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Global innovations: Evidence from patent data

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Global Innovations – Evidence from Patent Data

Peter Neuhäusler, Rainer Frietsch

**Studien zum deutschen Innovationssystem
Nr. 13-2017**

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0 Summary

Global innovations have been on the rise in the last decade. About 4.5% of all transnational patent filings are global innovations, i.e. research projects that are handled by teams in different continents, and the number has grown quite significantly since the 1990s. Global innovations have also gained importance in international cooperations per se. In 2013, nearly 70% of all international co-patents were global innovations. Global innovations also outperform the average patent in terms of patent quality, i.e. global innovations are significantly higher cited and are broader in terms of market coverage. Europe and North America show the highest numbers of global innovations in absolute terms. In relative terms, i.e. in shares of total filings, however, the countries from the "rest of the world" show the highest engagement in global innovations. German inventors are involved in more than 20% of all global innovations, i.e. every fifth global innovation stems from a cooperation with a German inventor, with North America being the most important "global" partner. Chemistry, pharmaceuticals and related fields show the largest shares of global innovations, from a technological as well as a sector-specific point of view. In mechanical engineering, especially automobiles and vehicles, global innovations play a minor role.

1 Introduction

The internationalization of research and innovation is an important factor for the technological performance of a country, since it facilitates access to international markets and resources and enables the sharing of knowledge across national borders, leading to possible technological spill-overs.

According to the economic literature, there are at least two different motivations for companies to carry out (parts of) their research and development abroad: access to markets or access to resources (Belitz et al. 2006; Cantwell/Janne 1999; Dalton/Serapio 1999; Patel/Vega 1999; UNCTAD 2005). Market access implies a clear commercialization strategy by accessing the market not only from outside but also from the inside. In addition, market-specific R&D is carried out abroad, so products can be adjusted or tailored to the demand on the respective national market. Therefore, the firms more often focus on development rather than research activities. Access to resources implies that companies find unique knowledge or skills in the host country that can be included in their own innovation chain. Special price- or administrative regulations can also be subsumed under the label of access to resources. Finally, special infrastructure, such as certain research or testing facilities as well as natural resources can motivate especially multinationals to transfer R&D activities to a foreign country.

In this chapter, we will take on a special perspective on the internationalization of research, development and innovation, namely by analyzing the extent of global innovations. Global in-

novations are research projects that are handled by teams in different continents. This form of cooperation does not only result in the advantage of being able to use complementary knowledge. It also enables multinational teams to work across time zones and basically perform research on a project around the clock. To date, it is not known to what extent companies perform "global" research on a project.

We thus aim to answer the following questions:

- What is the share of global innovations and how this proportion has changed over time?
- Are there differences in the shares of global innovations across continents? Do some continents focus more on global innovations than others? How does Germany compare to the worldwide average in this respect?
- Is global innovation a phenomenon of single technology fields or is it equally distributed across technology fields? Does this also hold for economic sectors?

We will approach these questions by analyzing patent data. We will hereby concentrate on patent filings on which inventors from at least two different continents (North America, Europe, Asia/Oceania, Rest of the World) are listed. Since global research processes often take place within a single company, i.e. nearly 80% of all global innovations only have one applicant (compare Figure 6); the investigation is based on the composition of inventor teams. The investigation of patent applicants from different continents would fall short at this point.

As we are primarily interested in how global innovations affect the global technological competitiveness, transnational patent filings (Frietsch/Schmoch 2010), i.e. EPO filings plus filings at the WIPO excluding double counts, by priority year will be analyzed. For our analysis, however, not only the absolute number or share of global innovations is important, also the quality of global innovations will be taken into account. For this purpose, it will be analyzed how often global innovations are cited by subsequent patents (within a 4-year time-window to avoid biases), which will be compared to the average number of forward citations in general. Citations, however, represent only one possible measure of patent quality. In addition, to the citations we will further take into account the average family size of global innovations, i.e. the number of jurisdictions a patent has been filed at. This enables us to answer the question whether global innovations have greater market coverage than inventions that were not made by global inventor teams.

2 Data and Indicators

As in the previous chapters, the patent data for this analysis were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT) in its September 2015 version. The patents in our analyses are counted according to their year of worldwide first filing, i.e. the priority

year. We here apply the whole-count method to assign the patents to the respective continents, i.e. each cooperative patent will be counted once per inventor on each continent.

The assignment of patents to continents will be based on the address of the inventor to be able to also count global innovations within a firm. If we would employ the applicant information instead, this would limit our perspective and only global cooperations between (and not within) firms could be counted. At the regional level, however, patent statistics suffer from what has been termed "commuter effect", meaning that employees often cross regional borders when commuting to their workplace. By applying the inventor principle, where a patent application is assigned to the country of origin of the inventor, the statistic so to say penalizes the federal states in which companies are located near the border. Within country (or in our case continent-wise) statistics, however, the commuter effect is of less consequence, in part because commuting to another country for work is not so frequently the case and partly due to the larger number of patent filings as well as a balance in reverse direction commuting. The commuter effect can therefore largely be neglected in international comparisons (Frietsch et al. 2014; Neuhäusler et al. 2015b). The residence of an inventor can thus be regarded as a good indication on where an invention actually took place, as it can be assumed that an inventor commutes to his workplace only within a given range. In addition, the coverage of inventor addresses is rather high. Miguélez and Fink (2013) showed that - in case of PCT applications - the inventor information is well covered (around 90%) in nearly all countries (PCT member states). This is different for the nationality information¹ in some countries, e.g. the USA. However, we do not analyze inventor nationalities. Another basic problem for analyses of names is the "who-is-who" problem, described by Trajtenberg et al. (2006) for the case of inventors on patent filings. The "who-is-who" problem targets the challenge of uniquely identify an inventor although his name might spelled differently across his patents. Name disambiguation puts a challenge to researchers when assigning patents to inventor names. In our case, however, we only look at the aggregate country information, which is why this is not a problematic issue here. A final remark might be made for inventors who list their residence address on another continent but do not actually work there in person. This cannot be controlled for in our analyses and there has not been any earlier research which provides information about the extent of the phenomenon.

As already stated in the introduction, not only the quantity of global innovations, but also the quality of global innovations compared to an average patent filing will be analyzed. We will do this with the help of two indicators of patent quality that have widely been applied in the literature, namely patent forward citations and the average patent family size.

¹ In PCT applications, also the nationality of the inventor is recorded.

The number of citations a patent receives from subsequent patent applications, commonly called forward citations, probably are the most common and widely used patent quality indicator. Many scholars argue that forward citations, besides indicating technological spill-overs, are able to indicate the technological as well as economic value of a patent (Narin et al. 1987; Trajtenberg 1990). The basic assumption is that the number of forward citations measures the degree to which a patent contributes to further developing advanced technology, thus this can be seen as an indicator of technological significance (Albert et al. 1991; Blind et al. 2009; Carpenter et al. 1981).

However, there are studies showing that patent citations can be a noisy signal of patent quality (Alcacer et al. 2009; Alcacer/Gittelman 2006; Hall/Ziedonis 2001). For this reason, we will also take into account the average family size of a patent as an indication of the breadth of market coverage and indirectly also patent quality. We analyze the average family size² of the global innovations identified in our dataset and compare it to the family size of an average patent. A patent's family size is determined by the number of distinct patent offices at which a patent has been filed. It can be argued that the family size of a patent is (at least partly) dependent on the firm's evaluation and goals with the patented technology, i.e. it might be linked to the quality of a patent (Van Zeebroeck 2011), especially since a firm has to bear additional costs when filing patents in foreign jurisdictions. In other words, it can be assumed that a patent is filed more frequently in foreign countries if the patented invention is assumed to be of high quality, which reflects the argument made by Putnam (1996) as well as by Harhoff, Scherer, and Vopel (2003), who stated that more valuable inventions generate larger patent families. In line with this argument, it has also been shown that (auction) prices of patents increase with family size (Fischer/Leidinger 2013). Due to increasing returns to scale in the commercialization of a technology, firms can further be expected to realize higher returns from their technologies if they target not only the domestic, but also foreign markets.

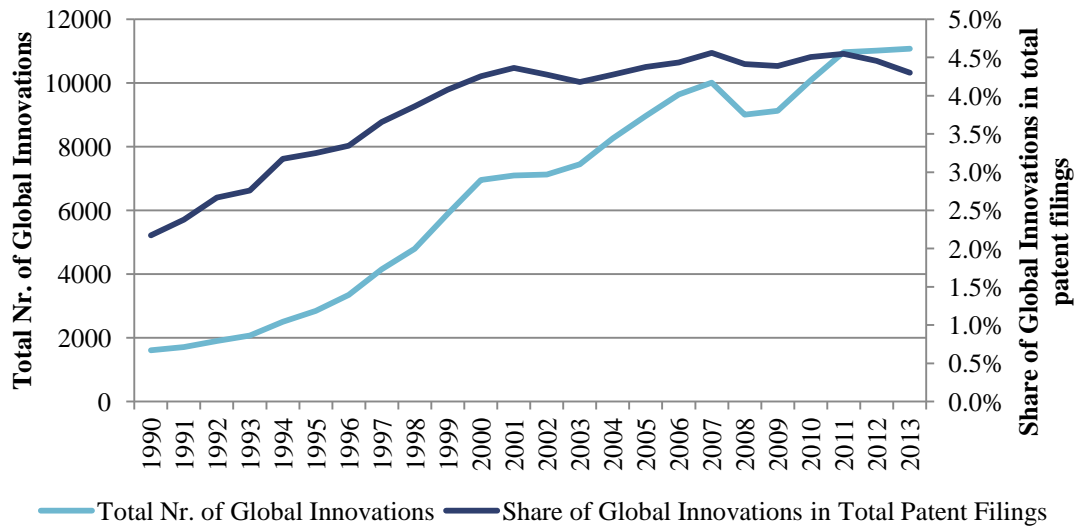
3 Results

The total amount of global innovations and transnational patent filings is shown in Figure 1. As we can see from the figure, there has been a significant rise in global innovations especially in the 1990s. The numbers rose from about 1600 in 1990 to nearly 7,000 in the year 2000. This results in a share of about 3% in total transnational filings. Between 2000 and 2003, stagnation in the number of global innovations can be observed, which could be related to the new economy crisis within this time period. Afterwards, another increase can be observed, which is once again interrupted by the financial crisis in 2008/2009. This results in a total of about 11,000

² "Singletons", i.e. patents that have only been filed at one patent office (Martinez 2010), are excluded from the analysis.

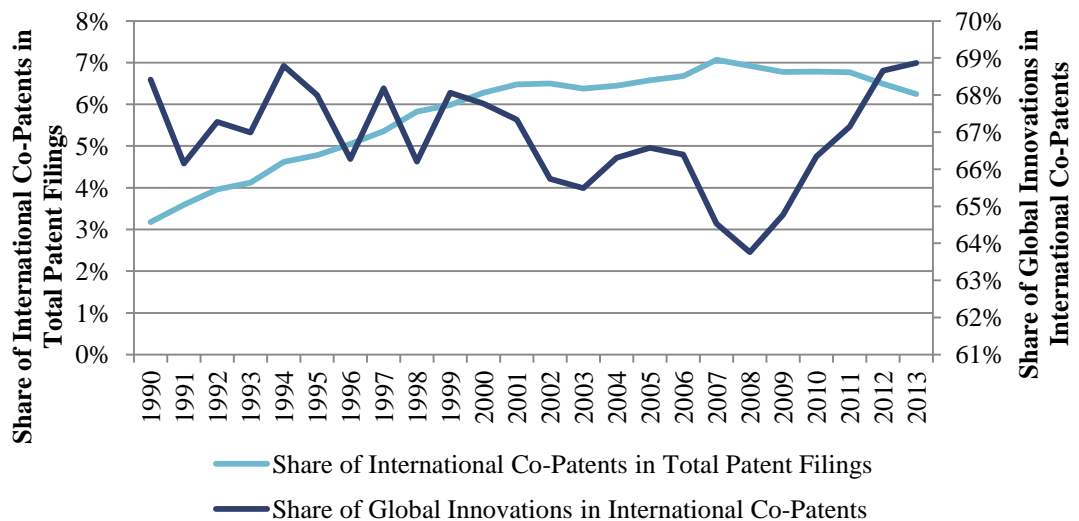
global innovations in 2013 implying that a share of more than 4.5% in total transnational patent filings can be reached. In sum, this already points to the fact that innovation becomes an increasingly global phenomenon, i.e. not only international cooperations are on the rise, but also co-operations across continents.

Figure 1 Amount of Global Innovations and share in total filings



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Figure 2 Co-Patents and Global Innovations

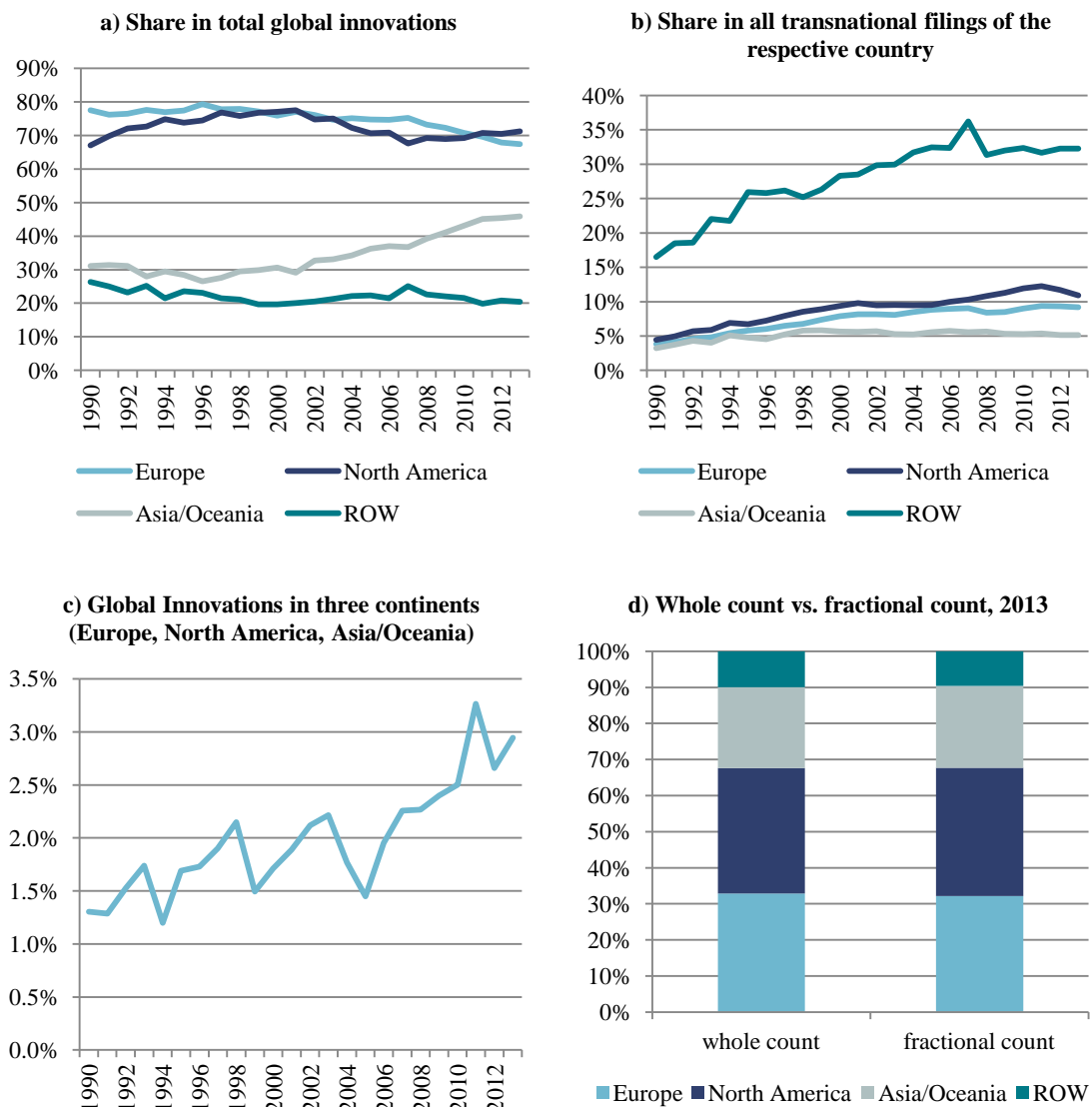


Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

In Figure 2, the relation of global innovations to international co-patents is plotted. As we can see, the share of co-patents in total transnational filings peaked in 2007 with a value of 7%, but declined afterwards. In 2013, only about 6.2% of all transnational filings were international co-

patents. In contrast to that, the share of global innovations in international co-patents increased especially after 2008 – after a rather sharp decline that might be explained by cost-saving strategies of firms during the economic crisis. Besides the fact that already 64% to 69% of all co-patents are global innovations, this implies that especially in the recent years global innovations have become more and more important within international innovation collaborations. This might be related to the fact that global innovations span across time zones, which means that inventors can work on projects more or less around the clock, resulting in efficiency gains. This phenomenon has increased especially in the recent years (Figure 3) but still only in 3% of all global innovations, researchers from more than two continents are involved.

Figure 3 Global Innovations by continents



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

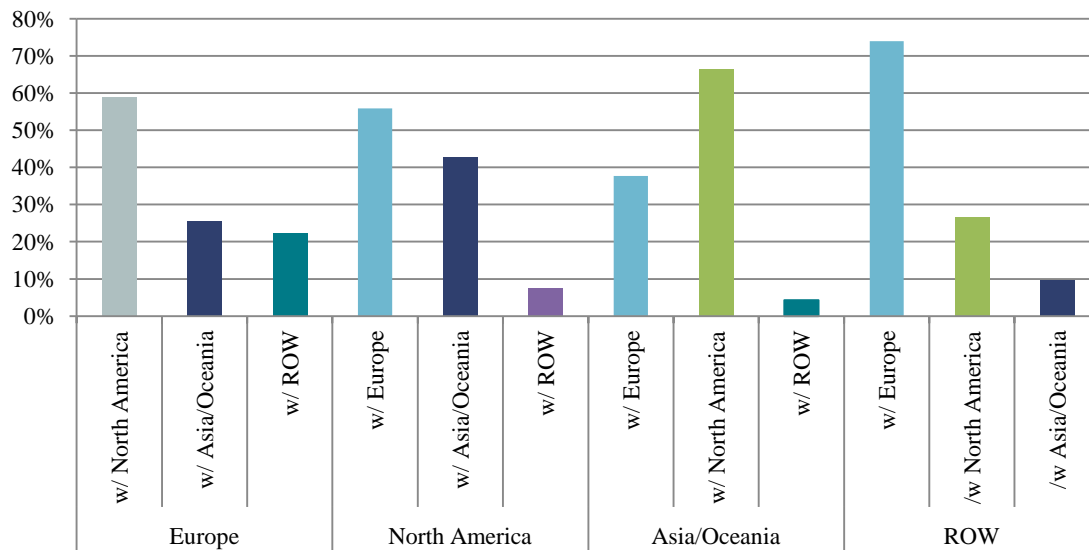
In Figure 3, global innovations are regarded by continents. In Figure 3a each continent's share of global innovations in total global innovations are shown.³ As we can see Europe and North America show comparably large shares in total global innovations. The shares are rather stable across the whole time period and range between 70 and 80%. However, slight declines can be observed from 2000 onwards, which has to do with the rather steep increase in global innovations from Asia/Oceania, which can mostly be attributed to Chinese firms. In 2013 inventors from Asia/Oceania are responsible for about 45% of total global innovations, whereas this share was only about 30% in 1990. With regard to the "rest of the world", a quite stable share of 20 to 25% can be observed. These shares, however, are not independent of size effects, i.e. larger countries in terms of total filings are overrepresented. Therefore, Figure 3b shows the share of global innovations in all transnational filings of the respective continent/region. It here becomes obvious that especially the countries from the "rest of the world" are highly engaged in global innovations. This probably has to do with the motive of gaining access to resources as well as markets, which explains the shares of about 32% in 2012. Amongst the other continents North America shows the highest shares of 11%, followed by Europe with a share of 9% and Asia/Oceania with a share of 5%.

In Figure 3c, additionally the share of global innovations (in total global innovations) that span across all time zones (North America, Europe and Asia/Oceania) is plotted. The numbers show that research projects that span across the globe, allowing researchers to work 24/7 on a project - are a rather rare event. Although the figures are increasing over the years, only in 3% of all global innovations, researchers from more than two continents are involved. Finally, we have included a comparison of whole vs. fractional counting of global innovations by continents in Figure 3d. Here, it can be found that the counting method does not strongly influence our results. We therefore stick with the whole count method for the remainder of the study.

In Figure 4, the shares of global innovations amongst the continents in the period 2011 to 2013 are shown. For Europe, it becomes obvious that North America is the largest partner in terms of cooperative patents. Nearly 60% of all European global innovations are co-invented with a North American inventor. In case of Asia/Oceania this share only equals 26% while it is 22% for the "rest of the world". For North America, Europe is the largest partner in terms of global innovations. However, the shares for cooperations with Asia/Oceania are much higher than for Europe. More than 40% of all American global innovations are filed together with an inventor from Asia/Oceania. The share for the "rest of the world", however, is much lower for North America.

³ These shares exceed 100% as the "whole-count" method is applied, i.e. patent is assigned once to each continent in case an inventor from the respective continent is named on the patent filing. Applying a fractional count, however, does not significantly alter the results (as shown in the lower right panel of Figure 3).

Figure 4 Global Innovations, continent by continent, 2011-2013



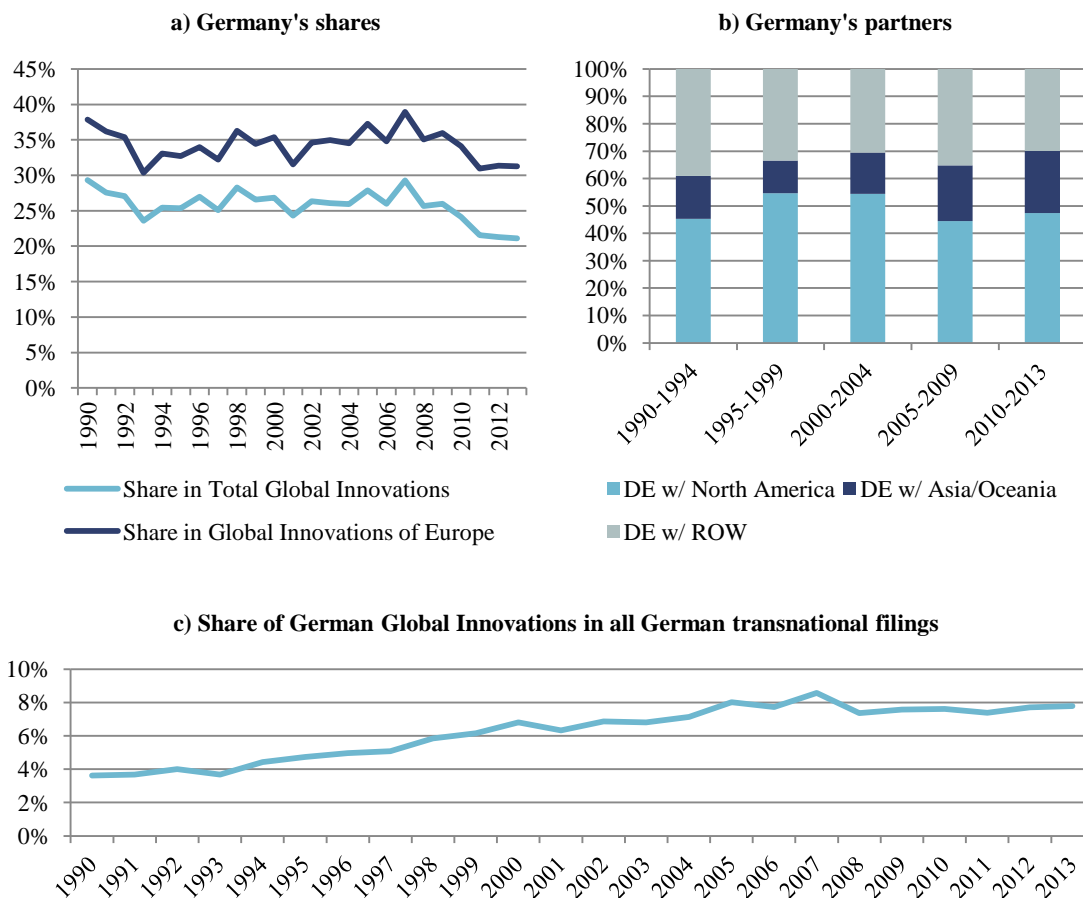
Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

For Asia/Oceania, North America is by far the largest partner. Nearly 70% of all global innovations from Asia filed together with a North American inventor, whereas Europe only reaches a share of 38%. The "rest of the world" states also only play a minor role here. In the case of the "rest of the world" states, European inventors are by far most often the partners in global innovations. More than 70% of all global innovations are filed in cooperation with a European inventor. The shares for North America (27%) and Asia/Oceania (10%) are comparatively low. In sum, two effects are striking here. The first one is that Asia/Oceania is not very cooperation-intensive. If the Asian/Oceanian states cooperate, they mostly do this with inventors from North America. This is a result that has already been found in earlier studies on co-patents (e.g. Neuhäusler et al. 2016). Second, it is interesting to see that the "rest of the world" states mostly cooperate with Europe. North America and Asia/Oceania do not seem to be that attractive for cooperative research.

In Figure 5, we take a closer look at Germany and its role in total global innovations. In Figure 5a, it can be observed that German inventors are involved in more than 20% of all global innovations, i.e. every fifth global innovation stems from a cooperation with a German inventor. Yet, the share has been decreasing especially in the recent years. When looking at European global innovations only, we can find that German inventors are involved with the share of slightly above 30%. This share has also decreased between 2009 and 2011 but seemed to recover in 2012 and 2013. In Figure 5b the patent numbers in collaboration with non-European German partners are plotted over time. As we can see, North American inventors became increasingly important as cooperation partners between 1990 and 2004. This mostly came at the expense of cooperations with partners from the "rest of the world". After 2005, the patent applica-

tions in collaboration with North America however dropped slightly, which is mostly due to an increase with partners from Asia/Oceania. Yet, still North America is the largest German (non European) cooperation partner. Nearly 50% of all global innovations of German inventors result from cooperative research with a North American inventors. In Figure 5c, the share of German global innovations in all transnational filings is provided. Compared to Figure 3a, where we have seen the same figures for the continents, it can be found that Germany is slightly below the European average of 9% in 2013.

Figure 5 Germany's Global Innovations

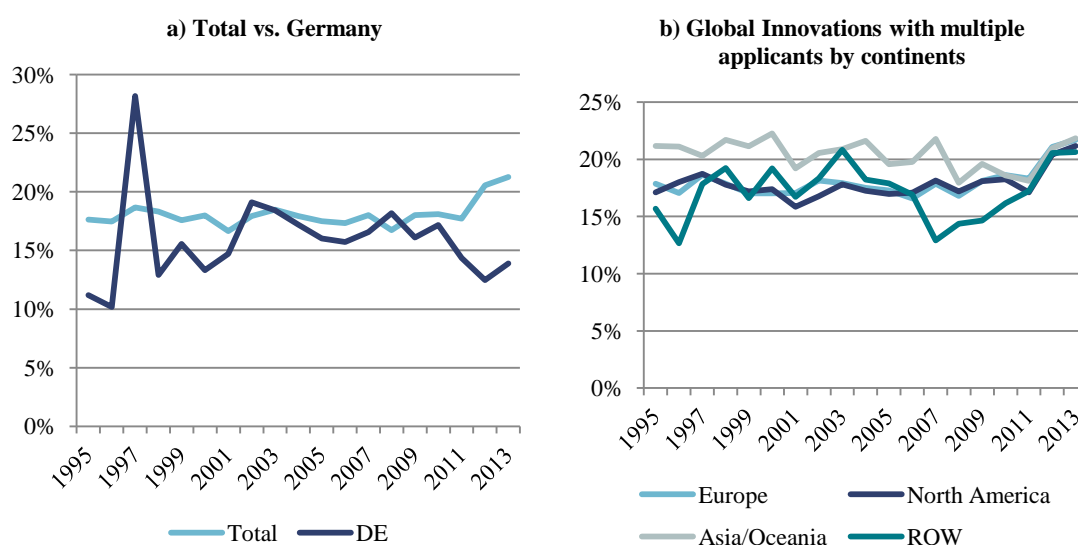


Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Finally, before looking into the field specificities of global innovations, we aim to analyze the question whether global innovation is a phenomenon that mostly happens within an organization, i.e. a firm, or across firms. To do this, we have calculated the share of global innovations with multiple applicants in total global innovations (please note that this is the only analysis that is performed at the level of applicants, instead of inventors). In case multiple applicants are included, we can assume that a certain global innovation is the result of cooperation between two firms, while a global innovation with only one applicant can be seen as an intra-firm inno-

vation process that spans across continents.⁴ When looking at the graphs depicted in Figure 6, it becomes clear that slightly more than a fifth of total global innovations is the result of a firm cooperation, i.e. the lion's share of global innovations are carried out within firms (Figure 6a). This is to a similar extent also true for global innovations with German inventors, although the share of global innovations across firms decreased in the recent years whereas it increased on average.

Figure 6 Share of global innovations with multiple applicants in total global innovations

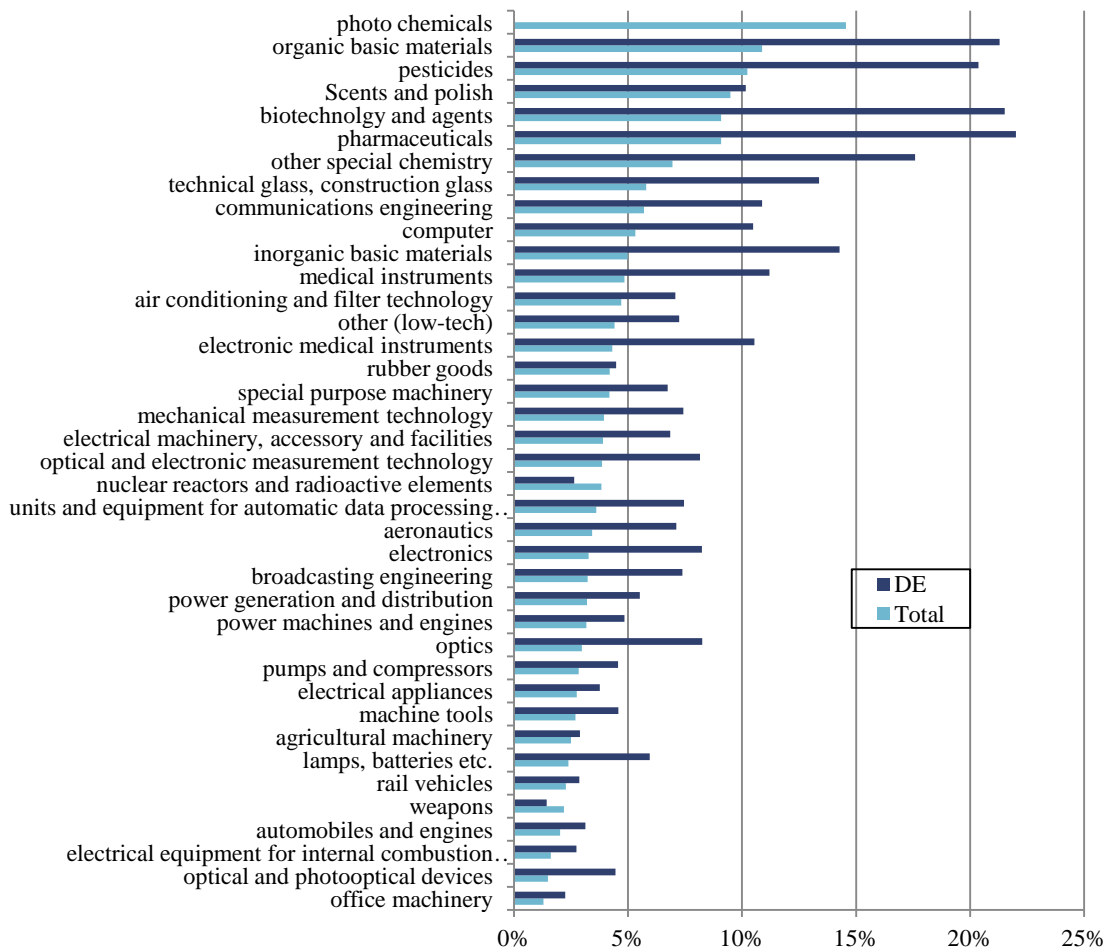


Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

The differentiation by continents reveals that the largest share of global innovations that spans across firms comes from Asia, followed by Europe, North America and the rest of the world (Figure 6b). Taken together with the result that inventors from Asia on average are not highly cooperation-intensive (with the exception of China), this implies that if Asian inventors cooperate they comparably often cooperate with other firms from different continents.

4 Though we use the harmonized applicant name developed by the K.U. Leuven (Du Plessis et al. 2009; Magerman T. et al. 2009; Peeters B. et al. 2009) for this analysis, multiple applicants listed on a patent not necessarily imply a cooperation across firms as one of the applicants might still be a subsidiary of the other. However, the presented figures can be seen as an upper-bound estimate of the real value.

Figure 7 Global Innovations by technology fields, 2011-2013

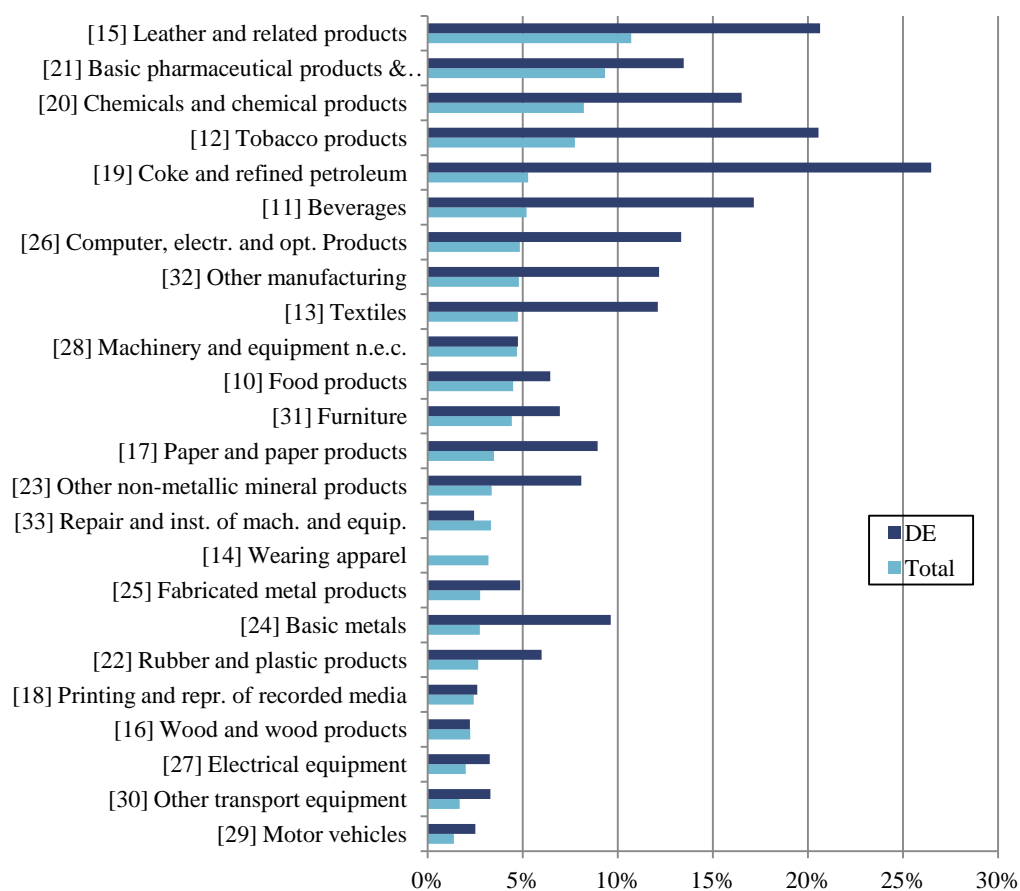


Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Up to now, we have only looked at country specific trends in global innovations. However, it is also interesting to see whether there are specific technology fields or sectors, where global innovations are more common than in others. The shares of global innovations in total patent filings by technology fields according to the NIW/ISI/ZEW list of 38 high-technology fields (Gehrke et al. 2013) are shown in Figure 7. Though it is a small field in terms of total patent filings, the field of photo chemicals shows the worldwide largest shares in global innovations. It is followed by organic basic materials, pesticides and scents and polish. It thus becomes quite obvious at first sight that chemistry, pharmaceuticals and related fields seem to be most prone to global cooperations. These fields are followed by a quite large group of fields with an intermediate intensity. Within this group mostly fields related to electronics, instruments and optics are located. At the lower end of the scale, mostly fields within mechanical engineering, i.e. motor vehicles, rail vehicles, agricultural machinery as well as weapons are located. For Germany, the picture looks quite similar, although the shares are generally higher as Germany has rather large shares in total global innovations. The profile itself, however, is not so different from the world

average. Especially chemistry, pharmaceuticals, biotechnology and related fields reach rather high shares of global innovations, whereas fields within mechanical engineering, e.g. automobiles, rail vehicles show comparably low shares. Especially for Germany, however, this fits the theoretical predictions with regard to the motive of seeking access to resources. Traditionally, Germany is rather strong in mechanical engineering, especially in automobiles and engines, implying that resource access in other countries/continents only plays a minor role.

Figure 8 Global Innovations by manufacturing sectors (NACE Rev. 2), 2011-2013

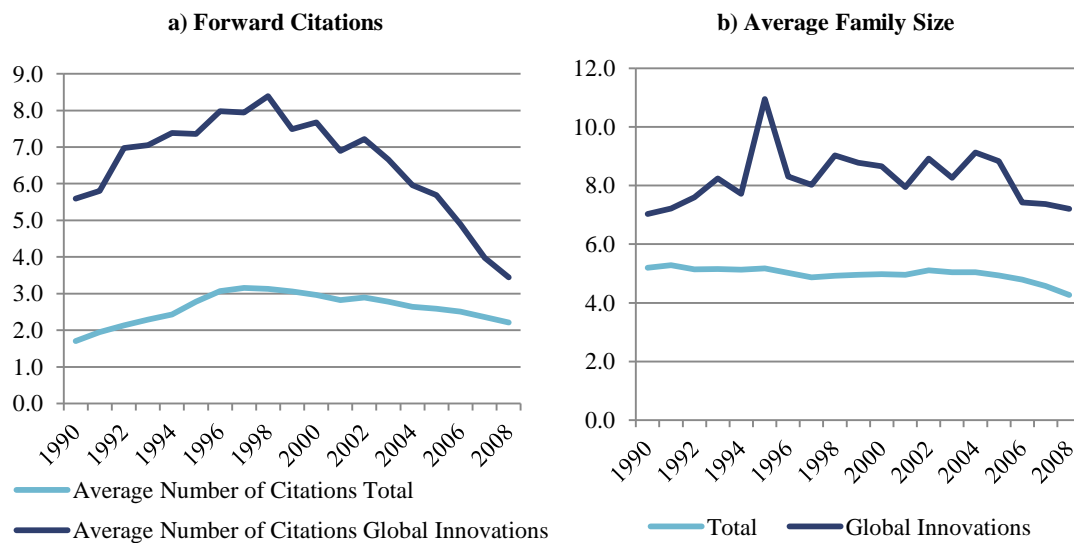


Source: EPO – PATSTAT, BvD – ORBIS, calculations by Fraunhofer ISI.

The sectoral distribution⁵ (Figure 8) reveals similar results as the field specific view. The largest shares in global innovations can be found in the pharmaceutical sector, the chemical sector as well as leather and related products, though this is also a comparably small field in terms of patent filings. The smallest shares can be found in motor vehicles, other transport equipment, electrical equipment and wood products.

⁵ The assignment of patents to NACE codes is based on a match between the PATSTAT database and the ORBIS company database by Bureau van Dijk. Here, a string matching algorithm was applied to match applicant names from PATSTAT to company names from ORBIS.

Figure 9 Forward-Citations and Average Family Size



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Finally, Figure 9 shows a comparison of forward citations and the average family size of global innovations and of the transnational patent filings to get an impression of the difference in patent quality. In Figure 9a first of all the average number of forward citations in a four-year time-window⁶ is shown. Although the average number of forward citations decreased in the recent years, which is a general trend, it can be found that global innovations are by far more highly cited than the average patent. The average patent is cited 2.2 times within a four-year time period, whereas global innovations are on average cited 3.4 times. This implies that global innovations contribute more highly to the development and evolution of technologies than the average patent does. Similar effects can be found for the average family size (Figure 9b). Global innovations on average target about seven different patent offices, whereas this value lies at 4.3 for an average patent. This surely has to do with the "home advantage" for domestic patent filings, i.e. at least two inventors from different continents are listed on a global innovation which basically makes "two domestic markets" to file the patent. However, this also corresponds to the literature on internationalization, which states that gaining market access is one of the key motives for international research collaborations.

⁶ The choice of a four year time window can be seen as a compromise of analyzing most recent data and the amount of citations that have already been made to a patent. Yet, it has to be mentioned that a patent can basically be cited for an unlimited amount of time. Therefore, typically not all citations to patents are covered.

4 Conclusion

In this chapter we have taken a look at global innovations with the help of patent statistics, defined as patents of inventors from at least two different continents. We have seen that global innovations have been on the rise in the last decade. Now, about 4.5% of all transnational patent filings are global innovations, i.e. research projects that are handled by teams in different continents, and the number has grown quite significantly since the 1990s. Global innovations have also gained importance in international cooperations per se. In 2013, nearly 70% of all international co-patents were global innovations, according to the definition employed here. Working on a research project across all time zones, i.e. in North America, Europe and Asia/Oceania, however, still is rather rare. Most of the global innovations are carried out in teams of inventors from two continents. With regard to quality, however, it could be shown that global innovations are cited far more often than the average patent and have broader market coverage, indicating a higher patent quality than average. It seems that global innovations more often contribute to follow-up innovations and generate spill-overs.

When looking at the distribution of patents across continents, it can be found that Europe and North America show the highest numbers of global innovations in absolute terms. Yet, especially the countries from the "rest of the world" are highly engaged in global innovations in relation to their total filing numbers. Interestingly, the cooperation intensity for inventors from the "rest of the world" is highest with inventors from Europe. Asia/Oceania, on the other hand, shows comparably low shares of global innovations within their patent portfolios, which is mainly driven by Japan and Korea that both show comparably low international collaboration activities in R&D as well as in patenting in general (Neuhäusler et al. 2016; Neuhäusler et al. 2015a). With regard to Germany we have found that German inventors are involved in more than 20% of all global innovations, i.e. every fifth global innovation stems from a cooperation with a German inventor. North American inventors are most important "global" cooperation partners for German inventors, although inventors from Asia/Oceania have gained increased importance.

The field- and sector specific analyses show rather straightforward results. Chemistry, pharmaceuticals and related fields show the largest shares of global innovations, from a technological as well as a sector-specific point of view. In mechanical engineering, especially automobiles and vehicles, global innovations play a minor role.

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