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Patent Performance of the German Vehicle Industry

An analysis of patent applications with the German Patent and Trade Mark Office, taking into account industry and technology-specific priorities

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O30 - Innovation; Research and Development; Technological Change; Intellectual Property Rights: General
C81 - Data Collection and Data Estimation Methodology; Computer Programs: Methodology for Collecting, Estimating, and Organizing Microeconomic Data; Data Access

Summary

Trends like power train electrification and autonomous driving are causing a major structural change in vehicle manufacturing. This study will analyse to what extent German vehicle manufacturers are ready to cope with these challenges. The study analyses the latest trends in vehicle-related patenting activity by German manufacturers, suppliers, and service providers, focusing on the following questions: What share of overall German patenting activity can be attributed to vehicle constructing companies? Do manufacturers or suppliers account for the majority of patent applications, and hence innovations? With respect to the International Patent Classification (IPC), what are the major technological fields of research that German vehicle manufacturers are focusing on? With the conventional power train losing its relative significance, what share of patenting activity does it still account for?

The data set comprises the latest annual tranche of patent applications and our results show that German vehicle manufacturers are already well suited for the "new age", thus sharply contrasting with those opinions which claim that German vehicle manufacturing is sleeping through the structural change. Specifically, we find the following evidence:

- German vehicle manufacturing accounts for a 40 percent share of overall German patent applications, making it by far the most innovative sector.
- A mere 30 percent share of vehicle-related patent applications are allotted to the conventional power train (combustion engine, power transmission, exhaust system, etc.). This and only this portion of innovations can be expected to be hit in a negative manner by the structural change towards power train electrification. The remaining 70 percent share is already allotted to "future-proof" areas like vehicle electrics and electronics, interior and exterior, chassis, tyres, brakes, locks, etc.
- German vehicle manufacturers are leading the way when it comes to digitisation, accounting for a 43 percent share of total entries in the IPC subclass "Electric Digital Data Processing", and for more than one in six entries in "Additive Manufacturing". Typical examples for vehicle-related digitisation technology are autonomous driving, additive manufacturing of light constructional components, and driver assistance systems.
- Two thirds of vehicle-related patent applications are allotted to suppliers, focusing heavily on system suppliers like Bosch, Brose, Continental, Schaeffler, and ZF. Even if manufacturers, too, are highly innovative, it is the suppliers that account for the core innovations in German vehicle manufacturing.

1 Introduction

Almost all relevant innovation indicators place German vehicle manufacturing amongst the innovation leaders by way of comparison with other industries. For example, around 30 percent of all innovation-related business expenditure is invested in the automobile industry (1st place), 10 percent of turnover is invested in innovation (3rd place), 64.6 percent of industry employees are science and engineering workers (3rd place) and 48 percent of industry turnover is achieved with products which have been launched within the past three years (1st place).[1]

But what about the patent applications of German vehicle manufacturers? Patents are among the most meaningful measures of the innovative strength of an industry, as they are an often necessary – albeit insufficient – condition for successful technology-based innovation (Koppel, 2011). In addition, they provide information about the areas of technology in which the companies in question conduct research, and thus about the internal technological structure of an industry. On the other hand, the issue of a patent necessitates a patent application which, upon successful examination by the Patent Office, grants the applicant exclusive rights of use for its technical invention for a typical period of 20 years, including the right to exclude others from using the invention.

The present study expands and supplements the previous indicators of innovative strength by identifying, for the first time, the patent applications of German vehicle manufacturers – and specifically those patents with an explicit reference to motor vehicles[2] – by means of a special evaluation of the German Economic Institute [*Institut der deutschen Wirtschaft*] (IW) patent database. The regional distribution of German patent applications already suggests that a high number come from German vehicle manufacturers. As measured by employees, of the 85 German economic areas, the majority of patents (regardless of technology or applicant) are registered in the regions around Stuttgart, Ingolstadt, Munich, Constance, and Wolfsburg (Berger et al., 2017a). These represent the regions in which the major German manufacturers and suppliers are headquartered.

Following an explanation of the analysis methodology in chapter 2 of this study, chapter 3 will provide answers to the following questions based on the results of the analysis: What share of overall German patenting activity can be attributed to vehicle constructing companies? Do manufacturers or suppliers account for the majority of patent applications, and hence innovations? What are the major technological fields of research that German vehicle manufacturers are focusing on and to what extent are they technologically prepared for the structural change that is already taking place in the vehicle sector?

[1] Cf. Anger et al. (2018, p. 10) and Rammer et al. (2018).

[2] Within the context of this study, a motor vehicle is defined as a trackless land vehicle which is fully powered by an engine and (also) used in road transport, i.e. an automobile, motorcycle or relevant tractor unit, but not trains, ships, aircraft, vehicles with auxiliary motors for power assistance (pedelecs, pallet trucks, etc.) or machinery not approved for road use (forklifts, ride-on lawnmowers, etc.). This definition is based on Section 1 Para. 2 German Road Traffic Act [*Straßenverkehrsgesetz*] (StVG)

2 Methodology

2.1 Creation of the data set

To measure the innovative strength of German vehicle manufacturers, this study considered first-time patent registrations (priority year) with the German Patent and Trade Mark Office (DPMA). As a rule, vehicle manufacturers based in Germany initially codify their innovation-relevant research results by means of an application to the DPMA, which thus has a protective effect within Germany. The applicant then has the opportunity, within one year, to extend protection with reference to this "priority" to other countries by filing a subsequent application with the European Patent Office (EPO) or the World Intellectual Property Organization (WIPO). As a general rule, EPO or WIPO applications from the German vehicle manufacturing industry tend to be subsequent applications of this type which follow on from first-time registrations with the DPMA. In a strictly case-based consideration, these subsequent applications would lead to double counting as they relate to the same inventions. First-time registrations with the EPO or WIPO are rare in German vehicle manufacturing, and as such these are excluded from the present analysis.

The approximately 420,000 DPMA first-time patent applications between 2005 and 2015[3] in which at least one applicant was based in Germany formed the starting point of the analysis. The related information was obtained using an algorithm-based big-data analysis and can be assigned to around 35,000 different applicant entries. As a rule, the applicant is generally a company and the inventors its employees. In most cases, the latter have assigned their rights of use for the patent to their employer within the framework of the German Employee Inventions Act [*Arbeitnehmererfindungsgesetz*] (ArbnErfG) (cf. also Figure 2-1). When a patent is therefore issued, the company acts as the holder of the rights of use. A small percentage of patents are also registered by what are known as "free inventors": private individuals who act as both inventor and applicant. An even lower percentage are registered by universities, publicly funded research institutions, federal institutes or similar bodies. Only applications from companies were considered in the present analysis.

2.2 Delineation of vehicle manufacturers

To be able to record vehicle-related patent applications in a meaningful way based on this data set, in a second step patent applicants whose business activities focus on or around vehicle manufacturing were filtered out by means of a comparison with company databases as well as using internet research. One approach for this is provided by the Statistical Classification of Economic Activities (Federal Statistical Office, 2010), which lists the industries 29.1 (Manufacture of motor vehicles), 29.2 (Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers) and 29.3 (Manufacture of parts and accessories for motor vehicles). Companies from these sectors formed the subject of this analysis. Manufacturers of other vehicles such as tractors or motorcycles which fall under industry 28.3 (Manufacture of agricultural

[3] Since patent information is generally disclosed 18 months following the application at the earliest, the year 2015 represents the latest available data inventory of a complete year.

and forestry machinery) and industry 30.9 (Manufacture of other transport equipment) were also included. The company sample also included other companies whose business activities focus on vehicle manufacturing. For example, a number of specialised service providers offer research and development services on behalf of or in cooperation with manufacturers and suppliers. These companies – which are assigned to industry 71.1 (Architectural and engineering activities and related technical consultancy) or industry 72.1 (Research and experimental development on natural sciences and engineering) are included in the analysis to the same extent as, for example, metalworking companies which primarily supply vehicle manufacturers. On the other hand, companies from the downstream sectors of motor vehicle repair and automotive trade are not taken into account as these do not record any quantitatively relevant patenting activity. Also excluded are companies which, while they do serve vehicle manufacturers, also serve customers in other sectors and customers beyond the area of motor vehicles to a relevant extent. Siemens and ThyssenKrupp are examples of companies in this category. Although it is possible that this neglects a segment of motor vehicle-related patent applications, it does serve to keep the population of vehicle manufacturers as selective as possible. The alternative would be to include numerous patent applications with no obvious vehicle reference, without then being able to eliminate these in a later check of technology area (cf. Section 2.3).

The analysis of applicant activity revealed that many companies register patents on behalf of their subsidiaries. To achieve accurate and comparable results, consolidation was undertaken at the level of the group, which proved to be a particular challenge. Between 2005 and 2015 alone, Continental AG used around 50 different applicant synonyms within the meaning of subsidiaries or alternate spellings.

2.3 Delineation of vehicle technologies

In addition to an industry perspective, the present study also considers a technological perspective. Although some companies, in particular technology groups such as Bosch, have a clear focus on vehicle manufacturing, they also register numerous patents for other products such as white goods and electric hand tools, for example. These patent applications are not connected with the topic of “motor vehicles” and are thus excluded from the present analysis. In a third step, the International Patent Classification (IPC) was used to screen the patent applications of the vehicle manufacturers identified in accordance with Section 2.2 for the technology classes which relate explicitly to motor vehicles. Each patent application mentions one or more IPC groups to which the underlying invention can be assigned. The IPC divides patent applications into a highly differentiated hierarchical system (DPMA, 2018), in which all subgroups at the lowest hierarchical level have been combined with their respective main group to form common IPC groups – around 50,000 in total – for the purposes of this analysis. German vehicle manufacturers filed patents in about 3,800 of these groups between the years 2005 and 2015. These 3,800 IPC groups were manually checked and classified into the IPC groups of “vehicle-specific”, “vehicle-related” or “non-vehicle-related”. The decisive criterion used in this classification was the technological relationship.

Vehicle-specific IPC groups have a dominant technological focus on "motor vehicles". One typical example of a vehicle-specific IPC group is B60K 6.[4] This IPC group was used 399 times in patent applications submitted in 2015, of which 378 (95 percent) were applications made by vehicle manufacturers. **Vehicle-related** IPC groups have the character of cross-sectional technology from the perspective of vehicle manufacturers; this means they exhibit a positive, but not exclusive, technological connection to the theme of "motor vehicles", but at the same time are used to a significant extent by companies outside of vehicle manufacturing. One typical example of a vehicle-related IPC group is C21D 1.[5] This IPC group was used 58 times in patent applications submitted in 2015, of which 32 (55 percent) were applications made by vehicle manufacturers. In combination with registration by a vehicle manufacturer, these vehicle-related IPC groups are very likely to feature an explicit reference to motor vehicles. **Non-vehicle-related** IPC groups, on the other hand, have no technological connection to the topic "motor vehicles", even if they are used to a significant extent by vehicle manufacturers in individual cases. A typical example of a non-vehicle-related IPC group is D06F 23.[6] This IPC group was used 9 times in patent applications submitted in 2015, of which 7 (78 percent) were applications made by vehicle manufacturers. In the course of the technological survey, almost 1,700 of the 3,800 IPC groups used by vehicle manufacturers were classified as non-vehicle-related. Patent applications which also included just one of these non-vehicle-related IPC groups were removed from further consideration in their entirety. These included, for example, refrigerators, washing machines, jigsaws, etc.

2.4 Evaluation of the data set

Given that the IW patent database is still under construction, the evaluation of results for the data set will initially be carried out for the year 2015. An extrapolation of the results and the development of a corresponding time series are planned. The assignment of a patent application to the result categories is given an equal fractional weighting across all evaluation dimensions. In the case of an individual patent applicant based in Germany, a patent application will generally be assigned a factor of 1; in the case of several applicants based in Germany, these will be assigned equal values which total a factor of 1. In the case of one or more applicants based abroad, these will also be assigned equal values, less the patent share attributable to foreign applicants; consequently, these values will total a factor of less than one.[7]

The fictitious example used is a joint application by a German supplier featuring a German manufacturer and a US-based service provider. This patent application notes three IPC groups, each categorised as either vehicle-specific or vehicle-related (cf. Section 2.3). In this case, each of the IPC groups receives a value of one third; in the case of the German applicants, this value is also attributed to one of the technology clusters from Section 3.4. However, if just one of the three

[4] Arrangement or mounting of plural diverse prime-movers for mutual or common propulsion, e.g. hybrid propulsion systems comprising electric motors and internal combustion engines

[5] General methods or devices for heat treatment, e.g. annealing, hardening, quenching or tempering

[6] Washing machines with receptacles, e.g. perforated, having a rotary movement, e.g. oscillatory movement, the receptacle serving both for washing and centrifugally draining

[7] Given that this analysis measures the innovation performance of German vehicle manufacturers (cf. also Section 2.5), this therefore serves to eliminate the shares of co-applicants based abroad.

IPC groups was categorised as non-vehicle-related, the patent application was eliminated from the analysis.[8]

In the applicant category, the manufacturer or supplier is assigned a value of one third, while the US-based service provider receives a value of zero. Thus overall, only two thirds of the patent application accounted for by the two German vehicle manufacturers are included in the valuation. Fractional values of applicants who are not categorised as vehicle manufacturers are omitted from the aggregation, as are generally those of applicants based abroad. All fractional values greater than zero are assigned to one of the categories of "supplier", "manufacturer", etc. according to the category of the respective applicant (cf. Section 3.2).

The bottom line is that the relevant question in the present study is not how many patents are registered by companies from industries 29.1 to 29.3, but how many patents are registered by German companies with a dominant focus on vehicle manufacturing in areas of technology which relate explicitly to motor vehicles. Accordingly, this study only analyses first-time DPMA patent registrations by companies in which:

1. at least one applicant is based in Germany (regional reference);
2. the primary focus of the applicant's business is in vehicle manufacturing or as a supplier for the vehicle sector (industry reference); and
3. the registered patent features an explicit reference to vehicle technology (technology reference).

[8] Two fictional patent applications, each assigned to the IPC group "Electrical motors" and one other IPC group, serve to illustrate this logic. In combination with the vehicle-specific IPC group B60J 1 (Windows; Windscreens; Accessories therefor), the patent application relates to a vehicle window regulator or similar; in combination with the non-vehicle-related IPC group B25D 11 (Portable percussive tools with electromotor drive) however, it relates to an impact drill.

2.5 Excursus 1: Patent applications of foreign parent companies

German vehicle manufacturers are particular in that the foreign parent companies of German subsidiaries regularly act as patent applicants. This is especially true of Ford and Opel. In 2015, Ford filed a total of 238 DPMA first-time patent registrations through Ford Global Technologies based in Dearborn, (USA); in all cases at least one – and often all – of the associated inventors were resident in Germany. In the same year, Opel filed 169 patent registrations of this type through GM Global Technology Operations based in Delaware, USA. Not least because of the generally close proximity of the inventors' residences (see Figure 2-1) to the German production and research facilities of Ford and Opel (e.g. in Cologne, Aachen, and Rüsselsheim), it can be assumed that these innovations were developed primarily in the German subsidiaries, but were registered in the names of the US parent companies.

Figure 2-1: Registration of a GM patent, presumably developed by Opel

(19) Deutsches Patent- und Markenamt

(10) **DE 10 2015 015 939 A1** 2017.06.08

(12) **Offenlegungsschrift**

(21) Aktenzeichen: **10 2015 015 939.9**
(22) Anmeldetag: **08.12.2015**
(43) Offenlegungstag: **08.06.2017**

(51) Int Cl.: ***B60N 2/42*** (2006.01)
B60N 2/015 (2006.01)
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(56) Ermittelter Stand der Technik:

DE	39 28 869	A1
DE	10 2010 045 997	A1
US	2006 / 0 202 513	A1

Rechercheantrag gemäß § 43 Abs. 1 Satz 1 PatG ist gestellt.

Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

(54) Bezeichnung: **Kraftfahrzeugsitzanordnung**

Source: DPMA, 2018c

This fact makes a decisive difference from the point of view of Germany as a business location, as the necessary control rights and rights of use for prospective patents are not located in Germany. In addition, prospective licensing fees do not flow to the subsidiary. Such royalties are fundamentally important for innovation, and subsidiaries otherwise tend to be reliant on licenses from the parent company. That this situation can represent a significant disadvantage for subsidiaries was made clear not least in the context of PSA Group's takeover of Opel. On the other hand, a patent application developed abroad but controlled by a German parent company (as in the case of VW's Brazilian subsidiary, for example), is diametrically opposed to this from

the point of view of Germany as a business location. Accordingly, in this study the latter are attributed to the German location; the former, however, are not. The Opel and Ford patent applications above represent a share of about 2.5 percent as measured against the patent applications filed and monitored by German manufacturers, suppliers, etc.

2.6 Excursus 2: Industry-Technology concordance

The concordance between industries and technologies developed by Schmoch et al. (2003) is still used regularly in contemporary analyses. In their influential work, the authors examined the relationships between IPC subclasses – i.e. aggregates from several IPC groups and industries – and used these to derive a corresponding matrix. For various reasons, however, this concordance was not used for the present study. In a first step, the concordance scheme by Schmoch et al. (2003) assigns IPC subclasses exclusively to certain industries – namely those with the highest proportion of patents in this IPC subclass. This approach makes it possible to capture the technological core of an industry, but not its entire technological structure. As might be expected, Schmoch et al. (2003) consider the internal combustion engine, as well as numerous other IPC groups also identified as specific to motor vehicles in the present study, to be the core of vehicle manufacturing. As documented in the list provided in the appendix (https://www.iwkoeln.de/fileadmin/user_upload/Studien/Report/PDF/2018/IW-Report_2018-34_Anhang_Patentleistung_KFZ_Unternehmen.xlsx; German only) to this study and in the results from Section 3.4, however, the complete vehicle manufacturing portfolio also includes numerous cross-sectional technologies such as digitisation and materials. These are fundamentally important to vehicle manufacturing and, while described in the concordance by Schmoch et al. (2003), they are assigned exclusively to other industries.

Secondly, the statements on the delineation of vehicle manufacturing in Section 2.2 show that restricting this to its core industries, as applied in Schmoch et al. (2003), ignores significant vehicle-specific companies. Thirdly, it has proven to be problematic that the data inventory in Schmoch et al. (2003) essentially comprises the years prior to 2000. As a result of technological progress, any concordance is valid for a limited period only and becomes less accurate over time. With regard to vehicle manufacturing, for example, entire IPC subclasses like B06W (e.g., Control Systems Specially Adapted For Hybrid Vehicles) and B33Y (Additive Manufacturing) have now been added, which did not even exist in the original concordance. Vehicle manufacturing has also seen major structural shifts within and between areas of technology in recent years. The additional category of “vehicle-related IPC groups” enables the present study to capture not just the core of vehicle technology, but its entire spectrum including cross-sectional technologies. All things considered, cross-sectional technologies such as electronics, materials, etc. are now of even greater importance than the traditional core area relating to the internal combustion engine (cf. Section 3.4).

3 Application: Evaluation of Patent Applications of the German Vehicle Manufacturing Industry in 2015

As described in the previous chapter, within the framework of the preparatory methodology work we used a bottom-up approach to identify companies and technology classes which we were able to allot to the German vehicle manufacturing industry. In a next step, we evaluated the patent applications submitted in 2015 on this basis and analysed the patent performance of the companies that we allotted to the German vehicle manufacturing industry. The results are in line with patent performance as it stands today (cf. footnote 3).

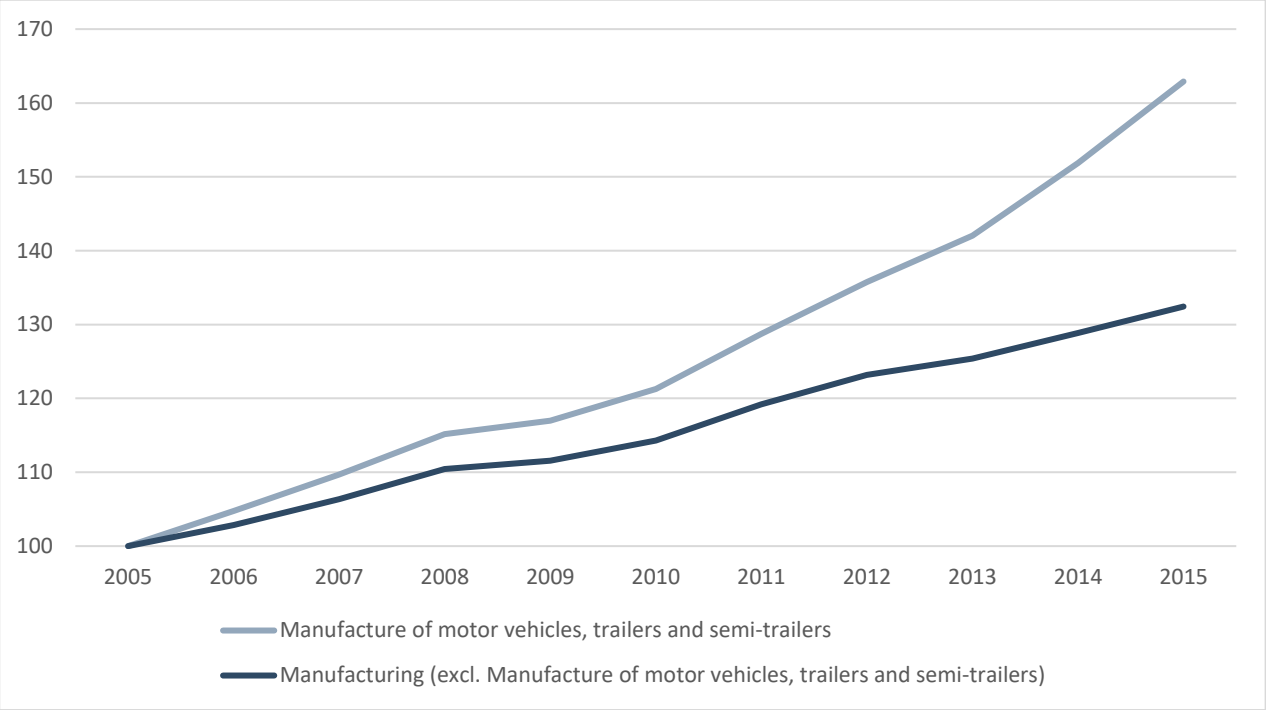
For the present analysis, a total of 38,196 first-time DPMA patent registrations were submitted in 2015, taking into account all technologies and applicants; of these – less the cumulative shares of co-applicants based abroad – around 38,080 full-patent-equivalent (FPE) applications can be attributed to applicants based in Germany (filter: Germany). Of these – excluding pure applications by non-vehicle manufacturers and less their cumulated share in co-applications with vehicle manufacturers – around 17,321 FPE applications can be attributed to vehicle manufacturers based in Germany (filter: vehicle manufacturers). From these applications, around 15,195 FPE applications can be attributed exclusively to vehicle-specific or vehicle-related IPC groups (filter: vehicle technology).[9] Consequently, motor vehicle patents (i.e. applications by German vehicle manufacturers in the field of vehicle technology) were responsible for 40 percent of all first-time DPMA patent registrations in 2015.

This very high share of FPE applications submitted in 2015 highlights the major role that vehicle manufacturers play in German innovation performance. The results are in line with other indicators of the importance of the industry as a driver of research and development in Germany. Of particular note here are the research and innovation-relevant indicators already mentioned in the introduction. Surveys of national accounts (Federal Statistical Office, 2018) also serve to underline the clearly disproportional share of Germany's research performance attributable to vehicle manufacturing. The development of gross fixed assets in other assets (intellectual property, livestock, and crops) since 2005 gives an indication of this. In line with the classification of industries of the Federal Statistical Office – which is not completely congruent with the classification developed in the study – manufacturers of motor vehicles and motor vehicle parts (i.e. industries 29.1 to 29.3) increased their intellectual property assets by just over 63 percent between 2005 and 2015 (see Figure 3-1). In the wider manufacturing sector on the other hand, i.e. excluding manufacturers of motor vehicles and motor vehicle parts, this asset class grew by around 32 percent.

[9] Put another way, a total of 2,126 of the cumulative 17,321 full-patent-equivalent applications submitted by German vehicle manufacturers, and thus a quantitatively relevant amount, were excluded because they lacked reference to motor vehicles; these related to washing machines, impact drills, and similar devices.

Figure 3-1: Gross capital stock "other products" at replacement cost; 2005 = 100

Other products: Intellectual capital investments (Software, Databases, Research and development, Copyrights, Mineral exploration), Lifestock, Crop plants



Source: German Federal Statistical Office, 2018

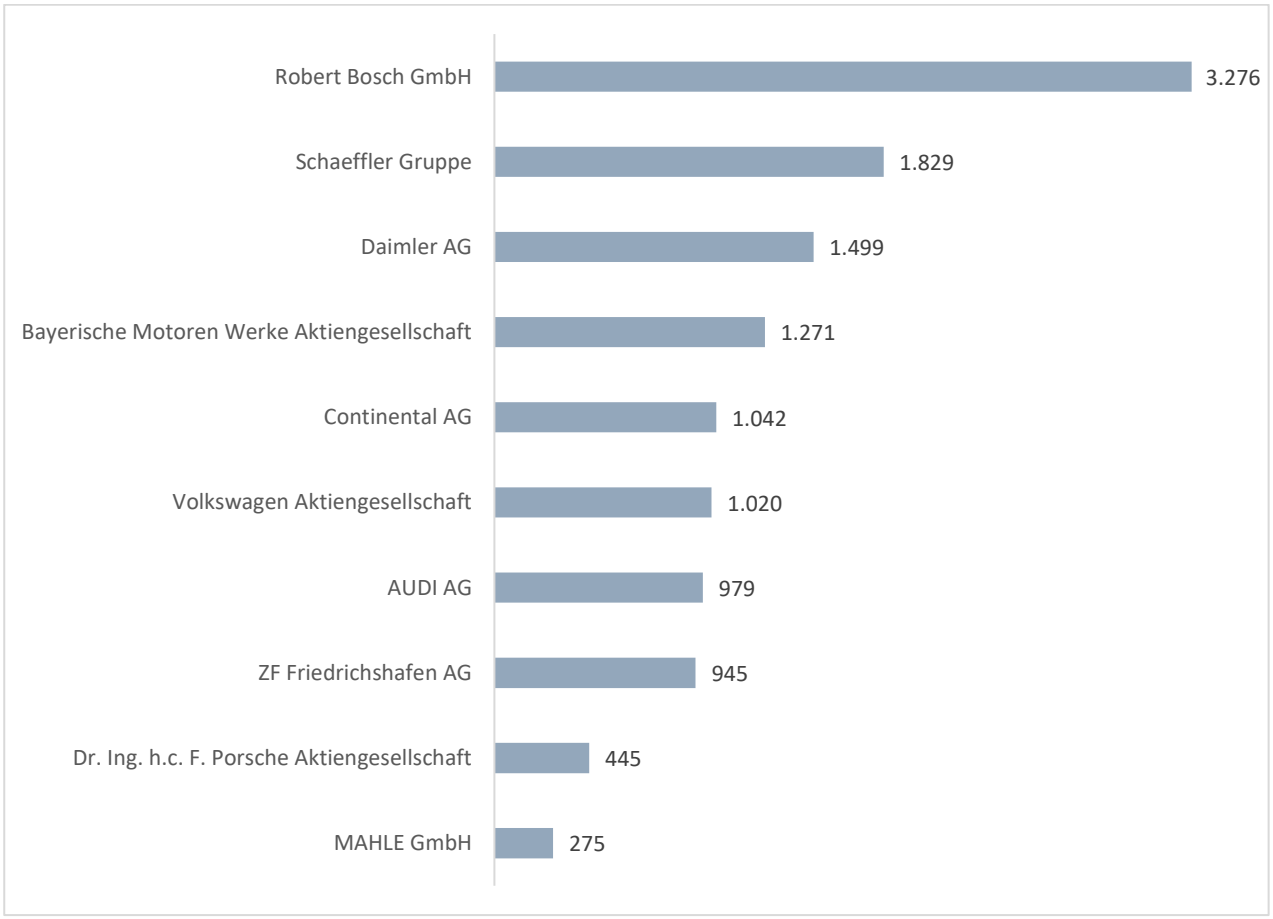
It should be noted that the gap between vehicle manufacturing and the wider manufacturing sector is visibly increasing at present. Up until the year 2000, however, there was no significant difference in development between the two groups. Taking into account the trends in the global vehicle industry such as power train electrification and autonomous driving (Buss/Berking, 2018), there is considerable evidence from today's standpoint that the share of vehicle manufacturing in patent applications is likely to increase in subsequent years.

3.1 Identification of companies undertaking patenting activity in 2015

As part of the preliminary methodology work, we identified a sample of companies undertaking patenting activity which we attribute to German vehicle manufacturing. Of this group, 226 companies undertook patenting activity in 2015, meaning they appeared as a patent applicant on at least one occasion. Further analysis of these companies also revealed significant differences in patenting activity between companies. Particularly striking is the concentration of patent applications on a relatively small number of companies. Considering the fractional counting method (cf. Section 2.4), only 84 companies reported more than five vehicle-related full-patent-equivalent applications, with just 16 companies reporting more than 100. However, a staggering 12,579 FPE applications were attributed to the ten most active patent applicants in the sample (see Figure 3-2).

Figure 3-2: The top 10 patent applicants from vehicle manufacturing in 2015

Full-patent-equivalent applications (vehicle-specific or -related IPC groups)

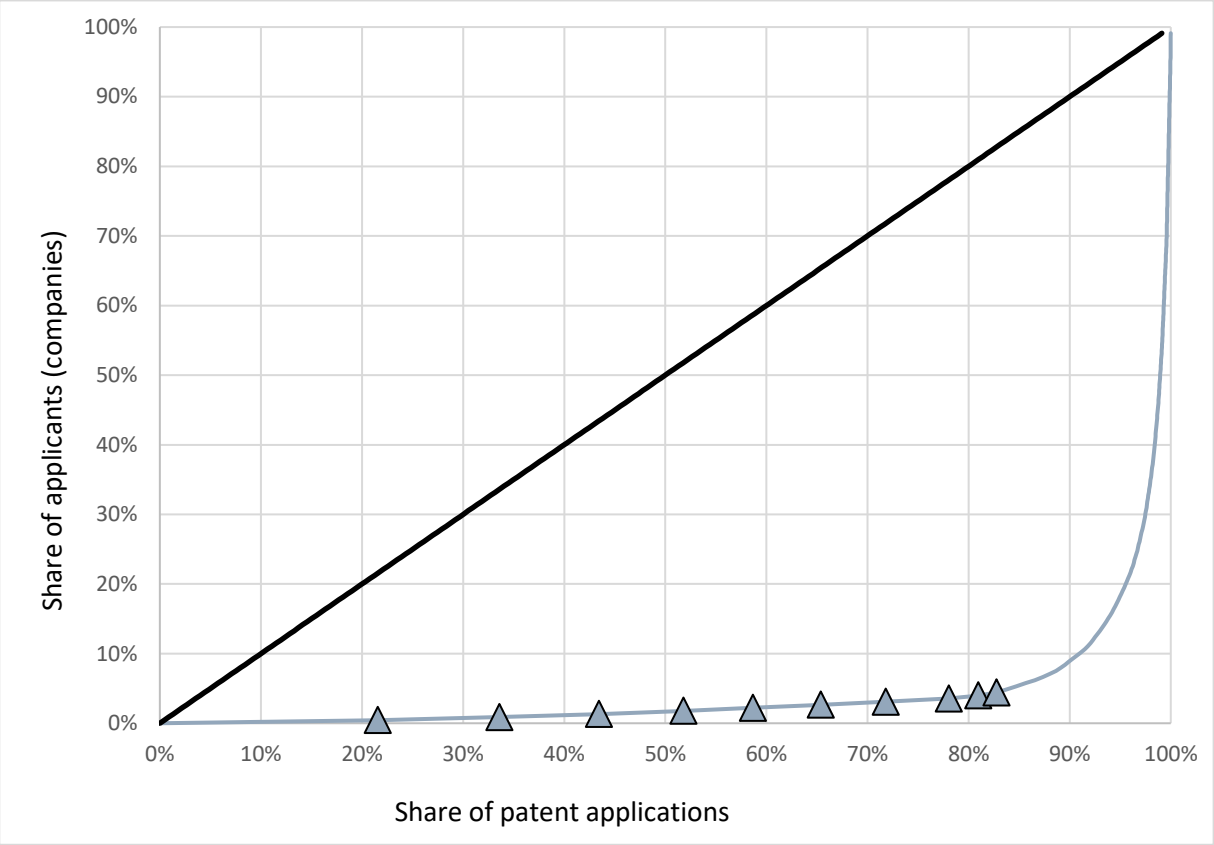


Source: IW patent database; DPMA, 2018c; own calculations

This corresponds to a share of almost 83 percent of the patent applications allocated to the vehicle manufacturing industry in the year under review. There are considerable discrepancies between the ten companies with the largest number of applications, however. The company with the highest number of applications in 2015 had nearly twelve times as many FPE applications as the company at number 10 on the list. Significant differences such as these result in patenting activity being concentrated on just few companies, as clearly illustrated by the Lorenz curve shown on Figure 3-3. The following graph shows the cumulative frequency of full-patent-equivalent applications for companies from the vehicle manufacturing industry undertaking patenting activity in 2015, with the ten companies listed in Figure 3-2 plotted separately.

Figure 3-3: Strong concentration of patent applications

Cumulated shares of full-patent-equivalent applications (vehicle-specific or -related IPC groups) and patenting vehicle companies; 2015



Source: IW patent database; DPMA, 2018c; own calculations

It should be noted that we have decided to consolidate patent applications for the Volkswagen Group at Group level in light of the patent application strategy used by the company and observed in the data set. If we combine the aforementioned patent applications submitted by Volkswagen, Audi, and Porsche and add to this the applications submitted by the commercial vehicle manufacturer MAN SE – in 12th place on the list of companies from the vehicle manufacturing industry undertaking patenting activity in 2015 – then the result for the Volkswagen Group based on the fractional counting method is a total of 2,589.6 full-patent-equivalent applications for the year under review. Consolidating the Volkswagen Group would increase the patent performance of the ten most active companies in 2015 to 13,014.1 FPE applications. This Group's share of total FPE applications within the vehicle manufacturing industry in 2015 was thus 85.6 percent, with the above Figure suggesting that this value is very stable.

3.2 Distribution of patent applications between manufacturers and suppliers

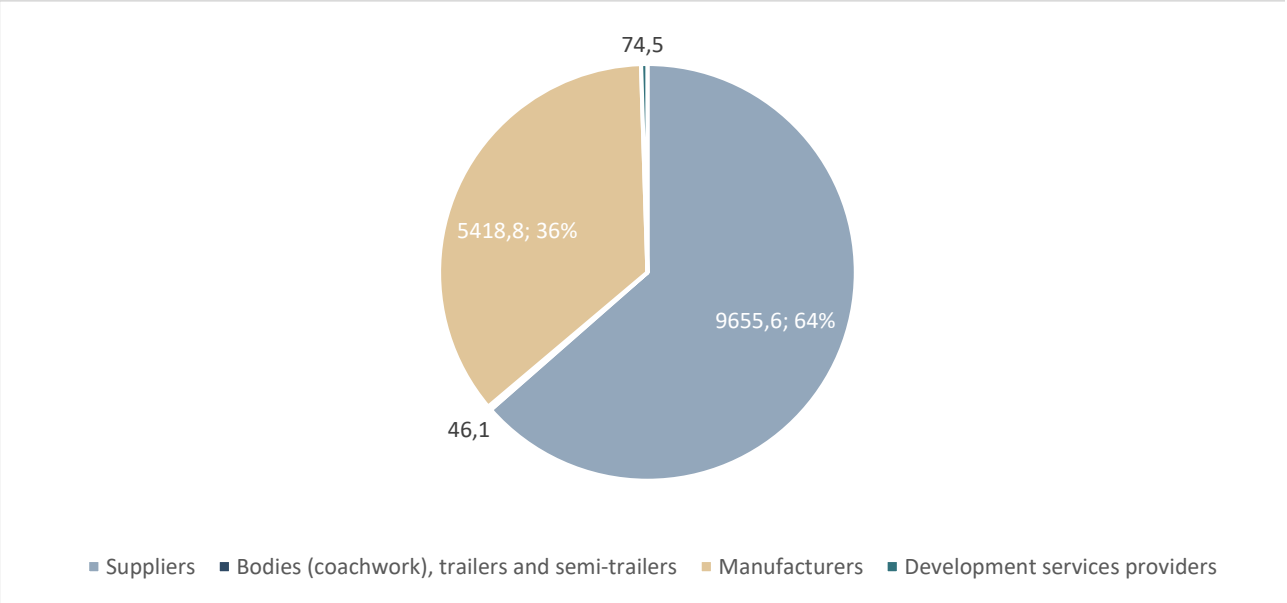
The list of the ten most active patent applicants (see Figure 3-2) includes only well-known industry names. In addition to well-known German manufacturers, the list also includes the largest automotive suppliers in Germany. This suggests that the majority of innovations are generated by large companies at the top of the value chain.

This study aimed to map the value chain of the vehicle manufacturing industry as completely as possible. All vehicle companies were therefore included among the analysed companies, however, the vast majority of the 226 companies from the vehicle manufacturing industry which undertook patenting activity fell into the supplier group. This group covers everything from system suppliers to the companies which manufacture individual components for suppliers. In addition to “Manufacturers” and “Suppliers”, we also included “Manufacturers of trailers, semi-trailers and special vehicles” and “Service providers” as separate groups in our company sample.

In a further analysis step, we allocated the patenting activity of 2015 to these four groups (see Figure 3-4) in order to determine where in the value chain the majority of patents were filed.

Figure 3-4: Innovative strength of the supply industry

Full-patent-equivalent applications (vehicle-specific or -related IPC groups) in 2015 by company type



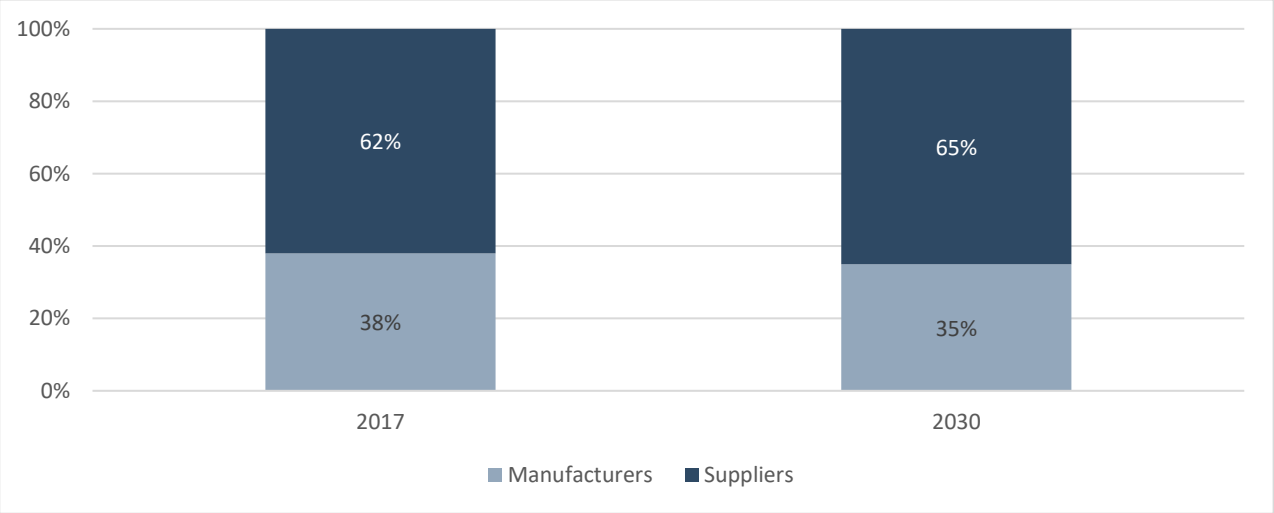
Source: IW patent database; DPMA, 2018c; own calculations

This figure, too, presents a clear picture. Almost two-thirds of the patenting activity was undertaken by suppliers, with the overwhelming majority of registrations attributable to the major system suppliers. In 2015, the ten most active suppliers registered slightly more than 8,017 FPE applications, i.e. around 83 percent of all FPE applications in this sub-class. Manufacturers registered slightly more than one third of the FPE applications registered by the German vehicle manufacturing industry, which represents a considerable proportion given the small number of manufacturers. It is important to bear in mind here that the analysis of patent applications is based on the rights of use of patented inventions. This can lead to contract research being allocated to the contractor rather than to the innovator. This offers an explanation for the supposedly low patenting activity of service providers: service providers are inevitably allocated lesser importance for patent applications in the present study because they often do not appear as patent applicants. This same issue can also present itself in the internal relationship between manufacturers and suppliers, as manufacturers outsource larger portions of the added value –

as well as research and development activities – to suppliers (Stifterverband, 2015). Even if actual research and patenting activity is slightly under- / overestimated at the lower / upper end of the value chain, the bottom line is that suppliers clearly dominate, and this is in line with other key figures from the industry. Suppliers also provide the majority of added value in the global vehicle manufacturing industry. At present approximately two-thirds of total value-added can be attributed to suppliers (see Figure 3-5). In Germany on the other hand, with its strong supply industry, a value-added share of up to 70 percent can be assumed.

Figure 3-5: Global value-added share by type of market participant

Percentage of added value in the production of automobiles



Source: Buss/Berking, 2018, p. 55

The above forecast assumes that the value-added share of suppliers will continue to increase in the future (see Figure 3-5). Here again, megatrends such as power train electrification and autonomous driving are emerging as drivers, and tend to favour the position of system suppliers. However, these trends will also lead to significant shifts within the supplier industry. Demand will increase for electrics and electronics expertise, while competencies in the production of conventional power trains or in metal processing will become less important. The processes of concentration evident in the supply industry for years can also be understood as preparation for these changes. System suppliers are increasingly expanding their range of skills in areas of technology which show promise for the future. In a further step, we will therefore examine the weighting of these particularly promising technological competencies on patenting activity in 2015. To do this, it is first necessary to carry out an analysis of the IPC groups used by the German vehicle manufacturing industry in 2015.

3.3 Analysis of the technology classes used in 2015

In addition to evaluating the patenting activity of German vehicle manufacturers in 2015 by company, this study will also conduct an analysis on the basis of technology. As part of the preliminary methodology work, we identified a total of 3,770 IPC groups that were used by German vehicle manufacturers for patent applications during the period from 2005 to 2015. Within the context of a manual inspection, we identified a total of 2,057 IPC groups which we have classified as either vehicle-specific or vehicle-related (see https://www.iwkoeln.de/fileadmin/user_upload/Studien/Report/PDF/2018/IW-Report_2018-34_Anhang_Patentleistung_KFZ_Unternehmen.xlsx). Of these, a total of 1,317 were cited in patent applications in 2015 which we attributed to the German vehicle manufacturing industry.

Given that a patent application is usually assigned to several technology classes, the total number of IPC group entries was 36,550 and thus far greater than the number of registered patents. Each IPC group was cited just under 28 times on average. However, an analysis of the data set shows that a strong concentration can be observed for the IPC groups used in 2015. Although this is not as pronounced as in the company breakdown, it is nevertheless noticeable. The findings here show that the 15 most frequently used IPC groups (see Table 3-1) account for 20 percent of the entries. Half of the entries are distributed across 80 IPC groups, and 75 percent can be allocated to just 223 IPC groups. The final decile of entries is made up of 865 IPC groups which are often used only for a single application. These figures serve to emphasise that German vehicle manufacturers have clear technological priorities in their patent applications. As shown in Table 3-1, the most commonly used IPC groups from 2015 relate to very different segments. One clear priority is electronic components, sensors, and electronic control devices. Three of the top 15 most cited IPC groups relate to the direct conversion of chemical to electrical energy (H01M 2/8/10), which essentially implies battery technology. Another two are concerned with the integration of different drives (B60K 6, B60W 10), i.e. hybrid vehicles. These five categories have also been attributed to alternative drives by other authors (Aghion et al., 2016), but within the framework of a top-down approach.

In a further step, we looked at all IPC groups used by German vehicle manufacturers in 2015 and analysed the number of entries for all companies across all applicants and patent applications, before calculating the resulting share of German vehicle manufacturers. This ratio turned out to be very high in the case of the most widely used technology classes (see Table 3-1). The lowest shares are found in the three battery-related IPC groups, which should come as no surprise given that batteries also have numerous applications outside of vehicle manufacturing. But even here, the share allotted to vehicle manufacturers is between 81.3 and 81.1 percent. This rate is even higher in the other categories, with a maximum value of 99.8 percent in the ‘Friction clutches’ category. These values underscore the fact that it is these IPC groups which shape the technological core of the vehicle manufacturing industry.

Table 3-1: The 15 IPC groups most frequently cited by German vehicle companies

Entries and share of all entries submitted by German vehicle companies; 2015

IPC group	Entries	Ratio	Description of IPC group (shortened in some cases)
B60R 16	793	93.8%	Electric or fluid circuits specially adapted for vehicles and not otherwise provided for; Arrangement of elements of electric or fluid circuits specially adapted for vehicles and not otherwise provided for
G08G 1	785	88.1%	Traffic control systems for road vehicles (excl. traffic signs)
B60W 30	740	96.2%	Purposes of road vehicle drive control systems not related to the control of a particular sub-unit, e.g. of systems using conjoint control of vehicle sub-units
F16D 13	572	99.8%	Friction clutches
F16F 15	543	92.5%	Suppression of vibrations in systems; Means or arrangements for avoiding or reducing out-of-balance forces, e.g. due to motion
B60W 40	493	97.0%	Estimation or calculation of driving parameters for road vehicle drive control systems not related to the control of a particular sub-unit
H01M 10	471	81.3%	Secondary cells; Manufacture thereof
F02D 41	433	94.9%	Electrical control of supply of combustible mixture or its constituents
H01M 2	419	85.1%	Constructional details, or processes of manufacture, of the non-active parts
H01M 8	390	84.7%	Fuel cells; Manufacture thereof
B60K 6	378	94.7%	Arrangement or mounting of plural diverse prime-movers for mutual or common propulsion, e.g. hybrid propulsion systems comprising electric motors and internal combustion engines
B60W 10	356	92.7%	Conjoint control of vehicle sub-units of different type or different function
B60R 21	342	93.9%	Arrangements or fittings on vehicles for protecting or preventing injuries to occupants or pedestrians in case of accidents or other traffic risks
F01L 1	330	92.7%	Valve-gear or valve arrangements, e.g. lift-valve gear
B62D 25	328	93.7%	Superstructure sub-units; Parts or details thereof not otherwise provided for

Source: IW patent database; DPMA, 2018c; own calculations

High shares are, though, not specific to the most commonly used technology classes (see https://www.iwkoeln.de/fileadmin/user_upload/Studien/Report/PDF/2018/IW-Report_2018-34_Anhang_Patentleistung_KFZ_Unternehmen.xlsx). A total of 8,276 entries are attributed to technology classes which we classify as vehicle-specific, for example. Of these, 313 are allocated to technology classes in which the share of total entries submitted by vehicle manufacturers is less than 75 percent. Just 42 entries were made in categories which we classify as vehicle-specific, in which fewer than 50 percent of the entries were attributed to German vehicle manufacturers.

As expected, this rate is somewhat lower for vehicle-related IPC groups, as it can also be assumed that other sectors are using these technology classes. Typical examples include patent applications for chemical processes, general electronic components or methods for processing plastics. The category of vehicle-related IPC groups accounts for a total of 28,494 entries, of which 13,766 are attributable to groups in which the share of total entries submitted by vehicle manufacturers is less than 75 percent. If we set the limit at a share of 50 percent, the number of entries in IPC groups with a lower share falls to 6,055.

Patent applications submitted by vehicle manufacturers in 2015 referenced IPC groups which resulted in the exclusion of the publication from our consideration a total of 3,086 times. Amongst these excluded applications were a number which referenced classes with both a relevant number of entries and a high share. However, a manual check of these technology classes clearly showed that these were specific to household appliances and tools and thus that the exclusion was justified.

Lastly, the ratios referred to above indicate that the present study has succeeded in mapping the full technological spectrum of the German vehicle manufacturing industry as accurately as possible. Moreover, the analysis by Schmoch et al. (2003, p. 34) using the Industry-Technology concordance reveals that the distribution of the IPC groups used in vehicle manufacturing has the most homogenous pattern across all sectors in an international comparison. We are therefore optimistic that it will also be possible to carry out comparable evaluations for vehicle manufacturing sectors in other countries. To facilitate such investigations, a complete list of the IPC groups examined as well as information regarding the number of references to these classes is available for download or on request.

3.4 Clustering of technology classes by application area

In the final step, we clustered the IPC groups used in 2015 by application area in order to identify the priorities of German vehicle manufacturers in relation to patenting activity. We also wanted to investigate the weighting of vehicle assemblies particularly affected by the upcoming technological change in the patenting activity during the year under review and how strongly this activity could be allotted to application areas which showed particular promise for the future. For this purpose, we subdivided the vehicle-specific and vehicle-related technology classes into a total of eight categories. We set ourselves the goal of forming clusters which give an impression of the extent to which German vehicle manufacturers conduct patenting activity in areas that are compatible with the global trends on the motor vehicle market. Here again we utilised

a bottom-up approach, assigning all IPC groups defined as vehicle-relevant or above to a cluster. The technology clusters were delimited as follows:

1. **Digitisation:** The selection of the relevant technology classes was taken from Berger et al. (2017b). This cluster includes a total of 88 IPC groups which appeared in publications of vehicle manufacturers in 2015. The focus of this cluster is on electronic communication and data processing.
2. **Conventional power train and mechanical power transmission**: This cluster includes technology classes representing vehicle components which will be adversely affected in terms of their significance by the continued electrification of the power train. This category includes a total of 408 IPC groups, 291 of which were utilised in 2015. The focus here is on patent applications for internal combustion engines (including their control systems) and mechanical power transmission systems (clutches, gearboxes, hydraulics). A further noteworthy area of application for this cluster is the exhaust gas system.
3. **Electrics, electronics, and sensors**: This cluster includes technology classes that deal with the use of electric current in the vehicle. This category includes a total of 345 IPC groups, 235 of which were utilised in 2015. The spectrum ranges from cables and plugs to components for electronic data processing. The focus here includes the conversion of chemical to electrical energy, control electronics, as well as all types of sensor and device for processing sensor data (provided not already included under cluster 1).
4. **Arrangements, procedures, tools**: This mixed cluster includes technology classes which are not related to specific devices but are aimed at the application of design and material knowledge. This category includes a total of 377 IPC groups, 272 of which were utilised in 2015. The focus here is on the configuration of components such as sensors and drives, measurement and testing procedures, as well as processes for the production of materials and components.
5. **Thermal management**: This cluster includes all technology classes related to the production or regulation of heat and cold in the vehicle. This category includes a total of 68 IPC groups, 48 of which were utilised in 2015.
6. **Other**: This cluster includes all technology classes which could not be assigned to any other cluster, such as those including adhesives or types of chemical compound which could not, with reasonable effort, be given a more specific assignment. This category includes a total of 409 IPC groups, 222 of which were utilised in 2015. Given that the IPC groups in this cluster tend to be referenced only a small number of times, no focus could be determined here.
7. **Vehicle components**: This cluster includes technology classes which relate to assemblies such as the interior, exterior or chassis. These classes in particular should be largely unaffected by the current megatrends. This category includes a total of 197 IPC groups, 137 of which were utilised in 2015. The focus here is on tyres and bodies (coachwork) as well as lighting and safety systems.
8. **Trailers, semi-trailers, and special vehicles**: This cluster includes technology classes which essentially relate to the construction of lorry trailers and semi-trailers. Also included are those for special vehicles, which includes everything from ambulances to combine harvesters. This category includes 169 IPC groups, 88 of which were utilised in 2015.

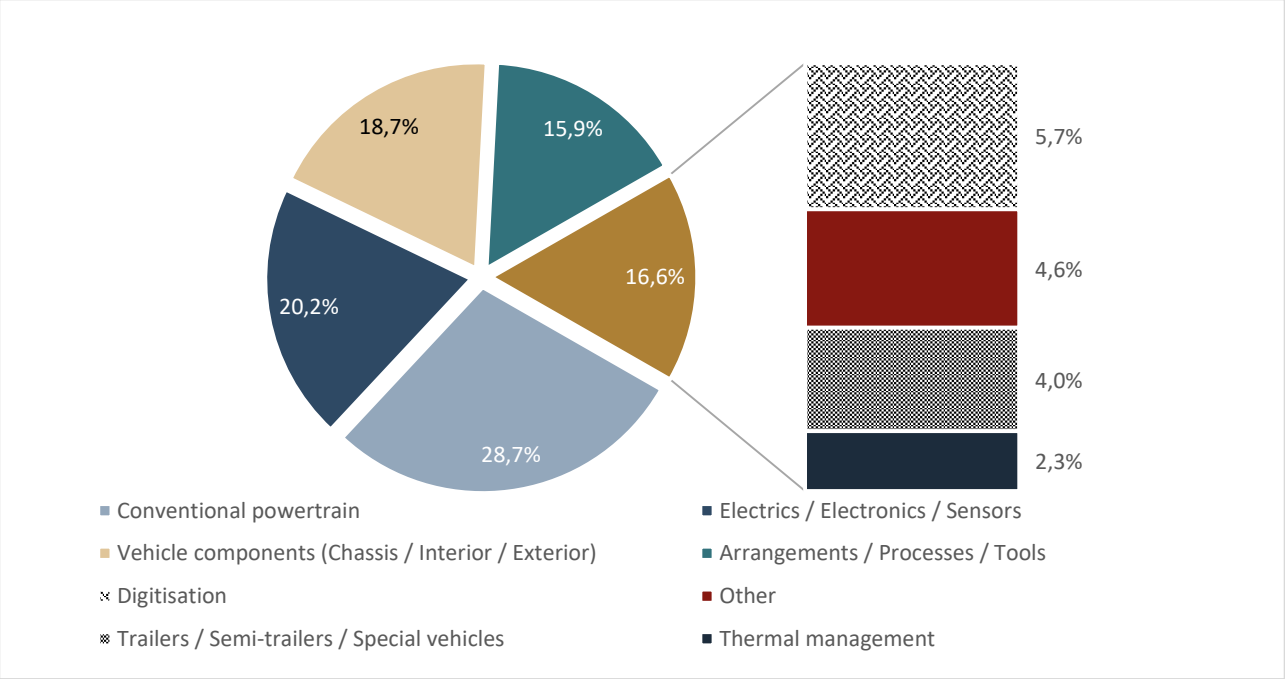
The above clustering allows us to map the full range of patent applications submitted by German vehicle manufacturers in as clear a way as possible. Uncertainties remain only in technology classes with a description that does not allow for unambiguous assignment. For example, it is not generally possible to determine whether a pump will be used in a hydraulic system or in a cooling system. In case of doubt, such IPC classes were assigned to category 4. This uncertainty tends to affect only less utilised technology classes, however, so the overall results are considered very stable. In any event, a comparison with clustering using the top-down approach (Aghion et al, 2016) showed a high degree of congruence in the classification of technology classes, whereby, as mentioned above, the authors restricted themselves to a few select technology areas such as the internal combustion engine or the hybrid drive.

Within the context of the evaluation, we used fractional weightings for patent applications which were allocated to technology classes from different clusters. Figure 3-6 illustrates the allocation of vehicle-related patent applications by German vehicle manufacturers and shows that the conventional power train still plays a significant, but by no means dominant, role in patent applications. The share of the "Conventional power train and mechanical power transmission" cluster across all 15,195 full-patent-equivalent applications is less than 30 percent. Thus 70 percent of the patenting activity is accounted for by clusters which should be comparatively less affected by the current megatrends within vehicle manufacturing. With a share of 5.7 percent in the area of "Digitisation" and 20.2 percent in the "Electrics, electronics, and sensors" cluster, it is already the case that the categories which are of particular importance for the introduction of alternative drives and autonomous driving are almost on a par with conventional power trains. With regard to the corresponding challenges faced by German vehicle manufacturers, Stifterverband postulated in 2015, for example, that "the digital components of a vehicle are at least as important as conventional production parts" (Stifterverband, 2015). The current evaluation indicates that German vehicle manufacturers have already successfully faced up to this challenge as regards digitisation and further development in sustainable high-tech areas. In a cross-comparison with other industries, it is also clear that vehicle manufacturing in Germany is now playing a pioneering role in the field of digitisation. In 2015, for example, approximately 43 percent of all patent applications in the IPC sub-class G06F (Electrical Digital Data Processing) were made by vehicle manufacturers.[10] As a further example from the field of digitisation, it should be noted that more than one in six German patent applications in the field of additive manufacturing were registered by a vehicle manufacturer.

[10] Schmoch et al. (2003) had assigned this IPC sub-class exclusively to the telecommunications industry.

Figure 3-6: Conventional power train not in dominant role

Patent applications submitted by German vehicle manufacturers in 2015 by technology cluster



N=15,195 full-patent-equivalent applications for vehicle-specific or vehicle-related IPC groups submitted by vehicle manufacturers
Source: IW patent database; DPMA, 2018c; own calculations

It should be noted that the entries in the "Arrangements, procedures, tools" cluster may also relate to digitisation themes. This applies in particular to sensor configuration and measurement procedures. The actual significance of digitisation technology for the vehicle manufacturing industry is thus likely to extend well beyond the digitization cluster. These figures confirm the high weighting of future-oriented themes in the development activities of vehicle manufacturers with the consistent further development of the conventional power train. Our results thus reflect the implementation of the diversification strategy and refute the claim often made in public and politics that "vehicle companies are sleeping through the structural change". Under no circumstances should the importance of the developments summarised in the "Vehicle components" cluster be underestimated. The specifications of brakes, steering systems, controls, seats, and locks have a major impact on a customer's willingness to pay, as these components strongly influence the perceived utility of the vehicle. Such components are therefore extremely important for market success, however they are still ignored in many considerations relating to innovative strength. The share of these components in patent applications of almost 19 percent indicates that consistent further development is also taking place in this area. This also serves to ensure the competitiveness of the vehicle manufacturing industry.

It should be noted that the evaluation is based on 2015 data. This year can be seen as a turning point, after which the development of alternative propulsion systems and autonomous driving systems once again gained considerable momentum. There is thus some evidence to indicate that the focus in subsequent years will tend to move further away from the conventional power train. Further research is required in order to verify this hypothesis.

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