	233	18	75	7	334	48	43	9	207
Blacksmiths, tool-makers and related trades workers	722	5	7	92	1	331	17	78	5	190	69	26	5	74
Automated-assembly-line and industrial-robot operators	817	4	12	86	3	225	33	63	4	24	53	41	6	236
Material-recording and transport clerks	413	3	9	87	4	160	26	65	9	152	50	43	7	98
Manufacturing labourers	932	3	41	59	-	51	46	50	5	131	66	27	8	128
Agricultural and other mobile-plant operators	833	3	24	76	-	105	35	64	1	146	61	35	4	46
Metal-processing plant operators	812	2	31	69	-	68	32	57	11	53	58	41	1	158
Administrative associate professionals	343	2	-	77	23	104	6	59	34	64	6	70	24	83
Electrical and electronic equipment mechanics and fitters	724	2	6	92	3	109	16	75	9	93	33	56	10	48
Safety and quality inspectors	315	2	3	87	10	130	14	70	16	64	20	38	43	40
Production and operations department managers	122	2	1	63	36	88	13	40	47	95	-	33	67	12
Finance and sales associate professionals	341	2	-	64	36	44	13	61	26	102	7	66	27	44
Rubber- and plastic-products machine operators	823	2	18	81	1	83	32	64	-	28	65	32	3	69
Other specialist managers	123	1	-	35	65	31	4	30	65	113	10	10	81	21
Other office clerks	419	1	-	70	30	10	20	59	21	91	22	73	5	59
Secretaries and keyboard-operating clerks	829	1	29	71	-	31	32	62	6	81	50	50	-	32
other occupations		16	63	-13	50	48	14	69	18	1,476	46	42	12	426
Total		100	13	79	8	3,920	18	63	18	5,165	48	41	11	2,789

Source: Labour force Survey (2006), EUROSTAT, own calculations

Official databases on sectoral skills and qualifications are unfortunately rare. The following discussion is based on the Labour Force Survey. This is a broad sample survey and should be interpreted with caution. Table 3.4 shows skill levels of employees in three aggregated regions (corresponding to CIS analysis and discussion of innovation performance in section 2)[22]

According to the ranking (based on Labour Force Survey data) in Table 3.4 “assemblers” (35% of automotive employees), “engineers and technicians” (11%), metal workers (8%), machine operators (7%) and machinery mechanics (7%) are the most common occupations in the automotive industry. The relative share of “engineers and technicians” in the EU15+Norway (13%) is considerably higher than in new EU member countries (NMC: 9 %) or in Southern Europe (10 %). The higher share of “engineers and technicians” corresponds with the location of large OEMs and tier 1 level suppliers. It should be mentioned that the data base does not account for temporary leased workers.

More than the half of all employees (64 %) in the automotive sector are medium skilled. 24% of the persons employed in the automotive sector are low skilled and 13% high skilled. The share of high skilled employees is considerable higher in the EU15+Norway countries than in the rest of Europe. Interestingly the highest share of low skilled employees can be found in Southern Europe. These differences are the result of the different education systems prevailing.

There is no denying that the automotive industry and comparatively high wages has been a very attractive employer for medium-skilled workers in new EU member countries (NMC).

However, employee turnover seems to be a significant factor in knowledge transfer. Automotive manufacturing is closely linked with many other supplying sectors. Electronics, mechanical and electrical engineering, information technology, steel, chemicals, plastics, metals and rubber are all key suppliers.

Table 3.5 is based on the Labour Force Survey and presents the share of employees in the automotive sector gained from other sectors (for five selected years). In addition, the table also shows the proportion of employees in other sectors (as a measure of employees in the automotive sector) leaving the automotive sector within the last year.[23] Again the sample-methodology used means that result can only be considered tentative.

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[22] Although 12,000 datasets were available for the automotive sector, the sampling methodology of the labour force survey doesn’t ensure representativeness at the NACE digit2 level for three skill levels. For the Czech Republic twice as many cases as in the German case are available for instance. Table 3.5 also shows the skill levels of employees for the most common occupations in the automotive industry. The differences in skill-structure are reflected at the level of different occupations.

[23] The proportions refer to the automotive employment of the respective region and skill level (for each even-numbered year of reference presented). Thus, 1998 in new member states (NMC) 8,3 % of “high skilled” employees were attracted from other sectors. That is: they had been employed in another sector in 1997.

Table 3.5 Regional differences of mutual gains and losses of employees of different skill levels of the automotive sector, as a share of total employees in the automotive sector

Region		NMC				EU 15+NO				SOUTH				TOT.
Skill Level		**Low Skill**	**Med. Skill**	**High Skill**	**Total NMC**	**Low Skill**	**Med. Skill**	**High Skill**	**Total EU15**	**Low Skill**	**Med. Skill**	**High Skill**	**Total South**	
1998	from other sectors to 34	5,9	12,1	8,3	11,1	5,4	7,2	6,8	4,1	6,9	6,1	6,6	6,7	5,2
	from 34 to other sectors	-	5,9	4,3	5,1	5,1	5,8	9,9	3,4	5,1	5,3	7,0	5,4	4,0
2000	from other sectors to 34	9,2	10,6	15,5	10,8	3,5	3,7	5,0	3,8	6,6	10,4	5,6	7,5	5,4
	from 34 to other sectors	6,1	6,1	7,5	6,2	5,6	4,3	3,6	4,4	5,4	7,1	4,5	5,7	4,9
2002	from other sectors to 34	5,8	9,4	10,9	9,1	5,0	4,0	5,8	4,6	6,0	7,3	5,1	6,2	5,5
	from 34 to other sectors	8,9	5,5	10,9	6,2	4,5	4,3	3,9	4,3	5,2	7,3	6,6	6,0	4,9
2004	from other sectors to 34	10,8	8,1	8,0	8,3	1,6	1,8	1,5	1,7	3,0	5,0	2,7	3,5	3,2
	from 34 to other sectors	6,5	5,9	8,0	6,1	2,5	1,4	2,0	1,7	3,1	4,2	1,7	3,2	2,7
2006	from other sectors to 34	7,7	6,5	4,4	6,4	4,0	2,7	3,5	3,1	6,7	7,5	6,6	7,0	5,8
	from 34 to other sectors	3,9	4,2	4,7	4,2	3,5	4,1	3,1	3,8	7,3	9,3	7,6	8,1	5,2

Source: Labour Force Survey (1998, 2000, 2002, 2004, 2006), EUROSTAT, own calculations

For the even-numbered years 1998 to 2006 the automotive sector attracted between five and six percent of its employment from other sectors. As confirmed in qualitative interviews, the cross-national exchange and mobility of technicians in the automotive industry is considerably low.

For the even-numbered years 1998 to 2004 the annual share of employees attracted from other sectors is considerably higher in new EU member countries (NMC) than in EU15+ Norway or Southern Europe. This is particularly marked for high skilled employees.

Table 3.6 completes the picture, and shows for selected even numbered years between 1998 and 2006 the sectoral origin of employees attracted by the automotive sector.[24]

As it is to be expected, the automotive sector gains considerable human capital from the metal production sector and from the mechanics and repair sector. Employees from the mechanics and repair sector seem to be particularly willing to move to the automotive sector (to work as assemblers, for instance) or to move back to their original sector after some years.

[24] Analogous to Table 3.5 the proportions refer to the automotive employment of the selected observed years.

Table 3.6 Mutual gains and losses of employees of the automotive sector and other sectors as a share of total employees in the automotive sector

"Other" Sectors FROM / TO	2006		2004		2002		2000		1998	
	to 34 from other sectors[25] (% of 34 in 2006)	from 34 to other sectors[26] (% of 34 in 2005)	to 34 from other sectors (% of 34 in 2006)	from 34 to other sectors (% of 34 in 2005)	to 34 from other sectors (% of 34 in 2006)	from 34 to other sectors (% of 34 in 2005)	to 34 from other sectors (% of 34 in 2006)	from 34 to other sectors (% of 34 in 2005)	to 34 from other sectors (% of 34 in 2006)	from 34 to other sectors (% of 34 in 2005)
Primary Sector	2.9	2.8	3.3	1.5	4.0	2.9	2.6	1.8	3.3	1.2
Food and Beverages	3.5	0.9	4.1	2.4	2.6	2.7	4.8	3.0	4.5	2.4
Textiles, Leather	3.9	0.9	5.3	1.0	1.6	0.5	1.9	1.5	3.6	2.4
Wood, Pulp, Paper	3.1	2.1	4.1	2.4	3.3	4.0	2.1	1.8	3.0	2.8
Chemical Products	0.4	1.3	1.2	0.5	1.2	1.9	2.1	2.7	0.6	1.6
Rubber, Plastics	2.7	6.2	1.2	4.9	3.5	3.7	3.2	5.3	3.0	1.6
Non Metal Products	1.3	1.7	2.0	1.5	1.2	1.1	2.4	0.9	1.5	-
Metal Products	9.6	11.5	7.0	11.7	8.4	8.5	5.8	11.3	8.0	11.5
Machinery	5.6	11.1	6.6	6.8	5.1	6.1	6.9	6.2	6.0	6.7
Electric, Electronics	9.8	7.0	6.6	5.3	8.2	5.8	7.1	11.0	5.1	7.9
Other vehicles (Aeron., Shipbuild.etc.)	3.3	3.4	0.8	1.0	2.3	1.6	2.4	3.3	1.5	2.0
Other Manufact.	2.3	3.6	5.3	2.4	4.9	2.7	3.7	4.7	3.0	4.0
construction	6.7	5.8	8.6	9.7	8.6	4.8	7.7	4.7	11.0	7.1
Mechanics, Repair	11.6	11.9	4.5	9.2	5.6	5.8	4.2	8.6	6.3	11.1
Retail, Wholesales	11.9	8.5	11.9	9.7	10.5	10.6	9.5	6.5	8.9	9.5
Other Distrib. Services (NACE 55 to 64)	9.2	7.9	11.9	12.1	9.8	10.1	9.0	6.2	10.1	7.1
Other Business Services (65 to 72)	1.9	3.2	1.6	1.0	2.3	5.3	3.4	3.6	3.3	4.3
R&D, Technical Business Services (73,74)	2.5	4.5	4.1	8.3	4.7	8.8	11.9	5.6	4.8	4.7
Education, Higher Education (75, 80)	3.3	2.8	4.1	4.4	5.6	7.2	5.3	5.6	6.8	7.1
Other Public Services	4.4	3.0	5.7	4.4	6.5	6.1	4.0	5.6	6.0	5.1
Total changes (%)	100	100	100	100	100	100	100	100	100	100

Source: Labour Force Survey (1998, 2000, 2002, 2004, 2006), EUROSTAT, own calculations

[25] Share of employees of the automotive sector (in the year under review) which changed within the last year to the automotive sector.

[26] Employees in other sectors (in the year under review) which disappeared from the automotive sector as a share of employees in automotive sector in the preceding year

It is interesting to note, that the automotive sector lost employees to the electronics sector in 1998 or 2000. However, after the ICT-bubble burst, the share of human capital attracted from the electronic sector continuously increased. This probably reflects the increasing awareness of automotive firms of the need to build up competences and knowledge in electronics, mechatronics and sensor technology in recent years. These competences are relevant for absorptive capacity in direct co-operation with suppliers in the electronic sector, and for the overall integration of electronic components and modules. During the last decade tier level suppliers in the automobile industry invested considerably in meeting the needs of OEMs and staying as flexible as possible in the face of increasing cost pressure and shorter development cycles.

As innovation activities cover a broad range of employees, from R&D to the transition from prototyping to production along the value chain, OEMs and suppliers partially implemented internal qualification programs and knowledge management activities. These are coordinated with on-going quality management.

At least a third of all employees attracted from other sectors came from services industries other than mechanics and repair. Beyond that a visible share of (mainly unskilled) employees has been attracted from the construction sector.

It is worth mentioning that the proportion of employees leaving the automotive sector to move to engineering and R&D services (NACE 73, 74) considerably outnumbered those attracted by the automotive sector (NACE 34) from engineering and R&D- services (NACE 73,74). This corresponds to the increasing role of highly specialized engineering consulting firms, arising during the last decade. In the years 1998, 2000 and 2002, the automobile sector lost a considerable number of employees to education and higher education. In 2004 and 2006 losses and gains in education and higher education sector balanced.

This leads us to R&D-personnel, which can discussed on the basis of national R&D surveys. The R&D expenditures per R&D employee vary considerably across Europe. This partly reflects differences in wage-costs, but it is primarily the result of respective firm position in both the supply chain and in the regional innovation system, and the associated costs.

Table 3.7 shows the number of R&D-employees in the automotive sector and corresponding R&D expenditures per R&D employee. A considerable share of R&D employees in the automotive sector in Europe is to be found in Germany. This corresponds to the relatively large number of persons employed in the automotive sector in Germany as a whole (see Figure 2-1; more than 2 Mio. employees in Europe).

High values can also be identified in Sweden, Italy, Spain and the Netherlands. The relatively low expenditures per R&D employee in new EU member countries indicate that there is great scope for future R&D-activities in these countries.

Table 3.7 R&D Personnel in full time equivalent in the automotive sector in 2005

	R&D Personnel in full time equivalent	**annual change (%)**	**expenditures per R&D-employee(%)**
Czech Rep.	10,417	9.0	87.70
Germany	178,964	2.2	215.97
Ireland	6,611	8.2	201.18
Greece	4,385	22.5	81.50
Spain	34,105	14.0	160.83
Italy	30,500	1.6	257.57
Hungary	5,499	5.5	65.76
Netherlands	24,529	9.3	210.73
Austria[27]	19,395	3.1	183.37
Poland	8,452	17.5	52.06
Portugal	6,102	0.7	75.72
Romania	10,086	2.8	16.12
Slovenia	1,669	16.0	145.54
Sweden	30,613	19.4	270.80
total	371,327	4.9	175.01

Source: own calculations. Eurostat

The automotive sector has been a job creation machine for a long time, and has grown hand in hand with the restructuring of a number of European regions. Notwithstanding interfirm and regional differences the relatively high qualifications of European automotive employees have generally been seen as a locational advantage.

Increasing demand for individual mobility and motor vehicles will not help the automotive industry avoid considerable structural change in the near future. This will entail adaptations of the value chain as well as development of, new technologies and new markets. The enormous attractions of Asian development are likely to witness much greater mobility of brain power in future.

3.3 Clusters and networks

The following section will focus on the role of inter-frim collaboration for innovation and knowledge diffusion and the relevance of clusters for innovation in the automotive sector.

In the automotive sector, the number of inventor teams and collaborations increases greatly over time. The reasons for this are manifold. First of all, the trend can be related to the strategies of multinational companies and the need to meet the demand of local consumers in different markets.

[27] Numbers for Austria refer to 2006

Hence, the products must be adapted to the peculiarities of a certain region with the support of local specialists (adaptive innovation). Another reason lies in the re-location of production activities to regions with relative comparative cost advantages. Thus, the R&D which is located in the home country has to interact with several production sites abroad. Third, many innovations in the sector rely on the interaction of OEMs and tier firms, increasing the number of linkages.

Regarding the networks it can be observed that at the end of the 1980s Germany played a very important role. Almost all nodes which are connected to each other have a link to Germany. This situation changes since the mid of the 1990s. As the number of connections increases dramatically, the connections between other countries in the networks gain importance. Within the EU 15 countries the United Kingdom changes from a little connected country to a central player, in spite of decreasing specialisation. France and Germany are strongly linked to each other and many of the New Member Countries join the network. (Grupp et.al 2010)[28]

Table 3.8 Relative growth of the amount of network connections

	All	Bio	El.&Opt.	Auto	Space	Const.	Food	Textiles
EU15-EU15	1.13	0.47	1.64	14.91	1.05	1.59	1.02	0.85
EU15-NewEU	1.98	0.80	5.22	1.00	0.00	3.36	0.47	5.65
EU15-NonEU	1.31	0.16	1.30	32.82	2.35	1.47	1.77	1.21
NewEU-NewEU	1.76	0.37	1.38	7.18	1.85	5.18	0.20	1.07
NewEU-NonEU	1.44	0.00	0.20	1.00	1.00	1.00	1.00	1.00
NonEU-NonEU	0.95	0.05	0.26	20.93	0.78	1.37	1.64	0.95

The first subsection will discuss the question, which collaborations throughout the value-chain can be identified and how far patterns of collaborations as potential source of innovation and knowledge diffusion changed.

The second subsection will discuss the significance of clusters and networks and analyse the role of policy driven initiatives in Europe.

3.3.1 Innovation co-operation and networking along the supply chain

Networking and interaction are important forms of innovative activity as emphasized by various strategic management and industrial dynamics approaches to inter-firm cooperation (Vonortas 2000). Such activity has also been extended to cover questions of identifying competences and capabilities in strategic management at different levels of economic interaction (Felin/Foss 2005).

[28] Grupp et al. (2010) National Specialisation and Innovation Performance; Europe INNOVA Sector Innovation Watch Task 4: Horizontal Report 1, for DG-Enterprise & Industry, March 2010

Mariotti and Delbridge (2001) speak of the necessity for firms – when declining with the ambiguity, tacitness and complexity of knowledge – to engage in the management of a portfolio of ties. The automotive and aerospace industry, as well as the computer industry or electronic equipment industry are all characterized by a high division of labour.

Innovation in the automotive sector is affected by powerful supply and network structures. While innovation in the aerospace Sector is still quite concentrated, it seems to be typical for the automotive sector, that innovation activities are interactively spread along the value chain implementing a decisive role of systems (mega) suppliers. (Steiner/ Ploder 2008) Innovation networks and ties in the automotive sector are thus defined to a certain degree by supply chain interactions. Innovation processes cannot be discussed independently of relevant supply chains, the division of labour, or knowledge production along the value chain of an industry.

As mentioned by Maxton and Wormald (2004) the approach used in of product development in the automotive industry has changed significantly throughout the last fifteen years. The traditional model of product development follows a sequential and task-driven pattern starting moving from planning in the marketing department, on to the design department and finally to the engineering and production department. The sequential pattern and necessary feedback loops resulted in a development time between six and seven years. This traditional process entailed frequent adaption and adjustment as the objectives of different departments all had to be taken into consideration. As a consequence, flexibility was low, the time to market long, and the opportunities to integrate suppliers in the process severely restricted. In many cases, almost a decade passed between the initial perception of consumer demand and the first product delivery to the consumer.

The whole design and development process has been reorganized in recent years as tasks have become more interactively synchronized. In addition to new multidisciplinary teams, the direct involvement of systems and component suppliers has also become necessary. The division of labour in innovation processes now reflects devolvement of responsibility and liabilities and also entails new challenges in inter-organizational exchange (e.g. in terms of residential engineers) and knowledge-management.

CIS 4 data now reflect the interactive, cross-national nature of innovation in the automotive sector. 33 % of the innovative firms in the sector confirmed their direct cooperation in the course of innovation activities (20% confirmed cross-national cooperation with partners in Europe, 9 % with partners in US-America).

24 % of the automotive firms cooperate with suppliers and 19 % with customers. A considerable share of automotive firms cooperates with universities (13 %), and public research institutions (8 %). Analogous to the innovation expenditures discussed above we can identify national differences in the

cooperation behaviour. This may be explained by the relative structure and position of firms in the value chain, or by their role in inter-organizational innovation processes. (Bidault et al 1999)

While the commercial vehicle sector still follows the traditional product development and innovation model, the passenger car segment mainly follows new patterns. Today, a typical automotive design cycle is approximately two to three years, which is much faster than the five year life cycle of five years ago. Short design cycle times in the passenger car segment imply a faster time-to-market and exert immense pressure on the sectoral innovation system devolved from OEMs to system suppliers and finally to component suppliers.

Both recent analytical results for the automotive sector (Sofka et al. 2008) and corresponding literature (Maxton and Wormald 2004, Steiner/ Ploder 2008, McAlinden 2002) verify the high significance of innovation co-operation in the automotive industry

Throughout the last two decades we have observed a shift of suppliers to OEM relations, from classical market transactions to more integrated partnerships (Midler 2005) This means the traditional vertical contracting structure along the value chain has largely been replaced by a structure where global mega suppliers hold key positions (Sturgeon and Florida, 2004). We thus find:

- Tier 1 suppliers, and in particular upcoming global mega suppliers, increasingly play an important in role in the course of the product emergence process. They occupy a unique position, are responsible for complex modules and systems, and have gained major degrees of freedom in terms of selection of materials and suppliers. Thus, tier 1 level suppliers increasingly coordinate the supplier and innovation networks. The challenge of coordinating networks affects the involvement of Tier "n" suppliers as well as the coordination and adjustments with other Tier 1 suppliers. Tier 1 suppliers have to build up innovation and coordination capabilities, while facing considerable economic uncertainty with respect to possible reduction of production an insourcing strategies of OEMs.
- In return OEMs try to retain influence in terms of project-organization, development-expertise and finally of course the selection of Tier 1 suppliers. Innovation drivers like electronic equipment are more or less out of reach for OEMs and partially concentrated in mega system suppliers. However, the given selection procedures and possible path dependencies make the high expenditure on R&D inherently risky. Thus, OEMs have increasingly started to focus on downstream business, that is, direct interaction with end-users by product-services bundles.

The following analysis is again based on international patent data (PATSTAT) and provides additional insight into the level of cooperation between OEMs and tier level suppliers of different national affiliation. The number of actors increased clearly between period A and period C.

Table 3.9 gives an overview of the patenting activities of OEMs, tier level suppliers and other organizations and actors. The degree of worldwide patent activity outside of Europe (Non-Europe) for the three organization types in the periods observed, is considerably higher than that for European activity.

Table 3.9 Patent activities (applications) of the three organisation types in Europe and non-Europe

	Period A (1988 - 1991)				Period B (1995 - 1998)				Period C (2002 - 2005)			
	Europe		Non-Europe		Europe		Non-Europe		Europe		Non-Europe	
OEM	2,318.14	40%	9,268	52%	5,081.17	34%	17,172.41	53%	10,151.78	38%	21,598.46	54%
TIER	3,433.67	59%	8,431.73	47%	9,683.7	64%	14,640.71	46%	16,441.83	61%	17,273.09	43%
OTHER	85.5	1%	131.5	1%	250.67	2%	348	1%	395	1%	1,053.17	3%
total	5,837.31	100%	17,831.23	100%	15,015.53	100%	32,161.12	100%	26,988.62	100%	39,924.72	100%

Source: PATSTAT (DPMA, JPO, EPO, WIPO)

Until the 1990s the OEMs were more or less the only innovation carriers with high in-house production. Due to changing market conditions (i.e. new competitors. individual customer requirements …) suppliers slowly gained more and more importance. As supply chains became more complex (lean production, Just-In-Time, etc.) OEMs reduced in-house production and became more flexible and focussed on core competences. The suppliers, now involved in research and development, started to be more innovative. Thus, Period A and Period B are snapshots of the market before and after this structural change, Period C reflects current activities. Here the share of patent activity for tiers level suppliers increased, while that OEMs in Europe (see Table 3.10) shrank.

Table 3.10 Growth-rates of patent activity for the three organisation types in Europe and Non-Europe

	Europe			Non-Europe		
	Growth-Rate Period A-->B	Growth-Rate Period A-->C	Growth-Rate Period B-->C	Growth-Rate Period A-->B	Growth-Rate Period A-->C	Growth-Rate Period B-->C
OEM	2.19	4.38	2.00	1.85	2.33	1.85
TIER	2.82	4.79	1.70	1.74	2.05	1.74
OTHER	2.93	4.62	1.58	2.65	8.01	2.65

Source: PATSTAT (DPMA, JPO, EPO, WIPO)

The growth-rates from period A to period B and from period A to period C in Europe (except the organisation type OTHERs) are much higher than in non-Europe.

In Europe the activity of OEMs and TIERs quadrupled from period A to C. In non-Europe the activity only doubled from period A to period C. Therefore, the difference in the patent activity decreases over time. Europe is catching up in absolute activities.

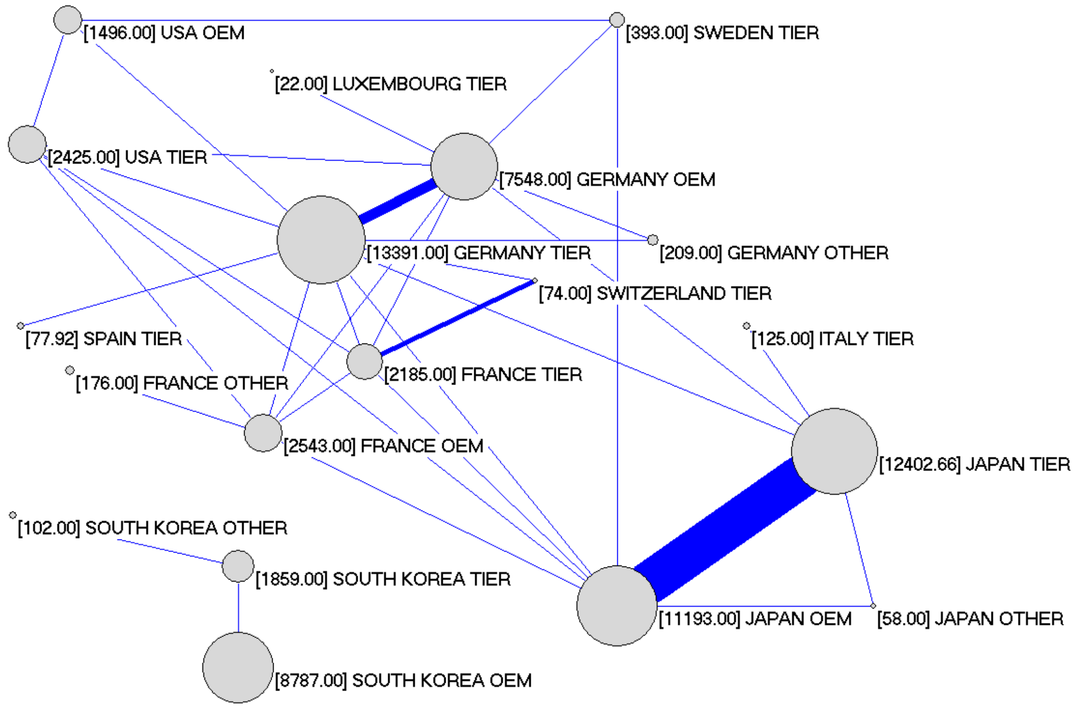
The PATSTAT database allows for an analysis of cooperative patents on the basis of registered co-inventors, and is an interesting indicator of R&D co-operation. As already mentioned, in all periods most actors registered as inventors (approximately 70%) do not cooperate in terms of patent activities.

Comparing data across nations for the three periods, it seems that international cooperation in the automotive sector while increasing is still not as intensive as national cooperation. In all periods, the European network is dominated by Germany. Japan always has the highest number of (patent) co-operations at the national level.[29] It also seems that the network of co-operation between the three organization types in period 2002-2005, at the country level, is getting denser compared to previous periods (period 1988 to 1991 and period 1995 to 1998). In all observed periods the OEMs in Europe and in non-Europe were always more central in the networks than the tier level suppliers.

Table 3.3 illustrates the network of (patent) co-operations between the organisation types (OEM, Tier level suppliers, others) in the period 2002 to 2005 on a country level. The data for patent co-operations can be used for a graphical representation of the transaction network of the observed organizations. The network diagram presented here is the traditional, basic methodology for formalizing network analysis. It is still a very helpful mean in interpretation and discussion. However, clarity suffers as the number of actor-dimensions (nodes) increases. Different organization types on the country-level are illustrated by nodes in Table 3.3. The size of nodes corresponds to total patent activities of these nodes (e.g. 7,458 patent activities for German OEMs in the period 2002 to 2005). Table 3.3 clearly corresponds to table 2.12. Germany is clearly the leading innovative country in the automotive sector in Europe. To a certain extent the strong position of Japanese firms derives from Toyota's patent activity

[29] This intensive cooperation could be a result of Keiretsu. The Keiretsu approach of organizing OEM-TIER relation enables Japanese OEMs to remain lean and flexible and therefore innovative. But Ahmadjian and Lincoln testify to a drift from once dominant "hybrid" or keiretsu governance modes toward the extremes of arms-length contracting and administrative control. Macroeconomic crisis and business uncertainty are eroding the cultural supports for keiretsu governance, giving greater legitimacy to new forms and new partnerships since the middle of the 90ies (Ahmadjian and Lincoln 2000).

Figure 3-3 Cooperation between the organisation types (OEM, tier level suppliers, others) in the period 2002 to 2005 on country level



Source: PATSTAT (DPMA, JPO, EPO, WIPO) 2002-2005, calculations by IWW-Karlsruhe

The lines connecting nodes illustrate patent co-operations (co-inventors), and the line width corresponds with the number of patent co-operations. [30] Table 3.3 shows the strong co-patenting activities of Japanese OEMs and tier level suppliers which seem to reflect the Keiretsu approach of organizing relations between OEMs and tier level suppliers. The illustration shows considerable co-patenting activities of German OEMs and German Tier level suppliers. Another intensive co-operation axis can be identified French tier level suppliers and tier level suppliers from Switzerland (Michelin).

Table 3.11 Stylized facts of the observed patent co-operation network (1988-1991, 1995-1998, 2002-2005)

	Period (1988 - 1991)	Period (1995 - 1998)	Period (2002 - 2005)
Number of Actors	454	819	1019
Number of Isolated, non-cooperating Actors (percentage)	313 (68.94%)	588(70.79)	739(72.52)
(Connected) Actors	141	231	280
All Degree Centralization	0.143	0.161	0.219
Betweenness Centralization	0.147	0.111	0.449

Source: PATSTAT (DPMA, JPO, EPO, WIPO) 2002-2005

[30] Interestingly, South Korea is isolated and not connected to any other country by patent co-operations in the period 2002 to 2005.

The data show considerable national differences for R&D and innovation co-operation among automotive firms, and these change significantly over time. Even when cross-national co-operations exist (as confirmed by R&D – expenditure and funding data) linkages and interaction on the national level still seem to dominate.

The numbers of actors increased between the period 1988-1991 and the period 2002-2005. The percentage of isolated actors remained constant. In all periods, most actors (approximately 70%) did not cooperate. Figure 3-4 illustrates the network of patent co-operations for the three periods 1998 to 1991, 1995 to 1998 and 2002 to 2005.[31] In order to retain clarity firms with patent activities not connected to any other firms in terms of co-inventions are ignored due. The size of points illustrating the cooperating firms corresponds to the level of patent activity.[32]

Social network analysis indicates that peripheral actors beamed more strongly connected to actors in the centre or less connected to other actors at the edge of the network. All degree centralization is a simple and widely used index of concentration in social networks. It reveals that the all-degree centralization constantly grew from 0.143 in period 1988 to 1991 up to 0.219 in period 2002 to 2005. This phenomenon is illustrated in Figure 3-4. Comparing the illustrations for all periods, we can see that the peripheral actors are increasingly connected to more important players in the centre of the network.

Based on the measure ‘betweenness centralization’ we can see that the networks contain more and more central actors and connected peripheral actors[33]

Figure 3-4 provides (analogous to figure 3.3) a clear picture for the intense cooperation of Japanese OEMs and tier level suppliers for all periods. A comparison of the illustrations for the periods 1995 to 1998 illustrates the appearance and considerable increase of activities of new players in Korea. The German automobile industry clearly dominated the picture for Europe. German tier- suppliers became more central over time. It is very interesting to observe that paten co-operations between Japanese, and European firms practically did not exist 20 years ago. In period 1995 to 1998 linkages between European and North American firms were present. In period 2002 to 2005 we can see considerable linkages of European and Japanese firms. The two “gatekeepers” in Japan are Toyota and Daihatsu. The counterparts in Europe are Peugeot PSA in France and Robert Bosch GmbH and Daimler Benz in Germany.

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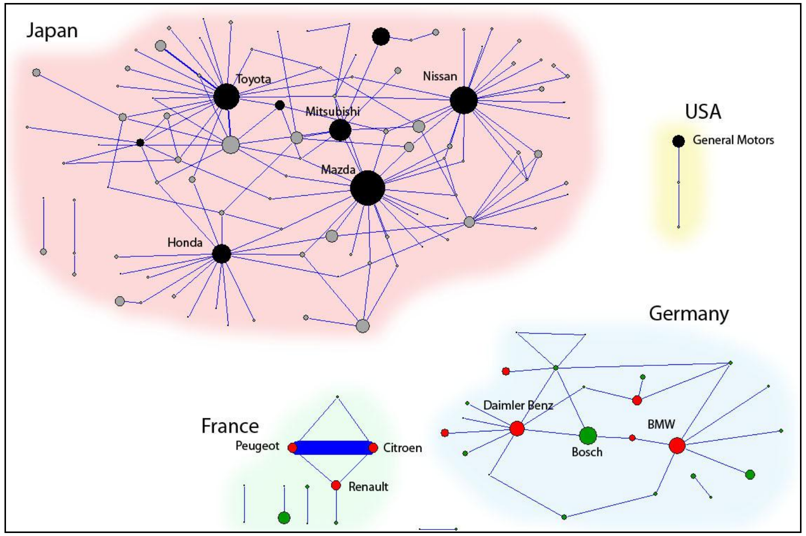
[31] For longitudinal analyses of networks we have to keep in mind that the character of actors (firms) might change via strategic reorientation, changing global IPR-strategies or mergers and acquisitions. In period 1988 to 1991 Peugeot and Citroen are considered separately in period 1995 to 1998 and 2002 to 2005 they are considered as the PSA-group.

[32] Almost all firms with considerable patent activity (at least 4 patents) show patent co-operations.

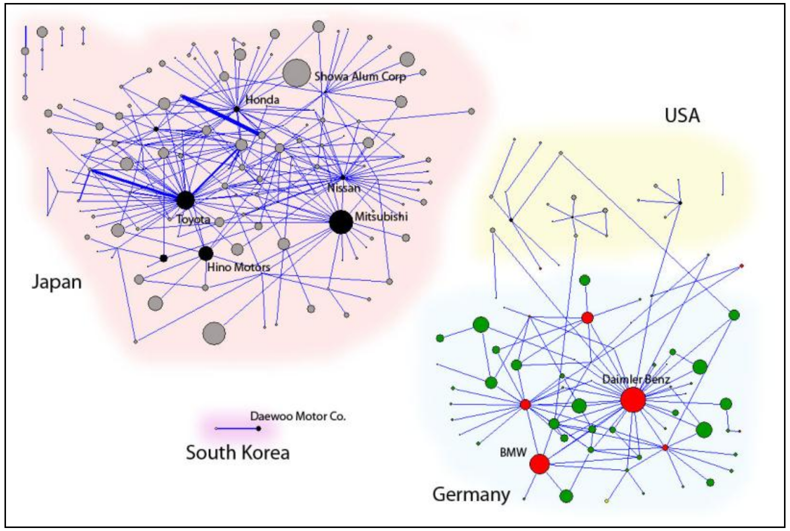
[33] ‘Betweenness centralization’ is a powerful tool in social network analysis. It refers to the entire network and measures the variation in betweeness centrality at the actor level.

Figure 3-4 Networks of patent co-operations of European and non-European actors for the three organisation types (1998-1991, 1995-1998, 2002-2005)

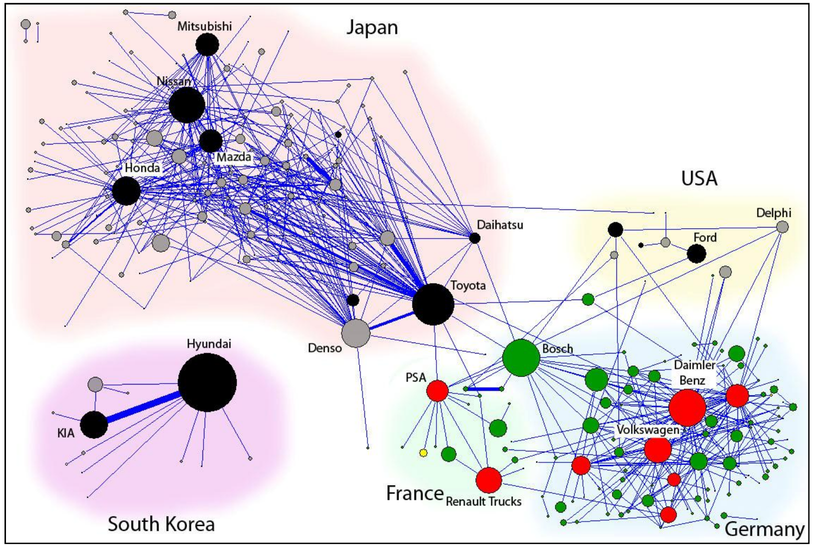
Period 1988-1991

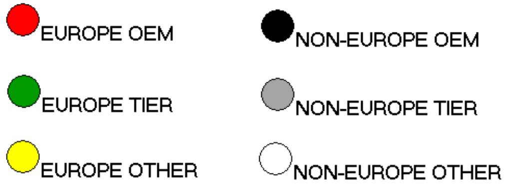


Period 1995-1998



Period 2002-2005





Source: PATSTAT (DPMA, JPO, EPO, WIPO) 2002-2005

The introduction and establishment of virtual engineering and design but also the increase in global technological integration and convergence opened the doors to new patterns of co-operative and interactive innovation. Empirical evidence as well as expert opinion substantiate the suspicion that the European automotive industry is not currently tapping its full potential for of innovation co-operation in the value chain. Alternative approaches such as open innovation or open source development etc. have not been adapted successfully for the automotive sector.[34]

Ultra low cost vehicles are a good example of the recent need for new co-operative approaches in supply chain innovation. The increasing importance of low-income target groups up to 2020 will be accompanied by increasing demand for low-cost mobility.

The market for ultra low cost cars (ULCC) is increasing enormously, and demands new forms of innovation. Toyota was one of the first OEMs worldwide to realize the potential of new low cost designs. The opening up of new markets in Asia will require new approaches for low cost production. European OEMs and automotive suppliers realized that pure downsizing and simplification of functions within the framework of existing products will be insufficient gain and maintain competitive position in the ULCC-segment.

Robert Bosch for example was instrumental in developing the “Tata Nano”, one of the first ULCC-products. This attracted worldwide attention, and now accounts for 15% of value added in production. The ULCC-segment requires a rethinking of existing technological concepts a re-setting of priorities, as well as, new design-solutions and cost and profitability models along the value-chain. While remaining dedicated to basic functions and reliability (but adapted to regionally specific needs) the ULCC- segment will become increasingly diversified in the future.

Eco-Innovations such as alternative powertrain concepts and their integration in totally new vehicle and mobility concepts provide a further challenge in the field of innovation. Again, supply chain innovation and the involvement of new partners (for instance energy providers and public authorities) are necessary. New coachwork structures and electric powertrains will open up new opportunities.[35]

Both examples imply an increasing loss of hegemony for Western (US-American, European) OEMs and a shift (possibly relocation) of centres of innovation to emerging markets (Asia, Eastern Europe). Players in emerging markets increasingly strengthen intellectual property rights by adopting strategies to improve innovation.

[34] The recent past shows examples of system suppliers and R&D consulters which invite specialists by providing early stage technologies as open source (e.g. EDAG in Germany which presented a light car in Geneva in 2009)
[35] Two examples which are representative for strong engagement of system suppliers in these field are Michelin or Magna Europe which presented new prototypes in new fields (beyond their current production) e.g. a prototype of a wheel hub engine and prototypes of electric vehicles respectively.

3.3.2 The role of clusters and policy-driven networks

The relationship between industrial clustering and innovation has been intensively discussed throughout the last decade. Empirical evidence shows that firms located in clusters that are strong in their industry introduce more innovations than more isolated firms (Breschi S. 2008)[36] Regional economic specialisation and innovative performance are closely related to each other. In this respect, the European Cluster Observatory emphasises that a clear specialisation profile is necessary for successful clusters to emerge in the global economy.

The most dynamic European economies[37] are specialised in large and fast growing technology fields. Furthermore, their technological strength in these areas is largely based on world class clusters, referring to the 3-star rating system of the European Cluster Observatory[38]. In the main areas of technological advantage, the European innovation leaders are in fact characterised by strong regional agglomeration of employment and regional focus.

Even in the case of large diversified innovative countries, in the sectors that exhibit a relative technological advantage production tends to be regionally clustered. Although this fact does not hold for all European countries, analogies can not be denied. To underline this point, table 3.12 compares relative technological advantages identified by the National Specialisation Report[39] to the evidence about European clusters provided by the Cluster Observatory, in accordance with the 3-star rating system in selected European countries. The German automotive sector is an example for this phenomenon: for this sector the European Cluster Observatory records seven 3-star clusters in Germany.

[36] Breschi S. (2008) Innovation-specific agglomeration economies and the spatial clustering of innovative firms; in: Karlsson Ch. (2008) Handbook of research in innovative clusters, Edward Elgar, Cheltenham
[37] the Leading Innovation countries according to the European Innovation Scoreboard 2008
[38] See European Cluster Observatory.
[39] Grupp F., Fornahl D., Tran C.A., Stohr J., Schubert T., Malerba F., Montobbio F., Cusmano L., Bacchiocchi E. (2010) National Specialisation and Innovation Performance; Europe INNOVA Sector Innovation Watch Task 4: Horizontal Report 1, DG-Enterprise 2010

Table 3.12 National technological specialisation and regional clustering in selected countries

	Technological specialisation	Highest star clusters (European Cluster Observatory)	
DE	Transport technology Mechanical elements Machine tools	Automotive Production Technologies Metal Transportation Business Services Finance	IT Chemical Food Power Aerospace Heavy Machinery
ES	Civil engineering Agricultural & food apparatus Consumer goods	Hospitality Metals Materials	Fishing Automotive Footwear
FR	Space technology - Weapons Transport technology Nuclear technology	Food Automotive Finance	
GB	Basic chemistry Civil engineering Organic chemistry	Finance Business Services Transportation Education	IT Automotive Oil and Gas Fishing
IT	Consumer goods Materials processing Handling - Printing	Automotive Footwear Production Technologies	
LU	Materials - Metallurgy Transport technology Thermal processes	Finance	
SE	Space technology - Weapons Nuclear technology Telecommunications	Automotive IT Forest	

Even if the automotive sector seems to be stereotypical for extensive supplier networks and regional agglomerations of suppliers, it should not be expected that policy driven cluster initiatives should reflect the broad picture of dense production networks or automatically create supplier networks.

The following table provides a selective overview of cluster initiatives in Europe, including valuations for Innovativeness and exports based on the methodology of the European Cluster Observatory. The heterogeneity of clusters and networks, and the diverse nature of their initiation makes it difficult to give a general statement for the role and impacts of clusters and networks in the automotive industry.

The effects of pro-active cluster promotion on individual firms were recently analysed for the automotive sector by Fromhold-Eisebith et. al. 2008[40]. It was found that policy initiatives and networks mainly create a forum to solidifying cursory linkages, and help to expand external and international connections. While firms in general receive better marketing information and support, in addition about a half of the firms in the two case studies “CAR e.V.” in Aachen, Germany and “ACStyria GmbH” in Austria, investigated by Fromhold-Eisebith (et. al. 2008), “received (minor) innovation impulses”.

[40] Fromhold-Eisebith et. al.(2008) Looking behind Facades: Evaluation Effects of Automotive Cluster Promotion, Regional Studies, Vol.4210 pp 1443-1356, December 2008

Table 3.13 Overview of automotive clusters in Europe[41]

Country	Region	Emp-loyees	Inno-vation	Exports	Country	Region	Emp-loyees	Inno-vation	Exports
Austria	Steiermark (Graz)	12,782	High	Strong	Espania	País Vasco (Bilbao)	23,710	High	Strong
Belgium	Vlaams Gewest	46,084	High	Strong		Cataluña (Barcelona)	74,086	Medium	Strong
Czech Republic	Stredni Cechy (Prague Surroundings)	29,511	Medium	Strong		Aragón (Zaragoza)	18,237	Medium	Strong
	Jihozapad (Plzén)	17,203	Low	Strong		Navarra (Pamplona)	11,146	Medium	Strong
	Severovychod (Hradec Králové)	31,578	Low	Strong		Castilla y León (Valladolid)	27,136	Low	Strong
Germany	Stuttgart	136,353	High	Very strong	France	Île de France (Paris)	61,351	High	Strong
	Oberbayern (München)	82,339	High	Very strong		Rhône-Alpes (Lyon)	26,345	High	Strong
	Braunschweig	79,997	High	Very strong		Alsace (Strasbourg)	20,155	High	Strong
	Karlsruhe	40,694	High	Very strong		Franche-Comté (Besançon)	24,767	Medium	Strong
	Köln	36,986	High	Very strong		Lorraine (Metz)	21,827	Medium	Strong
	Darmstadt (Frankfurt am Main)	33,828	High	Very strong		Haute-Normandie (Le Havre)	18,252	Medium	Strong
	Hannover	25,980	High	Very strong		Nord - Pas-de-Calais (Lille)	30,989	Low	Strong
	Rheinhessen-Pfalz (Mainz)	18,491	High	Very strong	Hungary	Kozep-Dunantul (Székesfehérvár)	17,091	Low	Strong
	Oberpfalz (Regensburg)	16,938	High	Very strong		Nyugat-Dunantul (Györ)	16,741	Low	Strong
	Unterfranken (Würzburg)	14,210	High	Very strong	Italy	Piemonte (Turin)	85,915	Medium	Weak
	Niederbayern (Landshut)	37,960	Medium	Very strong		Lombardia (Milan)	51,631	Medium	Weak
	Saarland (Saarbrücken)	25,123	Medium	Very strong		Basilicata (Potenza)	6,365	Low	Weak
	Kassel	21,080	Medium	Very strong		Molise (Campobasso)	4,496	Low	Weak
	Bremen	16,280	Medium	Very strong	Poland	Podkarpackie (Rzeszów)	13,367	Low	Strong
	Chemnitz	15,216	Medium	Very strong	Romania	Sud - Muntenia (Ploiesti)	32,935	N/A	Weak
	Weser-Ems (Oldenburg)	21,465	Low	Very strong	Slowakia	Bratislavsky kraj (Bratislava)	11,468	High	Very strong
Sweden	Västsverige (Gothenburg)	42,832	High	Strong		Zapadne Slovensko (Nitra)	21,261	Low	Very strong
	Småland med öarna (Växjö)	10,147	High	Strong	United Kingdom	W Midlands (Birmingham)	37,913	High	Weak

Source: European Cluster Observatory

[41] The overview of Automotive Cluster initiatives in Europe is based on the European Cluster Observatory, it is not exhaustive.

The significant and increasing role of innovation along the supply chain seems to be a challenge for future cluster activity. The potential of pro-active cluster promotion innovation depends on the structure of supply chain and innovation networks. International supply chain networks in the passenger car segment provide are not as concentrated supply chain and innovation networks which can be observed in the commercial and heavy vehicle segment.

As networks always reflect prior patterns of interfirm relationships, upon which latter the possibilities of linkages depend (Ahuja 2000)[42] it seems clear that the mere existence of structures established during the last decade predetermines the potential role of policy driven cluster innovation in the automotive industry. This is likely to be a considerable challenge in developing cross-cluster co-operation which aim at broadening the horizon of cluster activity.

[42] Ahuja G. (2000) The Duality of Collaboration: Inducements and Opportunities in the Formation of Interfirm Linkages; Strategic Management Journal 21, p. 317-343

4 Sectoral Innovation Futures[43]

The development of the automotive industry is traditionally driven by a number of technological, social, economic and environmental factors while at the same time innovations of this sector have influenced our every days life and mobility behaviour.

Historically, the automotive sector has established a couple of product and process innovations and served as lead customer for many new applications with an impact on the innovativeness of many supplying industries. For instance, the automotive industry established mass manufacturing in the 1920, internationalisation in the 1980s or lean manufacturing in the 1990s. Demand for new material, production technologies, electronics, and information and communication technologies (ICT) can be mentioned which delivered incentives for product development in other sectors such as the semiconductor industry. The dominance of global production and supply chain networks is an important feature of this sectoral innovation system.

The development of the automotive sector is influenced by changing customer values and by actors external to the firms such as governmental activities (e.g. regulation) as well as it is driven by the oil industry and the development of the oil price, respectively. Moreover, the public sector, to smaller amount also private companies, invest in infrastructure, roads, tunnels, etc. which heavily influence the development of the sector. Taxation is an important factor as well, by setting specific incentives for private behaviour and investments of organisations.

Currently, the automotive sector is considerably hit by the economic crisis: Car manufacturers are worldwide in the midst of dramatic change with significant structural consequences and opportunities for establishing new radical technologies. The challenge to produce sustainable automobiles has probably already triggered the next deep change of the automotive industry where a further concentration may occur while at the same time new entrants could emerge.

Based on an analysis of the co-evolution of technological and demand-based drivers a set of coherent scenarios for the possible future development of the automotive industry are presented in this section. Thereby we focus on the role of new technologies and innovations for the development of the automotive sector in Europe. In addition, the enabling and hampering factors in the respective sectoral innovation systems have been investigated in order to extract challenges and implications for European companies and public policy.

The Europe INNOVA Sectoral Innovation Foresight activity addresses medium- to long-term strategic issues for the future development of European industries. It thus aims at looking beyond time horizons

[43] The following section presents an excerpt of the Europe INNOVA Sector Innovation report summarizing the sectoral innovation foresight on the automotive sector (Leitner K.-H., 2010).

that can be addressed by simply extrapolating current trends. While for fast-changing sectors this may imply a time horizon of five to ten years, for others a much longer time horizon may be a more appropriate orientation. For the purpose of the automotive sector a time horizons of about 10 years from 2009 on was defined.

4.1 Emerging and future drivers of innovation between S&T and (market) demand

Combining the findings from a literature analysis and inputs from the involved experts a number of important drivers have been identified in the first phase of this exercise.

4.1.1 S&T drivers

The automotive industry benefits a lot from basic research in fields such as physics and chemistry and well as in technology fields such as ICT, electronics and robotics. The main scientific and technological trends considered as particular important for the future referring to the literature (e.g. FUTMAN 2002, May 2004, FURORE 2006, and HyWays2008), discussions within the community and the expert workshops are:

- Energy Storage
- Fuels
- ICT-based Manufacturing
- Material sciences

In addition to these more generic S&T drivers the following specific S&T drivers can be described:

- Optimisation of Conventional Engines
- Parallelism of New Technologies
- Safety

Energy Storage

Scientific progress in basic and applied science, particular in physics and chemistry are essential for the establishment of both incremental as well as radical new energy storage technologies.

Advances with respect to the fuel burn within the combustions engine, electrolysis to produce hydrogen or the charging of batteries are physical or chemical processes which all benefit from new discoveries, models and theories.

Fuels

Advances in the field of conventional and alternative fuels (clean energy, alternative fuels, crops/biofuel conversion technology, etc.) are a key S&T trend for the automotive industry (Hoed

2004). Alternative fuels such as natural gas, biomass-to-liquids (BTL), compressed natural gas (CNG) and liquid fuels made of biomass have been proposed as way to reduce the dependence from oil and to increase the sustainability of cars. Some of these fuels can also be used as a blend with conventional gasoline or diesel and thus gradually allow to decrease the CO_2 emission. Hydrogen is an intensively debated alternative fuel. However, due to the low efficiency of the internal combustion engine this technology seems to be rather inefficient compared to other alternatives (HyWays 2008).

ICT-based Manufacturing

The majority of innovations within the automotive sector are related to modern ICT-based manufacturing technologies. Flexibility, quality and cost reduction are here the aims for scientists and developers. New hardware and software architectures, programming languages and security concepts are hence relevant for the automotive industry which go beyond established concepts such as lean manufacturing (Siemens 2004).

Material Sciences

New materials are significant for many future applications and products. New materials include lightweight alloys and polymers, fluids, coatings and nanotechnology are expected to be used increasingly which is on the agenda of many research institutes across Europe. In addition, different materials such as steel, aluminium, plastics will be combined which leads to multi-material design. The design of tailored atom-by-atom materials can be referred too in this context (e.g. FURORE 2003). Basic science forms an important building block for developing new materials; and material science itself rests largely on and combines basic scientific disciplines.

Optimisation of Conventional Engines

The downsizing of spark ignitions engines and diesel engines (e.g. by turbocharging) is an important technological trend to increase efficiency of traditional engines in the future. Advanced internal combustion engines (ICE) technologies and currently offered as start-stop can give increasing fuel efficiency and very low levels of NO_x emission at a moderate cost increase per engine. Another trend is the development of “combined combustion system” of controlled spark ignition system and homogeneous charge compression ignition (HCCI) (e.g. FURORE 2003).

Parallelism of New Technologies

The parallel use and exploitation of (powertrain) technologies is another S&T trend which is regarded as important. Historical studies, for instance, showed, that during a technological transformation of a system, technologies are used for a certain period of time in parallel (e.g. from sailing ships to steamships) and “hybrid technologies” are used for a while which mitigate change.

Safety

Safety technologies can be considered as important S&T drivers which particular build on advances in the field of electronic and ICT. Vehicles today have already a high amount of electronic components and the share is expected to rise in the future. The adaptive control of the engine, steering, safety equipment such as intelligent braking systems and intelligent lights all rest on electronic components (semiconductor, diodes, generator, video cameras, etc.) (e.g Foresight Vehicles 2004, Global Insight 2008). Advances in pattern recognition can be mentioned here, too. A specific technological trend is the use of micro-systems.

However, in the future the automotive industry will even use findings from neuroscience and humanities (e.g. bionics), for instance, in order to study the behaviour of drivers and other participants on road transport.

4.1.2 Demand-side drivers

In this paper changes in customer preferences, expected market developments and developments due to political activities are considered as demand-side factors. In that sense, it is assumed that needs of customers, public, and the society are often mediated by the government, for instance by new regulations. Thus, consumers as well as governments are considered here as “pull factors”.

General social trends and drivers include demographics, life styles, choices, mobility requirements, working patterns. The increasing demand for health, safety and security is as well a social trend but is also increasingly associated with environmental issues and hence treated separately. Moreover, the transport industry has specific demands which are discussed as distinct demand-side driver.

There are a few broad social trends which will have a strong impact on the demand for vehicles in the future. These are:

- Income
- Environment and Resources
- Globalisation
- Price for Energy
- Organisational Inertia and Change[44]

In addition, the following more sector-specific drivers can be identified:

- Mobility Behaviour

[44] Organisational inertia and change is not a demand-side driver in the strict sense, although it is related often to the fact, that market related development would require organisational adaptation. However, as it is considered as important for the development of the automotive sector it was considered and discussed within the demand-side dimension.

- Infrastructure
- Market saturation
- Regulation

Income: The available income of individuals is a key driver for the demand of new cars. Currently, the economic crisis changes the consumption pattern which accelerates the demand for smaller cars. At the same time, private consumers try to expand the lifecycle of the use and spend more for repair and maintenance.

Environment and Resources: Between 20 and 30% of CO_2 derives from road transport. The reduction of CO_2 and other greenhouse gas emissions associated with road transport is an important goal of the European Commission and its Member States. The European Commission and ACEA have agreed on targets for passenger car of 120g/km CO_2 new care fleet average in the EU by 2012. The US ZEV regulation can be mentioned which has been expanded to some other states as well and is important as the US is an important export market for European car manufacturers.

The reduction of waste and conservation of resources is another important demand-side driven trend. (see: European End-of-Life Vehicle Directive; Legislation on electronic equipment (WEEE) and waste disposal).

The reduction of emissions of substances which can impact health which is particularly relevant for urban areas and can be considered as further environmental associated driver for change. Particulates, NO_x, ozone and hydrocarbons are emissions which have to be reduced. The European directive Euro 5 and Euro 6 will mandate pollutant levels for diesel and gasoline engines and it can be expected that further stringent regulations will be issued.

Customers are increasingly requiring low interior noise, too. The demand for lower exterior noise is mainly driven by the public and legislation.

Globalisation: Different national markets will require totally different vehicles and much more variety is expected in the future. While India and China will need inexpensive, safe cars, in industrialised countries OEMs have to serve the demand of a greying society. The increasing gap between wealth and poor will offer totally new market segments. Thus, there is a demand for more variants, individually tailor made vehicles and possibilities of usage (e.g. Global Insight 2008).

Price for Energy: The price development of oil is doubtless one of the key drivers for the development of the automotive industry (e.g. Landmann et al. 2008, PwC 2008).

Mobility Behaviour: The demographic shift will change market demand and mobility behaviour, too: In 2020 more than 25% of the European population will be older than 60 years and about 70% will live in urban and suburban agglomerations. At the same time it can be expected that working life will be extended, with specific mobility requirements. The availability and attractiveness of public transport is relevant in this context as well, e.g. provided by increased inter-modularity. There will be also a trend towards a stronger integration of customers into the design process. Thus, a car will have individual “character” in the future and have personalised features and control systems that are capable of learning.

Infrastructure: Particular in relation to electric vehicles and hydrogen driven cars new infrastructures are required (e.g. refuelling or charging infrastructure) to foster market diffusion. This is a costly proliferation of different technologies. However, the large investments in fuel distribution infrastructure required are a significant barrier for the adoption of alternative fuel solutions. However, it is yet not clear which re-fuelling route (e.g. in the case of hydrogen) will be favoured ultimately (e.g. Book et al. 2009).

With respect to hydrogen, two options with different implications for the distribution infrastructure are possible. Hydrogen can be produced off-board, which is then stored on-board, or hydrogen is produced on-board by reforming a hydrogen-containing fuel.

For the case of electric vehicles fuelling stations and more powerful grids are required with new intelligent features, nowadays often called smart grids.

Market Saturation: Market saturation in certain regions and product markets and a general overcapacity of the automotive industry can be considered as a further significant driver for the development of the automotive industry which has an impact on manufacturing strategies and product development policies (PwC 2008). This corresponds to an analysis of CIS 4 data for the automotive sector where benefits for the reduction of cost labour, and improvement of quality of products have been identified among the top drivers for innovation in the automotive (supplier) industry.[45] Road charging (e.g. tolls on motorways), the road infrastructure (e.g. green transport corridors with supply pint for biofuels) and standardisation (e.g. driver cabin, containers) have also important influences on the specific demand.

Regulation: The increase of safety was a main trend in the automotive industry in the past decade and customers increasingly called for safer technologies.

Airbags, intelligent wheel brakes (ABS), Electronic Stability Program (ESP) and other systems have become a standard equipment for many cars. Partly, these technologies have their roots or were initiated by regulations (Hoed 2008). National governments and the European Commission have also set targets to increase safety. For instance, the EU aims to reduce road deaths by 75% until 2020. The number of accidents, deaths and injuries is thereby quite different in the various EU member

[45] Montalvo C., Pihor K., Ploder M. (2010) Analysis of market and regulatory factors influencing sector innovation patterns – Automotive sector, Europe INNOVA Sector Innovation Watch, Task 3 Report, December 2011

states, whereas Sweden has the best record. The vision of an “accident-free driving” is therefore the ultimate long-term goal. More secure traffic will at the end also realise savings in terms of lives, damage and time. This may also lead to a trend where active safety will become more important than passive safety. Intermodality and interoperability are important in this respect as well and transport policy in co-operation with infrastructure providers and transport companies will demand and co-develop new solutions and strategies for transporting goods. Depending on the experiences with long and heavy vehicles (mega-trucks), which are presently tested (demonstration projects) in some European countries and which may lead subsequently to the establishment of new directives, we will also see a growing demand for mega-trucks in Europe (FreightVision 2009). This should have positive effects on the environment but would also contribute to the quicker abrasion of roads.

Organisational Inertia and Change: The diffusion of new technologies and implementation of product and process innovations requires organisational change and will be accompanied by new business strategies. Organisational inertia, resource dependency, incorrect market assessment or cannibalization of own technology are typical reasons for resistance of large firms to invest and develop new radical technologies.

4.2 Sector scenarios

Different drivers and developments which may influence the future development of the automotive industry have been described in the last section. Taken jointly together these drivers may have accelerating, disturbing, counteraction or confounding effects and may end up in different development paths and futures.

The large technological uncertainty, possible breakthroughs, dependence on the oil industry, governmental activities (e.g. regulation) and public awareness for global warming can be considered as key factors shaping the future development and likely scenarios. However, there are also other uncertainties such as the diverse consumer behaviour in different world regions.

The current economic crisis accelerates the structural change of the global automotive industry and may transform the competitive landscape.

The scenarios were drafted by combining a limited number of key drivers which is a common way to develop scenarios (see e.g. Fink et al. 2002).

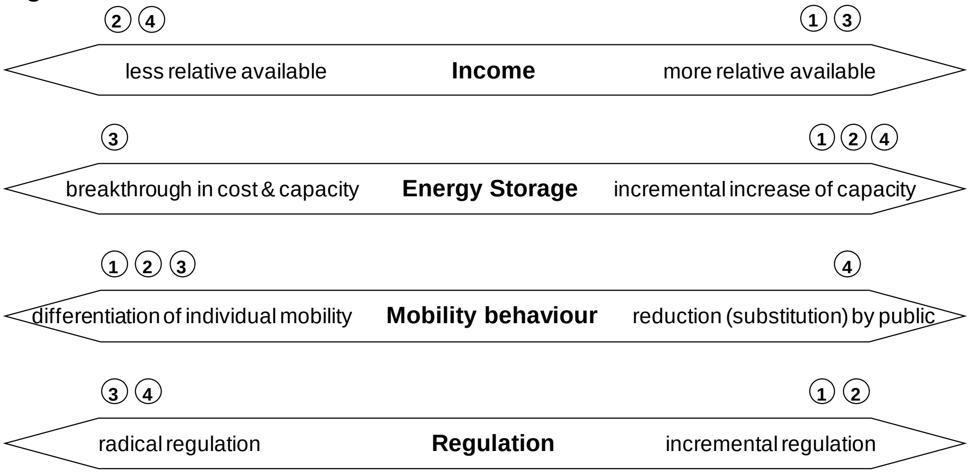
The following four drivers and dimensions - which were assessed as the most important and uncertain factors at the same time - were selected for the development of scenarios:

- Income (less relative available versus more relative available)
- Energy Storage (breakthrough in cost and capacity versus incremental increase of capacity)
- Mobility behaviour (differentiation of individual mobility versus reduction (substitution) by public transport)

- Regulation (radical regulation versus incremental regulation)

By combining different characteristics of these drivers (which can be interpreted as a morphological matrix) consistent and plausible future scenarios were generated. See Figure 4-1 for the combination of factors for the four scenarios.

Figure 4-1 Characterisation of scenarios



Scenario 1: Recovery and Business as Usual
Scenario 2: Low cost and Conventional Technology
Scenario 3: Green cars "You can have it All"
Scenario 4: Sustainable Revolution

Source: Leitner (2010)

The four scenarios can be described and assessed as follows:

Scenario 1: "Recovery and Business as Usual"

More *income*, incremental *energy storage* innovations, differentiated *mobility behaviour* and an incremental increase of *regulation* discern this scenario.

This scenario is a plausible and consistent picture of the future where a rather quick recovery of the economy will not lead to a considerably change of the behaviour of the actors, neither of companies, nor of customers or policy makers. There is a need for more sustainable cars, which though will be a slow transformation process; alternatively fuelled cars such as electric vehicles will not have a large market share.

Scenario 2: "Low Cost and Conventional Technology"

This scenario is a combination of less relative available *income*, incremental increase of capacity of *energy storage*, differentiation of individual *mobility* and an incremental increase of *regulation*.

In this scenario the economy will recover only slowly and we will see slow technological progress, too. As the public budgets remain tight it is plausible that the governments are not able to enforce rigorous regulations. As people stick on their cars and have only a low willingness to substitute travelling by public transport, an increased demand for (ultra) low cost cars is expected in this scenario. In this context hence even the European industry will start to develop and manufacture low cost cars.

Scenario 3: "Green Cars - You can have it All"

This scenario may become true if relative available *income* will increase, breakthrough innovation with respect to *energy storage* will be realised, the *mobility behaviour* becomes more differentiated and we will see a strong and quick increase of *regulations*.

Under such a frame we can expect the lucky situation that a breakthrough innovation solves problems of energy storage and allows the development of cost efficient new powertrain technologies such as full electric vehicles. In addition, stronger regulations create incentives for the development of such technologies. Within a relative short period of time we hence will see a greening of industry which obviously will initiate a deep structural transformation of the whole industry also affecting other industries.

Scenario 4: "Sustainable Revolution"

The combination for this scenario is the availability of less *income* for a longer period of time and only incremental advances in *energy storage* technologies, a change of *mobility behaviour* with a stronger use of public transport, and a strong *regulation* regime. This is a radical scenario where at the end regulation triggers the development of new alternatively fuelled cars over a longer period of time. Car users shift their mobility behaviour towards public transport which is also supported by public policy which invests in public transport but may also subsidising public transport in a very early stage. However, due to rather slow scientific and technological progress the diffusion of new alternatively fuelled vehicles is incrementally

Comparing the four scenarios reveals the difficulty to assess them taking into account the manifold economic, environmental and social impacts occurring in the short and long term.

The four presented scenarios offer a variety of different futures which quite divergent impacts on the competitive landscape, technological progress, environment and society. The scenarios can guide policy makers which may particularly support the development of a single scenario but also may try to be prepared for more than one future. This is also related to the question to what extent policies and strategies aim to maintain flexibility ("robust strategies") or to what extent strategies and policies are focused on one single scenario ("focussed strategies").

4.3 Future innovation themes and corresponding linkages with other sectors

Following section will discuss innovation themes which can be identified at the intersection between the S&T drivers and the demand-side drivers discussed and which reflect relevant development trajectories and opportunities for the future. The innovation themes can be specific products, processes or technologies, but also major organizational changes and novel strategies and offer new markets opportunities. The innovation themes are not equally relevant in all scenarios and hence specified in the different scenario contexts.

Based on the identified S&T and demand-side drivers the following main innovation themes are regarded as highly important for the automotive industry:[46]

- Powertrain technologies (Conventional Internal Combustion Engines, Hybrid, Electric and Alternatively Fuelled Vehicles)
- Traffic management systems, drive-by-wire and safety technologies
- Design process and manufacturing systems

Although all described innovation themes are relevant to some extent in every scenario context, they differ in certain ways with respect to their market opportunities. The following table discusses the importance of the different innovation themes for the four scenarios:

Table 4.1 Overview of scenarios, innovation themes and markets

Scenario	Specific Innovation Themes	Markets
Recovery and Business as Usual	• Powertrain technologies: we will see optimised ICE, the use of cleaner fuels (CNG), the use of biofuels and hybrids (both not more than 10%) • Manufacturing process (cost pressure, use of ICT) • Design: Usability • Safety: further improvements are expected • Incremental progress towards "drive-by-wire" (ICT-assisted driving), additionally GPS needs to be become real-time with full coverage	• Continued mass customization and product differentiation (e.g. by design, electronics, user profiles) will lead to even more diversified and differentiated products
Low Cost and Conventional Technology	• Downsizing and efficiency improvement of ICE • Manufacturing systems and processes development focusing on low cost production	• For European car manufacturers Europe becomes a relevant market for low cost cars which are produced in Europe. In addition, European manufacturers may build up new production plants in emerging markets (and

[46] These innovations themes are in line with a couple of recently published studies on the future of the automotive industry. See for instance May (2004), FURORE (2003), UK Powering future vehicles strategy (2004), FUTMAN (2002).

	• Increased recycling • New materials • Specific design (capabilities)	will transfer technology).
Green cars – "You can have it All"	• Alternatively fuelled vehicles: battery, fuel cells • Manufacturing systems: here the entirely new design/definition of cars and construction methods become essential • Safety technologies and systems: challenges due to new powertrain technologies, requirement for new safe zones • Alternatively fuelled vehicles offer good opportunities to incorporate technologies for driver-assistance	• A (mass) market for green cars is expected, which is a highly differentiated market with a lot of product variance and diversity (e.g. achieved by mass customization) • As the infrastructure is not necessarily available outside Europe, a global market for green cars is rather unlikely; however, in some countries a new infrastructure may be build up immediately, e.g. if so far no adequate infrastructure exists at all (sunk costs) • A large market for 2-wheelers and 3-wheelers can be expected (e.g. scooters, strikes), propelled by new powertrain technologies (though competition from India and Asia strong) • Large public and private organisations will buy green cars • Growing markets for new types of public transport vehicles (e.g. buses) and services, but to a lesser extent than in scenario "Sustainable Revolution" • New powertrain technologies may also be used for other purposes and even for generating electricity (e.g. able due to intelligent grids), which, though, is beyond the 10-year time horizon
Sustainable Revolution	• The innovation themes particular relevant in this scenario are similar to the ones of the scenario "Green Cars", however, in this scenario the development will happen slower with less breakthrough innovations	• Large public and private organisations will use more frequently sustainable cars and can enhance the demand and push the development • The product market will be more standardised (compared to the Scenario "Green Cars") • New infrastructure is needed which generate demand outside the conventional car markets • New types of public transport vehicles such as small buses will be developed • Car sharing will also become more widely diffused • New (mobility) services will be offered, e.g. associated with car sharing and "buy per kilometre", which like other new products is associated with new business models • Growing market for "mass transit", e.g. buses (due to increased use of public transport) • Growing demand for small and medium-sized trucks • New powertrain technologies may also be used for other purposes (e.g. propulsion of machines) and even for generating electricity (e.g. able due to intelligent grids), which is beyond the 10-year time frame

4.4 New requirements for sectoral innovation: new forms of knowledge, organisational and institutional change, regulatory frameworks

In the next section the requirements are discussed necessary so that the innovation themes are turn into successful new markets. Most requirements are of cross-cutting nature and to a large extent relevant for all innovation themes and at least to some degree for all four scenarios.

With exemption of the low cost scenario a key challenge for automotive companies (OEMs) is to put considerable resources into the development of new powertrain technologies. Many companies have already announced to introduce electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) for 2012 which reflect that they are currently developing these products (considering the long development times for new innovations and products). Moreover, new manufacturing technologies have to be adopted as well in order to increase flexibility and reduce cost. In addition, common efforts to standardise technological development have to be realised.

Generally, research has shown (e.g. Utterback 1994, Christensen 1997) that established or incumbent firms have difficulties in dealing with radical technologies. Fuel cell technology and electric vehicles are radical technologies which overturn existing core competences of car makers. This change may happen in short period of time or incrementally over a longer period (as proposed by our scenarios).

The development and diffusion of new technologies such as advanced driver assistance systems, electric vehicles or hydrogen fuelled cars can be interpreted as radical innovations. These types of innovations and technologies build on a different set of engineering and scientific principles and substitute existing technologies and competencies of the established industry. Organisational change requires that OEMs adapt their (successful) organisational routines and strategies. They have to unlearn current beliefs and routines and have to develop their core competencies in a way that they do not become core rigidities (Leonard-Barton 1992). Consultants and academics see the danger that OEMs struggle to change their business models, marketing strategies, the management of expectations and the management of suppliers, networks and partners. Although, for instance, many large OEMs have mastered successfully the increasing integration and exploitation of electronics, information and communication technologies, particularly by using and integrating powerful Tier 1 suppliers[47]. However, in the future a more comprehensive shift may be required, particular as many innovations such as electric vehicles or ICT-assisted driving are of systemic nature. In low-cost scenario context, organisational change and the adoption of new firm strategies could be interpreted as radical shift, too.

[47] See for more details the analysis of co-operation networks in the automotive industry in the Task 1 Report (Ploder et al. 2010).

Another challenge particular for the engineering teams will be the handling of inherent trade-offs in designing new vehicles. The achievements of different goals related to sustainability, effectiveness and safety is associated with difficult decision-making, for instance in relation to the use of new materials. The need for recycling may limit the number of different materials and plastics being used and will also require labelling of components. The design process of the car needs to take into account at an early stage the requirement for recycling and improved dismantling technology. New logistic strategies and services in relation to the re-use may have to be adopted, too. Again, this is relevant in all scenarios.

New powertrain technologies and the increasing role of traffic management and safety systems require new partnerships from car makers with other industries. Traditionally, the automotive supply industry is as large or even larger as the automotive industry (OEMs). In the last decade vertical disintegration happened, as a consequence, car makers are increasingly reliant on suppliers.[48] Although the exploitation of new suppliers may offer the possibilities to introduce new technologies existing supply chain relationships and networks may at the same time harm organisational adaptation and the search for new scientific, technological or market knowledge. In general, it is expected that suppliers will become important agents for specific technological developments and the introduction of new (more radical technologies). Companies will have to establish (new) horizontal and vertical relationships with OEMs but also other organisations in order to establish standards and decrease costs. Co-operation between energy suppliers and car producers are already formed. In Germany, for instance, Daimler will co-operate with RWE, VW with e.on, and Toyota has formed a partnership with the French eDF. Such strategies are relevant in all scenarios except the “Low Cost” strategy scenario. New partnerships with infrastructure providers, public authorities, private transportation providers, etc. will hence be emerging in the future. Public-private partnerships will likely emerge as the public sector alone will not be able to finance the huge investments in the infrastructure. This requires an adequate business model from the side of private providers, governments are challenged to provide the infrastructure and optimize the use of that infrastructure. OEMs may particular offer new services and focus on design, marketing and branding while technological innovation in specific areas will more driven by suppliers.

It is unavoidably that industry communicates honestly about what can be expected form new technologies. There is a danger that the creation of false expectation will lead to dissatisfaction and lower sales. Hyped expectations about the availability of new technology will lead to dissatisfactions and lower sales in short term, since customers tend to wait for the new technology. Thus, OEMs have to manage customer expectations. Accordingly, OEMs have to develop technological roadmaps and share them with their customers, partners and employees.

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[48] See in this respect also the findings from the Task 1 Report, which particularly discusses the role of supply chains (Ploder et al. 2010).

In addition, global car manufacturers are acting in different context and environments and hence have to follow divergent strategies in order to respond to manifold challenges on different geographical markets and locations due to different taxations, environmental awareness, regulation, etc. Due to diverging and more heterogeneous market needs manufacturer have to enlarge their portfolio and to invest in flexible manufacturing technologies.

New vehicles may change the business rules and models and we may even see a development such as in the mobile phone industry where companies sell solutions (mobility), hence OEMs will become more a service provider than an equipment manufacturer and will increasingly start to focus on downstream business (Ploder et al. 2010). Offering new (mobility) services can be considered especially relevant in the scenario “Sustainable Revolution”, and may also allow exploiting national or European competitive advantages due to specific regulation, close co-operations between private and public actors, etc., which then may not be imitated so easily by non-European competitors. Some European companies (e.g. Daimler offers the mobility service Car2go in the City of Ulm) have already started to launch specific services.

New technologies have also many implications for the OEMs’ service and sales networks. OEMs need also well-trained dealers which are able to support and advice the customers in relation to new clean vehicles and powertrain technologies. Otherwise the competitive advantage of having a service network cannot be exploited. In addition, high-voltage electricians are needed to work in electric powertrain components.

Particularly in relation to electric vehicles and hydrogen driven cars new infrastructures (see also above) are required (e.g. refuelling or charging infrastructure) to foster market diffusion. This is a costly proliferation of different technologies. The large investments in fuel distribution infrastructure required are a significant barrier for the adoption of alternative fuel solutions. However, it is yet no clear which re-fuelling route (e.g. in the case of hydrogen) will be favoured ultimately. Such an infrastructure may be build up in key regions in Europe, the US and Asia, focusing on urban areas, which may be regarded as potential lead markets. Recently initiated pilot programs in Denmark, Israel and France can be referred to in this context.

The availability of a specific infrastructure with sensors is a necessity for the development of innovations around the theme of driver assistance and safety. Such innovations and applications require an infrastructure which enables the communication and system-level control.

The automotive industry can also benefit greatly by using knowledge from the aircraft and aviation industry but also the computer and consumer electronics industry, mostly regarding the (co-) development and use of new materials, navigation, driver assistance and safety systems. In addition, the automotive industry may co-operate with developers and producers of alternative biofuels such as biogas.

From the perspective of the innovation system, the automotive industry so far has often rather enacted the institutional environment and created new market needs and seldom responded just to customer demands, hence innovations were rather technology driven (push innovations).[49] However, consumer preferences have changed and will change and may have a stronger impact on the business policy and product portfolio of car manufacturers (OEM) in the future.[50] We will see a stronger involvement of end customers in the development process and hence user innovation and open innovation models will have to be adopted by automotive firms to address this issue and keep their competitive position. The initiative to develop an open source car can be referred to in this context.[51]

Social structures such as norms, values, expectations, procedures, standards and routines are part of the institutional environment being a strong driver for the development of the automotive industry. As history shows institutions are relatively resistant to change and have a high level of resilience in general. The transformation of (innovation) systems often happens over a long period. The introduction of airbags, air conditions and low emission engines demonstrate institutional change, which are now accepted and internalised while they were unaccepted 20 years ago.

Apart from providing the infrastructure, policy shapes the development of new automotive technologies and mobility solutions by diverse forms of regulation. In the past, policy has played an important role regarding the introduction of new technologies and innovations, particular in respect to safety and sustainability. The Californian Zero Emission Vehicle (ZEV) regulation, for instance, delivered an important force to develop cleaner and more efficient cars. In 1990, ZEV regulation mandated carmakers to sell at least 10% of their vehicles without any local emissions (i.e. NOx, CO, etc.) in 2003. This regulation created the incentive for many OEMs to start developing alternatively propelled powertrains such as electric vehicles (EV) or fuel cell vehicles (FCV). Finally, the emergence of personalised, intelligent, networked vehicles will require the establishment of an appropriate legal framework, another related challenge for governments.

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[49] Modern organisational and institutional theory argues that institutions do not only constrain the behaviour of firms but that firms influence and enact institutions. This is for sure the case in the automotive industry. In this context, Levy and Rosenberg (2002), for instance, have argued, that strategic behaviour of firms related to climate change is highly political. They have shown that the automotive industry forms coalitions to shape public opinion, and alliances are built between companies and governments in order to exert influence and gain acceptance for their own strategies.

[50] The quote in a Siemens VDO Report: „What Consumers Want. Demand for driver assistance systems is also (!) coming form consumers themselves …“ (Siemens 2002, p. 25) reflects the current attitude of the automotive industry which creates markets based on the potential of new technologies (technology-push) and nut just respond to market or customer needs.

[51] OScar the open source car, http://www.theoscarproject.org/

4.5 Sectoral innovation policy in a scenario framework

The future development and transformation of the automotive industry is a complex phenomenon which is driven by the interplay of technical, market-related, social, economic, and political factors. Different actors and institutions such as OEMs, suppliers, research institutions, other industries, the government, and customers co-evolve together and negotiate and change rules and standards over time. Usually, new radical technologies, new market entries by entrepreneurial firms, shifts in market demands, and external crises or shocks such as the prevalent one have the potential to trigger and accelerate structural change.

The innovation theme “Powertrain technologies” and “Manufacturing technologies” are relevant for all four scenarios presented above, while the innovation theme “Traffic management system, drive-by-wire, and safety technologies” has particularly potential for the latter three scenarios but is less relevant for the “Low Cost” scenario. We will begin to discuss how policy may support specific innovation themes and the emergence of associated markets.

Policies to support specific innovation themes

With respect to the support of powertrain technologies a number of activities should be taken, particular to foster the development and diffusion of alternative technologies such as fuel cell or battery technologies.

- The typical instruments of R&D and innovation policy would allow enhancing the development of innovative and efficient technologies.[52] The development of new powertrain technologies requires in particular co-ordination between the various actors on the European level and for instance fleet testing facilities, innovation platforms and Joint Technology Initiatives should be established.
- Education and training programs and facilities (infrastructure) will be needed.
- Moreover, new infrastructures (e.g. hydrogen, charging spots) are required where the development of new financing models may become important and supported by policy.
- In addition, fiscal measures, public procurement and regulation are policy measures to be realised.

[52] Synergies with the ICT and consumer electronics industry (e.g. navigation, design of control devices) and biotechnology, e.g. biofuels, bio- refinery, etc., may be exploited as well when supporting R&D and innovation activities.

Fostering traffic management systems was particular seen as relevant for the scenarios 3 (“Green Cars”) and 4 (“Sustainable Revolution”).

- For this innovation theme the whole set of well-known R&D policies are needed. Instruments such as the promotion of pilot programs, fleet testing facilities, and innovation platforms can be mentioned.
- For this innovation theme, policy has also to take initiatives for the (co-)provision of the infrastructure.
- Finally, open standardisation (not proprietary) procedures should be followed which is particular relevant for this innovation theme. Moreover, synergies with the aerospace industry can be exploited.

The promotion of manufacturing technologies may lead to more changes in the entire value chain.

- Specific R&D programs for manufacturing technologies such as supporting the establishment of competence centres in manufacturing and the launch of benchmarking projects could foster innovation down the value chain.
- Standardisation and regulation as well are important for this innovation theme. (e.g. the recycling regulation, ELV directive).
- In addition, policies such as taxation and subsidies are able to attract more manufacturing sites which requires a co-ordinated policy on the European and international level.

The four presented scenarios offer a variety of different futures which quite divergent impacts on the competitive landscape, economic development, technological progress, environment, and society. Policy is a critical factor in every scenario and is captured in the scenarios by the way it regulates the development of the sector, i.e. radical or incremental regulation. Indeed, regulation was even a factor selected as key driver for the development of the automotive industry (see chapter 4). Moreover, policy can shape each individual scenario by establishing specific research and innovation promotion programs and other innovation policy measures.

As integral part of each scenario, policy can significantly influence the future development, emergence or co-development of different scenarios and futures. The four presented scenarios are possible options how the automotive industry may evolve which can be influenced and shaped by policy.

Considering Europe’s tradition as well as past and current policies such as the Lisbon agenda, policy support for scenarios 3 (“Green Cars”) and 4 (“Sustainable Revolution”) can be favoured, - although has to be regarded as challenging at the same time. Moreover, these scenarios allow realising more complex business models (e.g. offering mobility services) which are more difficult to imitate by non-European competitors. Particularly in this context it should be stressed that we should not talk about the future of the automotive industry but about “Mobility of the 21st century”. In contrast, the need for innovation policy support (and its justification) for scenario 1 (“Business as Usual”) and 2 (“Low Cost”) was considered as rather modest. Moreover, one may also address the question to what extent policy should foster already a certain technology (‘picking winners’), especially with respect to powertrain technologies.

Certainly, the future will not develop exactly as described in one of the scenarios. It may also be fruitful to discuss what combination of different aspects of the four scenarios we will see in the future. The experts, for instance, discussed that if industry and policy would go for scenario 1 (“Business as Usual”), we will end up at the end at scenario 2 (“Low Cost”) in the long term. In reality we will probably see a combination of some scenarios. Thus, for instance, there will probably emerge a niche market for low cost cars even in Europe while at the same time green cars are bought by specific (wealthy) customer groups.

The future development of the automotive industry reveals also conflicts and trade-offs between short-term competitive, environmental, transport and social policies and interests. Policy has an interest that the safe and sustainable cars are produced, at the same time it aims to strengthen the competitiveness of the automotive sector. Generally, co-ordination with transport but also with energy policy will become more important in the future, irrespectively of the scenario.

5 Barriers to innovation[53]

Firms in the automotive sector clearly engage more in innovation related to 'manufacturing methods' and 'products'. The level of innovations is significantly high in logistics manufacturing methods, support activities and layout changes. Innovation in 'relations with other firms or public institutes is the type of activity which is less developed by automotive firms. In the automotive industry, upstream innovation activities (supply) are more important than downstream activities. The value chain in the automotive sector is characterized by a high division of labour and a dense supply chain network in Europe. The average automotive firm is a supplier at lower levels of the value chain confronted with clear specifications from the OEMs.

Most of the automobile suppliers during the 1970's and 1980's worked as component suppliers; as in other areas of the machinery sector, automobile OEMs began as a result of growing technological complexity, higher cost-pressure and (because of the customer-orientation) broader product portfolios. Increased outsourcing raised the value added by systems suppliers.(Rutherford 2001) Most of the value added (60 % to 70%) of a modern car is now provided by a multi-tier system of suppliers. Therefore the average supplier is affected by regulation and standards merely in an indirect way.

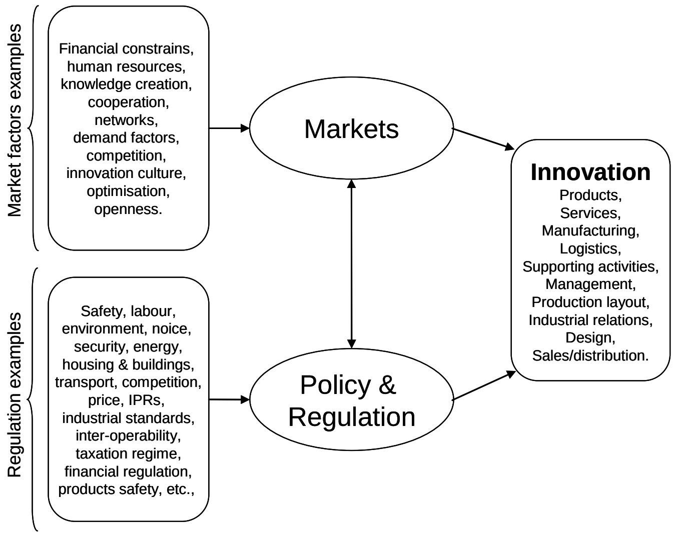
An analysis of CIS 4 data for the automotive sector adumbrates that the lack of demand for innovation, high costs of innovation, the lack of information on technical opportunities, the need to reduce materials and energy usage might be hindering for innovation.

The most frequent and common barriers affecting innovation in the automotive sector are grouped under market and regulatory factors. Market factors having a negative effect on innovation in this sector include brand competition, fuel prices and supplier's market power. Regulatory factors having a negative effect on innovation in this sector comprise design protection and car taxation.

The approach adopted in this study to assess the relationship of markets and regulation with innovation, while building on some aspects of the SIW-I, addresses the caveats at the conceptual and methodological levels identified in the previous section. The approach adopted is highly complementary to the standard sector analysis conducted with data from CIS. Conceptually, the approach has an easy heuristic. We seek to test relationships of dependence between innovation outcomes, innovation activities, market factors and regulation. Figure 5.1 below shows the type of relationships that this study is exploring.

[53] This section is based on the analysis performed in Task 3 of the SIW-II. The full analysis is available in Montalvo and Koops (2011).

Figure 5-1 Causality paths amongst innovation, markets and regulation



Note: The diagram has implicit feed-backs and loops between the concepts. The arrows denote the influences of interest for this study.

The types of innovation included in the survey are the same as those included in the Community Innovation Survey 2008.[54]

5.1 Market factors affecting innovation

An efficient market is one that where prices reflect all available information about the good, asset or service concerned (Black, 1997). In reference to market efficiency, market failure refers to an instance where an idealised system of price market institutions fails to reflect correctly the social cost and benefits or fail to sustain desirable activities or to stop undesirable activities. The desirability of an activity is in turn evaluated in reference to a maximum-welfare function with Pareto efficiency (Bator, 1958). From an economic perspective innovation is an event or set of events that are desirable. In many instances policy makers and academics argue that there is innovation market failure when the market conditions do not favour a climate for innovation to occur (Martin and Scott, 1999). These definitions open an opportunity and a challenge to assess the effects of a wide range of factors that may affect the innovation output of firm. In the remaining of this section we conduct a synthetic review of salient market factors affecting innovation

[54] CIS 2006 is based on the Oslo Manual (2nd edition, 1997). It gives methodological guidelines and defines the concept of innovation, and on Commission Regulation No 1450/2004. The innovation categories followed by the SIW-II survey are fully aligned to the definitions provided by the Eurostat/OECD Oslo Manual used in the EU-Community Innovation survey (CIS). Innovation is understood as…" the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations".

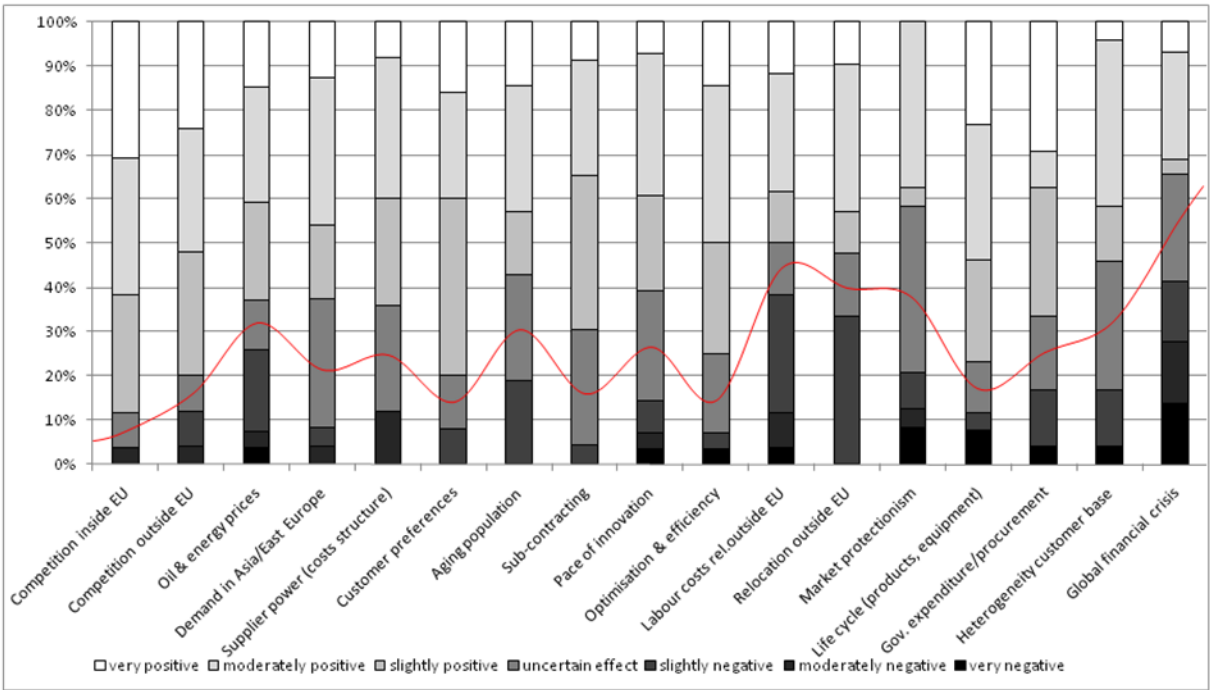
While innovation has for decades been driven by technological considerations, market factors are becoming ever more decisive (both as potential barriers and drivers) in innovation activity. Competition is perhaps the most important issue facing the automotive industry. As a highly regulated, oligopolistic industry, it relies on product innovation and process innovation to help combat any adverse competition effects.

- Literature on the effects of markets on innovation has stressed that customers' preferences and increased demand from Asia and Eastern Europe are important drivers for innovation. The European Union is the major market for passenger cars and commercial vehicles. In contrast to Asian OEMs, the strong home market still provides the backbone of success for European automobile producers. The European market is nevertheless very challenging owing to the high quality and technical standards required, as well as to the relatively low growth rates. At present, a considerable share of European car makers focuses almost exclusively on the European market. In the long term the European automotive industry will have to target (and factor into innovation activities) new non-European customers and markets which cannot be served with established patterns of product development and innovation.

  While the automotive industry is confronted with declining growth rates in North America and Europe, new markets with divergent demand profiles are emerging in Asia (CICERO, 2001; RNCOS, 2008; UNIDO, 2003). As the American market is converging to the European, the increasing concordance of demand is expected to affect innovation positively (Jürgens, 2003; Maynard, 2006).
- Competition, fuel prices and concentration of supplier power can have either positive or negative effects on innovation. Increased inter- and intra-brand competition can have positive impacts for producers since the margin of secondary distribution and car dealers decreases (ZEW, 2005). Increasing fuel prices could lead to change in customers demand in the long term, which should enforce innovations in technological alternatives (Prognos, 2006).
- There is a concentration of supplier's market power capabilities of innovation and path dependence. For instance, new global mega-suppliers, such as Magna, Denso, Bosch and Delphi are participating in the product design and innovation (MIT, 2006; Monteverde and Teece, 1982). Especially tier-n suppliers are frequently faced by ruinous price competition partly fostered by internet tender-auctions leaving no degrees of freedom for co-operative or bottom-up innovation.

Figure 5.2 presents an analysis of effects of markets on innovation on the basis of an empirical survey carried out in Task 3 of the SIW-II (see. Montalvo et al. 2010)

Figure 5.2 Effects of markets on innovation



- The survey results confirm that consumer preferences and increased demand in Asia and Eastern Europe are positive drivers for innovation; this was brought out in the literature. The same applies to competition, fuel prices and supplier power. In addition, the survey results found a number of variables that are also contributing to innovation in automotive firms but are not covered in literature.[55]
- The most significant barriers for innovation are perceived to be the global financial crisis and market protectionism, however the effect of this is yet to be reported in the literature.

The correlation analysis suggests that all five factors positively affecting innovation mentioned in literature are correlated with at least one innovation type in the automotive industry and that all correlations are positive. It is interesting to note that when competition originating inside Europe is positively correlated to logistics, industrial relations, design and to a lesser extent to sales or distribution methods, then competition originating outside of Europe has no impact on innovation. This reflects a focus of suppliers and OEMs on intra or alternatively extra European markets to certain extend. At present, a considerable share of European car makers focuses heavily on the (comparatively large) European market.

[55] These additional factors include: new consumption fashions, geographic proximity, optimization and efficiency, client power, sub contracting, incumbents market position, market structure, pace of innovation, new consumption fashions, product life cycle and government expenditure.

It is worth mentioning that the relocation of manufacturing and business activities outside Europe is negatively correlated to product innovation. Although coherent the argumentation that product innovations are important elements of the maintenance of manufacturing locations in Europe cannot be derived immediately. Although labour cost relative to outside EU and relocation of manufacturing are seen as having a rather neutral effect on innovation according to the survey, the correlation analysis shows a positive and negative impact respectively.

Surprisingly, the correlation analysis implies that there is also no correlation between innovation and the global financial crisis, which was perceived to be an important barrier according to survey results.[56]

5.2 Regulation and innovation

Due to its highly complex products, the automotive industry is one of the most regulated sectors in the EU. Regulation has a significant impact on the manufacture of motor vehicles and vehicle parts. The most important regulations concern safety standards, environmental compatibility, norms and standardization, and IPR-regulations.

- Regulations could be a barrier to innovation if the passenger car market is fragmented into national markets with divergent policies in respect of car taxation, which is real challenge in Europe (EC 2002). In 2005 the Competitive Automotive Regulatory System for the 21st century (CARS 21) a high level group comprising major stakeholders (EC, member states, trade unions, industry etc.) was founded.
- A already mentioned above a broad bundle of regulation is related to environmental issues and safety. Literature on innovation in the automotive sector suggests that an extensive and extending regulatory framework may either hamper or open new trajectories to innovation. Regulations such as vehicle safety, reduced vehicle weight or noise of tyres, fuel consumption, recycling, composite materials, avoidance of toxic materials and alternative drives hamper innovation (Eads, 1980).
- The Community Strategy to reduce CO2 emissions from passenger cars and light-commercial vehicles aims to reduce CO2 emissions from new cars sold in the EU. These regulations might be positively accompanied by innovations. The End of Life Vehicle Directive aims at preventing waste generated by vehicles below 3.5 tons, through the reuse, recycling and recovery of end-of-life vehicles and their components. This directive will enforce innovations in terms of new and recyclable materials. Increasing standards, such as COM (2003), in the field of active and passive vehicle safety are in favour for innovations in the field. Chemical substances that may harm the environment are inevitable and the pressure to substitute could

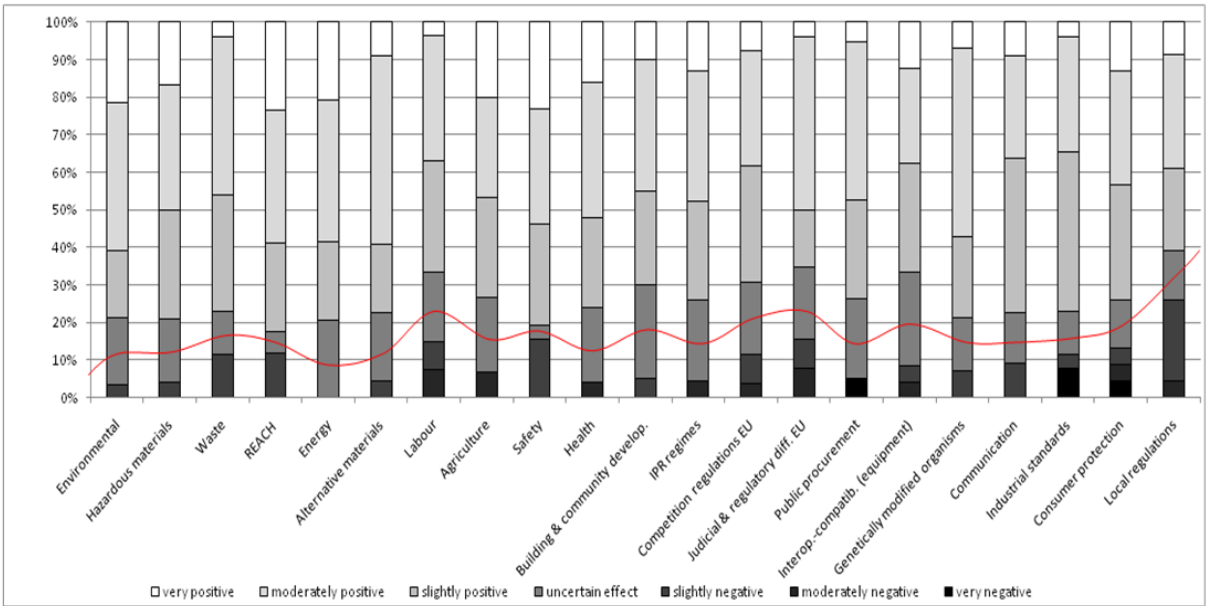
[56] No correlation with innovation was found for competition originating outside Europe, client power to influence cost structure, inputs, raw materials and components prices, incumbents current market situation and market structure, geographic proximity, market expansion, trade agreements and new fashions in consumption.

work in favour of innovation (EC 1907/2006). In conclusion, areas covered in the literature show a positive impact on innovation in areas of safety, alternative materials and waste regulations. Negative impacts come from environmental regulations (hazardous materials). Energy regulations and REACH (registration, evaluation and authorization of chemicals) can influence dual effects (positive or negative) on innovation.

- As far as environmental objectives are not shared worldwide and EU regulations are not binding for other markets this could be hampering factor for a quick adaption of higher standards or global competitiveness.
- Intellectual property rights could also be a barrier to innovation. The Directive 98/71/EC on the legal protection of designs maintains the overall incentive for investment in designing because it does not affect the design protection for new parts incorporated at the manufacturing stage of a complex product. As it is not sure that lower licence costs will be referred to final costumers by lower prices, the directive could hamper radical innovations in favour of adaptive innovations changing the design of single parts (ACEA, 2004)

Figure 5-3 presents an analysis of effects of regulation on innovation on the basis of an empirical survey carried out in Task3 of the Sector Innovation Watch project (see. Montalvo et al, 2010)

Figure 5-3 Effects of regulation on innovation



Survey results identify no barriers to innovation from regulatory side.

- The survey results confirm that safety, alternative materials and waste are important drivers of innovation in the automotive sector. On the contrary to the literature, where environmental (hazardous materials) regulations are perceived to have a negative impact on innovation, the survey results show these to be drivers of innovation.

- Energy and REACH regulations in literature are covered in literature to have either positive or negative effects on innovation; according to the survey, they are the drivers of innovation. All relevant regulation factors are perceived if anything as drivers of innovation.
- In the literature, IPR protection was seen as a negative impact on innovation, although according to the survey it is also a driver, i.e. it has a positive impact.
- Overall, the results of the correlation analysis suggested a rather moderate association between regulation and different types of innovations in the automotive sector. The results showed no impact of regulations on innovation in products and services. All correlations are positive which confirms the results from the survey.

Division of labour in the automotive sector has become increasingly complex in the last few decades. New models of organizing the production process like Just in Time or Lean Manufacturing also influenced the interaction along the value chain.

Therefore the propensity to innovate in logistics and delivery and distribution methods are relatively widespread along the automotive value chain.

The devolvement of responsibility of innovation outcome and product liability to suppliers could be one explanation for significant correlation of innovation of those closely co-operating with car manufacturers and the regulatory factors mentioned. Patent activities significantly increased in the automotive sector throughout the last decades furthermore suppliers have become more strongly connected to actors in the centre during the last two decades.

6 Horizontal issues relevant to the automotive sector

The following section will present additional insight into the automotive sector for four selected horizontal issues:[57]

- Implications of technological specialisation and economic performance
- The role of High-growth companies (gazelles)
- The role eco-innovations in the automotive sector
- Lead market potentials in the automotive sector

6.1 Technological specialisation and economic performance – implications for the automotive sector[58]

Technological competences in the automotive sector are located in Europe (EU 15 countries and New Member States). Especially Germany, France and Luxembourg have continuously increased their specialisation in this sector. Germany, France and Luxembourg have also continuously expanded their technological advantages in the automotive sector, while Spain has lost its leading position.

Evidence provided by Malerba and Orsenigo (1997) and by Malerba et al. (1997) suggests a positive association between international technological specialisation and concentration in innovative activities. Malerba and Montobbio (2003) show that international technological specialisation is affected positively by technological concentration and technological entry in 135 technological classes in three broad sectors (chemicals, electronics and machinery). They show also that some differences across sectors exist. In particular they find that technological entry does not have a positive impact on specialisation in electronics.

Following discussion builds on this approach and expands it in many respects. It asks whether increased technological specialisation in a country affects the growth of Total Factor Productivity (TFP)[59] at industry level. More precisely the next sections will point out that, for example, Germany and Italy are more specialised transports.

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[57] More details of the analyses of these horizontal issues are presented in horizontal reports (Task 4) of the Sectoral Innovation Watch project:

- Mitusch K., Schimke A., (2011) Gazelles -High-Growth Companies; Europe INNOVA – Sectoral Innovation Watch Task 4 Horizontal Report 5; for DG Enterprise & Industry, January 2011
- Montalvo, C, Diaz-Lopez, F.J. and F. Brandes (2011) Potential for eco-innovation in nine sectors of the European economy; Europe INNOVA – Sectoral Innovation Watch Task 4 Horizontal Report 4, for DG Enterprise 2011

[58] This section is based on the analysis performed in Task 4 of the SIW-II. The full analysis is available in Grupp et al. (2010).

[59] Total factor productivity (TFP) measures the value added per unit of input and indicates the portion of growth in total economic output (value added) that is not explained by the quantitative growth of the most important inputs. It therefore captures all those elements that make the inputs more productive. TFP is importantly linked to innovative behaviours, as innovative processes tend to reduce the amount of inputs for a given output level. TFP

TFP is importantly linked to innovative behaviour. Innovative processes tend to reduce the amount of inputs for a given output level. Product innovations increase output and value added. It is a therefore a fundamental question for policy to understand whether countries are able to turn their technological activities into more efficient production activities and ultimately to higher wealth (i.e. more value added per unit of inputs). On average, technological leaders (Sweden, Finland, Germany, Denmark and the UK) have higher TFP growth.

The analysis showed that countries vary significantly in terms of technological entry and that the quantity of variation attributable to countries is bigger than those coming from the sectors. The mean for the patent share of Top5 patenting firms in the automotive and other transport vehicles sector (transport) is similar to the average of all other observed sectors.

Grupp et al (2010) found out that the variability due to country differences is (less significantly) higher than the one due to sector differences in terms of patent share of Top5 patenting firms. The mean for the patent share of top 5 patenting firms in the automotive and other transport vehicles sector (transport) is smaller than the average of observed sectors.

However, these evidences have important implications. First, barriers to technological entry – other things being equal - depend principally upon country-specific characteristics. So it is the institutional environment and the structure of incentives at the national level that are more or less conducive to entry. Conversely, for what concerns the patent share of the top 5 companies the nature and the characteristics of the sectors seem to play a more relevant role. As a result, at the country level the relative role of big innovators is crucially driven by the sectoral composition of the innovative activity.

Grupp et al (2010) finally provide an econometric analysis, which investigates whether and in which way technological specialisation patterns and other features of the innovation process affect the innovative and economic performance. Being specialised in a specific sector reinforces the positive relationship between technological activities and productivity in that sector, this means in detail:

- innovative activities contribute importantly to productivity growth at industrial level.
- international technological specialisation is an important factor driving factor productivity. It is important to underline that both innovative activities and specialisation affect productivity at the sectoral level.
- Large innovative companies play a crucial role in driving the sectoral productivity growth.
- Finally the technological dynamism - measured by technological entry - plays also a strong role in productivity growth at industry level.

growth is thus interpreted as capacity to turn technological efforts into more efficient production activities and ultimately to higher wealth (i.e. more value added per unit of inputs). Total factor productivity growth varies substantially across sectors. Overall there is considerable variation in terms of TFP growth across sectors.

This result is confirmed by results on specialisation at the regional level. Regional economic specialisation and innovative performance are closely related to each other. The relationship between specialisation and productivity growth at sectoral and national level is particularly strong for large countries and in traditional sectors. This suggests that innovation policy can be an important leverage of productivity also in traditional sectors. However, it is not guaranteed that this positive effect at the sectoral level generates economic growth at the macro level.

6.2 High-growth companies – implications for the automotive sector[60]

In the empirical literature on gazelles, there is no explicit consensus of how to define a cut-off point in terms of high growth. In fact, there is a wide range of different explanations on how to choose (a probably largely arbitrary) such a cut-off point of growth. In general, the cut-off point indicates the frontier at which high-growth firms become gazelles. The following cumulative examples give an overview on the existing descriptive literature. Different studies, most of them are widely used in the literature; define high growth firms as having a turnover growth rate of at least 20 % p.a. for three or more consecutive years (Birch & Medoff, 1994; Birch, Haggerty, & Parsons, 1993; Reuber & Fischer 2005; Nicholls-Nixon, 2005, Sims & O´Regon, 2006; Tatum, 2007). Autio, Arenius, & Wallenius (2000) and Acs, Parsons, & Spencer (2008) define high growth firms as firms that obtain at least 50% turnover growth during each of three consecutive financial years. Further studies employ a relative cut-off point and use the top growing 5 % or 10 % of high growth firms (Kirchhoff, 1994; Schreyer, 2000; Davidsson & Delmar, 2003, 2006; Parker et.al., 2005).

For analysis, we use the following databases:

- The Community Innovation Survey IV (CIS IV) at Eurostat offers very detailed information on the firm level which can be used to identify gazelles and to analyse factors affecting their emergence. CIS provides data on the growth rates of turnover and number of employees and, hence offers the possibility to identify gazelles in different ways.[61]
- The European Cluster Observatory database provides a wide variety of data on clusters in Europe.[62] A weakness in European Cluster Observatory data is that we are not able to identify high-growth firms; hence, the information cannot be linked to other data.

Concerning age and firm size, gazelles tend to be small and relatively young firms, mainly new business start-ups. A start-up faces a large number of obstacles in the beginning, e.g. limited access

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[60] This section presents an excerpt of the Europe INNOVA Sector Innovation report analysing the impact of innovation on high-growth companies This section is based on the analysis performed in Task 4 of the SIW-II. The full analysis is available in Mitusch K., Schimke A., (2011) Gazelles -High-Growth Companies; Europe INNOVA – Sector Innovation Watch Task 4 Horizontal Report 5; for DG Enterprise & Industry, February 2011.
[61] Find out more about CIS see http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis
[62] For a detailed definition of these three types of industries see “Creation of cluster definitions”, European Cluster Observatory, http://www.clusterobservatory.eu/index.php?id=46&nid=

to human capital, finance, network, knowledge; failure of external resources and agents (networking) as well as bureaucratic barriers. Having a more detailed look, the availability of qualified human capital is central to the successful development of a new firm.

The results obtained for cooperation confirm the assumption that firms being active in cooperation's might be more likely to become gazelles. The report on Sectoral Innovation Systems in Europe (2008) points out that gazelles may act in clusters and that collaboration may have an impact on these firms to become gazelles. Nevertheless, the results show that there are decisive differences when different innovation cooperation's are used. Most of the high-growth firms have cooperation arrangements on innovation activities. Gazelles tend to have more national clients and customers and are more active in innovation cooperation's (e.g. consultants, private R&D institutes) in other countries.

Table 6.1 shows the distribution of gazelles at the sectoral level (NACE-codes: industries / sectors) sorted by different growth categorizations. [63]

Table 6.1 shows relatively low shares of gazelles for the automotive sector. As analysed by Mitusch et al. (2010)[64] gazelles tend to emerge in growing industries and earlier phases of business- life-cycles. Gazelles emerging in a declining industry might realise growth at the expense of job losses in other firms. Thus, net effects on employment might be small. Although the proportion of gazelles in the sector Manufacture of transport equipment is small. Gazelles in other sectors are integrated in the value and supply chain of the Automotive and broader the transport equipment sector.

Gazelles in the textile industry or the knowledge intensive business sector are often oriented towards attractive supply-markets of the automotive industry, for instance. Thus, suppliers in the textile industry can generate considerable growth rates on the basis of their supply function to local producers in the automotive industry and their indirect integration in a global supply chain.[65]

[63] This implies two different definitions of gazelles (Gazelles build 5 % or 10 % of all growing firms, depending on specific criteria). The percentage values refer to all gazelles within the category – not to all growing firms. Following the chosen definition the share of gazelles is relatively small in the sector manufacture of transport equipment (and automotive as a part of it).

[64] Mitusch K., Schimke A. (2010) Gazelles – High Growth Companies, Horizontal report 5, Sector Innovation Watch, for DG-Enterprise & Industry

[65] See European Commission (2008): Sectoral Innovation Systems in Europe: Monitoring, Analysing Trends and Identifying Challenges- Textiles, p. 86.

Table 6.1 Gazelle distribution at the sectoral level

NACE_pro	industrie / sector [NACE-code]	Gazelles: 10 % of growing firms		Gazelles: 5 % of growing firms	
		Number of Firms/Frequency	Percentage	Number of Firms/Frequency	Percentage
C: Mining and quarrying	10 Mining of coal and lignite; extraction of peat 11 Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying 12 Mining of uranium and thorium ores 13 Mining of metal ores 14 Other mining and quarrying	141	1,76	73	1,82
DA: Manufacture of food products, beverages and tobacco	15 Manufacture of food products and beverages 16 Manufacture of tobacco products	549	6,85	250	6,98
DB: Manufacture of textiles and textile products	17 Manufacture of textiles 18 Manufacture of wearing apparel; dressing and dyeing of fur	505	6,3	267	6,66
DC: Manufacture of leather and leather products	19 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	89	1,11	47	1,17
20 21	20 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials 21 Manufacture of pulp, paper and paper products	286	6,57	146	3,64
22	22 Publishing, printing and reproduction of recorded media	113	1,41	59	1,47
DF DG	23 Manufacture of coke, refined petroleum products and nuclear fuel 24 Manufacture of chemicals and chemical products	124	1,55	53	1,32
DH	25 Manufacture of rubber and plastic products	181	2,26	89	2,22
DI	26 Manufacture of other non-metallic mineral products	219	2,73	113	2,82
27	27 Manufacture of basic metals	74	0,92	32	0,80
28	28 Manufacture of fabricated metal products, except machinery and equipment	369	4,6	149	3,72
DK	29 Manufacture of machinery and equipment n.e.c.	278	3,47	132	3,29
DL: Manufacture of electrical and optical equipment	30 Manufacture of office machinery and computers 31 Manufacture of electrical machinery and apparatus n.e.c. 32 Manufacture of radio, television and communication equipment and apparatus 33 Manufacture of medical, precision and optical instruments, watches and clocks	332	4,14	164	4,09
DM: Manufacture of transport equipment	34 Manufacture of motor vehicles, trailers and semi-trailers 35 Manufacture of other transport equipment	172	2,15	94	2,34
DN: Manufacturing n.e.c.	36 Manufacture of furniture; manufacturing n.e.c. 37 Recycling	341	4,25	181	4,51
E: Electricity, gas and water supply	40 Electricity, gas, steam and hot water supply	65	0,81	31	0,77
F: Construction	45 Construction	971	12,11	465	11,60
50	50 Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	100	1,25	48	1,2
51	51 Wholesale trade and commission trade, except of motor vehicles and motorcycles	1127	14,06	589	14,69
52	52 Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	121	1,51	57	1,42
H	55 Hotels and restaurants	71	0,89	39	0,97
60_61_62	60 Land transport; transport via pipelines 61 Water transport 62 Air transport	431	5,38	232	5,79
60_61_63	nn	3	0,04	2	0,05
63	63 Supporting and auxiliary transport activities; activities of travel agencies	185	2,31	84	2,1
64	64 Post and telecommunications	98	1,22	61	1,52
J: Financial intermediation	65 Financial intermediation, except insurance and pension funding 66 Insurance and pension funding, except compulsory social security 67 Activities auxiliary to financial intermediation	190	2,37	99	2,47
70	70 Real estate activities	44	0,55	20	0,5
71	71 Renting of machinery and equipment without operator and of personal and household goods	14	0,17	8	0,2
72	72 Computer and related activities	237	2,96	1174	2,84
73_74	73 Research and development 74 Other business activities	547	6,82	262	6,54

Source: IWW illustration based on CIS IV data (2009)

Table 6.2 shows a matrix which not only displays gazelles' allocation to different NACE-2 codes but also to different countries (see columns) as relative proportions.

Table 6.2 Gazelle distribution at the sectoral and national levels[66]

	Country code															
NACE_PRO	BE	BG	CZ	DE	EE	ES	GR	HU	IT	LT	LV	NO	PT	RO	SI	SK	**Total**
10 - 14	0,013	1,392	0,125	0,038	0,238	0,201	0,000	0,150	0,226	0,088	0,426	0,038	0,063	0,514	0,038	0,038	3,585
15, 16	0,038	0,552	0,013	0,025	0,050	0,100	0,000	0,100	0,088	0,013	0,038	0,063	0,013	0,238	0,025	0,063	1,417
17, 18	0,013	0,150	0,038	0,025	0,000	0,088	0,013	0,025	0,201	0,038	0,050	0,013	0,013	0,176	0,013	0,075	0,928
19	0,038	1,429	0,150	0,063	0,150	0,552	0,000	0,238	0,564	0,113	0,176	0,063	0,025	0,489	0,201	0,376	4,626
20, 21	0,050	0,000	0,100	0,000	0,000	0,301	0,000	0,000	0,288	0,176	0,163	0,000	0,000	0,000	0,176	0,000	1,254
22	0,263	6,519	0,150	0,075	0,226	0,501	0,013	0,288	0,313	0,213	0,301	0,188	0,288	4,388	0,288	0,113	14,13
23, 24	0,075	0,000	0,125	0,000	0,000	0,226	0,000	0,000	0,213	0,213	0,527	0,000	0,038	0,000	0,100	0,000	1,517
25	0,138	2,056	0,125	0,088	0,226	0,176	0,000	0,201	0,514	0,226	0,313	0,251	0,050	0,689	0,188	0,163	5,403
26	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,038	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,038
27	0,088	0,639	0,025	0,050	0,075	0,125	0,013	0,050	0,514	0,050	0,201	0,075	0,050	0,251	0,038	0,075	2,319
28	0,000	0,301	0,050	0,038	0,063	0,188	0,000	0,013	0,075	0,063	0,050	0,075	0,063	0,176	0,050	0,025	1,229
29	0,000	0,000	0,063	0,000	0,000	0,276	0,000	0,000	0,088	0,000	0,100	0,000	0,000	0,000	0,025	0,000	0,552
30 - 33	0,000	0,000	0,013	0,000	0,000	0,113	0,000	0,000	0,000	0,000	0,025	0,000	0,000	0,000	0,025	0,000	0,176
34, 35	0,113	0,451	0,113	0,113	0,150	0,476	0,000	0,138	0,326	0,063	0,075	0,326	0,163	0,276	0,050	0,138	2,971
36, 37	0,201	0,326	0,263	0,263	0,125	1,178	0,000	0,138	1,567	0,301	0,614	0,201	0,852	0,389	0,301	0,138	6,857
40	0,000	0,288	0,075	0,025	0,038	0,163	0,013	0,013	0,276	0,163	0,125	0,100	0,113	0,288	0,025	0,063	1,768
45	0,025	3,861	0,050	0,013	0,150	0,514	0,038	0,125	0,276	0,063	0,338	0,088	0,075	1,116	0,050	0,100	6,882
50	0,013	3,460	0,075	0,000	0,188	0,163	0,000	0,113	0,414	0,113	0,263	0,025	0,263	1,116	0,063	0,063	6,331
51	0,000	0,364	0,013	0,000	0,013	0,088	0,013	0,013	0,000	0,013	0,025	0,000	0,088	0,426	0,038	0,025	1,116
52	0,025	0,288	0,063	0,063	0,063	0,351	0,000	0,050	0,176	0,063	0,075	0,000	0,013	0,263	0,013	0,050	1,554
55	0,013	0,564	0,050	0,025	0,113	0,201	0,000	0,125	0,188	0,125	0,138	0,063	0,063	0,389	0,063	0,150	2,269
60, 61, 62	0,000	0,990	0,050	0,013	0,125	0,464	0,000	0,075	0,138	0,075	0,075	0,063	0,050	0,451	0,075	0,100	2,745
nn	0,050	1,191	0,125	0,075	0,176	0,426	0,000	0,213	0,238	0,063	0,263	0,050	0,050	0,288	0,113	0,163	3,485
63	0,013	0,715	0,226	0,201	0,188	0,426	0,000	0,201	0,426	0,238	0,138	0,125	0,188	0,664	0,138	0,276	4,162
64	0,050	0,201	0,075	0,025	0,163	0,464	0,013	0,125	0,176	0,088	0,063	0,088	0,088	0,401	0,063	0,075	2,156
65, 66, 67	0,050	1,304	0,138	0,038	0,150	0,389	0,025	0,125	0,188	0,213	0,251	0,088	0,125	0,890	0,113	0,188	4,275
70	0,000	0,075	0,038	0,038	0,075	0,050	0,000	0,038	0,226	0,038	0,038	0,025	0,038	0,088	0,013	0,038	0,815
71	0,088	0,000	0,163	0,000	0,000	1,128	0,000	0,389	7,497	0,589	0,815	0,376	0,138	0,000	0,627	0,364	12,17
72	0,000	0,000	0,100	0,000	0,000	0,201	0,000	0,000	0,364	0,000	0,176	0,000	0,000	0,000	0,050	0,000	0,89
73, 74	0,088	0,426	0,063	0,063	0,113	0,088	0,050	0,125	0,301	0,238	0,138	0,000	0,100	0,426	0,063	0,100	2,382
Total	1,44	27,54	2,66	1,35	2,86	9,62	0,19	3,07	15,90	3,64	5,98	2,38	3,01	14,39	3,02	2,96	100
	caption:		**> 1,000**		**0,500 ≤ X ≤ 1,000**											

Source: IWW calculations based on CIS IV data (2009)

The comparatively high proportions of gazelles in the sector manufacturing transport equipment (including the automotive sector) can be identified in Bulgaria, Spain, and Italy on the basis of CISIV data. However, there is not too much evidence that the sector has a large impact on the emergence of gazelles. It is rather the growth of the industry.

[66] All values in the matrix are percentage values and especially high values are highlighted, which points out the crucial differences between the countries.

6.3 Eco-innovation opportunities for the automotive sector and eco-innovation clusters

Recently eco-innovation has come to the forefront of policymaking discussions and forums. Evidence of this fact is found in the agendas of recent meetings held at the highest political level (e.g., OECD, World Economic Forum, UNEP, UNFCCC, etc.). In these forums policy makers have already considered eco-innovations as very real economic multipliers. In Europe, the EU 2020 strategy highlights that smart, sustainable and inclusive growth are mutually reinforcing priorities.

The automotive sector is strongly challenged by issues of climate change and energy efficiency nowadays and a great deal of R&D and applied technology is currently under development. Non-technological innovations are also high in the agenda of this sector, especially in relation to alternative modes of transport (OECD 2010). As mentioned in section 0 environment, the availability of resources and price for energy are (among others) important drivers for future development in the automotive sector.

The following section presents an excerpt of the Europe INNOVA Sector Innovation report analysing the potential for eco-innovation for the automotive sector. (Montalvo et al., 2011).[67] It intends to provide an examination of the potential for eco-innovation, to provide an overview of emerging eco-innovations in the automotive sector, the impact of regulation and an indication of associated investment trends, to identify the current and potential applicability of eco-innovations in the automotive sector and finally to provide an indication of policy implications for the support of eco-innovation.

Eco-innovation means all forms of innovation reducing environmental impacts or optimising the use of resources throughout the lifecycle of related activities. This is the definition adopted in this report.

Automotive is a highly dynamic and competitive industry with global players within an extensive network of suppliers and sub-suppliers along its value chain. In this tier system, lower level organisations provide input to the higher level supplier until the final car assembly. Currently major automakers exclusively contract with Tier 1 suppliers, which assemble automotive components into large modules. To create these modules, they use parts from Tier 2, Tier 3, or even smaller suppliers. The components industry gains on importance regarding value added, because vehicles are getting equipped with more and better components, plus there is also a growing tendency towards outsourcing (AutoBlog 2009). Modern car manufacturing production processes are often time critical,

[67] Montalvo, C., Diaz-Lopez, F.J. and F. Brandes. (2011) Potential for eco-innovation in nine sectors of the European economy; Europe INNOVA – Sector Innovation Watch Task 4 Horizontal Report 4, for DG Enterprise & Industry 2011

thus the cooperation between suppliers and final assembler important is more and more a key issue in supply chain management.

The manufacturing process of motor vehicles includes the transformation of raw materials and energy, which results into a variety of environmental consequences. The most important of these are the negative impact on climate change and the depletion of non-renewable resources. In addition, there are also other environmental stresses associated with the use and disposal of cars. The use of motor vehicles releases harmful gases to the atmosphere, such as nitrogen oxides, volatile organic compounds, sulphur dioxide, carbon dioxide, carbon monoxide, particulates, and other pollutants. The use of cars in combination with their manufacturing process (e.g., iron and steel production: 2%) and all necessary petroleum refining (4%) contribute to CO2 production and thus to climate change (EEA 2009).

Road transport accounted for 23% of all CO_2 emissions in the EU-15 in 2007 (EEA 2009). According to the EIPRO study transport accounts for about 15% of the environmental impacts related to global warming. The two more important contributors were driving motor vehicles and passenger car bodies with 15% and automotive repair shops and services with 1,22% of the impacts (Tukker, Huppes et al. 2006).[68]

Energy, metal and fossil fuels are accounted in the list of resources used in this sector. It has been estimated that almost 20% of energy consumed throughout the whole life of a car is spent during the manufacturing process. An indicative figure suggests that 66-105 gigajoules of energy are necessary to produce a motor vehicle, depending on how much recycled materials are used. This is equivalent to the energy contained in 2000-3100 litres of gasoline, or the amount of fuel consumed by 16000-26000 km of driving (Environment Canada 2009). Another resource is metal, from which 70-80% of a car is made. Finally, the use and consumption of fossil fuels in the combustion engine is not only depleting the earth’s non-renewable resources, but is also accompanied by many environmental damages which are related to the exploration, extraction, refining, storage, delivery, and the disposal of fossil fuels. It is well know that a car motor causes pollution due to combustion, which can lead to a number of environmental and human health problems (Environment Canada 2009).

Eco innovation opportunities in the automotive industry can be found along the entire value chain. Nonetheless, it has been suggested that the stage of (intermediate and end) production is perhaps the most interesting in terms of policy and economic relevance (Nemry, Leduc et al. 2008). The table below contains 9 eco-innovation opportunity areas focusing more on the intermediate and end product stages of the value chain. Within the production process, automation and optimisation techniques are predominant to reduce material and energy use. New alternative energy sources are

[68] This study also presents the results for the following categories (not reported here): abiotic depletion, acidification, Eco toxicity, eutrophication, human toxicity, ozone layer depletion and photochemical oxidation.

the main driver for innovations, such as bio-fuels, hybrid or hydrogen power trains to create more efficient and environmental-sound engines. Also new materials are developed to reduce the weight and thus fuel consumption and CO_2 emissions of motor vehicles. Next to this, new materials are also investigated from a recycling perspective, where vehicles could be either dismantled in a more efficient way or vehicle parts could be recycled and reused. Eco-innovation opportunities in the use-phase of the car life cycle are not covered in our review, in particular related to driving behaviour or optimisation of air conditioning systems. The previous two blocks of the chain are well covered in the IMPRO-car report (see Nemry, Leduc et al. 2008).

Table 6.3 Eco-innovation opportunities in the automotive sector

Eco-innovation	Brief description	Example
Biofuels	Bio-fuel-powered cars are still an emerging market. Current developments in the automotive industry are related to developing biofuel powered complementary engines and power trains.	• E85 bio-fuel mixtures (mostly 1st generation)
Fuel cells	Fuel cells generate electricity through a reaction between a fuel and oxidant. The combination of fuel and oxidant are manifold, e.g. hydrogen (fuel) and oxygen (oxidant), hydrocarbons and alcohols (fuel) with chlorine and chlorine dioxide (oxidants), etc. Fuel cells vehicles e.g. hydrogen based have been already developed by major car manufacturers and are seen as a promising option for the coming years.	• Fuel cells: • Fuel cell vehicles: Honda's FCX Clarity, DaimlerChrysler F-Cell, Toyota's highlander. GM's Chevy sequel, Ford Focus FCV, etc.
Hydrogen storage	Hydrogen storage is a long-term complementary hybrid system to hydrogen fuel cells. The goal is to store H_2 in a compact, lightweight and efficient way in order to use it in motor vehicles and other mobile applications. There are several parallel developments for hydrogen storage, such as high pressure cambers or cryogenic containers. But the most promising approach is based on chemical reactions, where hydrogen is stored in a hydride form and reversibly extracted upon heating.	• H2 multi-capillary arrays storage technology from Swiss C.En. Ltd
Advanced batteries	High-capacity long-lasting batteries with longer life cycles are a core complement of electric vehicles. Advanced batteries aim to reduce the pressure on infrastructures (e.g. charging stations), while enabling longer travelling time. The continuous reduction of safety concerns (e.g., malfunctions, explosions) and the increased applicability of these batteries (e.g., extreme temperatures, shocks) further improve the rate of adaptability for electric cars.	• Silicon anode technology for next generation Li-ion batteries from British Nexeon Ltd
Hybrid vehicles	Given current limitations in alternative batteries and fuel cell technologies hybrid configuration which includes an internal combustion engine and an electric motor is currently seen as the most competitive power train alternative. Hybrid technology options, such as electric motor assistant and electric drive, are becoming increasingly available from almost every car manufacturer. Current eco-innovations lie in combining different energy sources. Hybrid cars with gasoline or diesel engine in combination with an electric engine can leverage the advantages of both systems. Smaller eco-innovations for hybrids are for example regenerative braking or similar energy management tools.	• Several car makers have prototypes of hybrid-electric (HEV); a plug-in hybrid electric (PHEV); and battery-electric (BEV) vehicles
Vehicle components & engineering	This category refers to incremental innovations to improve the efficiency of engines and drive trains to reduce fuel consumption. One example are incremental innovations to improve the efficiency of engines and drive trains to reduce fuel consumption, which is seen as an intermediate solution until it is feasible to make a more radical transitions to alternative energy sources. Another example is the development of continuous variable transmissions, which reduces the driving resistance of cars. This is achieved by sleeplessly changing	• Green Gen II ® active transfer case technology for improved torque distribution /fuel economy from Global supplier Magna Inc.

Eco-innovation	Brief description	Example
	through an infinite number of gears. This flexibility makes it possible that the engine runs at its most fuel-efficient ratio (RPM = rounds per minute), regardless of the travelling velocity of the car.	• Optimiser ™ technology for multi-fuelling system (diesel/LPG) of simultaneous combustion from British G-volution
Automotive powertrain retrofitting	An alternative to end-of-life vehicle disposal is automotive power train retrofitting of used and new vehicles, reaching European labels 4 and 5. Power train retrofitting is a plausible alternative for vehicles driving more than 100,000 miles a year e.g., taxis/cabs, limos, shuttle buses, police vehicles, etc. and for campers, all terrain vehicles, and luxury cars. The feasibility of vehicles to be retrofitted also depends on a good condition of the car's body and chassis (e.g., better preserved in dry environments).	• Electric drive train retrofitting of luxury and all terrain vehicles from British Liberty Electric Cars Ltd • Electric and hybrid train retrofitting of taxi cabs from British EVO-electric
Nano/bio catalyst	Eco-innovations concerned with developing new catalyst and carrier materials in order to reduce CO_2 emissions. Older catalysts in motor vehicles were only able to eliminate other pollutants, such as CO or NO_x. New biotechnology and nanotechnology catalysts can transform CO_2 to less harmful or even useful new substances.	• -XTS ™ catalyst reformer for stationary hydrogen fuel stations from Swedish ReformTech
Advanced (nano)materials	This category includes new materials for the car body in order to improve corrosion resistance. New lightweight materials, such as high speed steel, aluminium alloy sheets and advanced plastics reduce the overall weight of vehicles and improve fuel economy.	• Lightweight Structural Composite material from UK-based Amber Composites

Source: Montalvo et al. 2011

Eco-innovation opportunities in the automotive sector attempt to respond to minimise their contribution to climate change and the environmental impacts of their manufacturing activities. But these innovations are not radical in nature – they do not challenge the concept of mobility as we know it. Eco-innovations are aimed to ease impacts of the sector due to the current high consumption of fossil fuels, which in turn results in large amounts of CO_2 emissions. There is a wide range of incremental eco-innovations in this sector, covering almost all environmental aspects of motor vehicles and for different time horizons. In the short-term, there are eco-innovations in the fields of electric and hybrid vehicles, new intelligent car components, materials and catalysts, which aim to reduce CO_2 emissions through achieving higher efficiency levels. On the long-term, developments in bio-fuels, fuel cells, advanced batteries and hydrogen storage may have a larger potential to foster an automotive industry less dependent of fossil fuels.

It is often perceived that the automotive sector is one of the most dynamic and innovative of all, bringing many innovations into the market in yearly basis. For more than a decade, a large number of technological options called to contribute to lower GHG emissions of car manufacturing continue to be developed and commercialised around the dominant design of petrol or diesel passenger cars (e.g. the options listed in Weiss, Heywood et al. 2000). Alternative and more systemic transport solutions are needed and acknowledged, but the focus of the European environmental policy of products is at the stage of assessing the environmental impacts and identifying and assessing eco-innovative options related to car efficiency and car usage (Nemry, Leduc et al. 2008). A survey conducted by DuPont and the Society of the Automotive Industry (SAE) reveals that for the first time in 14 years, environmental concerns outrank cost reduction to top the list of challenges facing the automotive industry (DuPont Automotive 2008). In the Dupont and SAE survey more than half of the surveyed automotive designers and engineers said that environmental factors, such as fuel economy, emissions or clean air regulations, are the industry’s biggest challenges.

The automotive sector is one of the most regulated ones in developed economies. In emerging markets the level of legislation is increasing at a higher pace than many markets are. For the case of the European Union, climate change and other environmental issues have been important concerns for policy makers. To address these issues, a large variety of policies and legislations were put in place, putting car makers and suppliers under increasing pressure to confirm with all regulations regarding the use of resources, manufacturing processes, plant operations and recycling of products (Bilsen, Rademaekers et al. 2009). This is due to the fact, that legislations about environmental issues are often not synchronised with the automotive innovation cycles. This problem gives car makers in Europe a large disadvantage over other countries, which have a lower degree of competition or even receive financial support from the government (e.g., Japan, Korea) (Gottschalk and Kalmbach 2007).

The European Commission adopted a proposal for legislation in December 2007 to reduce the CO2 emissions of new passenger cars by 19% until 2012. In principle this proposal provides car manufacturers an incentive to decrease emission gases by imposing an excess emission premium in case the levels are above the regulation. Since most manufacturers are likely to meet this target, this legislation is expected to be a driver for innovation (EC 2009f). The same holds for other regulations, such as the EU Directive on alternative car fuels, the end-of-life vehicles directive (2000/53/EC) and the Euro 4 and 5 emission limit values (Kuik 2006). Although these regulatory changes are introduced in steps, it puts continuously pressure on automakers and suppliers to accommodate their processes and products to these regulations because the automotive industry operates in a complex social, economic and legal environment.

Despite the apparent pressure in major brands the survey results conducted by the Sector Innovation Watch project (see. Lopez et. al) indicated that the overall size and frequency of environmental regulations in the automotive significantly associated with innovations is relatively low compared to other sectors monitored in the Sector Innovation watch. This is indicated by the number of correlations between innovation type and regulation type found significant.

Montalvo et al (2011) also accentuate implications of eco-innovations for suppliers along the value chain. Along the value chain these are companies that bring all kinds of inputs and components to integrate a final product. Most of the regulatory attention focused on energy efficiency in final automotive goods the rest of the provision system is not pressured directly by regulation to eco-innovate. The pressure might be transmitted through the supply chain management dominated by main brand companies. Normally the dominating company indicates desired changes in intermediate goods to suppliers through new standards and designs modifications. This is supported by the strong and significant correlations between innovations on designs and regulations on alternative and hazardous materials. This is also supported by the strong relationship between innovation in Logistics, relations with others and sales and distribution methods. These three types of organisational innovation indicate a chain of associations with regulation through innovation in logistics. As confirmed by survey data logistics is the type of innovation that holds the strongest relationship with environmental regulations.

Furthermore, the observed lack of association of any type innovation with the prevention of regulatory risk indicates that to a large extent firms down the supply chain have a more reactive rather than active innovative behaviour in the face of potential environmental regulations.

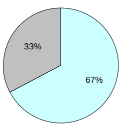
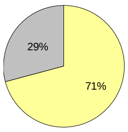
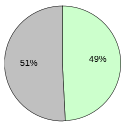
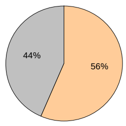
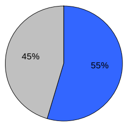
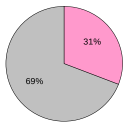
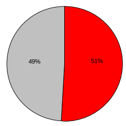
This has important implications for the level of policy intervention. Their eco-innovative could be mainly driven by pressure coming from major brands, their clients and reason of existence.

Montalvo et al (2011) provided an analyses of the potential contribution of eco-innovation opportunities to firm level strategies and EU priorities based on a micro-data survey (within the work of the SIW Task 4 “Eco-innovation Potential”). This survey included 1819 firms developing eco-innovations for the sectors of interest of the SIW. According to this, relatively high perceptions of eco-innovators in the automotive sector can be identified for to their contributions to “energy efficiency”, “green house gas abatement” or “waste minimisation”. The picture of perceptions of the potential contribution eco-innovations that potentially could be applied (second response group) corresponds very much to the perception for eco-innovations applied now, as presented in table 6.4 and 6.5 (see for more details: Montalvo et al., 2011).

Concerning the potential of eco-innovations in a sector for contributing to a policy priority again the eco-innovations opportunities identified and included in the eco-innovation survey were used. This analysis is performed along the applicability of eco-innovation in sectors and along the categories provided by eco-innovation policy priorities. Comparing to other sectors the automotive sector proves true to be a strategically important sector for the advancement of European environment and climate policy.

Table 6.4 shows the potential contribution of automotive eco-innovations to different eco-innovation priority areas (validated by frequency ranks for respondents in the automotive sectors).[69] In terms of eco-innovation potential of automotive eco-innovations for the first response group, energy efficiency (71%) and GHG abatement (67%) are the areas with the largest potential. Corresponding to the results presented in Figure 6.2 this is followed by waste minimisation (56%), with recycling and reuse (51%), eco-design (55%) and material efficiency (49%) next in line. New advanced eco-materials is the area with the lesser contribution (31%).

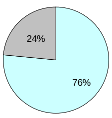
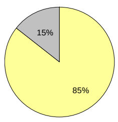
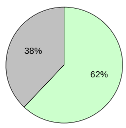
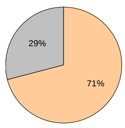
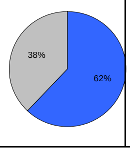
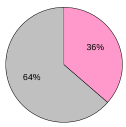
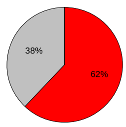
Table 6.4 Contribution of automotive eco-innovations to different eco-innovation priority areas (response group: eco-innovations applied now)

GHG ABATEMENT	ENERGY EFFICIENCY	MATERIAL EFFICIENCY	WASTE MINIMISATION	ECO-DESIGN	NEW ADVANCED ECO-MATERIALS	RECYCLING AND REUSE
						

Source: Montalvo et al., 2011

In terms of eco-innovation potential of automotive eco-innovations for the second response group, energy efficiency (85%) and GHG abatement (76%) are the areas with the largest potential. This is followed by waste minimisation (71%), with material efficiency, eco-design and recycling and reuse next in line with 62% each. New advanced eco-materials is the area with the lesser contribution (36%). The figures hitherto presented suggest a contribution that exceeds the share of potential currently in use.

Table 6.5 Additional contribution of automotive eco-innovations to different eco-innovation priority areas (response group: eco-innovations that could be applied, but are not applied now)

GHG ABATEMENT	ENERGY EFFICIENCY	MATERIAL EFFICIENCY	WASTE MINIMISATION	ECO-DESIGN	NEW ADVANCED ECO-MATERIALS	RECYCLING AND REUSE
						

Source: Montalvo et al. 2011

[69] In each pie chart the coloured area represents the contribution to a priority area from an eco-innovation being applied (current) or from those that could be applied (not currently applied). The grey area represents the missed applicability. The addition of both percentages represents the potential for eco-innovation in relation to an eco-innovation priority area, so this is the reported value (see below).

6.4 Impact of innovation on new lead markets[70]

The role of demand as such has received relatively scant attention in public policy, as Jakob Edler and Luke Georghiou (Edler and Georghiou 2007; Edler 2009) have concluded in their broad review of the subject (see also Beise 2004; Beise and Cleff 2004). In contrast, demand and customers dominate the approach to innovation in firms and other private actors. Thus the need to update and reformulate government approach to demand as innovation policy instrument has given rise to considerable academic and policy development effort in recent years.

Demand encompasses a very broad spectrum of issues bearing upon all aspects of innovation, ranging from well functioning market, heralded by William Baumol (2002) as the “free-market innovation machine”, to different types of government measures, such as different types of public procurement, regulation, and standardization.

6.4.1 A short reference to the market and demand for automotive products and services

The European Union is the major markets for passenger cars and commercial vehicles. The European market is nevertheless very challenging owing to the high quality and technical standards required, as well as to the relatively low growth rates. The markets and demand for automotive products and services will change considerably over the next few years:

In the case of passenger cars OEMs usually address individual consumers directly, and the customer and user are identical. Passenger cars are usually mass-products (> 100,000 vehicles). The annual kilometrage per vehicle is less than 50,000 and the replacement is not affected by consideration of depreciation or reinvestment. Mass-production and standardization mean that large international production networks are necessary, thus entailing a considerable role for tier1 level suppliers in innovation. In addition, innovation and product life cycles are considerably shorter than in the commercial vehicle segment. Also, purchasers’ rationale is not merely driven by practical value in use. Self-expression (or social status), and therefore branding and image cultivation, are of considerable relevance in pricing decisions. The customer awareness and needs are important drivers (or barriers) of innovation (Maxton et. al.2004).

The passenger car segment therefore seems to be predestined for demand side policy measures. Most of the European countries implemented incentive programs to hasten the scraping of older vehicles and the purchase of new ones. These demand side measures seemed to be successful in

70 The following section presents an excerpt of the Europe INNOVA Sector Innovation report analysing the potential implications of the Lead Market Concept for the automotive sector. For more details, please see Dachs, B., Wanzenböck I., Weber M., Hyvönen M., Toivanen H. (2011).

the sense that purchases in specific segments (new small or city vehicles) significantly increased. Even if these demand side measures seem to be successful in the short-term (especially for OEMs and suppliers focussing on compact and sub-compact cars) it can be expected that the positive impact of early replacement will to some extent be neutralized by the long-term irritation caused in downstream business.

Emission standards and regulations spur development and innovation in powertrains and therefore exert considerable influence on the future structure of the supply chain of the automotive industry. In combination with regulative measures, demand side measures could be highly relevant for the establishment of new vehicle and mobility strategies (e.g. the compensation of switching costs or 'launch customer' risk). In spite of the high environmental standards and strict regulations currently prevailing in Europe, the demand side conditions for eco-innovations and alternative mobility concepts still seem to be more favourable in some Asian countries at the moment. At present, a considerable share of European car makers focuses heavily on the (comparatively large) European market. However, patterns of global purchasing power are shifting to Eastern Europe and Asia (China, South East Asia) as a result of increasing prosperity. In the long term, the European automotive industry will have to target (and factor into innovation activities) new non-European customers and markets.

Commercial vehicles are investment goods. Thus, maintenance costs and residual value are crucial in the purchase decision. (Passenger cars are still consumer products to a certain extent.) Customers in the commercial vehicle segment usually hold vehicle fleets[71] and thus the commercial and heavy vehicle segment is much more vulnerable to business cycle developments than the passenger car segment.[72] Demand side measures such as the 'scrapping premium' are not applicable in the commercial vehicle segment. Commercial vehicles have to be adapted for a broad range of purposes (different wheelbases, gauges, transmissions, powertrains or driving cabs etc.). Compared to the passenger car segment production volumes are considerably small. This causes high variance (variety of options) in vehicle configuration during development. Thus, production and innovation networks are much smaller and less standardized than is the case for passenger cars. Commercial and heavy vehicles are more closely matched to given infrastructure than passenger cars. European heavy trucks are practically not exported to the Asian or US-American market, for instance. [73]

Finally it needs to be noted that the market for automotive industry may not be reduced to the products in CAP Division 34 alone, i.e. upstream business. Downstream business and its various services are gaining increasingly in importance. Downstream Business includes OEMs and

[71] Large logistics firms order eight to ten vehicles per day.
[72] A reduction of production immediately impinges on demand for transport services and in rapid succession to demand for commercial or heavy vehicles.
[73] Although specific innovations (anti-lock brakes, automatic driving assistance etc.) have been introduced for passenger cars and commercial vehicles more or less at the same time, direct co-operation between the passenger car segment and the commercial or heavy vehicle segment remain seldom.

franchised-dealer networks, not involved in innovation activities or strategic planning. Formerly, downstream business was considered an additional secondary business (financing and insurance, used car market, parts and service, as well as vehicle fleets and rental etc.). Today, OEMs aim to expand their participation in the customer life-cycle value chain and improve profit ratios by engaging in sectors with relatively little need for capital. The isolated production of goods vehicles has had its day. Innovation activities for new products increasingly include service innovations, for instance leasing services for batteries, or special service packages for new/ ‘launch’ customers (e.g. for hybrid and electric vehicles), or mobility services. Markets for passenger cars and commercial vehicles in the EU 15+ Norway, seem to have reached their limits In terms of market development and growth. By contrast, enormous market potential is still evident in Asia or Eastern Europe. New environmental regulations, costs of infrastructure (road and congestion charges), urbanization and demographic change (aging society) will all change demand for mobility in the long term. While innovation has been driven for by technological impulses, market and demand side factors now seem to be becoming decisive (both as potential barriers and drivers) in innovation activities in the automotive sector.

6.4.2 Lead markets in the automotive sector

The concept of Lead Markets has been developed in order to reconsider and step-up the role of demand in innovation and innovation policy. The concept has been put into political practice by the Lead Market Initiative (LMI) of the European Commission (EC) in cooperation with the Member States in order to augment the impact of traditional innovation policy measures. The objective of the Lead Market Initiative is to create added value at European level, and, in more concrete terms, to foster European leadership in sectors and markets, where Europe or European actors claim global leadership. Currently, Lead Market Initiative is still at its inception phase in Europe. Its short term impact is best visible in amounting learning about the instrument itself and its refinement, whereas the true economic, social, and environmental impacts of Lead Market Initiative cannot be expected sooner than 5-10 years from now.

Following the definition used by the European Commission (2007c), a lead market is the market of a product or service in a given geographical area, where the diffusion process of an internationally successful innovation first took off. This definition denotes that lead markets identification basically has to find a) promising artefacts or technology designs, and b) the geographical area where chances are high that this technology will emerge.

In the following, the lead market potential of countries is assessed for the automotive industry with particular respect to characteristics of the mentioned innovation themes.

Technological development in the automotive industry is driven by technological challenges in the field of production and storage of energy and alternative fuels as well as material sciences. Present social trends and a shift of customer preferences additionally shape technological development. The following future innovation themes can be identified (see Leitner 2010, section 0), each creating potential for European countries to establish a Lead Market position in the automotive industry:

- *Development of advanced and new powertrain technologies:* The main development trajectories regard technological advance of internal combustion engines, the enhanced utilization of alternative fuels such as natural gas, liquid fuels made of biomass and hydrogen, hybrid vehicles and electrified powertrains.
- Development of new applications and technologies in the fields of *traffic management systems, technology-assisted driving (drive-by-wire) and new safety systems* in order to increase comfort, safety as well as efficiency of driving and mobility.
- Development of *advanced production technologies* in terms of flexible manufacturing structures and new material technologies influence manufacturing systems and are important to benefit from increased vehicle performance and lower energy consumption.

Domestic demand is one of the decisive factors within the Lead Market approach. A high degree of demand specialization (i.e. a comparatively high share of the automotive sector on total consumption within a country) indicates a competitive advantage of a country compared to other countries. Moreover, the anticipation of global trends is an important driver for the international diffusion of innovation designs. Future social trends may primarily concern environmental issues such as climatic change and global warming as well as the price for energy and the dependence on oil. These global challenges shift customer preferences and mobility behaviour requiring innovative and sustainable solutions. The development of eco-efficient production methods and new materials may provide market opportunities for the automotive sector.

Demanding customers towards alternative fuels and fuel-efficient vehicles (through advanced powertrain technologies) create potential for Europe to become a Lead Market and provide other markets with appropriate solutions for global problems. A demand advantage may also arise through the build-up of new infrastructures for vehicles powered by alternative fuels (e.g. refuelling stations for hydrogen) or electric (e.g. charging possibilities for batteries). Concerning the development and diffusion of innovative traffic management systems, customer acceptance and willingness to adopt such technologies is a key issue to achieve demand advantages. Demand specialisation is high in *Denmark, Slovenia, Hungary and Latvia* compared to the EU-25 average. Thus, these countries most likely benefit from a demand advantage in the automotive sector and might establish themselves at the forefront of an international trend.

If innovative products or services can be sold at a low relative price on a Lead Market, the probability of diffusion to other markets increases. Competitive market structures favour the realization of price advantages. Relative price advantages of innovative products can be achieved either by cost reductions of production and input factors or by economies of scale of mass productions. The increase of fuel efficiency may compensate for moderate cost increase of vehicles providing potentials for mass customization of sustainable cars. High public and private demand may further cause price reductions achieved by economies of scale. Within the EU-25, Cleff et al. (2007) show that countries with relatively low price levels and relatively high propensities to consume in the automotive sector are those countries with a car manufacturing tradition, such as *Germany, France, UK, Belgium* and *Luxemburg*. Lead Market advantages may arise from a price-dependent demand advantage due to high price elasticities.

Countries with flexible manufacturing structures and technologies can adapt their products more easily to different market conditions and thus, may achieve greater export opportunities. Domestic mass customization will enhance product differentiation making products more exportable without substantial changes. Similarities of cultural, social and economic factors between countries facilitate the exportability of innovative designs. Orientation on foreign customers' needs and preferences increases the sensibility towards global trends and developments. Lead market advantages can be received from a high degree of export orientation especially in conjunction with high domestic demand for a specific product. *Germany, France, Belgium, UK and Denmark* possess considerable advantages in exploiting domestic demand for successful exports.

Transfer possibilities of innovation arise from a high degree of internationalisation and close interactions with other countries (e.g. by MNEs). The adaption of innovation design on the Lead Market may at the same time reduce uncertainties inherent in the usage of innovative product and services abroad (demonstration effect). Moreover, information about the specific foreign demand can be received more easily due to strong communication ties. International linkages and cross-border manufacturing processes provide potential for transfer advantages in the automotive industry. Again, *Germany and France* as well as *Sweden* show an above-average proportion of foreign direct investments in the automotive sector and thus, have a transfer advantage compared to other EU members.

Competitive markets have a higher probability to become a Lead Market, as more innovative designs have to be created in order to persist in a competitive environment. Particular pressure on the domestic automotive industry is induced by strong competition from India and Asia. New and factor saving manufacturing systems and technologies may compensate for high input factor costs for production (labour costs) and utilisation (petrol costs) of vehicles in Europe. Automotive manufacturers are compelled to redefine and differentiate their products and services in order to meet customers' needs. Moreover, customers tend to be more demanding in competitive markets than in highly regulated or monopolised markets, inducing product differentiation (e.g. varieties of alternatively fuelled vehicles) and requiring flexible manufacturing technologies. An indicator of the domestic market structure is the entry rate of new firms in the automotive industry. At this, competition is high in *Hungary, the UK, Estonia and Latvia*, while below-average competition can be found in Germany, Portugal and Sweden.

Summing up, the analysis suggests that *Belgium, France, Germany, Luxemburg*, and, to a lesser degree, *Italy, Sweden and the UK* are the countries with the best conditions for lead markets development in the automotive industry. This is also largely confirmed by the patent analysis of Task 4 (Grupp et al. 2010) presented in section 6.1.

7 Policy analysis and conclusions

The EU-25 automotive sector represents about 8% of total value added in the EU-25 manufacturing industry and shows impressive figures for R&D- and Innovation expenditures are significantly above the average of medium-high-technology manufacturing. Although new EU member countries are advancing rapidly, both on supply and demand side, view countries (in the first place Germany) clearly dominate the sectoral economic and innovation system in Europe. Even if statistical data elides the difference between passenger cars and commercial vehicles it is of considerable relevance for innovation and market development.

Our results show a differentiated picture of innovation in automotive sector, reinforcing significant strengths of the automotive sector but also posing future challenges and need for policy intervention.

Innovation expenditures in the automotive sector are considerably above industry average, but are frequently driven by external factors, e.g. developments in machinery and equipment, materials, electronic equipment. Innovation throughout the value chain plays a significant role.

The automotive sector is dominated by enterprises belonging to a few very large enterprise groups. Innovation in the automotive sector is affected by powerful supply and network structures with a decisive role being played by systems (mega) suppliers. The whole design and development process has been reorganized in the recent years as tasks are organized parallel and interactively synchronized. Beyond a new organization of innovation processes in multidisciplinary teams the direct involvement of systems and component suppliers became necessary. We could show that peripheral actors have become more strongly connected to actors in the centre since the end of the 1980s. Nevertheless, both, empirical evidences and expert opinion substantiate the suspicion that the European automotive industry is currently not able to tap its full innovation potential along the value chain. Alternative concepts (open innovation etc.) requiring the softening of established hierarchical structures have not been successfully to date but need to be advanced in the near future. Policy measures should consider that the dominating large firms also represent major R&D and funding capabilities in Europe and indicate desired changes in intermediate goods to suppliers through new standards and designs modifications. Finally they predefine major lines of allocation of public and private R&D funding in the automotive sector. Vice versa bottom up dynamics have be fostered pro-actively by innovation policy at the European level.

The European automotive sector was already undergoing a process of restructuring before the onset of the current financial and economic crisis. While the current crisis merely served to compound existing inherent structural problems it will be a barrier for innovation in the short-term. The analysis of potential barriers to innovation verified global financial crisis but also market protectionism as barriers of innovation.

While innovation has for decades been driven by technological considerations, market factors are becoming even more decisive (both as potential barriers and drivers) in innovation activities.

In contrast to Asian OEMs, the strong home market still provides the backbone of success for European automobile producers. The analysis suggests that Belgium, France, Germany, Luxemburg, and, to a lesser degree, Italy, Sweden and the UK are the countries with the best conditions for lead markets development in the automotive industry. Nevertheless, in the long term the European automotive industry will have to target (and factor into innovation activities) new non-European customers and markets which cannot be served with established patterns of product development and innovation. Thus, it might be characteristic that analyses showed that competition originating outside of Europe has no impact on innovation in the automotive sector.

European policy can support the reorientation towards new emerging markets via supporting technological development but also via fostering the establishment of European standards in foreign markets.

The automotive sector has been a job creator for a long time. The relative high skill levels of European Automotive employees have to date often been seen as a locational advantage. However, the enormous attractions of Asian development are likely to witness much greater mobility of brain power and relocation of knowledge intensive activities in the future.

Scenario analyses indicates that energy storage, fuels, optimization of conventional engines, safety technologies and more general material science, ICT-based manufacturing and the parallelism of new technologies are the main science and technology drivers of innovation in the automotive sector. Furthermore broad social trends and income, globalization and market saturation, environmental issues, resources and the price for energy, and finally changing mobility behaviour and corresponding requirements for new infrastructure have been identified as demand side drivers of future innovation. The four presented scenarios offer a variety of different futures which quite divergent impacts on the competitive landscape, economic development, technological progress, environment, and society. Policy is a critical factor in every scenario and is captured in the scenarios by the way it regulates the development of the sector. The automotive sector is one of the most regulated ones in developed economies. Analyses showed that regulation played a significant and positive role for innovation in the automotive sector in the past and is expected to by a (compensating) demand-side driver for future innovation in the automotive sector. Comparing to other sectors the automotive sector proves true to be a strategically important sector for the advancement of European environment and climate policy.

The analysis of eco-innovation opportunities also showed a wide range of incremental eco-innovations in this sector, but firms down the supply chain have a more reactive rather than active innovative behaviour in the face of potential environmental regulations. Several recent technology roadmaps for the automotive industry[74] have painted a relatively clear picture of the technological alternatives under way which might gradually lead to a new area of mobility. The projected image of a smooth manageable transition to a new paradigm proved illusionary.

More ambitious policy objectives have to overcome potential conflicts and trade-offs between short-term competitive, environmental, transport and social policies and interests at the European and national levels. Furthermore paradigmatic shift towards alternative concepts of mobility and transport requires long term structural change of industry and transport infrastructure and a better synchronization of legislations (about environmental issues) and automotive innovation cycles.

[74] FURORE 2003, FORESIGHT Vehicle 2004, UKs Powering Future Vehicle Strategy 2004

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Annex 1 Statistical definition of the sector – detailed remarks

Table A.1 reports the structure of the automotive sector in NACE Rev. 1 and NACE Rev. 2 coming into effect in 2007. The NACE-2 sector 2931 “manufacturing of electrical and electronic equipment for motor vehicles” and the NACE-2 sector 2932 “manufacturing of other parts and accessories for motor vehicles” are defined separately at the digit 4.

Countries included in Tables 2.2, 2.3 and 2.4

Belgium. Bulgaria. Czech Republic. Germany. Estonia. Greece. Spain. France. Italy. Hungary. Netherlands. Poland. Portugal. Romania. Finland

Table A.1 Classification of activities: automotive industry. NACE Rev. 1.1 and Rev. 2. 4-digit level

Description Nace 1.1	This item includes for NACE 1.1	This item excludes for NACE 1.1	Description NACE 2	This item includes for NACE 2	This item excludes for NACE 2
3410 Manufacture of motor vehicles	This class includes: - manufacture of passenger cars - manufacture of commercial vehicles: vans. lorries. over-the-road tractors for semi-trailers. dumpers for off-road use. etc. - manufacture of buses. trolley-buses. coaches - manufacture of motor vehicle engines - manufacture of chassis fitted with engines - manufacture of other motor vehicles: snowmobiles. golf carts. amphibious vehicles. fire engines. street sweepers. travelling libraries and banks. etc. This class also includes: manufacture of motor cycle engines	This class excludes: - manufact. of agricultural and industrial tractors. see 29.31. 29.52 - manufact. of electrical parts for motor vehicles. see 31.61 - manufact. of bodies for motor vehicles. see 34.20 - manufact. of parts and accessories for motor vehicles. see 34.30 - maintenance. repair and alteration of motor vehicles. see 50.20	2910 Manufacture of motor vehicles	This class includes: - manufacture of passenger cars - manufacture of commercial vehicles: vans. lorries. over-the-road tractors etc. - manufacture of buses. trolley-buses. coaches - manufacture of motor vehicle engines - manufacture of chassis for motor vehicles - manufacture of other motor vehicles: snowmobiles. golf carts. amphibious vehicles. fire engines. ATVs. go-carts. race cars etc. This class also includes: factory rebuilding of motor vehicle engines The maintenance and repair of vehicles produced in this division are classified in 45.20.	This class excludes: - manufact. of electric motors (except starting motors). see 27.11 - manufact. of lighting equipment for motor vehicles. see 27.40 - manufact. of pistons. piston rings and carburettors. see 28.11 - manufact. of agricultural tractors. see 28.30 - manufact. of tractors used in construction or mining. see 28.92 - manufact. of off-road dumping trucks. see 28.92 - manufact. of bodies for motor vehicles. see 29.20 - manufact. of electrical parts for motor vehicles. see 29.31 - manufact. of parts and accessories for motor vehicles. see 29.32 - manufact. of tanks and other military fighting vehicles. see 30.40 - maintenance and repair of motor vehicles. see 45.20
3420 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	This class includes: - manufacture of bodies. including cabs for motor vehicles - outfitting of all types of motor vehicles. trailers and semi-trailers - manufacture of trailers and semi-trailers: tankers. caravan trailers. etc. - manufacture of containers for carriage by one or more modes of transport	This class excludes: manufact. of trailers and semi-trailers specially designed for use in agriculture. see 29.32	2920 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	This class includes: - manufacture of bodies. including cabs for motor vehicles - outfitting of all types of motor vehicles. trailers and semi-trailers - manufacture of trailers and semi-trailers: tankers. removal trailers etc.. caravans etc. - manufacture of containers for carriage by one or more modes of transport	This class excludes: - manufacture of trailers and semi-trailers specially designed for use in agriculture. see 28.30 - manufacture of parts and accessories of bodies for motor vehicles. see 29.32 - manufacture of vehicles drawn by animals. see 30.99
3430 Manufacture of parts and accessories for motor vehicles and their engines	This class includes: - manufacture of diverse parts and accessories for motor vehicles: brakes. gear boxes. axles. road wheels. suspension shock absorbers. radiators. silencers. exhaust pipes. catalysers. clutches. steering wheels. steering columns and steering boxes	This class excludes: - manufact. of batteries for vehicles. see 31.40 - manufact. of electrical equipment for	2931 Manufacture of electrical and electronic equipment for motor vehicles	This class includes: - manufacture of motor vehicle electrical equipment. such as generators. alternators. spark plugs. ignition wiring harnesses. power window and door systems. assembly of purchased gauges into instrument panels. voltage regulators. etc.	This class excludes: - manufacture of batteries for vehicles. see 27.20 - manufacture of lighting equipment for motor vehicles. see 27.40 - manufacture of pumps for motor vehicles and engines. see 28.13

	- manufacture of parts and accessories of bodies for motor vehicles: safety belts. airbags. doors. bumpers This class also includes: manufacture of inlet and exhaust valves of internal combustion engines	motor vehicles. see 31.61 - maintenance. repair and alteration of motor vehicles. see 50.20	2932 Manufacture of other parts and accessories for motor vehicles	This class includes: - manufacture of diverse parts and accessories for motor vehicles: brakes. gearboxes. axles. road wheels. suspension shock absorbers. radiators. silencers. exhaust pipes. catalytic converters. clutches. steering wheels. steering columns and steering boxes - manufacture of parts and accessories of bodies for motor vehicles: safety belts. airbags. doors. bumpers - manufacture of car seats	This class excludes: - manufacture of tyres. see 22.11 - manufacture of rubber hoses and belts and other rubber products. see 22.19 - manufacture of pistons. piston rings and carburettors. see 28.11 - maintenance. repair and alteration of motor vehicles. see 45.20

Annex 2 Overview of SIW deliverables

Overview of the deliverables from the Europe INNOVA Sectoral Innovation Watch

Deliverables can be downloaded from www.europe-innova.eu

Task 1 Innovation Performance Sectoral Reports

Ploder, M., C. Hartmann, E. Veres, B. Bertram (2010) Sectoral Innovation Performance in the Automotive Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010, revised December 2010

Enzing, C.M. and T. van der Valk (2010) Sectoral Innovation Performance in the Biotechnology Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, November 2010

Squicciarini, M. and A.-L. Asikainen (2010) Sectoral Innovation Performance in the Construction Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Broek, van den T. and A. van der Giessen (2010) Sectoral Innovation Performance in the Electrical and Optical Equipment Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Leis, M. (2010) Sectoral Innovation Performance in the Food and Drinks Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

Gotsch, M., C. Hipp, J. Gallego and L. Rubalcaba (2010) Sectoral Innovation Performance in the Knowledge Intensive Business Services, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Giessen, van der A. and M. Poel (2010) Sectoral Innovation Performance in the Space and Aeronautics Sectors, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010, revised April 2011

Dachs, B. and G. Zahradnik (2010) Sectoral Innovation Performance in the Textiles and Clothing Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, May 2010

Schaffers, H., F. Merino, L. Rubalcaba, E.-J. Velsing and S. Giesecke (2010 Sectoral Innovation Performance in the Wholesale and Retail Trade Sectors, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Task 2 Foresight Reports

Leitner, K.-H. (2010) Sectoral Innovation Foresight – Automotive Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Valk, van der T., G. Gijsbers and M. Leis (2010 Sectoral Innovation Foresight – Biotechnology Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Schartinger, D. (2010) Sectoral Innovation Foresight – Construction Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Broek, van den T. and A. van der Giessen (2010 Sectoral Innovation Foresight - Electrical and Optical Equipment Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Leis, M., G. Gijsbers and F. van der Zee (2010) Sectoral Innovation Foresight – Food and Drinks Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Dachs, B. (2010) Sectoral Innovation Foresight – Knowledge Intensive Business Services Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Brandes, F. and M. Poel (2010) Sectoral Innovation Foresight – Space and Aeronautics Sectors, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010, revised April 2011

Zahradnik, G., B, Dachs and M. Weber (2010 Sectoral Innovation Foresight - Textiles and Clothing Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Giesecke, S. and P. Schaper-Rinkel (2010) Sectoral Innovation Foresight - Wholesale and Retail Trade Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Task 3 Market and Regulatory Factors

Montalvo, c. and O. Koops (2011) Analysis of market and regulatory factors influencing innovation: Sectoral patterns and national differences, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., K. Pihor and M. Ploder (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Automotive Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., F. Diaz Lopez, C. Enzing and K. Koman (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Biotechnology Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., K. Pihor, J. Hyönen, T. Loikkanen (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Construction Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

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Montalvo, C., M. Mayer and F. van der Zee (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Food and Drinks Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., F. Diaz Lopez, M. Gotsch and C. Hipp (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Knowledge Intensive Business Services Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

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Montalvo, C., K. Pihor and B. Dachs (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Textiles and Clothing Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

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Task 4 Horizontal Reports

H. Grupp[†], D. Fornahl, C.A.Tran, J. Stohr, T. Schubert, F. Malerba, Montobbio F., L. Cusmano, E. Bacchiocchi, F. Puzone, (2010) National Specialisation and Innovation Performance, Final Report Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

H. Grupp[†], D. Fornahl, C.A.Tran, J. Stohr, T. Schubert, F. Malerba, Montobbio F., L. Cusmano, E. Bacchiocchi, F. Puzone (2010) Appendix to National Specialisation and Innovation Performance, Final Report Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

Rubalcaba, L, J. Gallego, C. Hipp, and M. Gotsch (2010) Organisational Innovation in Services, Final Report Task 4, Horizontal Report 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2010

Dachs, B., I. Wanzenböck, M. Weber, J. Hyvönen and H. Toivanen (2011) Lead Markets, Final Report Task 4, Horizontal Report 3, for DG Enterprise and Industry, European Commission, March 2011

Montalvo, C., Diaz Lopez F.J., and F. Brandes, (2011) Potential for eco-innovation in nine sectors of the European economy, Final Report Task 4, Horizontal Report 4, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, December 2011

Mitusch K. and A. Schimke (2011) Gazelles – High-Growth Companies, Final Report Task 4, Horizontal Report 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, January 2011

Task 5 Input and Output Papers

Mitusch, K., C.A. Tran, J. Stohr, F. Montobbio, L. Cusmano and F. Malerba (2010) National Specialisation Report, Input Paper to the workshop ´Tomorrow's innovative industries: Regional and national specialisation patterns and the role of the regional business environment', Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, May 2010

Mitusch, K, C.A. Tran, F. Montobbio, L. Cusmano and F. Malerba (2010) National Specialisation Report, Output Paper to the workshop ´Tomorrow's innovative industries: Regional and national specialisation patterns and the role of the regional business environment', Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Rubalcaba L., J. Gallego and Hipp C. (2011) Organisational innovation, service innovation, and the value chain: New trends and policy implications. Input paper for the Workshop on the 25th of January 2011, Task 5, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, January 2011

Rubalcaba, L, J. Gallego, C. Hipp, and M. Gotsch (2011) Organisational innovation, service innovation, and the value chain: New trends and policy implications. Output paper of the Workshop Services Innovation and Value Chains on the 25th of January 2011, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2011

Mitusch, K. and A. Schimke (2011) Gazelles – High-Growth Companies, Input Paper to the workshop 'Gazelles as drivers for job creation and innovation: How to support hem best?', Task 5, Europe

INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission January 2011

Mitusch, K. and A. Schimke (2011) Gazelles – High-Growth Companies, Workshop Output Paper ‘Gazelles as drivers for job creation and innovation: How to support hem best?’, Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2011

Final Sectoral Reports

Ploder, M. (2011) Sectoral Innovation Watch – Automotive Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Enzing,. C. (2011) Sectoral Innovation Watch – Biotechnology Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Loikkanen, T. and J. Hyvonen (2011) Sectoral Innovation Watch – Construction Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

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Leis, M. (2011) Sectoral Innovation Watch – Food and Drinks Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Gotsch, M., C. Hipp, J. Gallego and L. Rubalcaba (2011) Sectoral Innovation Watch – Knowledge Intensive Services, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Schaffers, H., L. Rubalcaba, F. Merino, S. Giesecke, P. Schaper-Rinkel, E.-J. Velsing, and C. Montalvo (2011) Sectoral Innovation Watch – Wholesale and Retail Trade Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Giessen, van der A. (2011) Sectoral Innovation Watch – Space and Aeronautics Sectors, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Dachs, B., G. Zahradnik and M. Weber (2011) Sectoral Innovation Watch – Textiles and Clothing Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, December 2011

Final Synthesis Report

Montalvo C. and A. van der Giessen (2011) Sectoral Innovation Watch – Synthesis Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011.