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We take the brains: effects of post-WW2 knowledge exploitation programs on German inventors' networks

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Abstract

We look at the effect of involuntary short-term stays abroad on inventors' networks. We use a British post-WW2-program aimed to exploit German knowledge as a natural experiment to investigate its effects on German scientists and technicians. We use a newly created dataset to test if short but involuntary stays abroad have the same positive effects on inventors' networks that have been found for other types of migration. We use a Swiss control group to do a difference-in-differences estimation to find the effect of the treatment. We find a clear increase in productivity (measured by patent output) for the treated Germans and a higher probability to find employment in the UK, while only very few Germans shifted all of their activity to the UK. On the other hand, we only find weak evidence for the productivity increase being caused by an extended knowledge base (as measured by patent citations) in the UK, and no evidence for new relationships between German experts that were interned together.

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Introduction

Previous research highlights the importance of inventors' social networks for the diffusion of knowledge. Multiple studies have shown that knowledge has the characteristics of a club good, and that knowledge flows seem to always be bi-directional (Breschi & Lissoni, 2005; Schrader, 1990; von Hippel, 1987). In this paper we shed some more light on these issues by showing that even when one person is forced to reveal her knowledge to another expert in her field, there will be an exchange rather than a draining of knowledge and thus a profit for both sides. However, we find that a knowledge exchange needs to be intentional rather than coincidental to result in a higher innovative output.

We use a British post-WW2-program aimed to exploit German knowledge as a natural experiment to investigate its effects on German scientists and technicians. We use a newly created dataset to test if short but involuntary stays abroad have the same positive effects on inventors' networks that have been found for other types of migration in previous research.

In the following section, we will give a short overview over the state of literature, then we will put our study in its historical context and formulate three hypotheses. Afterwards, we present the data and show our results. In the last section we discuss the results and give some conclusion as well as some policy implications.

Knowledge networks and migration

In economics and other social sciences, the diffusion of knowledge has been debated for the past decades. While it does not behave like a private good, knowledge does not have all the characteristics of a public good, either. Empirical research has been done to find out more about the characteristics of knowledge, its creation and its diffusion. Jaffe et al. (1993) first used patent citations as an indicator for (local) knowledge transfers, with the assumption that if one patent cites the other, a knowledge transfer has to have happened from one patentee to the other. Breschi and Lissoni (2001) ventured doubts on knowledge as a local public good, suggesting knowledge as a club good which is exchanged openly within a closed community.

Building on these thoughts, Breschi and Lissoni (2005) show the importance of knowledge networks for the emergence of local knowledge clusters. They found that knowledge flows are especially strong within an inventor's social network and that this network stays intact and important even when the inventor migrates.

The club-good theory of knowledge finds support by the work of Schrader (1990) and von Hippel (1987). Both found unexpectedly high levels of informal knowledge exchange between (even competing) firms. Employees are found to trade information with each other, and the knowledge exchange is characterized by reciprocity. Thus, knowledge exchange among experts is described as a bidirectional process.

The importance of outside knowledge on the inventive outcome of industrial researchers is shown in the work of Hoisl (2007). She uses data from the PatVal survey on German inventors, where researchers were asked about the use of outside knowledge sources such as scientific literature or patents from other firms. Knowledge sources from outside the firm used by highly skilled researchers are found to significantly raise the researchers' productivity (measured by patents filed).

Another stream in the literature is focused on effects of inventors' social environment on knowledge creation processes. For inventors who migrate to other countries, strong changes of their social networks are expected. Agrawal et al. (2006) were able to show that, through preexisting personal relations, knowledge seems to flow back to migrated inventors' home countries. Franzoni et al. (2014) found that migrated scientists profit greatly from their extended networks. They find that those scientists that migrate and do their research in different teams later have larger networks and are more likely to receive top ranking publications. Even short term migration, such as scientists' research stays abroad, can lead to long-lasting network extensions (Jöns, 2009). However, self-selection might bias the obtained results. Research stays abroad usually take place when both parties involved wish to establish long lasting contacts. It is our aim to find out if such effects hold even if the long lasting network extension was not intended.

Knowledge diffusion and creation seems to depend strongly on the social environment of inventors. Social contacts through which new knowledge is expected to diffuse can be expanded by migration. In this context, exogenous shocks that cause a large number of knowledge-carrying people to migrate can serve as natural experiments. Borjas and Doran (2012) give a good example for the importance of well selected natural settings, because they may gain rather unexpected results. The authors studied the effects of Soviet mathematicians moving to the USA, right after the fall of the iron curtain, on the structure of US-American mathematics research. While an increase in productivity due to the highly skilled migrants was expected, a crowding out of US-American researchers was observed.

By comparing treated to non-treated scientists, the special characteristics of knowledge diffusion can be further investigated. Our aim is to explore the previously discussed issue of knowledge networks in the context of a natural experiment that took place after the second World War.

Historical framework

Pre-WW2 German industry was highly developed, with international competitive advantages in sectors such as the chemical industry and rocket science. Already in 1944, months before the war was over, the Allies started different programs to get a hold of this knowledge, as some kind of “intellectual reparations” (Gimbel, 1990 b). These programs quickly evolved and grew bigger and bigger. The USA and the United Kingdom first only acquired knowledge for military purposes, which was justified with the need for advanced technology to win the war against Japan. However, later they also started targeting the private sector. Industry sites of interest were identified, secured and systematically searched by specialists. Many of the documents captured were not self-explanatory, thus German experts had to be questioned. In the aftermath of WW2, German scientists and technicians were held captive in special camps in the occupied zones in Germany. This also helped the USA and the United Kingdom to keep these Germans from falling into Soviet hands. Those experts who proved to be useful were brought abroad “whether they liked it or not” to reveal their expertise (Gimbel, 1990 b). A number of them even migrated permanently, for which there were clear incentives. Some liked the idea of being able to avoid the denazification process, which was made possible for them if they were useful enough to the Allies, and some gained the opportunity to keep on working in their fields of expertise, which might have been prohibited in occupied Germany. The research group of Wernher von Braun that was flown to the USA shortly after the war had ended is only the most prominent example (Lasby, 1971; Jacobsen, 2014). The military documents keeping record of these programs were only recently and gradually declassified. To our best knowledge, this study is the first empirical analysis conducted on the basis of this data.

In this study, we focus on the “BIOS” program (British Intelligence Objectives Sub-Committee), which was set up by the United Kingdom in order to get as much information out of selected German experts as possible. They were brought to the United Kingdom and held captive in a detention center. According to one of the German experts who experienced the internment, they spent most of their time alone with each other, only to be questioned from time to time by public officials or by company representatives. In rare cases, they were even taken to other parts of the United Kingdom by the request of companies to be questioned there. For most of them, this treatment came unexpected. Before being brought to the UK, they had been told they would be “guests of the British Empire” and they had been promised a short stay. Instead, they spent weeks or even months in a camp secured by barbed wire. To pass the time, academics and engineers in the camp started giving each other lectures about their areas of expertise. Some of the experts had pre-existing contacts to British firms, which they believed they could renew during their stay in Britain. However, this was mostly prohibited by British officials. Expert

talks between the Germans and employees of UK firms thus established new contacts, but even they were completely steered by the British. The German experts had no say in whom to meet (Gimbel 1990 a). Nevertheless, they talked to experts from their fields that wanted the Germans' expertise for problem solving. Thus, some information had to be given to the Germans. It can be said that during their stay in the United Kingdom, the German experts were able to gain and exchange knowledge with each other and with their British counterparts. This can thus be seen as an involuntary short-term stay abroad that led to an extension shock of knowledge sources.

Hypotheses

The interaction of German experts with British specialists active in the same field in combination with the aforementioned theory about bi-directionality of knowledge exchanges leads us to our first hypothesis:

H1: For the German experts that visited the UK through BIOS, an increase of direct interaction with UK inventors and applicants can be observed.

Theory suggests that knowledge exchanges between experts are not unidirectional. Even if German scientists got fully utilized, just revealing their knowledge might have given them information about ideas British researchers were concerned with. This makes us expect that German experts were able to at least take some inspiration for future research from the exchange with their British counterparts. This inspiration may have resulted in a higher productivity after their return from the UK. Of course, with British sources as a driver for their rise in productivity, the number of British collaboration partners and the number of British sources used for research should also rise. However, not only the interaction with the British might have been fruitful for the German experts. Since all Germans were experts of their fields, knowledge exchanges among them could also have increased the Germans' productivity. We thus anticipate to find proof that not only the British were able to benefit from BIOS by a gain in knowledge, but we also expect the German experts and their networks to benefit from the newly won channel for knowledge flows between the two countries. Proceeding from these considerations, we formulate Hypotheses 2 and 3:

H2: For the German experts that visited the UK through BIOS, an increase in productivity measured by patent output can be observed.

H3a: Post WW-2 productivity can be linked to UK knowledge sources, visible through patent citations made to UK patents.

H3b: Post WW-2 productivity can be linked to treatment group internal knowledge sources, visible through patent citations made to other treated Germans.

Dataset of German and Swiss inventors

Our primary data source was made publicly available by the British Ministry of Supply in 2006. It consists of lists of scientists and technicians that were brought to Great Britain between October 1946 and August 1947 to be questioned and to be denied to the (Soviet) enemy. The lists are separated into three projects, “BIOS” (the British Intelligence Objectives Sub-Committee), the “Darwin Panel Scheme” and the “DCOS Scheme”. We set our focus on BIOS, the objective of which was to get German experts to the UK for a short period of time to be questioned by public officials and by interested parties from the local industry. The latter two schemes were not as big and were set up to move Germans to the UK permanently.

After retrieving the scientists’ names and the duration of their stay from the lists, we searched for their names on patents in DEPATISnet (the online database of the German patent office). In total we counted 249 experts who stayed in the UK for at least one week (mean duration: 6 weeks). 169 were involved in patenting activities. 40 of those matched to several inventors sharing the same name. Because we do not have any further criteria (except the name) we could not clearly distinguish which of the matched inventors is the one on our list. Thus we decided to exclude them from the sample. Of the 129 experts left, we found 74 to have patenting activities both before and after 1947, which is the year during which the treatment occurred. We found 4206 patent documents published by the inventors on this list. We examined all documents manually to identify the country of residence of the experts, their applicants and co-inventors. Beside this, we tracked the foreign patent citations. To trace the patent citations we used the PATSTAT database (Version April 2009). We matched our list to PATSTAT via the publication number.¹

In order to measure causal effects the treatment had on our German experts, we needed a control group. For two reasons, we were not able to use German inventors for the control group: firstly we cannot be sure that inventors not in the BIOS program were not in another similar program, and secondly it is to be expected that the treated experts were chosen by the British for a reason, so there should be systematic differences between the treated and not-treated Germans. Therefore we decided to look for Swiss inventors, since

¹ Some of the patents retrieved from DEPATISnet could not be found in PATSTAT. Other documents were not digitally available in DEPATISnet. The 4206 documents mentioned are priority patents (of DOCDB patent families) which could be found in both databases. Originally we obtained 5510 patents from DEPATISnet (including all patent family members). Furthermore, citation reports were only available for patents published at the German patent office. This limited us in the possibilities for citation analyses.

at the time, the Swiss industry was active in almost similar fields as the German one, the two cultures can be seen as similar in many ways (especially the language barriers should be similar for most Swiss inventors), Switzerland lies close to Germany geographically and its neutrality during WW2 should make it a better match than any of the allies.

Our aim was to identify one Swiss patentee for each German patentee who was as similar as possible in patenting activities until 1947. We picked our “twins” based on several criteria: First of all, we searched for patentees active in the same patent classes as the German inventors. At the most detailed IPC level, we found potential matches for 43 of the German experts. We went through the list of potential matches and compared the inventors’ productivity (measured by patent output) before 1947 selecting the most similar one for each German. We only included Swiss inventors who were also active after 1947 which ensures a reasonable comparison in the post 1947 period. For the remaining 31 Germans we repeated the same procedure using the four-digit IPC level.

For the Swiss control group, we then repeated the patent scanning procedure we had already undertaken for the German experts. For 6 German inventors no appropriate twin could be found, leading to 68 Swiss inventors on the list.

Not for all patents all bibliographic information was accessible. For some patents, none of the information required for our analysis could be found. We decided to exclude all patents lacking information. This, however, further reduced our sample by 11 German inventors who then had no patents left in either the pre 1947 or the post 1947 period. Thus, we were left with a sample of 63 German and 68 Swiss patentees.

Some descriptive statistics of our sample are presented in Table 1. In addition to the number of patents filed before and after 1947, Table 1 also shows the UK affiliation (which we set to 1 if a patentee’s address was British) and the average number of UK-applicants and UK-co-inventors. As one can see, the Swiss control group fits well, since there are no significant differences between the average statistics before 1947 and there are no significant differences between the time spans during which Germans and Swiss were active.

	full sample	German inventors	Swiss inventors	
n	131	63	68	
patents pre	1763	937	826	
patents post	3036	2461	575	
average numbers (median in brackets)				p-value difference mean(German) - mean(Swiss)
number of patents pre	13.46 (7)	14.87 (8)	12.15 (7)	0.39
number of patents post	23.18 (5)	39.06 (11)	8.46 (4)	0.02
year first patent filed	1929.24 (1931)	1930.51 (1931)	1928.06 (1929)	0.14
years active	30.44 (31)	30.7 (31)	30.19 (31.5)	0.80
UK affiliation pre	0.01 (0)	0.02 (0)	0 (0)	0.32
UK affiliation post	0.06 (0)	0.11 (0)	0.01 (0)	0.03
UK applicants pre	0 (0)	0 (0)	0 (0)	
UK applicants post	0.12 (0)	0.25 (0)	0 (0)	0.01
UK co-inventor pre	0.01 (0)	0.02 (0)	0 (0)	0.32
UK co-inventor post	0.05 (0)	0.11 (0)	0 (0)	0.11

Table 1: descriptive statistics.

However, for the post 1947 period, significant differences can be found between the two groups. The number of patents filed after the treatment is significantly higher for German inventors, which seems to support Hypothesis 2. We can also observe that 11% of the German inventors actually stated their residency to be in the UK after 1947, which can be interpreted as a sign for direct interaction. Here, the difference between the German and the Swiss group also becomes significant after the treatment. The number of UK-applicants affiliated to patents increases for Germans as well and becomes significantly different to that of inventors in the control group. Though an increase in the average number of co-inventors from the UK is observable (from 0.02 to 0.11), the difference between treatment and control group is not significant.

Results

The diff-in-diff-estimation shown in Table 2 supports Hypothesis 1. We expected an increase in UK-interaction of our treatment group compared to the control group. We test this with three different variables measuring different types of interaction. The first variable, “UK address” measures whether or not an inventor moved his residency to the UK. The second one, “total number of UK co-inventors”, measures the number of co-inventors from the UK listed for the inventors in our two groups. The third variable, “total number of UK applicants”, does the same for applicants from the UK. Only two of our German experts seem to have shifted all their activities to the UK (with their residency,

co-inventors and applicants all being listed as UK), others seem to have kept in contact with German inventors and applicants while also moving some activity (residency and/or co-inventors/applicants) to the UK. To test whether the difference of the means deviates from zero we calculated the distribution by random resampling. The quantile cutting zero received by the bootstrapping is presented in the last column of Table 2. The quantiles point to a low chance of receiving similar results by random. All of this goes in line with Hypothesis 1.

number of inventors with	German pre	German post	Swiss pre	Swiss post	diff-in-diff estimator	quantile cutting zero *
UK address	1	7	0	1	0.08	0.02
UK co-inventor	1	4	0	0		
(total number of UK co-inventors)	1	7	0	0	0.10	0.08
UK applicant	0	10	0	0		
(total number of UK applicants)	0	16	0	0	0.25	0.00
any kind of UK interaction	2	11	0	1		

* bootstrapped with 1000 iterations

Table 2: UK interaction - Diff-In-Diff estimates.

To test Hypothesis 2 (concerning the productivity increase), we estimate the number of patents filed during the pre and post 1947 periods. Pooling the data of both time periods leads to a total of 262 observations (131 pre and 131 post). Since the number of patents is count data, we use a negative binomial model. The regression results are presented in Table 3. To control for age effects, we include a variable for the year the first patent was filed. The estimated coefficient is significant and negative (however, the coefficient is relatively small). Inventors who started patenting early are associated with a slightly smaller number of patent publications. We include another time variable for the year of the last patent filing. Inventors who are active longer have a slightly higher total number of patents published. We also include the number of co-inventors to control for group effects. Inventors working in larger groups together might achieve systematically higher patent outputs. Differences in patent activities caused by industry specific aspects might further bias our results. We include a dummy variable on the broadest IPC level (A-H) since all industries are represented in our dataset.

To obtain the treatment effect, we include a dummy variable for the post- and pre-treatment periods (post, taking the value 1 for post 1947 activities) as well as for the treatment group (German, taking the value 1 for the treated Germans). The interaction term takes the value one if the observation belongs to a German inventor in the post 1947 period. To ensure that our results are not driven by outliers (highly productive inventors) we exclude in a second model inventors with more than 200 patent publications in the post 1947 period (which was found to be true for three German inventors). In an additional model, we include a further dummy to control for those inventors that moved to the UK.

Post 1947 is significant in all three models. However, the coefficient takes rather unexpected negative values. The productivity (measured by the number of patents) is decreasing for inventors in our dataset. Germans in general do not seem to be more actively patenting than their Swiss counterparts. However, a strong positive coefficient is found for the interaction term. The coefficient proves to be robust in the second and third model although the coefficient is reduced by almost a third of its value, showing the strong impact of the outliers. For inventors who moved to the UK, we cannot find evidence for a higher productivity, though. This result ensures that the productivity increase in our treatment group was not mainly driven by those inventors that moved to the UK. Hypothesis 2 can be confirmed by these results.

negative binomial model

	model 1 full sample	model 2 excl. outliers	model 3 excl. outliers
<u>dependent variable: number of patents filed</u>			
Intercept	-27.0623 (21.381)	-13.6753 (20.2977)	-13.143 (20.3621)
Post 1947 * German	1.0288 *** (0.2384)	0.7179 *** (0.2265)	0.7002 *** (0.228)
Post 1947	-0.5101 *** (0.1683)	-0.4787 *** (0.1574)	-0.4805 *** (0.1574)
German	0.138 (0.1782)	0.1048 (0.1694)	0.1048 (0.1694)
Year first patent filed	-0.0315 *** (0.0068)	-0.0312 *** (0.0064)	-0.0314 *** (0.0064)
Year last patent filed	0.0453 *** (0.0093)	0.0383 *** (0.0088)	0.0381 *** (0.0088)
UK address			0.1534 (0.3221)
IPC dummies	TRUE	TRUE	TRUE
n	262	256	256
AIC	1824.6164	1719.3557	1721.1367
Log-likelihood	-1794.6164	-1689.3557	-1689.1367
(p > chi2)	0.0000	0.0000	0.0000

*** p < 0.01, ** p < 0.05, * p < 0.1

regression coefficient (standard errors in brackets)

Table 3: Regression results on the productivity of inventors.

In Hypothesis 3a, we expressed our expectation that the German experts' interaction with British experts resulted in a broadening of their knowledge base (meaning that they for example became familiar with new technologies), which could then, among the extension of knowledge networks, explain the rise in productivity observed in models 1-3. We use patent output as a measure of productivity to test whether the use of British technology is associated with a higher productivity level. The underlying assumption is that a UK patent is based on an invention from the UK. Backward citations to British patents are seen in this context as the observable result of the extended knowledge base.

The lack of information on non-German patent documents, however, made a comparative analysis between treatment and control group impossible. Search reports from other patent offices were not digitally available, neither in PATSTAT nor directly at the national patent offices' websites. Since Swiss inventors filed their patents mostly at the Swiss patent office, we can only estimate the productivity increase by certain factors for Germans. If an extension of knowledge sources caused the productivity increase, the inventions made by the treated Germans should be related to British knowledge sources which became accessible through their stay in the UK.

To test Hypothesis 3a, we define the number of patents filed in the post 1947 period as a measure of productivity. The productivity is, according to Hypothesis 3a, expected to depend on extended knowledge sources used. As in models 1 to 3, we use a negative binomial model because the number of patents is a count variable.

In models 4 to 7 we use the share of UK patent citations on all citations made as a proxy for the inventions' relatedness to British technology². The number of UK-citing patents is expected to be positively correlated with the overall number of patents filed. The more one inventor files patents related to British technologies, the higher the perception of British knowledge is assumed to be. Since the number of UK patent citations is corrected for the overall number of citations made, biases caused by an increasing use of citations can be excluded. It is not possible to control for internationalisation processes, because the citation share of other countries as France or the USA are correlated with the UK share. We control for the share of German citations instead (since it is the opposite of internationalisation). We also control for the total number of citations made, since we find a large variation on the number of citations between inventors, ranging from none at all to several hundred.

In all three models including the variable measuring the share of UK citations, we find evidence supporting Hypothesis 3a. However, the share of citations to German patents is positive and significant as well.³ We suspect that citations, no matter to which country, are related to a higher productivity.

In models 5 and 6, we include a dummy variable for UK applicants. Here, one can see that the share of UK citations and UK applicant reduce each other's effects. This makes sense, because it seems rather credible that firms from the UK further develop british inventions.

² Only 31% of all patents filed by the Germans on our list included citations at all. The majority of these citations (to UK- and other patents) is found in the post-1947 period.

³ The high values of the coefficients, in comparison with the number of patents citing UK patents, occur because the share of UK citations is a percentage which cannot exceed the value of one.

These results lead us to accept Hypothesis 3a.

Additionally to the explanatory variables discussed above, we include the number of patents filed pre 1947. Inventors more active in patenting pre 1947 might continue to be highly productive in the post 1947 period. Indeed we find in all four models a positive and significant relation between the number of patents filed pre and post 1947.

As in models 1 to 3, we control for the year the first patent was filed and the year of the last patent filing. While the year of the first patent filing is not found to be associated with the number of patents after 1947, the year of the last is found to have a positive relation. The fact that more productive inventors are active in patenting longer does not seem to be too astonishing.

Another dummy, included in model 7, controls for UK addresses of inventors. We include this dummy because migrating inventors could be the more productive ones who have a higher probability to make inventions related to preexisting British technology. However, we do not find any evidence and can neglect this concern.

negative binomial model

	model 4	model 5	model 6	model 7
dependent variable: number of patents filed post 1947				
Intercept	-95.9125 ** (38.607)	-89.2608 ** (37.233)	-106.6713 *** (36.433)	-93.3452 ** (38.4322)
Share UK citations	3.6627 *** (1.3465)	2.6398 * (1.377)		3.4445 ** (1.3518)
Share DE citations	1.1921 *** (0.2898)	1.224 *** (0.2791)	1.1362 *** (0.2809)	1.2043 *** (0.2878)
# patents pre 1947	0.0108 * (0.0058)	0.0135 ** (0.0057)	0.0148 *** (0.0057)	0.011 * (0.0057)
# co-inventors (post)	0.0121 (0.0205)	0.0162 (0.0197)	0.0203 (0.0201)	0.0125 (0.0204)
UK applicant		0.2145 * (0.1204)	0.2777 ** (0.1163)	
UK address				0.2216 (0.2896)
Year first patent filed	0.0082 (0.0132)	0.006 (0.0127)	0.0081 (0.0127)	0.0071 (0.0132)
Year last patent filed	0.0412 *** (0.0143)	0.0401 *** (0.0138)	0.047 *** (0.0135)	0.041 *** (0.0142)
# backward citations	0.0006 ** (0.0003)	0.0007 ** (0.0003)	0.0008 *** (0.0003)	0.0006 ** (0.0003)
IPC dummies	TRUE	TRUE	TRUE	TRUE
n	60	60	60	60
AIC	415.6731	351.659	415.3597	417.1674
Log-likelihood (p > chi2)	-381.6731		-381.3597	
	0.0000		0.0000	

*** p < 0.01, ** p < 0.05, * p < 0.1

regression coefficient (standard errors in brackets)

Table 4: Regression results explaining post 1947 patent output of Germans.

To see whether the increase in productivity was mainly driven by cooperations between the German experts that were established during their detention, we checked for citations made between these experts' patents. We found one citation from a pre-1947 patent to a patent from the same period, 10 citations from the post-1947 period to the pre-1947 period, and 26 citations from the post-1947 period to a patent from the same period. All of these citations were identified as self-citations. The post 1947 filed patents seem to be

unrelated to each other, so no proof could be found for knowledge transfers between the German experts that stayed together in the UK. Also, no co-authorship was found between any of our experts. Thus, Hypothesis 3b is not supported. This is rather remarkable, since the literature suggests there to be such an effect. Maybe the interaction in the UK was too random and did not lead to further developments. This would support our earlier suggestion that the literature on short term stays abroad so far has only investigated cases where the interaction was wanted from all parties, and not cases like ours, in which the interaction was not planned before.

Concluding remarks

We were able to find certain impacts the participation in BIOS had on the German experts. First of all, we found that, compared to similar Swiss inventors, a relatively higher number of Germans migrated to the UK after 1947. This is not surprising since the circumstances of the time set clear incentives for Germans to take this step, and not so for the Swiss.

We were also able to find an effect of the treatment on German inventors' networks. Again, relative to the trend of Swiss inventors, the number of British co-inventors and applicants associated with our German experts increased. Meanwhile, only few inventors shifted their activities to the UK completely, which suggests a network extension rather than a clean cut. We also found the treatment to have a positive impact on the German inventors' productivity. We tried to explain this increase in productivity with an extended knowledge base. We found some weak evidence for an increasing knowledge base, but could only find this effect for the UK citation share. A relation to previous patents of their German internment fellows could not be found by tracing patent citations.

This study adds another step to the literature on knowledge diffusion. We can find evidence for the bi-directionality of knowledge flows even for forced short term stays. While the direct network extension effect observed is rather small (though positive and significant), the treatment effect on the patenting activity we find is rather big. We thus conclude that the German scientists and technicians that were forced to take part in BIOS actually gained some benefits from this treatment. But, we also found evidence for completely coincidental knowledge exchanges being without effects, since no observable result could be found within the group of Germans.

Our results seem to support the hypothesis that Germans did profit from a broader (British) knowledge background, because they were more aware of British technologies. This made them more productive in terms of patents filed. The expert talks in the UK might have led to this fruitful outcome. While the British's intention only was to access as much knowledge as possible from the German experts, even in this special situation knowledge

rather seems to have been traded than drained. Part of the Germans even stayed with the British firms and kept on inventing for them, to both sides' benefits. This supports the theory that knowledge exchanges are always bi-directional. Furthermore, it supports the description of knowledge as a club good. If one person gains access to the closed community within which knowledge is shared openly, everybody in this club can gain a substantial amount of knowledge. But once a person is in the club, even when this entrance is controlled by one side, expelling her is difficult.

The new dataset allows to test for multiple future research questions that we could not yet follow up on in this paper. But before we devote ourselves to those questions, we want to address the issue of limited sample size. The report of a BIOS participant in Gimbel (1990 b) suggests that there were several hundred Germans interned in London, thus we do believe that the lists we based our analysis on were incomplete. Our first step in further research should be to get a hold of the complete sample.

Literature

Agrawal, A.; Cockburn, I.; McHale, J. (2006): Gone but not forgotten: knowledge flows, labor mobility, and enduring social relationships. In: *Journal of Economic Geography* 6 (5): 571–591.

Breschi, Stefano; Lissoni, Francesco (2001): Knowledge Spillovers and Local Innovation Systems: A Critical Survey. In: *Industrial and Corporate Change* 10 (4): 975–1005.

Breschi, Stefano; Lissoni, Francesco (2005): Cross-Firm Inventors and Social Networks: Localized Knowledge Spillovers Revisited. In: *Annales d'Economie et de Statistique*: 189–209.

Borjas, G. J.; Doran, K. B. (2012): The Collapse of the Soviet Union and the Productivity of American Mathematicians. In: *The Quarterly Journal of Economics* 127 (3): 1143–1203.

Franzoni, Chiara; Scellato, Giuseppe; Stephan, Paula (2014): The mover's advantage: The superior performance of migrant scientists. In: *Economics Letters* 122 (1): 89–93.

Gimbel, John (1990) a: Deutsche Wissenschaftler in britischem Gewahrsam. Ein Erfahrungsbericht aus dem Jahre 1946 über das Lager Wimbledon. In: *Vierteljahrshefte für Zeitgeschichte* 38 (3): 459–483.

Gimbel, John (1990) b: Science, technology, and reparations. Exploitation and plunder in postwar Germany. Stanford, Calif.: Stanford University Press.

Jacobsen, Annie (2014): Operation Paperclip. The secret intelligence program that brought Nazi scientists to America. First edition. New York: Little, Brown and Company.

Jaffe, Adam B.; Trajtenberg, Manuel; Henderson, Rebecca (1993): Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. In: *The Quarterly Journal of Economics* 108 (3): 577–598.

Jöns, Heike (2009): 'Brain circulation' and transnational knowledge networks: studying long-term effects of academic mobility to Germany, 1954-2000. In: *Global Networks* 9 (3): 315–338.

Hoisl, Karin (2007): Tracing Mobile Inventors—the Causality between Inventor Mobility and Inventor Productivity. In: *Research Policy* 36 (5): 619–636.

Lasby, C. G. (1971): *Project Paperclip: German scientists and the Cold War*: Atheneum.

Scellato, Giuseppe; Franzoni, Chiara; Stephan, Paula E. (2014): *Migrant Scientists and International Networks*. In: *SSRN Journal*.

Schrader, Stephan (1991): *Informal Technology Transfer between Firms: Cooperation through Information Trading*. In: *Research Policy* 20 (2): 153–170.

Von Hippel, Eric (1987): *Cooperation between Rivals: Informal Know-How Trading*. In: *Research Policy* 16 (6): 291–302.