B 2 INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS AND ITS IMPACT ON INNOVATION

When scientists or inventors are internationally mobile, knowledge is disseminated, new combinations of knowledge occur and innovation is facilitated. The balance of inward and outward migration flows[257] displays systematic cross-country differences – thus resulting in diverging stimuli for innovation. In an international comparison, Germany – as detailed in sections B 2 – 1 to B 2 – 3 – has a rather moderate balance. The results can be summarised in a few sentences and are rather sobering.

Scientists: In an international comparison of mobile scientists as a proportion of all a country's scientists, Germany is ranked in the middle field. Germany loses many of the best scientists as a result of migration. Although there are also returnees, Germany does not succeed in winning back scientists of the same quality on average.[258] Germany at the same time is successful in improving the knowledge pool with new inflows of foreign scientists who have a comparatively high impact (number of citations), but it is not successful in keeping the best of them. Consequently, Germany manages to retain or bring back but a few of the really good scientists. Particularly for the best scientists (highest impact numbers), the German research system does not currently appear to be attractive enough.

Inventors: In international comparison, patenting inventors from Germany display a moderate, slightly decreasing migration rate.[259] At the same time, in international comparison, immigration to Germany is ranked in the middle field at best. However, there are systematic differences in the mobility patterns of the various industries. International inventor mobility freezes Germany's R&D specialisation profile: technology fields in which Germany is strong tend to display a low migration rate and technology fields in which Germany is weak tend to display a high migration rate.

Innovation capacity could be increased if Germany's research and innovation system was made more attractive, especially to top scientists and inventors.

THE MOBILITY OF PUBLISHING SCIENTISTS IN INTERNATIONAL COMPARISON B 2 – 1

The mobility of scientists is not measured in official statistics but it can be mapped using a range of different proxy indicators (cf. Box 9). A current study[260] examines the international mobility of scientists from 36 countries based on data from the publication database "Scopus Custom Data Elsevier". The analysis covers scientists who have published in the period from 1996 to 2011. A distinction is made between "stayers" and "movers", whereby the latter distinguishes "returnees" and "new inflows".[261] The results are presented in Figure 20.[262]

Between 1996 and 2011 there was a total of 19,521 new inflows and 23,460 outflows of publishing scientists in Germany (cf. Figure 21). With a negative balance of around 4,000 outflows, Germany was only ranked 19th in international comparison and thus significantly below the majority of the other OECD and BRICS countries.

Germany ranks in the middle field in the proportion of internationally mobile scientists

In international comparison, Germany benefits from the immigration of internationally mobile scientists to a moderate degree. The level of immigration is ca. 10 percent, of which just under two-thirds are returnees and just over one third new inflows.[263] However, the United States are ranked even lower as regards inflows, situated in the bottom third (with a level of inflows of 7.5 percent, of which around one half are returnees (3.7 percent) and around one half new inflows (3.8 percent)).[264] It is striking that Switzerland scores much better in this regard than either Germany or the United States. With a level of almost 20 percent, of which more than 10 percent are new inflows and 8.5 percent returnees, Switzerland is the top country in terms of knowledge inflow. Switzerland thus has a higher proportion of returnees than Germany (6 percent) or the United

BOX 09

Mobility indicators for scientists and inventors

Author affiliation in scientific publications can serve as the starting point for developing a mobility indicator for scientists in order to establish whether a change of affiliation and country has occurred over time. For example, the OECD study "Researchers on the move" is based on this indicator.[265] In a similar fashion, a change of an inventor's residential address documented in patents can serve as an indicator for a change of country;[266] alternatively, certain patent application procedures collect information on the nationality of the inventor.[267]

However, both indicators are subject to similar problems. They only record mobility for scientists with publications or inventors with patents. As a consequence, mobility is systematically underestimated as persons who have not (yet) published or filed patents are not recorded. In particular, this leads to an underestimation of the mobility of younger people, i.e. those in or prior to the post-doctorate phase. This also applies to mobility in disciplines or technologies where neither publications in international journals nor patents are standard. An additional problem with the publication indicators is the fact that publication is often delayed. In turn, it is not always clear where the publication was actually written (especially shortly after moves or during frequent moves).[268] If a scientist or inventor is recorded for the first time it is possible that the country of origin does not correspond with either the person's nationality or the country where they receive education and training. For example, foreign students who moved to Germany to study and earn a doctorate degree and published for the first time during their stay in Germany, and then returned to their home country, are recorded as "outflowing German" scientists. Conversely, Germans who travel to the United States after their studies in order to earn a doctorate degree, publish for the first time while there and then return to Germany are recorded as "inflowing US" scientists. Such indicators are thus especially diffuse when it comes to recording the country that invested in education and training or assessing the quality of a national education and training system. In contrast, they are more meaningful when it comes to mapping the international knowledge flows during the course of a scientific career and the resulting productivity effects in the country of origin or destination.

However, an advantage of both the publication and patent based indicators is that they provide a complete picture of all the scientists who are actively publishing and patenting. The data is not subject to any sampling bias, non-response bias etc. They even provide reliable information on small scientific disciplines, countries or regions.

Other options for measuring international mobility include surveys among mobile scientists, e.g. within the context of the GAIN network, secondary analyses of the administrative data of mobile scientists from funding programmes, e.g. the Alexander von Humboldt stipends[269] or European Research Council (ERC) grants, as well as the analysis of official statistics such as the Microcensus, Social Security Records or similar data sets.[270] Here it is primarily demarcation problems and small sample sizes which pose problems for a detailed analysis.

States (3.7 percent). It appears that Switzerland is especially successful at bringing back mobile scientists.[271] Austria, Canada, Sweden and Belgium show a similar success to Switzerland in respect of the inflows of scientists.

However, it is not just the number of inflows or outflows of scientists that is important for a country's innovation capacity, but also their quality and performance.

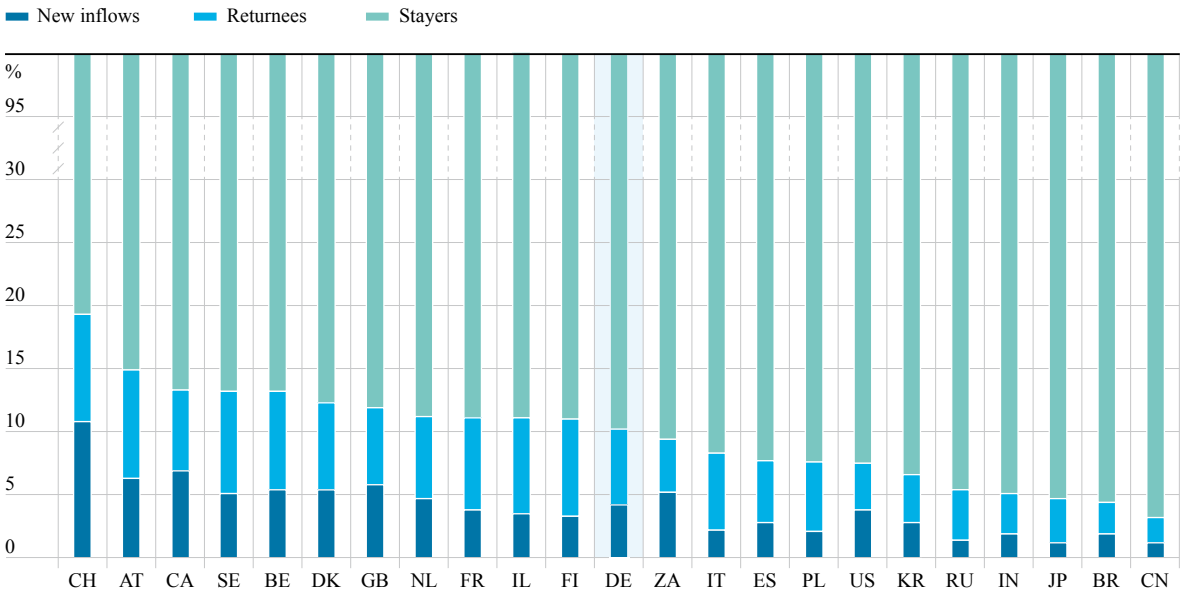
On balance Germany loses especially the best scientists

In order to account for differences in scientific quality and performance, the OECD (2013b) employs the so-called "SNIP Impact Factor". This measures the quality of a journal's authors according to the number of citations the journal receives.[272] Figure 22 provides an overview of the relative quality of stayers, inflows (returnees and new inflows) and outflows. It shows that in Germany – as in other countries except the United States – the outflows have the

International mobility patterns of publishing scientists in international comparison
(shares of stayers, returnees and new inflows among all publishing scientists of a country between 1996 and 2011)

FIG 20

DATA DOWNLOAD



Source: own depiction based on OECD (2013b: 1).

How to read: between 1996 and 2011, approx. 4 percent of publishing scientists in Germany were "new inflows", approx. 6 percent were "returnees" from abroad and approx. 90 percent were "stayers".

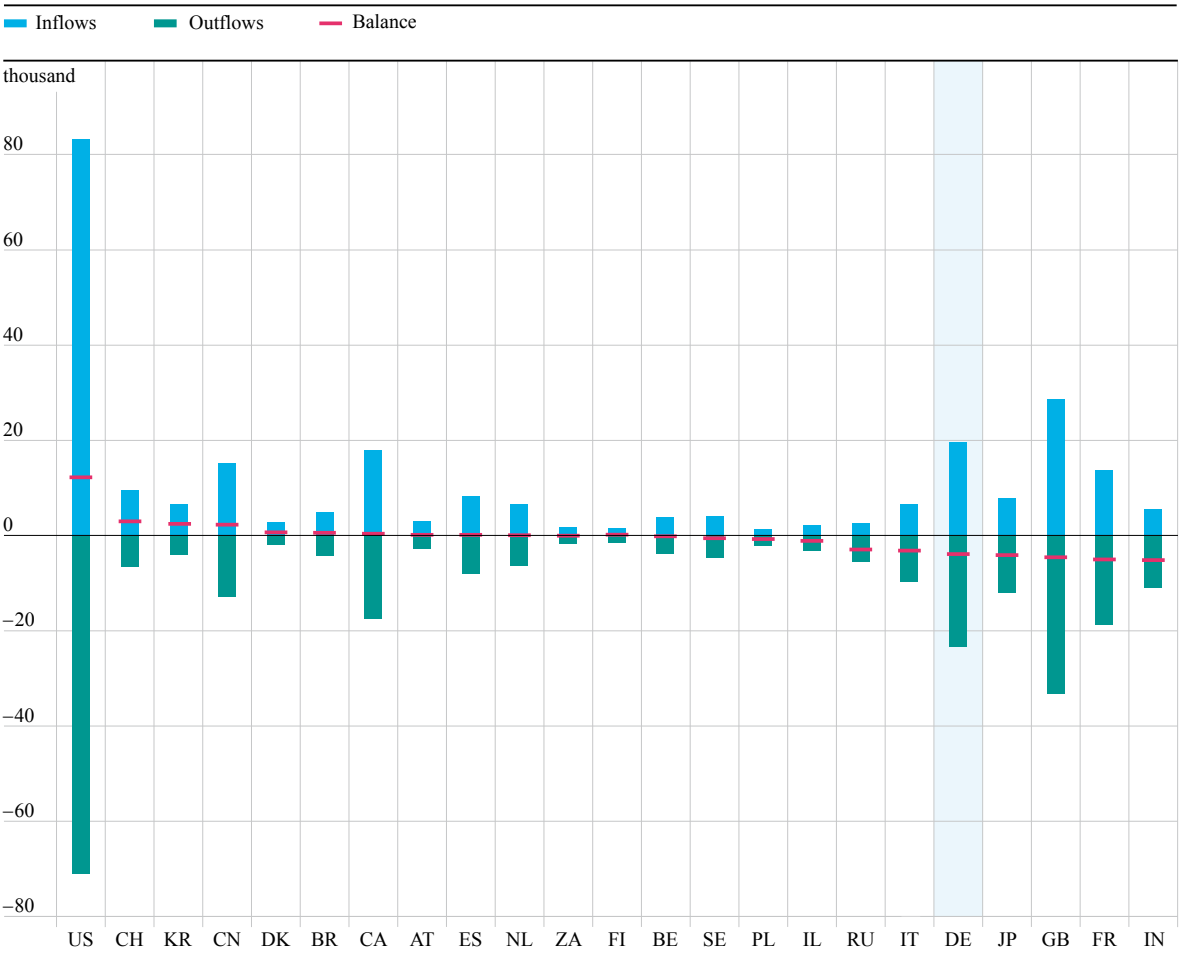
highest impact factor (1.212), followed by new inflows (1.202) and returnees (1.168), while the factor for stayers is considerably lower (1.030). One decisive factor for the change in the knowledge pool, and thus Germany's innovation capacity in international competition, is the relative quality of the inflowing scientists compared to those outflowing, illustrated in Figure 23. In countries to the left of the 45 degree line, the outflows have a higher impact than the inflows. In countries to the right of the 45 degree line, the reverse is the case. Germany is situated to the left of the 45 degree line, i.e. outflows from Germany have a higher impact factor than inflows, so that the international mobility of scientists tends to lead to a reduction in the research quality in Germany.

In the United States, the international mobility of scientists systematically contributes, via various channels, to a continual improvement in research quality: inflows are characterised by scientists with above-average impact (especially in the case of returnees, but also new inflows), and outflows are characterised by scientists with below-average impact. The United States are the only country in which outflows (triangle; 1.202) display a lower impact factor than stayers (square; 1.209). As a result, migration in the United States – if only slightly – contributes to an improvement in the average quality of scientists. In all other countries, the stayers have on average the lowest impact factor, which is often considerably lower than that of the mobile scientists.[273] In the United States, the returnees (1.389) have the highest impact factor in comparison to all other scientists and all other countries. This means that following a stay abroad, it is apparently only the best scientists, who actively published in the United States prior to leaving, that return to the US. The outflowing scientists, who have on average lower impacts, do not return to the United States but remain in new target countries.[274] Furthermore, as the new inflows (1.243) in the United States have a higher impact factor than the outflows, the international mobility of scientists contributes to a continual improvement in the United States' knowledge base.

Similar inflow effects as those in the US are observed in the Netherlands, Great Britain and Canada thanks to a high number of very good returnees. In the Netherlands and in Canada, there

FIG 21 **Inflows and outflows of publishing scientists between 1996 and 2011**
(figures in thousand)

DATA DOWNLOAD



Sorted by balance in descending order.
Source: own depiction based on OECD (2013b).

How to read: approx. 20,000 scientists were new inflows to Germany, while approx. 24,000 were outflows from Germany. Germany thus has a negative balance of approx. 4,000 individuals.

is still an outflow of even the best scientists – a phenomenon that cannot be observed in the United States. In Great Britain, however, it is scientists with a low impact factor that tend to outflow, but their impact is still higher than that of the stayers.

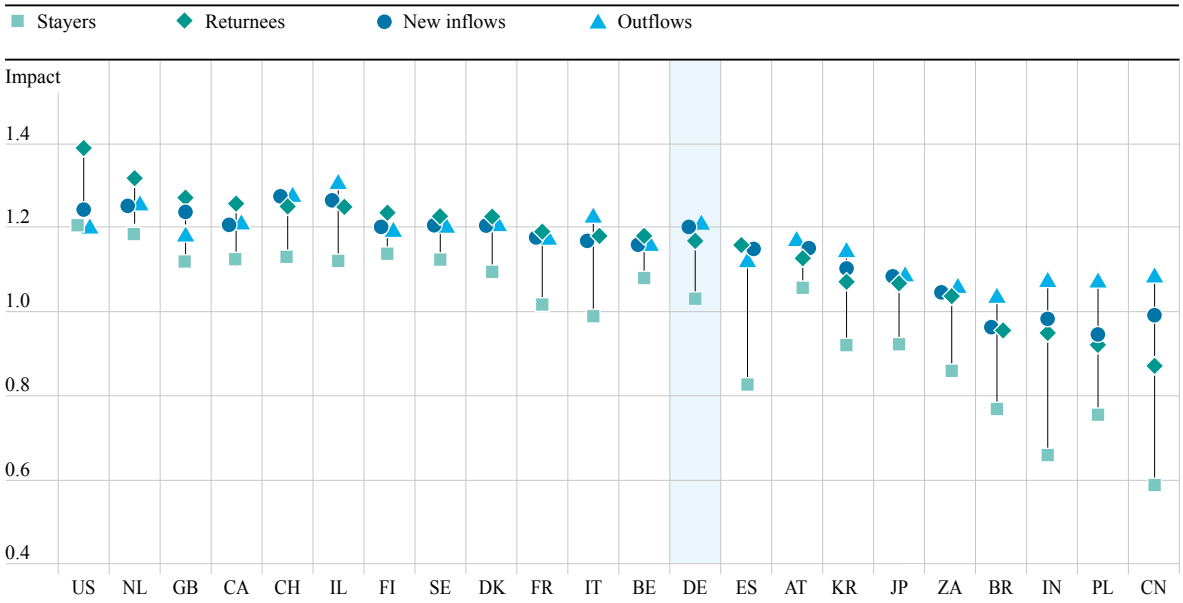
The mobility pattern in Switzerland displays a special feature. This country is consistently improving its knowledge pool through an inflow of excellent new scientists and the ability to win back or keep the best scientists. Switzerland has the highest impact level amongst new inflows (1.277) and a very high impact level (the fifth highest) amongst returnees (1.250). At the same time the impact factor of outflows (1.276) is slightly below that of new inflows. This is also reflected in the very high impact factor of Switzerland‘s stayers (1.130) in international comparison.

In comparison to the above mentioned countries, the effect of international mobility is less positive for Germany‘s knowledge pool. The best scientists outflow, but seldom return to Germany once they have left.[275] They remain in attractive research destinations abroad.[276] In this context, a survey among natural scientists at academic institutions[277] shows the importance of outflowing German scientists for the United States and European countries such as the Netherlands, Belgium, Denmark, Sweden, Switzerland or Great Britain. With up to 36 percent, German

Scientific impact of movers and stayers among publishing scientists between 1996 and 2011

FIG 22

DATA DOWNLOAD



Source: own depiction based on OECD (2013b).

How to read: "outflows" from Germany have an average impact factor (median) of 1.21; "new inflows" have the second highest impact factor (1.20), closely followed by "returnees" (1.17). "Stayers" display the lowest impact factor (1.03).

natural scientists represent the largest group of foreign scientists in the respective countries.[278] Furthermore, regarding impact factors, the data show that the average impact of outflowing scientists from Germany (1.212) compares well with the average impact of scientists coming from other countries (Canada: 1.210; Sweden: 1.207; Denmark: 1.206) or is only slightly lower (US: 1.243; Great Britain: 1.236). However, few of the best scientists can be retained or brought back. The German research system seems to hold little attraction for the best scientists.

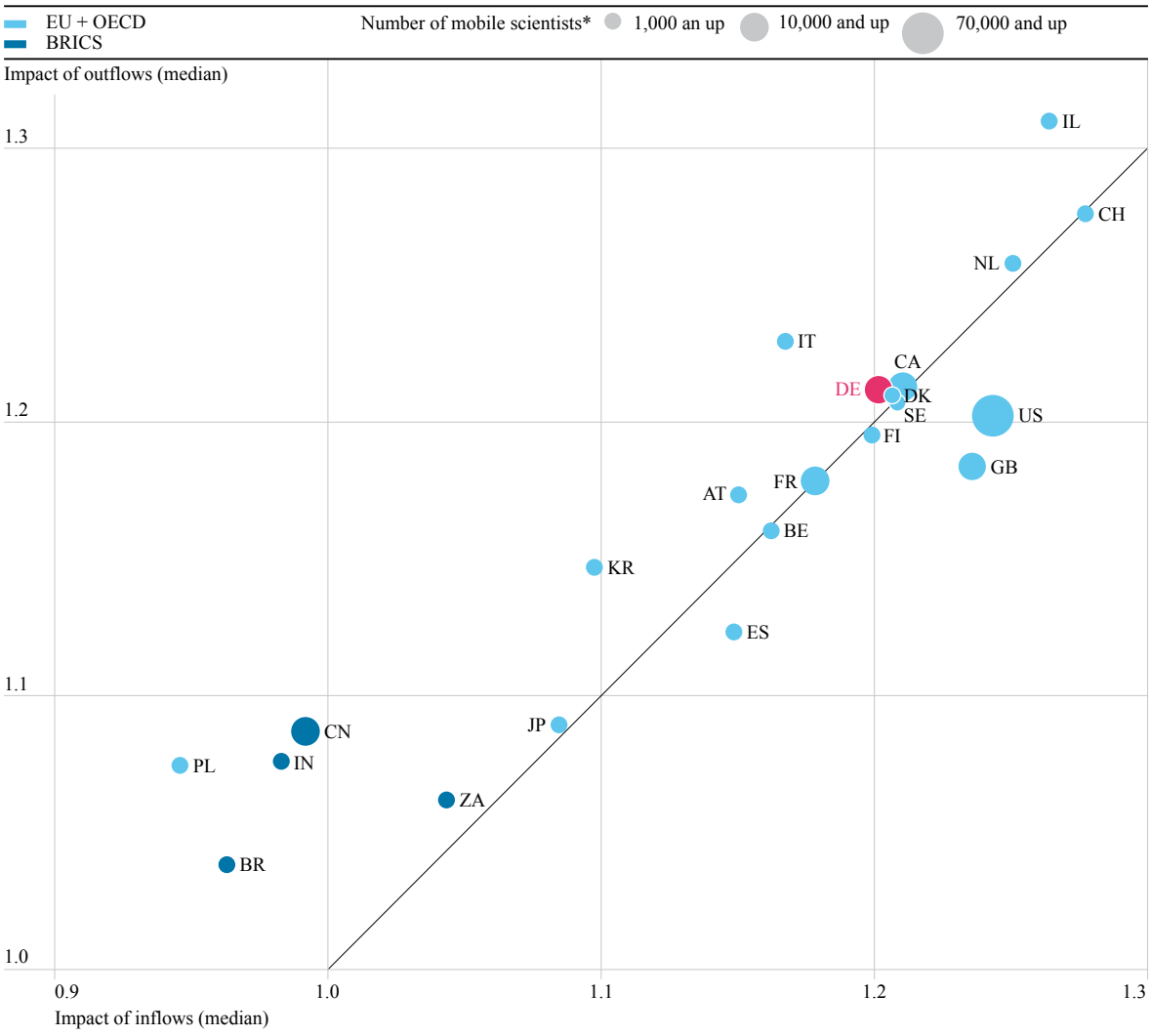
A ray of hope is that close to one third of all German scientists doing research abroad plan to return to Germany in the long term. A further third report that they would consider returning if there were suitable job offers. Only Swiss, Canadian and Swedish scientists report a higher likelihood of returning to their homeland.[279] Therefore, an improvement in the framework conditions for top scientists in Germany – in combination with corresponding returnee programmes which remove organisational hurdles for returning – could have a sizeable positive effect in the longer term.

For these reasons, the Expert Commission welcomes the introduction of measures to win back excellent scientists from abroad. Such measures (cf. Box 10) are important and deserve the full support of the Federal Government.

Furthermore, measures launched by the Excellence Initiative may already be highly attractive to scientists abroad. Although systematic evaluations of the Excellence Initiative's causal effects on the mobility of scientists, in particular on returnees to Germany, have not been conducted so far, descriptive results indicate a positive effect: whereas in 2011 the proportion of foreign staff within the entire university system was 10 percent, the proportion in graduate schools was 36 percent, in Clusters of Excellence 24 percent and in the Future Concepts *(Zukunftskonzepte)* 37 percent.[280] The large number of well-established scientists from the US who were recruited within the context of the initiative suggests that this also includes numerous German returnees from US research institutions (cf. Box 10). However, the Expert Commission currently has no evidence that the initiative has resulted in systematic "group appointments" of entire research teams from abroad.

FIG 23 **Relative impact of inflowing and outflowing publishing scientists between 1996 and 2011**

DATA DOWNLOAD



Source: own depiction based on OECD (2013b: 3).
*Average of new inflowing and outflowing scientists

How to read: Germany is positioned left of the 45 degree line, i.e. outflows have a higher average impact factor (median) than new inflows. The size of the circle ndicates that Germany has a relatively high total number of mobile scientists.

Returnee programmes for the recruitment of German scientists abroad

BOX 10

Several mobility programmes initiated by the German Research Foundation (DFG) aim to recruit foreign scientists, and in particular, target the return of top German scientists from abroad. These include, amongst others, the Heisenberg programme, the Emmy Noether programme, the "Research Stipends" programmes, and in particular, support measures within the Excellence Initiative which may have contributed to the return of excellent scientists to German institutions.

The DFG's funding statistics do not provide detailed information on the international transfer of scientific personnel or returnees to Germany, especially with respect to the nationality of the scientists. However as early as 2008 – in the first phase of the Excellence Initiative – more than 20 percent of the around 4,000 scientific posts were awarded to scientists who had previously researched abroad. In 2011 this had risen to 30 percent. In the graduate schools the proportion of foreign scientists was 36 percent (2008: 26 percent); in the Clusters of Excellence it was slightly lower at 24 percent (2008: 23 percent).[281] Within the context of the Future Concepts funding line *(Zukunftskonzepte)* around 37 percent of the scientific personnel came from abroad.[282] Important regions of origin for scientists at the graduate schools and Clusters of Excellence in 2008 were Europe, Asia and North America. While primarily postgraduates were recruited from the Asian countries, the majority of scientists recruited from Europe, and in particular North America, were in more advanced stages of their careers.

The Emmy Noether programme is directed at young foreign and German scientists who plan to establish their own scientific group at a German research institution. The funding generally extends over a period of five years. In 2012 the DFG approved 58 new projects. This represents an approval rate of 22 percent. The programme was systematically evaluated in 2008, including the long term mobility of the funded individuals:[283] Although only 8 percent of the Emmy Noether stipends awarded between 1999 and 2006 went to foreigners, almost 25 percent of stipend winners were working abroad after funding had ceased – and thus 5 to 10 percent more than the estimated figure for post doctorate scientists in general.[284] The motives of outflowing stipend winners were, above all, the lack of career opportunities and unsatisfactory remuneration in Germany.

The research stipend programme of the DFG also contains a funding line for German returnees from abroad; 58 applications from such scientists were approved in 2012.[285]

B 2–2 EMPLOYMENT OF FOREIGN SCIENTISTS IN GERMANY AND THE UNITED STATES IN COMPARISON

In this section, instead of the migration flows of actively publishing scientists, the focus is on the stock of foreign scientists employed in Germany[286] as well as an illustrative comparison with the United States. The legal framework for the employment of foreign scientists in Germany is described in Box 11. Overall, the observed employment patterns for foreign scientists in Germany and in the US confirm the above identified mobility patterns of publishing scientists.[287]

Improving the knowledge pool of highly qualified workers in the US – reducing shortages of low-skilled workers in Germany

If scientists are identified by the occupation they work in,[288] and if their citizenship is used as an indicator for their country of origin,[289] then, ca. 135,000 out of a total of 2.47 million people employed in scientific occupations in Germany in 2010 were immigrants. Almost half of them were engineers, architects or scientists in related occupations (67,000), a further 24,000 were computer scientists and 23,000 social scientists. The proportion of foreigners in scientific occupations was thus significantly lower (5.5 percent) than for non-scientific occupations (10.8 percent) – and has even fallen since 2007.[290] Obviously, immigration in Germany plays a greater role in

BOX 11

Legal basis for the immigration of scientists

On principle, EU citizens enjoy freedom of movement of persons and services.[291] In addition, Swiss citizens are granted the same rights. Furthermore, additional bilateral agreements between the EU and third countries such as for example Turkey apply.

Citizens of other countries are eligible for a German residence permit as regulated by the German Residence Act *(AufenthG)*. On the one side, scientists can immigrate in accordance with clause 20 of the *AufenthG*, specially drafted for this purpose (established in 2007 on the basis of the Directive 2005/71/EC for the migration of scientists to the EU). On the other side, there are and have long been additional possibilities for foreign workers, irrespective of their profession, to obtain a residence permit for employment in Germany. These options have been in place before the introduction of the special clause for scientists. Naturally, these options can be and are also used by scientists.[292]

The granting of a residence permit in accordance with clause 20 of the *AufenthG* is subject to a series of conditions. The first condition is that the foreign scientist has a corresponding educational qualification. The second condition is that the foreign scientist has signed a hosting agreement with a recognised research institution. Furthermore, the livelihood of the foreign scientist must be guaranteed, which according to the implementation provisions is given when the scientist has a minimum monthly income of EUR 1,703 in the old federal states and EUR 1,493 in the new federal states. In this context, the Federal Office for Migration and Refugees correctly points out that providing proof of such a net income is a great hurdle. This frequently requires a full E13 position; however, in practice, postgraduates or foreign scholars are often only offered a part-time position. In such cases where the minimum income has not been reached, proof of a guaranteed livelihood can also be provided by way of an individual assessment. This involves, above all, assessing whether current income from sources such as stipends are sufficient to reach the above minima.[293] If, according to the assessment, the livelihood is not guaranteed, then no residence permit can be granted. A positive feature is that an analysis of the labour market conditions is not required prior to the granting of a residence permit in accordance with clause 20 of the *AufenthG*. According to a study, at the end of 2011 only 588 people were living in Germany with a residence permit granted in accordance with clause 20, whereby the majority were relatively young (between 25 and 34 years of age).[294] They came mostly from China, India and the United States. The main destinations in Germany are the federal states of North Rhine-Westphalia (NRW), Baden-Württemberg and Bavaria.[295] The number of residence permits granted over recent years has risen continually.[296] However, the steadily increasing numbers should not disguise the fact that the absolute number of residence permits granted according to clause 20 is still very low. This may be due to the fact that comparatively few research institutions (180) possess an accreditation for the granting of hosting agreements. One of the reasons for the low take-up is that the research institutions must commit themselves to covering the costs should the foreign researchers outstay their residence permit. This is especially problematic for universities when the research is funded by third-parties.[297]

Furthermore, foreign scientists, just like other employees from abroad, are eligible for a temporary or unlimited residence permit when moving to and working in Germany in accordance with clause 18 or clause 19 of the *AufenthG*. They can apply for either a (temporary) residence permit or an (unlimited) settlement permit. The precondition for obtaining either one of these permits is a concrete job offer. Furthermore, both residence permits require a labour market need, i.e. the Federal Employment Agency must explicitly authorise the granting of the permit – unless regulated differently by international agreements. Both types of residence permit are granted e.g. to management staff, workers in the fields of science, research and development, IT specialists or academics. For highly qualified workers an unlimited settlement permit can be granted in special cases.[298]

Since 1 August 2012, highly qualified scientists from third countries can move to Germany for a period of employment of between one and four years on the basis of the "EU Blue Card". This also requires a minimum income, which is equivalent to two thirds of the income threshold for

contributions to the pension insurance (or 52 percent in the case of professions for which there is a special need).[299]

Finally, citizens of third countries who intend to enter Germany for the purpose of self employment or the founding of a business, can obtain a residence permit according to clause 21 of the *AufenthG*. The precondition for this permit is that there is a special economic interest or regional need and that a positive effect on the economy can be expected. Furthermore, the financing must be secured by either the individual's proprietary capital or a loan commitment. An initial residence permit for self-employed persons is in principle temporary and is granted for a maximum of three years; once the business idea has been successfully realised and the means of subsistence is guaranteed, then an unconditional settlement permit can be granted.[300] Surveys among foreign (self-)employees have shown that so far the majority of scientists from third countries have come to Germany by means of residence permits granted according to clauses 18,19 or 21 of the *AufenthG* – and not by means of the special clause 20.

reducing shortages of low-skilled workers than expanding the pool of highly skilled scientists. Similar findings, if not so striking, emerge if one identifies scientists according to their employment sector, not their occupation.[301]

A comparison of employment structures of foreign scientists in Germany with the United States confirms patterns observed in the publication data: it is the highly qualified scientists with a doctorate that tend to immigrate to the United States. However, the result very much depends on how "scientists in the USA" are defined. In the case of a broad definition of academics (ISCED 5 + ISCED 6), the proportion of foreign "scientists" is low, while in the case of a narrow definition (ISCED 6 only, i.e. only those with a doctorate degree) the proportion is very high. On the other side, the proportion of foreign employees with no or only a low qualification (ISCED 1 + ISCED 2) is also higher than that of native employees. So obviously in the US, the workforce is supplemented by foreign immigrants in the least qualified and the highest qualified sectors. German academics, and in particular those with a doctorate degree, contribute significantly to improving the United States' knowledge pool.[302] Over 14 percent of all the Germans employed in the US have a doctorate (ISCED 6)[303] – with an upward trend.[304] At the same time, only 1.4 percent of the native employees have a doctorate.[305] If one takes a closer look at the occupations, immigrants from Germany display a very balanced occupational structure. The largest single share is that of the university teachers with 5.4 percent,[306] followed by life, natural and social scientists (4.8 percent), employees in IT and mathematical professions (4.6 percent) as well as architects and engineers (4.4. percent).[307] If one takes into account that the proportion of university teachers amongst the native population in the US is only 0.9 percent and that of the life, natural and social scientists only 0.7 percent, then this shows once again that the pool of highly qualified scientists in the US is improved by German immigrants.

MOBILITY OF PATENTING INVENTORS IN INTERNATIONAL COMPARISON B 2–3

Patents provide legal protection to innovative technical ideas and therefore are often used as an indicator for measuring the innovation performance of an inventor, a company or research institution, or a country. If patenting inventors move across borders, then innovation capacity changes at the different levels.

Current studies on inflows to the US have shown on numerous occasions that the inflow of highly qualified inventors has a positive effect on the innovation activity of companies, start-ups or research institutions in the destination country.[308] A more recent study[309] has shown, for example, that in the period from 1940 to 2000 inventors inflowing to the US registered twice as many patents as native inventors.[310]

Only a very limited number of reliable studies is currently available for Germany. However, they point at least to the positive effect of cultural diversity on the patenting of highly qualified inventors and the start-up intensity at regional level.[311] Studies which assess the effect of outflows of highly qualified inventors on companies and research institutions in Germany are currently not available.

Available patent statistics focus on the outflow movements of those inventors who possess high quality patents.[312] Mobility of inventors has a wide variety of causes. These include, amongst others, intra-firm mobility of R&D personnel in multinational enterprises (MNEs), patenting scientists moving to a research institution abroad, or possibly starting a business abroad (cf. in more detail Section B 2–5).

Moderate but selective outflows of patenting inventors from Germany

In international comparison, as shown in more detail below, patenting inventors from Germany display a moderate outflow rate. This is characterised by systematic industry differences in the mobility patterns. International inventor mobility thus contributes to freezing Germany's R&D specialisation profile: technology fields in which Germany is strong tend to display a low outflow rate and technology fields in which Germany is weak tend to display a high outflow rate. For multinational enterprises, the outflow of inventors is associated with less knowledge loss than for small and medium-sized enterprises (SMEs) if the migration takes place within intra-firm R&D networks.[313] The number of German inventors working in public research sectors abroad is disproportionately high especially in research institutions in the United States. In addition, there is a high incidence of German inventors founding high-tech companies in the US.

Around 6 percent of the inventors patenting in Germany in 2000, were – according to the their address – internationally mobile inventors between 2000 and 2009.[314] At the same time, according to a current study[315] the percentage of mobile German inventors abroad has grown significantly in the period between 1990 and 2010.[316] Despite this relatively strong growth in the past, the outflow rate for inventors is still higher in the majority of the other OECD countries (cf. Figure 24).[317] Only the United States, Japan and Korea display a lower, and in some cases declining, outflow rate for national inventors.

Interestingly, the United States and Switzerland combined currently recruit more than 50 percent of all inventors of German origin (German inventors) living abroad.[318] German inventors appear to be among the most important founders of high-tech companies in the US (if one assumes that the founding of a high-tech company goes hand in hand with a patent). A study has shown that Germany – measured in terms of its contribution to the total number of foreign company founders and foreign patenting inventors – is already in fifth place in the US and thus only ranked behind foreign founders and inventors from India, China, Great Britain and Canada.[319] German founders are especially active in ICT, biotechnology and R&D services. They make up the seventh-largest national group among the high-tech start-ups in Silicon Valley.[320] Only two out of 100 patenting German inventors are active in the US. However, for every 100 newly founded high-tech companies in Germany, there are on average four to five new high-tech companies founded by Germans in the US.[321] Conversely, this means for Germany as a location for innovation, that precisely those mobile (patenting) inventors outflow who successfully translate their ideas into innovation, value added and jobs, and who benefit from more favourable framework conditions for start-up businesses in the United States.

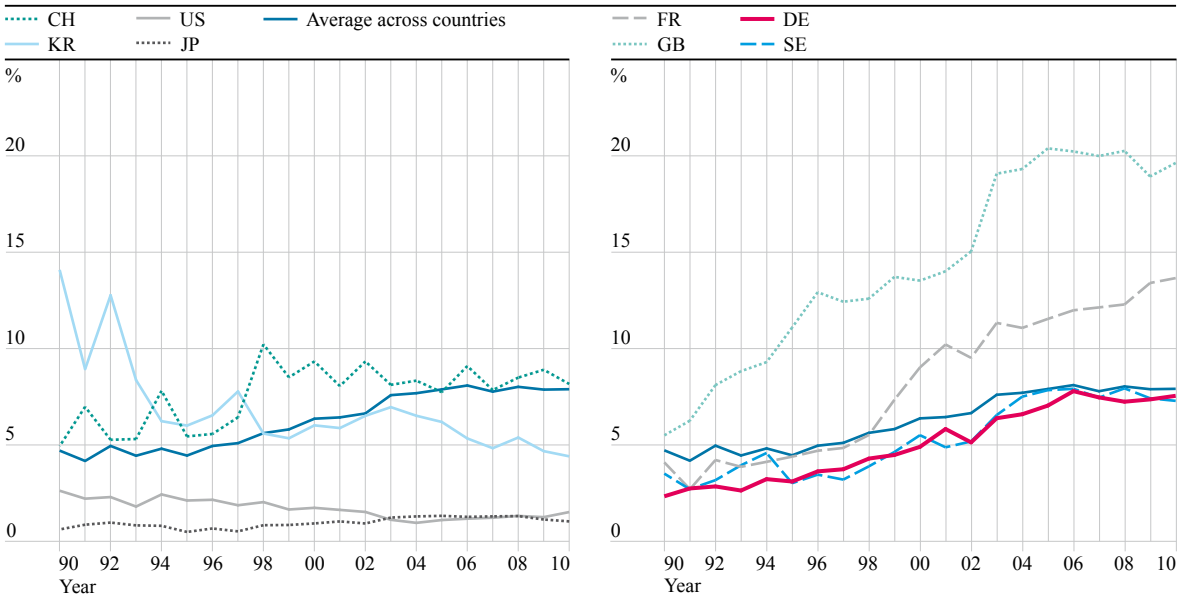
According to a recent study, MNEs applied for more than 80 percent of patents by mobile inventors in the base year of 2000.[322] Just under 20 percent of the patent applications were from SMEs.[323] If one accounts for size effects of patenting, inventors in SMEs are generally more mobile than inventors in MNEs, i.e. at 8 percent, mobile inventors are responsible for a higher proportion of all SME patent applications (compared to 6 percent for MNEs). Although MNEs apply for many of the patents by mobile inventors, inventors tend to leave their existing employer, rather than moving to an R&D site abroad within the same company.[324] More precisely, this means that around two thirds of mobile inventors switch to a different company or to a different research institution abroad, while the remaining third remain within the company when moving abroad.[325]

Furthermore, different mobility patterns for the various industries are identifiable. In 2009 the highest proportion of mobile inventors moving abroad were from the German pharmaceutical and biotechnology industry, as well as from the communications engineering industry (more than 10 percent respectively).[326] These industries also show an especially high level of migration from the previous company. In contrast, mechanical engineering is characterised by

Outflow rates of patenting inventors in international comparison between 1990 and 2010

FIG 24

DATA DOWNLOAD



Source: own depiction based on WIPO (2013).

a relatively low overall level of outflows paired with a high-level of intra-firm migration.[327] Thus the mobility patterns freeze Germany's existing specialisation profile for research and development. Technology fields and industries in which Germany is strong display a low level of inventor outflows over time, which, in addition, tend to be intra-firm.

If outstanding inventors can only be kept in those fields where Germany is already scientifically strong, then it is to be feared that additional investment in education and training designed to close gaps in Germany will be less effective than expected. There is a danger that many of the well-educated inventors will be lost again as a result of international mobility. Consequently, additional investment in education and training must be sufficiently concentrated and strong to create a new technology field that can compete internationally.

High outflows of German patenting inventors to foreign public research institutions

As highly qualified and highly productive scientists at universities and research institutions – including academic spin-offs – are very important for Germany as a science and innovation location, we take a closer look at the outflow of patenting scientists to foreign public research institutions. According to a study,[328] the outflow rate of German scientists employed in foreign public research sectors was 13 percent between 2001 and 2010. In comparison, the outflow rate of US scientists working at foreign public research institutions is only just under 2 percent. Consequently, the US and other European countries successfully retain patenting scientists at domestic public research institutions.[329] At the same time, Germany as a science location loses a relatively high number of top patenting scientists, in particular due to outflows to the excellent scientific systems in the US, Switzerland and Great Britain.[330]

However, the outflow of patenting German inventors does not necessarily lead to a shortage or constitute a brain drain, if it is offset by a corresponding level of inflows, i.e. brain gain. This will be examined in the following section.

Germany shows a low inflow rate of patenting inventors and a weak overall position

In international comparison, inflows to Germany are at best in the middle field, with a slight upward trend. If one examines the total sum of those inflowing to and outflowing from Germany, then Germany is well integrated in the international brain circulation. Yet, in comparison to other OECD and BRICS countries, Germany is only ranked in the lower third with a slightly negative net position of inflowing and outflowing inventors. With respect to its relatively moderate outflow rate, the German company sector is considerably more successful at keeping inventors in Germany when compared to the German public research system.

Again, the situation is considerably better in the United States. While according to the WIPO study (2013) the share of foreign inventors of all patentees in Germany for the period between 2001 and 2010 was around 5.5 percent, in the United States foreign inventors made up more than 18 percent in the same period. There are also clear differences between Germany and the US in respect of the inventors‘ countries of origin.[331]

Foreign inventors can also be identified at firm level. The proportion of foreign inventors amongst the top ten German patent applicants (both companies and research institutions), was generally in the single digit range across industries (between ca. 2 percent and 8 percent; cf. Table 8), and thus very low in international comparison. In the case of patented inventions in companies and research institutions in the USA, Switzerland or Great Britain the proportion of foreign inventors was considerably higher, often more than 50 percent, with Switzerland again in the forefront. As a consequence, German companies miss out on considerable innovation potential which companies in other countries are acquiring through the recruitment of foreign inventors and a corresponding increase in diversity (cf. Chapter B 4).[332] In the view of the Expert Commission, there is room for considerable action on the part of companies in this area.

Finally, if one compares the inflows of patenting inventors in major OECD countries between 1990 and 2010, country-specific trends can be identified (cf. Figure 25). While Japan has attracted hardly any foreign patenting inventors over time, the US and Switzerland have succeeded in continually extending their leading positions. Germany is ranked in the bottom group of the comparison countries with respect to the inflow of patenting inventors. Yet, along with Great Britain and Sweden, Germany has shown an upward trend since the middle of the 1990s. However, this upward trend is below the average increase in this sample of countries.[333] Amongst the selected OECD countries, the only ones that showed above-average increases were those that already had the highest inflow rates for inventors. Thus the gap between Germany and these countries has widened even more since 2000.

In turn, the inflow rate for foreign inventors entering the German public research sector is especially low. In Germany the rate for these inventors was ca. 8 percent for the period between 2001 and 2010. In comparison, it was 25 percent in the US and 48 percent in Switzerland. In contrast, France and Sweden with a rate of 7 and 10 percent respectively, are at a similar level as Germany.[334]

If one considers the net position of all inflowing and outflowing patenting inventors, then Germany has a negative balance over the past decade: there were around 7,000 more outflows from Germany than inflows into Germany. In an international comparison of OECD and BRICS countries, Germany as an innovation and science location is ranked in the bottom third with respect to its net mobility position (cf. Figure 26). Therefore, Germany ranks poorly compared to the leading countries Switzerland and the United States.[335] In addition, Japan and many smaller European countries such as the Netherlands, Sweden, Belgium or Finland also show balanced or positive net mobility patterns. This shows that Germany, as an innovation and science location, needs to improve its capacity for recruiting and keeping foreign patenting inventors.[336]

However, the “turnover” of mobile inventors in Germany, i.e. the sum of inflows and outflows (brain circulation) is the highest worldwide behind the United States. This at least points to Germany‘s tight integration into the international knowledge and know-how circulation. That said, it appears that too few mobile inventors actually choose to stay in Germany. Arguably, Germany at least benefits from indirect innovation effects as a frequent destination and

Share of foreign inventors among the top 10 PCT patent applicants of companies and research institutions in selected countries between 2006 and 2010

TAB 08

DATA DOWNLOAD

	Share of foreign inventors	PCT applications	PCT inventors
DE			
Robert Bosch	2.8	6,480	17,484
Siemens	6.4	4,555	11,753
BASF	14.4	3,562	15,427
Bosch-Siemens Hausgeräte	3.2	1,679	4,575
Fraunhofer-Gesellschaft	5.4	1,532	5,521
Continental Automotive	8.6	1,337	3,447
Henkel	6.4	1,210	4,420
Daimler	3.8	1,196	3,601
Evonik Degussa	5.6	974	4,103
ZF Friedrichshafen	2.4	958	2,702
US			
Qualcomm	50.8	6,528	19,907
Microsoft	57.4	3,020	11,297
3M	11	2,577	8,852
Hewlett-Packard	18.6	2,360	6,114
E.I. Dupont De Nemours	17	2,118	5,916
IBM	21.4	2,006	6,854
University of California	28.2	1,754	5,598
Motorola	23.4	1,573	4,488
Procter & Gamble	10.2	1,540	4,953
Baker Hughes	12.8	1,461	3,552
CH			
Nestlé	56.4	619	1,781
F. Hoffmann-La Roche	46.6	564	1,385
Novartis	62.6	489	1,179
Syngenta	66.6	308	972
Actelion Pharmaceuticals	30.2	272	879
Alstom	67.6	212	506
ABB	65	201	529
Swiss Federal Institute of Technology	49.2	186	534
Sika	30.4	179	426
Inventio	23.6	174	338
GB			
Unilever	10.4	594	1,536
GlaxoSmithKline	12.6	409	1,590
British Telecommunications	20.2	389	861
BAE Systems	3.2	305	644
Imperial College	29.8	246	648
University of Oxford	29.8	242	618
Dyson	10.4	237	579
Astrazeneca	8.2	210	640
Cambridge University	36.6	205	572
QinetiQ	2.2	185	458

Source: own depiction based on WIPO (2013:27).

FIG 25 **Inflow rates of patenting inventors in international comparison between 1990 and 2010**

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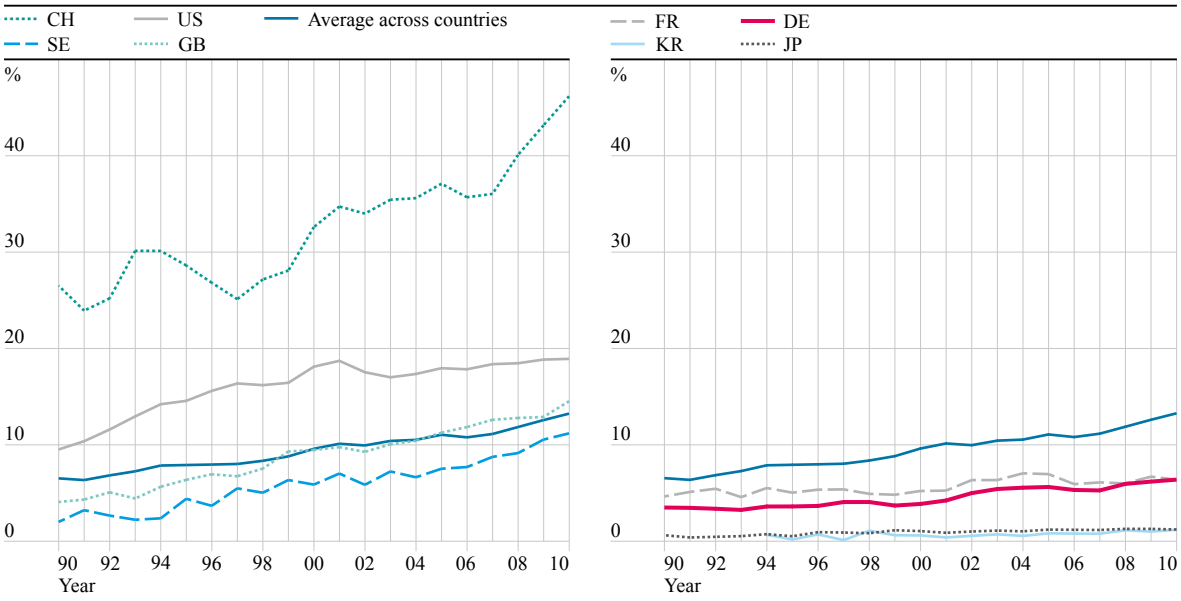

Source: own depiction based on WIPO (2013).

country of origin for mobile inventors. Yet, whether the sum of direct effects (high outflow rate) and indirect effects (high knowledge circulation) is positive or negative at large cannot be determined on the basis of the conducted descriptive analysis.

With respect to a qualitative assessment of inventor mobility in Germany, there is clear evidence on a self-selection process of the best German patenting inventors into public and private research institutions abroad, to the detriment of Germany. This applies in particular to German patenting inventors who decide to found a high-tech company in the United States or self-select into the US science system. At the same time, this trend is not counterbalanced by a positive self-selection of inflows to Germany. Comparatively few highly-qualified inventors intending to found a company move to Germany from abroad. Similarly, few patenting inventors move to German research institutions.

DIRECT AND INDIRECT EFFECTS OF THE INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS ON RESEARCH AND INNOVATION CAPACITY

B 2–4

Direct effects of the mobility of scientists are generated by changes in the knowledge pool as a result of inflows and outflows. Indirect effects can occur if scientists remaining in the country, keep in contact with colleagues who have migrated. For the scientists remaining in the country this leads to an improvement of personal networks and participation in the international knowledge pool, enabling them to become more productive. If such indirect effects are large, then the negative impact of migration is less strong than expected.[337]

International mobility can thus affect a country‘s innovation capacity through numerous channels. A comprehensive analysis of the literature[338] uncovers three effects of international mobility: First, the positive selection of inflows plays an important role with respect to the direct effects, whereby the attraction of “star scientists” is decisive.[339] Second, innovation capacity can be improved directly through an increase in the diversity of scientists. Third, a

Inflows and outflows of patenting inventors between 2001 and 2010
(figures in thousand)

FIG 26

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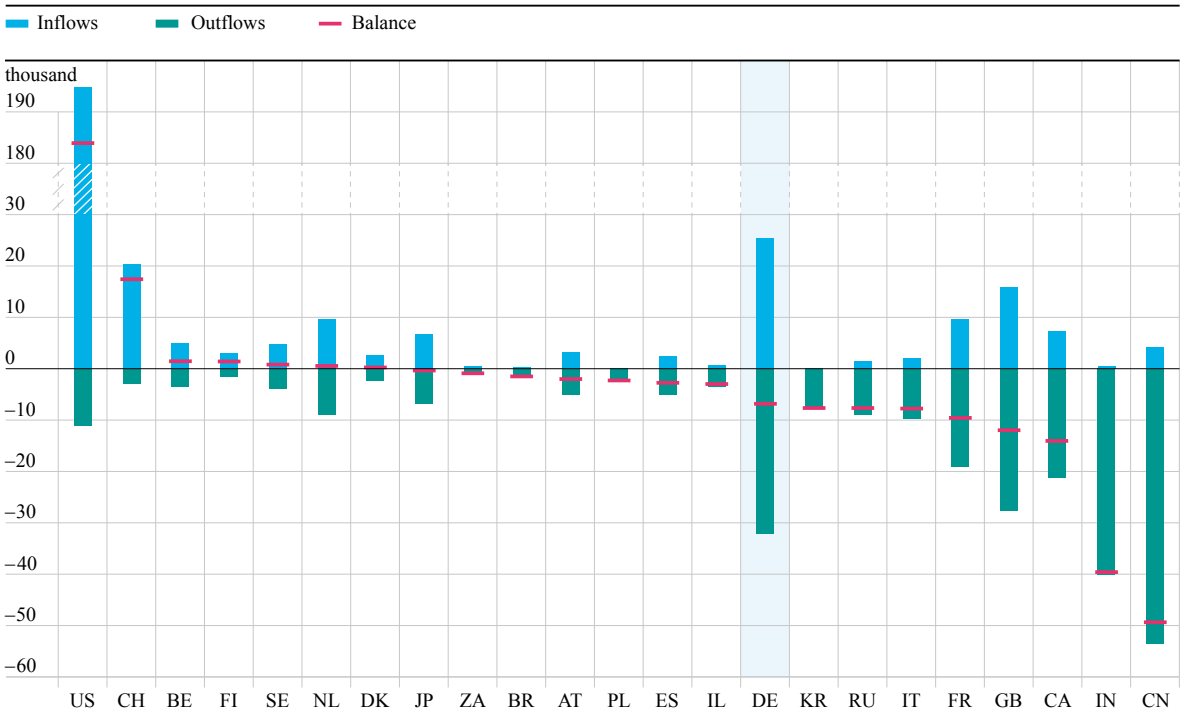

Sorted by balance in descending order.
Source: own depiction based on WIPO (2013).

How to read: approx. 25,000 inventors were inflows to Germany, while approx. 32,000 inventors were outflows. Germany thus has a negative balance of approx. 7,000 individuals.

so-called "diaspora network effect" can have an indirect positive influence: through close contacts between scientists in the home country and those who have migrated abroad, international information and communication costs can be substantially reduced. This network effect enlarges the knowledge pool and increases the likelihood of innovations.[340] Conversely, the outflow of knowledge is likely to generate corresponding negative effects.[341]

Empirical evidence, in particular that relating to indirect and longer term effects, is relatively sparse and methodologically extremely heterogeneous,[342] however it is possible to extract a number of stable patterns.

Positive direct effects of scientist mobility on the United States' knowledge pool

In the US, the inflow of foreign scientists de facto enlarges the knowledge pool without a displacement of native scientists.[343] The inflow of scientists leads to a disproportionate increase in the number of patents in the United States.[344] Hence inflows do not simply substitute patenting by natives, but they induce additional patenting.[345] Furthermore, evidence shows that scientists inflowing to the US apply for twice as many patents as native scientists and that foreign college graduates lead to a doubling of patents in the respective regions.[346] The great significance of foreign scientists or inventors is also underlined by the finding that around one in eight of the world's most frequently cited scientists (1981–2003) were born in a developing country, however 80 percent of them migrated to a developed country – often the US – during their career.[347] Thus in the USA the research and innovation knowledge pool is

systematically enlarged as a result of the high level of immigration.

Negative direct effects of scientist mobility on Germany's knowledge pool

A historical study[348] examines the research performance of German universities affected by Jewish emigration during the period of National Socialism. The study shows that the primary cause of the deterioration in Germany's research performance at that time was the loss of top scientists, whereas the destruction of university buildings during the Second World War played a much smaller role.

As a current indicator for the loss of research capacity the country of the hosting institution and the nationality of scientists funded by the European Research Council (ERC) can be employed as an indication for the loss of research capacity due to migration.[349] This shows that while German researchers are highly successful in acquiring ERC grants, German researchers at the same time acquire by far the highest number of grants while employed at institutes abroad (221) (with Italy in second place with 143 grantees hosted abroad; all other countries have an average of around only 30 grantees hosted abroad). Here Germany at least temporarily loses substantial research potential.

Strong indirect effects of scientist mobility in the USA and also to a reduced extent in Germany

Historical studies also examine the indirect effects of the displacement of Jewish and politically undesirable professors on the publication success of their doctoral students who remained in Germany.[350] They show that the outflow of the best scientists during the period of National Socialism, i.e. in a situation in which it is unlikely that there were any systematic network ties with the home country, had a strong negative affect on the productivity of the researchers remaining behind. However, this finding does not exclude the possibility that international networks could have a dominantly positive effect in a situation where a regular exchange between movers and stayers is easily possible.

If one uses co-authorship as an indicator for such network effects, then in the case of the most frequently cited publications of international co-author teams worldwide, it can be observed that the corresponding authors of co-author teams – and thus often the most important or decisive authors – are most frequently residing in the US.[351] This indicates the importance of good networking with co-authors residing in the United States. To this extent, networks between scientists who migrated to the US and their former colleagues have a clear potential for positive spillovers, with benefits for those scientists that remained in the home country, but also for those returning. For example, Switzerland's international publication patterns provide evidence on the large importance of such international researcher networks. Compared to other countries, Switzerland has the highest number of frequently-cited publications as a proportion of all publications, however almost half of the corresponding authors live abroad. The impact of the scientific output can be systematically increased through cooperation in international networks, in particular when partnering with authors in the US.

Indirect effects resulting from the knowledge flows between home and abroad can also be demonstrated in the case of inventors, namely on the basis of the joint patenting by inventors in Germany and inventors of German origin abroad. Here Germany performs well in international comparison: teams composed of German inventors abroad and inventors in Germany are responsible for around one quarter of all PCT patent applications.[352] In international comparison, only US inventors abroad have a greater tendency to exchange knowledge with inventors in their home country and submit joint patents.[353]

In conclusion, an assessment of international mobility of scientists should not only account for the net position as regards inflows and outflows of scientists, i.e. the relationship between brain drain and brain gain, but also for the positive network effects resulting from brain circulation. Outflows, particularly of top scientists, result in a loss of German research capability. Nevertheless, national research can be strengthened to some extent through positive network effects and greater integration in international knowledge circulation. However, Germany still has ground to make up in this area – for example in comparison to Switzerland. The

Nationality of grantees funded by the European Research Council between 2007 and 2013

FIG 27

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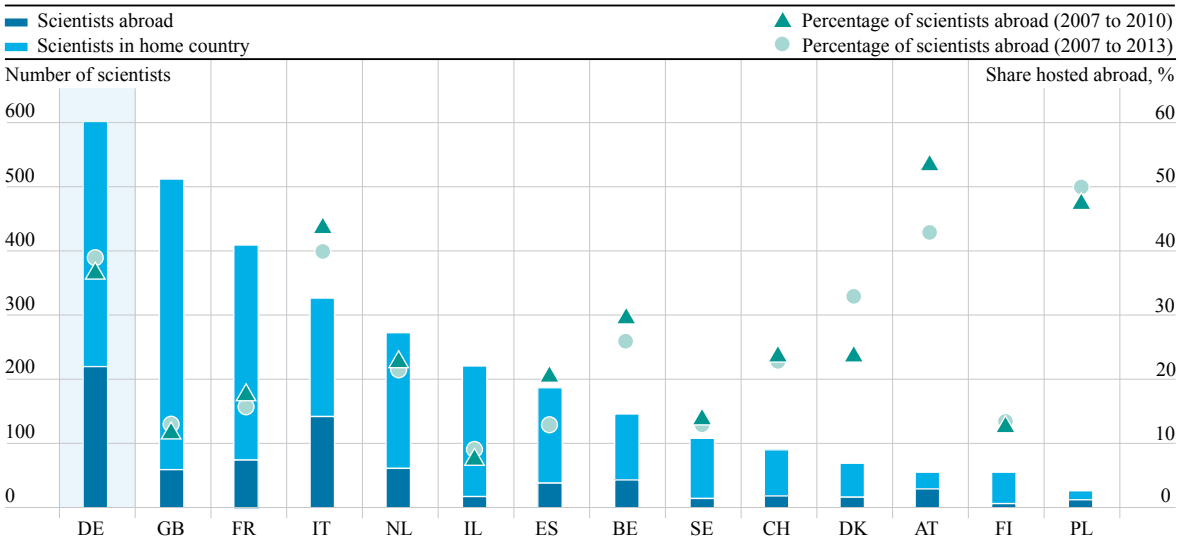

Source: own depiction based on EFI (2011); calculations according to EU-ECORDA database.

How to read: between 2007 and 2013, approx. 600 German scientists received ERC funding (left axis). From among these scientists, nearly 400 performed their research in Germany, and more than 200 performed their research abroad. The share of scientists hosted at foreign research institutions is nearly 40 percent (right axis).

strengthening of indirect effects – again, as exemplified by the Swiss case – requires a strong scientific base and an attractive science system in the home country, as these facilitate the best possible interaction with the global science system.[354]

However, whether in sum the positive network effects are sufficiently large to compensate for the direct negative effects of outflows from Germany cannot be answered on the basis of the very sparse empirical evidence. Yet, it can be concluded that Germany's innovation capacity increases when its science and research system is made more attractive, especially to top scientists, thus strengthening the direct and indirect positive effects of researcher mobility. Therefore, the decisive question is what motivates the best scientists to leave their own country or migrate to another country, respectively.

REASONS AND BARRIERS FOR THE INTERNATIONAL MOBILITY OF SCIENTISTS AND INVENTORS

B 2–5

Excellence of the science system as the most important factor

The most important reasons for international mobility of scientists are academic motives: "... a dynamic, well-funded science system seems to trump all other incentives."[355] This is especially confirmed in a comparison between Germany and the United States.[356] Surveys among natural scientists[357] provide detailed information on the most important factors for international mobility: improved career opportunities, cooperation with outstanding colleagues and research teams, the excellence of the foreign host institution in one's own research field as well as better infrastructure and faculties (cf. Figure 28).[358]

Above all, scientists are internationally mobile in order to gain better access to leading scientists in their field, to the best research centres or to important networks. This explains the leading role of the United States, as well as Canada, Great Britain

and Switzerland as destination countries: as Figure 29 shows, scientists in the US (2003 – 2011), who are often chosen as co-authors by foreign scientists, have the highest publication productivity, measured in terms of the annual number of articles (as indicated by the size of the circle). Furthermore, they also display a very high average impact factor (as indicated by the high vertical position of the circle).[359] However, as there is also a large number of publications in the US produced without foreign co-authors, – primarily a consequence of the size of the home market – the proportion of international co-publications is rather low (as indicated by the position of the circle relatively far to the left).

Canada and Great Britain have an impact factor that is almost as high as that of the US, however, they have a relatively high proportion of publications with international co-authors (as indicated by the position of the circle further to the right), which is an indirect consequence of smaller home markets. In contrast, Germany with its less favourable international mobility patterns than the US, Canada or Great Britain – as shown in the previous section – has approximately the same number of publications (size of the circle) and a slightly higher share of international co-publications (position of the circle to the right) compared to these countries, but a significantly lower impact factor (lower position of the circle).

The situation is strikingly different in Switzerland or the Netherlands where – as shown in the previous sections – mobility patterns are considerably more favourable than those in Germany. Both countries have a far above average impact factor – albeit based on a very small number of publications. This is accompanied, especially in Switzerland, by a very high level of international cooperation, which appears to leverage the impact of these publications. Favourable international mobility patterns are exhibited by those countries where the best scientists, i.e. the best scientific research environments are to be found. Thus the primary goal of internationally mobile scientists, of migrating to locations with excellent research conditions, generates a self-reinforcing process.

Working conditions and personal motives are important but secondary causes of international mobility

The aforementioned survey results[360] clearly show that only after a large number of academic motives other motives for international mobility are mentioned. These include the attractiveness of the lifestyle in the destination country, the better quality of life, better working conditions such as vacations or working hours, or family and personal motives. According to this study, access to third-party funds and monetary or non-monetary compensation packages (wages, corporate social benefits etc.) have a relatively low priority. One possible reason for this low priority is that relatively generous endowments and compensation packages are taken for granted in the typical destination countries of internationally mobile scientists. This assumption is confirmed by empirical studies which show a strong correlation between research budgets and inflowing researchers[361] or between wage differentials and international mobility.[362]

Legal restrictions on residency and cultural barriers reduce the attractiveness of Germany as a destination for internationally mobile scientists

Beyond this, internationally mobile scientists are naturally also migrants like any other, and they struggle with the same problems. These range from obtaining a visa and integrating children into a foreign school system to occupational opportunities for partners and overcoming cultural differences. Here public policy can assist in facilitating the international mobility of scientists through transparent and immigration-friendly immigration policy. These should include straightforward visa and working conditions for scientists and their families[363] and could include financial subsidies or other integration and moving allowances or relocation services.[364]

Germany's current visa regulations are often perceived as a bureaucratic hurdle, although they hardly represent a barrier for today's mobile scientists (cf. Box 11).[365] However, the complexity of visa regulations and the range of administrative institutions involved prevent an optimisation of the statutory regulations and their application. More user-friendly and simpler

Reasons for international mobility of scientists

FIG 28

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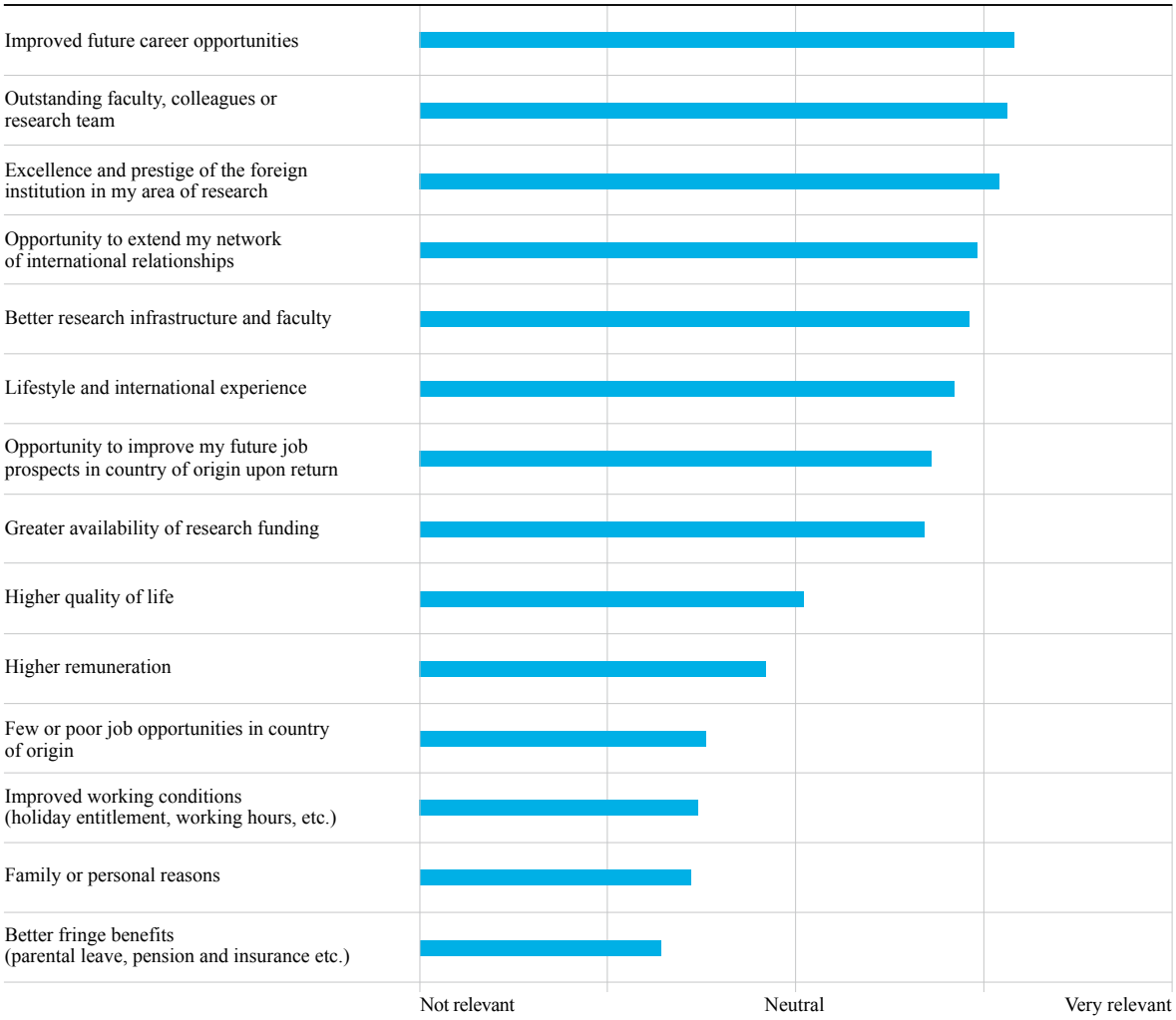

Source: own depiction based on Franzoni et al. (2012a).

processes are indispensable if immigration is to be made more attractive to foreign scientists. The EU Blue Card has had a positive effect in this context. Only recently introduced, it has already become an extremely attractive residence permit for newcomers. With around 2,500 awarded permits within one year (end of 2012 to end of 2013), it has brought more academically qualified workers to the country than any previous residence permit for this target group. Between 2005 and 2012, under the former provisions for highly qualified workers (clause 19 of the *AufenthG*), only a total of 2,796 persons immigrated and are still resident in the country. The Blue Card reached this figure within less than a year and is considered a step in the right direction.

The organisational structures of the German research system often present a barrier for returnees

For those returning from abroad the situation is different. Visa regulations or integration problems present no or hardly any barrier. Family and personal reasons are often the primary motive for returnees. In contrast, organisational structures in the German

FIG 29 **International scientific collaboration and impact of scientific publications between 2003 and 2011**

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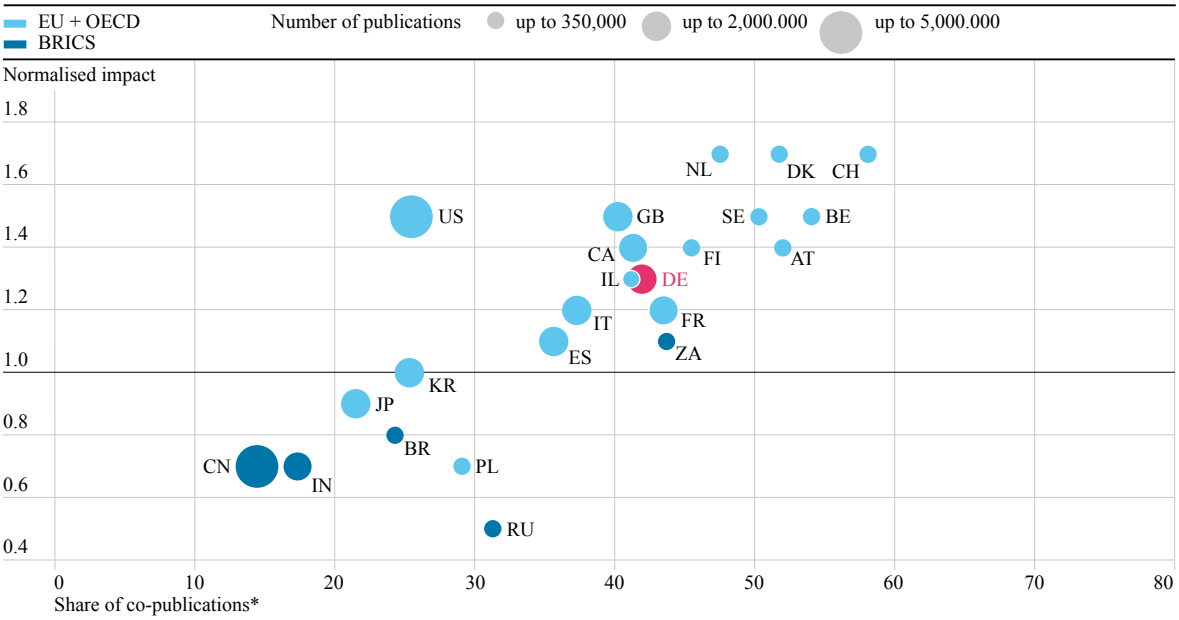

Source: own depiction based on OECD (2013b: 6).
* including foreign co-authorship in all publications of national research organisations

How to read: Germany has a relatively high number of total publications (size of the circle) and occupies a similar position in its share of international scientific collaborations (position of the circle to the right). Yet, Germany's impact factor is significantly lower (lower vertical position of the circle).

research system or incompatible social security systems and family policies frequently represent barriers.[366] The causes and barriers for returnees thus differ from the general motives of international scientists. If one simply aims to bring back Germans to Germany, then it may be possible to achieve a great deal with only a few organisational measures.[367] However, if one wants to benefit from the mobility of all of the best international scientists, then this requires large-scale investments to strengthen the German science system and to create internationally visible fields of excellence. In turn, this will also facilitate the return of the best German scientists abroad. To create an internationally visible site of research excellence, the goal should be to create a research infrastructure that is strictly directed towards excellence, which provides the necessary freedom and flexibility for the recruitment and integration of top international scientists – instead of focussing on the needs of a large and strong middle field. Naturally, generous financial resources (basic funding, third party funds and compensation packages) are needed, however, dynamic organisations and flexible systems of financing are also important.[368]

RECOMMENDATIONS B 2–6

Today more than ever, science is conducted within a competitive international environment in which countries with highly developed, financially well endowed and dynamic research systems lead the field. Scientists and inventors migrate to those locations where research conditions and financing are especially attractive. The best, most talented scientists are attracted to the best colleagues in their field worldwide. This leads to self-reinforcing effects. To break through them, massive countermeasures are required. In order to improve Germany's position in the international competition for the best scientists and inventors, and to benefit more strongly from their mobility, it must systematically and comprehensively expand and develop its research system's existing strengths so as to create internationally competitive research and working conditions in the leading segment.

This will also alleviate some of the problems for research in the university medicine sector as discussed in Chapter B 1 and facilitate the strengthening of the

ICT industry as called for in Chapter B 3. In order to increase the competitiveness of the German research system in the leading international segment, the Expert Commission recommends ensuring good basic funding and excellent project financing opportunities. At the same time, organisations within the top tier must be granted more freedom to experiment with new personnel or budget structures, and thus keep pace with international developments.

In addition, Germany must intensify efforts to attract international research talent to Germany and retain the best scientists in the country. The Expert Commission recommends undertaking greater efforts to attract young foreign scientists in the post-doctoral, but also in the doctoral phase to Germany, and to offer the best of them attractive conditions for a future stay in the country. As recommended in the 2012 Report, increased efforts also need to be made to attract outstanding foreign students on the Bachelor or Master level and convince them to take up employment in Germany following graduation.[369]

To simplify the employment of foreign doctoral candidates within the framework of the existing wage structure, the Expert Commission recommends reducing the minimum income requirement for residence permits granted in accordance with clause 20 of the *AufenthG*. Furthermore, applying for residence permits should be made easier to understand and more user-friendly. In addition, the general public and interested foreign scientists should be better informed of the current, improved options for obtaining residence permits for scientists. This should counteract the widespread perceptions regarding potential bureaucratic hurdles.

Furthermore, efforts need to target the return of top German scientists and inventors working abroad. "Pooled appointments" – e.g. recruiting entire groups of scientists, can quickly provide these returnees with an attractive research environment. This would be especially advantageous in strategically important scientific disciplines and future core fields where a significant leap forward could be achieved by appointing renowned research groups.

The effectiveness of existing returnee programmes should be systematically evaluated. After a careful evaluation, they should be expanded and strongly focussed on attracting leading scientists. In addition to excellent research conditions, personal mobility requirements for both well-established and young foreign scientists also need to be addressed if they are to be motivated to work in the German science system. "Dual career" issues are becoming increasingly important and must be given greater attention during both the development of visa regulations and the targeted recruitment of top talent. Furthermore, efforts need to be made to increase the compatibility of social security systems for researchers and scientists across Europe as the existing differences hinder cross-border appointments and mobility.

In order to be able to identify new trends in the international mobility of scientists and inventors at an early stage, the Expert Commission recommends a systematic monitoring of brain drain and brain gain.[370] In addition, an "opinion barometer" which regularly records the mood amongst leading scientists (foreign and domestic scientists in Germany and in important competing countries) could help to identify problems and the need for action at a very early stage.