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

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Abstract

Researchers' social environment is expected to have a strong positive influence on knowledge creation activities. The findings of Breschi and Lissoni (2003) suggest that migrating inventors depend on their old network of co-inventors for a while. Channeled through preexisting personal relations, knowledge seems to flow back to migrated inventors' home country (Agrawal et al., 2006). Even short term visits can have a positive influence on the collaboration network, as shown by JÃ¶ns (2009) for the case of scientists' research stays in Germany. Scellato et al. (2014) show that migrated scientists profit from wider international networks.

We explore this issue in the context of a natural experiment that took place after WW2. Pre-war German industry was highly developed, with international competitive advantages in sectors such as the chemical industry and rocket science. After winning the war, the Allies started different programs to get a hold of this knowledge, as some kind of "intellectual reparations" (Gimbel, J. 1990 p.52). The USA and the United Kingdom first only acquired knowledge for military purposes, but later also for the private sector. To actually make the knowledge accessible, simply copying documents did not suffice, German experts had to be questioned. German scientists were brought abroad "whether they liked it or not" to reveal their expertise. A number of these experts even migrated permanently, for which there were clear incentives. Some were able to avoid the denazification process, others gained the ability to keep on working in industries constricted in occupied Germany. The research group of Wernher von Braun is only the most prominent example (Lasby, C. G. 1971 p. 33ff.; Jacobsen, A. 2014 p.67ff.). The military documents keeping record of these programs were only recently declassified.
Allied forces spent a lot of effort to ensure that all valuable knowledge was discovered before the Russians could seize it. Lists of interesting personnel were prepared before the war ended. The German scientists and technicians had no

choice whether or not to collaborate and share their knowledge and expertise. As far as we know, this is the first empirical analysis of this data.

While the British intended to gain as much knowledge as possible, the German scientists might also have benefited from their forced network extension. The treated scientists might provide a link back from Britain to Germany or vice versa, thus creating a new channel for knowledge flows between the two countries.
We expect that German scientists made use of this opportunity, observable by an increase of collaboration partners from the UK as well as by an extension of knowledge sources which their research is based on. Further we expect to observe an increase of productivity due to the extended information base.

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 the United Kingdom between October 1946 and August 1947 to be questioned. After retrieving the scientists' names and the duration of their stay, we searched for their names on patents in DEPATISnet (the online data base 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.
In a first attempt we limited the data to patents filed between 1937 and 1958. We identified 53 German inventors to be active before and after 1947 on a total of 1760 patent applications. 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.

Preliminary results show an increase of interactions with the UK. While we cannot observe any interaction with the UK before 1947, afterwards 8 of the 53 Germans are found to interact with Britain. 6 seem to have moved to the UK, two invented for British firms or had British co-inventors. It is striking that some of the migrated experts have only British co-patentees after 1947. These results stay in contrast to the interaction with the United States. None of the Germans is found to migrate to the US. The number of Germans with co-inventors or applicants from the US declines from 6 before to 3 after the treatment. However, for most researchers we find no signs of direct interaction, and if we do, there is no clear evidence yet. While some seem to move all activities to the UK, some keep in contact with German inventors and applicants.
To understand the knowledge base the inventors build on, we investigate the patent citations. 646 patents in our dataset refer to other patents. 144 patents cite at least one British patent. The majority of these citations is found on post 1947 patents. The increase of British citations proves to be stronger than the increase of German citations, however we find an even higher increase for US citations.
The change in productivity points in a rather unexpected direction. While theory is suggesting a positive influence, we observe a lower increase in the average number of patents filed by inventors interacting with the UK. This finding might be caused by those who lose their pre-existing contacts, since inventors active in and with the UK are not always observed to stay in contact with their previous co-inventors and applicants.

So far, our empirical findings are constrained by the small sample size. To increase the number of observations we currently apply two distinct strategies. Using a wider time span allows to include further researchers active in both post and pre-war periods. We intend to assign to every German scientist a Swiss "twin" who is active in similar technology classes to generate a control group. The procedure described above can be repeated for the control group as well.

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Introduction

In this paper, we use a British post-WW2-program aimed to exploit German knowledge as a natural experiment to investigate the effects it had 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 are found for other types of migration in previous research.

In the following chapter, 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 we used, then we show the results we have come to so far and we end this paper with a conclusion and a short discussion of our results and a look towards future research.

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. A lot of 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 like scientific literature or patents from other firms. Knowledge sources from outside the firm in combination with 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).

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. The example of Borjas and Doran (2012) precisely shows the importance of well selected natural settings, because they may gain rather unexpected results.The authors studied the effects of Russian 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-war 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 and secured and then 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. 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. As far as we know, this study is the first one trying to conduct an empirical analysis of this data.

In this study, we focus on "BIOS" (British Intelligence Objectives Sub-Committee), which was a program set up by the United Kingdom in order to get as much information out of 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 this was completely steered by the British, the German experts had no say in whom to meet (Gimbel 1990 a). 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 a extension shock of knowledge sources.

Hypotheses

This interaction of German experts with British specialists active in the same field in combination with the aforementioned knowledge network theory 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 scientist 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 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. 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.

H3: The increase in productivity from H2 can be explained by the use of additional knowledge sources.

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 data bank 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 in 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: 1) we cannot be sure that inventors not in the BIOS program were not in another similar program and 2) it is to be expected that the treated experts were chosen by the British for a reason, so there should be systematical differences between the treated and not-treated Germans. Therefore we decided to look for Swiss inventors, since 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 (=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 31 Germans we did not find a match for on the most detailed IPC level, we repeated the same procedure on the four-digit level.

[1] Some of the patents retrieved from DEPATISnet could not be found in PATSTAT. Other documents where not digital 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 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, as can be seen in the models we estimated.

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 required information could be obtained. For some patents not any information 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 and a list of all of their patents, co-inventors and applicants.

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 breakets)				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 fist 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 ukapplicants 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 are 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 does not become 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, others seem to have kept in contact with German inventors and applicants while also moving some activity 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	post	Swiss pre	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.

H 2: Increased productivity

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.

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 activity) as well as for the treatment group (Germans, 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 half 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	
dependent variable: number of patents filed						
Intercept	-100.0351	***	-64.2892	***	-63.2676	***
	(23.5388)		(22.255)		(22.2953)	
Post 1947	-0.5481	***	-0.476	***	-0.476	***
	(0.1937)		(0.1801)		(0.1801)	
German	0.0855		0.1134		0.1145	
	(0.1969)		(0.1849)		(0.1849)	
Year first patent filed	-0.0363	***	-0.0367	***	-0.0371	***
	(0.0074)		(0.0069)		(0.0069)	
Year last patent filed	0.0881	***	0.0702	***	0.07	***
	(0.0103)		(0.0097)		(0.0097)	
UK address					0.1747	
					(0.358)	
Post 1947 * German	1.1517	***	0.6396	**	0.6158	**
	(0.275)		(0.2596)		(0.2612)	
n	262		256		256	
AIC	1903.0701		1787.9656		1789.7283	
Log-likelihood	-1889.0701		-1773.9656		-1773.7283	
(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.

H3: UK knowledge sources

In Hypothesis 3, we expressed our expectation that the German experts' interaction with British experts in the same fields 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.

As we already mentioned above, there is a drawback to this analysis, namely the lack of information on non-German patent documents. Search reports from other patent offices were not digitally available, neither in PATSTAT nor directly at the patent office's website. Since Swiss inventors filed their patents mostly at the Swiss patent office, we can only estimate which factors actually made Germans productive. If an extension of knowledge sources caused the productivity increase, those Germans who made use of additional knowledge sources which became accessible through their stay in the UK should be the ones that are more productive.
In our dataset, 1037 patents (31% of all patents filed) of German inventors include patent citations, 927 of which were filed post 1947. 212 patents cite at least one British patent. The majority of these citations (182) is found on post 1947 patents.

To test Hypothesis 3, we define the number of patents filed in the post 1947 period as a measure of productivity. The productivity is, according to Hypothesis 3, expected to depend on extended knowledge sources used. As in the models 1 to 3, we use a negative binomial model because the number of patents is a count variable.
In models 4 and 5 we use the number of patents which cite at least one British patent as a proxy for the awareness of British technology. 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. In models 6 and 7, instead of using the number of UK patent citations, we use the share of UK patent citations. We define this as the number of UK patent citations divided by the total number of patent citations for each inventor. 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. To control for internationalisation processes, we include the share of US citations as well in models 6 and 7[2].

In all four models, we find evidence supporting Hypothesis 3. In models 4 and 5, the number of patents with UK citations is positively associated with the overall number of patents filed. In both models the coefficients are significant on the one percent level. The share of UK-citations is included in models 6 and 7 as an explanatory variable. In both models, a positive relation with the overall number of patents filed after 1947 is observable. The coefficients are significant on the five percent level. These results lead us to accept Hypothesis 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 can not exceed the value of one.

[2] The share of US and UK citations is only weakly correlated with a correlation of 0.3, so collinearity is not seen as an issue in this case.

Contrasting the positive relations of the UK-citation-share, we do not find a significant effect of the US-share. We interpret this as further support of our Hypothesis 3.

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, 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.

In models 4 and 6, we include a dummy for UK applicants. UK firms might be more likely to keep on developing pre-existing technologies, which were once filed in the UK. This might cause the patents of inventors with British applicants to be more likely to cite UK patents. While we do find a positive and significant effect (on the 10 percent level) in model 1, we cannot confirm this result in model 6. Another dummy, included in models 5 and 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	-110.085	***	-113.1256	***	-139.5114	***	-139.7588	***
	(41.9583)		(41.5512)		(44.8085)		(44.7441)	
# patents UK backward	0.1474	***	0.1477	***				
	(0.0381)		(0.0385)					
Share UK citations					3.5005	**	3.6723	**
					(1.7844)		(1.7547)	
Share US citations					0.4174		0.466	
					(0.4076)		(0.4017)	
# patents pre 1947	0.012	*	0.0112	*	0.0294	***	0.0289	***
	(0.0066)		(0.0067)		(0.0057)		(0.0057)	
UK applicant	0.2444	*			0.0788			
	(0.1393)				(0.1606)			
UK address			0.5134				0.1218	
			(0.3247)				(0.3581)	
Year first patent filed	0.0015		0.0043		0.0092		0.0102	
	(0.0138)		(0.0137)		(0.0154)		(0.0152)	
Year last patent filed	0.0557	***	0.0545	***	0.063	***	0.0621	***
	(0.016)		(0.016)		(0.0179)		(0.0179)	
n	60		60		60		60	
AIC	430.3314		431.6607		441.6686		441.8114	
Log-likelihood	-416.3314		-417.6607		-425.6686		-425.8114	
(p > chi2)	0.0000		0.0000		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.

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, and we were able to show that the more productive inventors actually do have a higher number of patents citing UK patents as well as a higher share of UK citations in their patent portfolio. We argue that this shows more than just a stronger internationalisation of research, because no such effect can be found for US patent citations.

We can find evidence even for 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. Our results seem to support 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. 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, 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. The first issue we want to address is that of limited sample size. The report of a BIOS participant in Gimble (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.

Models 4-7 should furthermore be expanded by variables controlling for certain industries to make sure that the observed effects are not only industry-dependent.

One further topic we did not yet address is the effect of the German experts spending a lot of time together in British internation. If the time there was as full of lectures and talks as is stated in Gimbel (1990 a), we would expect an increase in interaction between the German experts after their return to Germany.

We would also like to include time effects in our future research of the topic, in order to find out whether the effects of the treatment stay with the experts permanently, or if there is a kind of fading out of the effects.

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