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Mobility of Scientists and the Spread of Ideas

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We use data on newly hired university scientists to provide evidence on the impact of labor mobility on the diffusion of ideas across space. To do this, we compare local citations to pre-move articles of a newly hired scientist with citations to runners-up for the same position, before and after the move. Post move, a scientist's articles receive twice as many citations from patents of local companies and 70% more citations from local university scientists than the articles of the runners-up do. However, the overall number of citations does not change, suggesting a relocation of local spillovers. Local knowledge flows to the private sector originate mainly from academic stars and the hard sciences. Within academia, the effects are homogeneous across fields and quality of researchers. These results suggest that labor mobility changes the access to local knowledge which in turn affects the direction of innovation in a region.

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I. Introduction

Labor mobility of scientists is thought to facilitate innovation by spreading ideas in the economy. The reason is that researchers that are at the same location can more easily communicate the results of their research, their new ideas and their research methods. Much of a researcher's valuable knowledge is non-codified and only available through direct communication. Thus co-location might facilitate the recombination of ideas across researcher and thus increase follow-on innovation. For example, failed experiments are not published but valuable to avoid dead-ends (Agrawal, 2006). Based on this reasoning, governments try to attract top researcher to their region to increase local innovation. Similarly, outstanding universities are seen to build the basis for local economic clusters and high-tech entrepreneurship.

Yet, recent research suggest that the spread of scientific ideas has little geographic dimension and takes place within the invisible college of like-minded scientists (Azoulay *et al.*, 2010; Waldinger, 2012). Starting with the Republic of Letters in the 17th century, the use of communication technology and the opportunity to travel ensured quick world-wide dissemination of scientific ideas that was stopped only in times of war (Iaria *et al.*, 2016).[1] Even more, technological advances in telecommunication in the last 30 years might have further decreased the importance of distance for knowledge dissemination (Rosenblat and Mobius, 2004; Griffith *et al.*, 2011; Kim *et al.*, 2009). If this is true, cluster-based policies might make little sense today and hiring researcher to get preferential access to their knowledge might be a useless waste of funds.

So is labor mobility of scientist important for the dissemination of ideas in an economy? Do companies get preferential access to ideas of a researcher that lives close-by? Answering this question is difficult, because we cannot just simply compare the use of ideas at the destination before and after a researcher moved

1. For example in January of 1939 it just took three days, for the Meitner-Frisch theory of nuclear fission to travel from Denmark to the US scientific community.

there. Researcher move for a reason and in particular they might move to places where others are interested in their work. So, any observed correlation between labor mobility and increased diffusion of ideas might be due to other factors influencing both. As a consequence, we need a counterfactual of what would have happened had the researcher not moved.

To address this identification problem we exploit that university hiring committees in Germany are required to create a short list of suitable candidates for each appointment.[2] In our study we use candidates on these ranked lists as counterfactual for the moving researcher. All candidates on the list are very similar due to the incentives inherent in the legal set-up of university appointments in Germany: First, salaries for each position are capped by law, so the quality of applicants for the position is restricted from above by the market wage.[3] Second, the hiring committee has strong incentives to weed out unsuitable candidates: professors are appointed for life and it is difficult to predict who will accept an offer. Thus, even a low-ranked candidate might receive and accept an offer and stay until retirement. Lastly, hiring no-one has an option value because the total number of positions is few and fixed. We provide evidence that all candidates on the lists are indeed comparable in term of their local spillovers at the destination university.

For our study, we collect data on 1,608 lists with 4,572 researchers across all fields at one German university between 1950 and 2005. The data covers all fields and all appointed professors in this period. We link the researchers on these lists with data on their publications and patents between 1965 and 2005. We use citations of corporate patents to academic articles (PtA citations) to measure knowledge flows to the private sector and article-to-article citations (AtA citations) to measure the spread of ideas within academia. As research articles are the main output of

2. Offers are then made in the order of candidates until one accepts.

3. In the years under consideration a professor could not get more than the German public sector salary category B10 what is the category of an Admiral in the German military. In 2003 this was about Euro 120,000. The salary cap was abolished in 2004.

academic researchers, patent-to-article citations and article-to-article citations are a natural measure for knowledge flows stemming from academic research (Azoulay *et al.*, 2011).[4]

Using all scientists on the list as counterfactual for the moving researcher in our empirical analysis, we show that hiring a professor significantly increases the use of her ideas at the new university. After a researcher moves to the university, citations from academic articles to her pre-move articles increase by around 70%. The effect starts in the second year after the move and is measurable ten years after the move. The effect is larger for high-quality professors and of similar absolute size across fields. This supports the notion that labor mobility increases the use of knowledge at the destination. Yet, we do not find that the overall citations to a researcher's work increase: The number of citations at the origin goes down by the same amount they increase at the destination. Thus, reallocating the scientist also reallocates the access to ideas. This contradicts previous findings that labor mobility is per se conducive to the spread of ideas.

The effect of localization is even stronger for the private sector: The number of citations from patents of local companies to articles of movers more than double. The increase is particularly strong in the hard sciences such as physics, chemistry or medicine. We do not find any effect in the humanities even if we exclude topics that do not have any relation with private sector innovation. Within the hard sciences, the impact of localization on private sector innovation is much stronger for academic stars. This points to academic quality as a major determinant for the effect of scientists on the private sector. Consistent with this idea, we find a strong positive correlation between lifetime article-to-article and patent-to-article citations across all researchers in our sample. Small and young companies react most to a newly arriving scientist suggesting that absorptive capacity plays a role

4. Patent-to-patent citations are often used to measure knowledge flows to industry but only account for a small proportion of knowledge transfers from universities (Agrawal and Henderson, 2002; Henderson *et al.*, 1998; Belenzon and Schankerman, 2013).

for overcoming informational barriers. Again, overall citations from patents to the mover's articles do not increase.

We provide evidence that our estimates can be interpreted causally. First, citations are very similar for movers and non-movers prior to the move and the total number of citations are also the same post-move. This supports the notion that researchers on the list are of comparable quality and points to parallel trends in citations in the absence of the move. Second, there are no differential citation trends for articles of higher and lower ranked non-movers, suggesting parallel trends of non-moving scientists and that the ranking of candidates by the hiring committee is not predictive for local knowledge flows. Third, when using the rank of a professor in an intention-to-treat analysis, we find virtually the same effects of localization. Thus, self-selection of professors based on future knowledge flows does not seem to drive the effect.

Our contribution to the literature is threefold: First, our research design cleanly isolates the effect of a change in geographic distance on knowledge flows within the university and to the private sector. We can thus show that geographic distance is important for flows of academic knowledge. Thus, companies that are co-located with exceptional universities, such as MIT or Stanford, might have better access to scientific advances and thus a competitive advantage in the production of science-based products. Similarly, outstanding university scientists might be concentrated in just a few universities because they benefit from intellectual exchange with their peers.

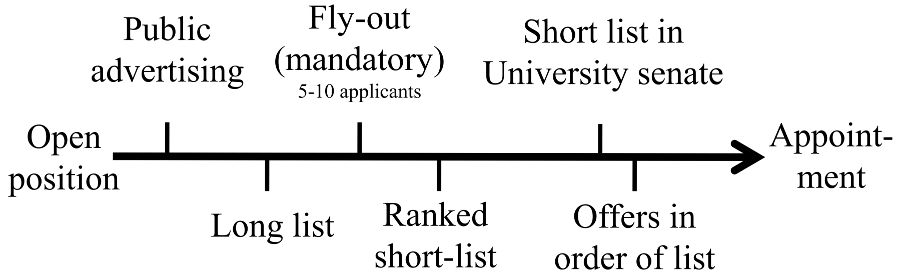
These results stand in stark contrast with several recent studies that find that spillovers are localized in social space or in idea space and that the effect of geography is very small (Azoulay *et al.*, 2010; Borjas and Doran, 2012; Waldinger, 2012). For example, looking at the forcible expulsion of Jewish scientists, Fabian Waldinger and co-authors find no geographic knowledge spillovers to other senior researchers but strong spillovers to PhD students and private chemical companies working in the same field as emigres (Waldinger, 2010, 2012; Moser *et al.*, 2014).

Second, we expand previous findings to the humanities, to scientists who are not stars in their fields, and to the private sector. We find that academic quality matters for the size of the spillovers and that the hard sciences are particularly relevant for the effect of a university on patenting in the private sector. Third, our identification strategy uses the runners-up to a moving scientist as the control group. We thus provide evidence from a frequent real-world setting that is immediately policy relevant. Compared to studies using moves of scientists induced by large political events, it is much less likely that our results are driven by other simultaneous policy changes.

Lastly, this paper also contributes to the debate how universities matter for society and how university systems are optimally organized. Starting with Jaffe (1989) and summarized in Foray and Lissoni (2010) and Veugelers and Del Rey (2014), a large number of studies try to measure the impact of universities on regional innovative output. They find that local spillovers from university research are substantial and that small companies benefit disproportionately. We add to this literature by using a runners-up methodology to provide credible estimates of the impact of changes in the boundaries of universities on local innovation. Our estimates correct for the fact that university research is not exogenous to the local economic environment and that companies might also benefit from scientists who are located further away.

The rest of this paper is organized as follows. In the next section we look at the institutional setup and the data sources. Then we describe the empirical set-up. In section 4 we discuss our results and their interpretation. Section 5 concludes.

Figure I: PROCEDURE OF APPOINTING A PROFESSOR IN GERMANY



II. THE GERMAN SYSTEM OF APPOINTING PROFESSORS

In Germany, almost all university professors are civil servants and thus are hired in a highly regulated multi-step process (Figure I). The procedure is designed to give every qualified applicant equal access to jobs in the public service independent of personal connection. To implement equal access, every open position must be advertised in a national newspaper. The advertisement must contain a list of criteria by which the candidates are compared in the remainder of the process. These criteria might include publications in international refereed journals or experience in raising third party funding. Using these criteria, the hiring committee creates a long list of 5 to 10 candidates who are invited for fly-outs. After the fly-outs, the hiring committee creates a ranked short-list of two to four candidates. All candidates on the short-list are reviewed by at least two external referees that suggest their own independent ranking of the candidates. The ranked short list and the reference letters are submitted to the university senate for review. If the ranked short list is approved by the senate, offers are made to the candidates on the short-list in order of the rank. The first candidate to accept is then appointed.

The hiring process contains several mechanisms to make the process objective and fair. First, internal candidates are usually not eligible to apply for tenured positions, so almost all new professors are external hires from other university.[5]

5. Internal promotion are in theory possible but must follow much more stringent rules than

This rule prevents nepotism because it requires researchers to move at least once at the senior level to get a tenured position. Second, the composition of the hiring committee is fixed and contains many external members. The hiring committee has at least one professor in the same field but from another university, one member of the university senate from another field, a women's representative, a representative of non-tenured scientific employees and one undergraduate student representative. Third, the whole process is subject to court review: if one of the non-appointed candidates suspects that the university did not follow due process, the candidate can sue for non-appointment of the chosen candidate, compensation and invalidation of the list ("Konkurrentenklage").

According to the Gemeinsame Wissenschaftskonferenz, a joint institute of all German universities and the German government, on average every open professorship attracted 41.8 applications in Germany in 2013 (Wissenschaftskonferenz, 2014). Around 10% of these candidates were considered suitable for the short list, which implies that the average list had four candidates. Of all candidates, 45% received an offer for the position at one point in time. If a candidate received an offer, the probability that she accepted was around 50%.[6]

The short-list of suitable candidates gives us a counterfactual for the mover.

Due to the incentives inherent in the legal set-up of academic appointments in Germany the candidates on the short-list are no only acceptable, but also similar in quality. This gives us the opportunity to use all other candidates on the list as

external hires. The rules are so stringent that for all practical purposes this is perceived (and labeled) as forbidden (Ban of internal promotions - "Hausberufungsverbot").

6. The data is not exact as open professorships are counted in a two year interval. According to the data 1,612 professor were appointed in Germany in 2013. The universities received 67'117 applications for these positions. 6'954 researchers made it on the ranked list and 3'175 received an offer.

a counterfactual for the moving candidate. [7]

The main reason is that the hiring committee has a strong incentives to weed out unsuitable candidates. In Germany, all professors are appointed for life and for the hiring committee, it is very difficult to predict who will accept an offer. Candidates can receive competing offers during the selection process and thus might have better offers on the table once the process is complete. What is more, receiving an offer from a different university usually opens the door to renegotiations at the current university. Even a low-ranked candidate might therefore receive and accept an offer and stay until retirement, as appointment to civil service is for life. As a consequence, the hiring committee has incentives to only put acceptable candidates on the list. Even more, hiring no one has an option value because the number of professorships is restricted. Therefore, if there is a suitable candidate in the following year, the university might not be able to hire her, because all positions are filled. As a consequence, the hiring committee might choose to hire no one.

A second reason why researchers on the list are similar is that in all but very rare cases, only professors who applied to the position are put on the list and the possible salary and teaching obligations are fixed in pre-determined range. Only researchers that are interested to work at this university for the offered conditions thus apply. Each position in Germany is associated with a category determining the possible salary range, the pension benefits and the status of a professor. For example, a highest remunerated professorship today is the W3 professor what is comparable to a tenured full professorship at a public doctoral institutions in the US. A W3 professor is usually expected to lead a research group. The associated salary is in between Euro 60,000 and Euro 110,000 depending on the federal state and seniority level.[8] Even more, at the time of the study, there was salary cap: No

7. In Section IV.C., we provide statistical evidence that the candidates on the short list indeed are indeed very similar to moving researchers.

8. An overview of salaries for different salary category can be found here: http://www.w-besoldung.net/

professor could earn more than category B10 which corresponds to the category of an General or an Admiral in the German military. Taken together, these restrictions lead to a self-selection of applicants ensuring a more homogeneous applicant pool.

Every researcher moves at least once and moves are frequent.

In the traditional German university system, there is no internal promotion to tenure. The only way to receive a tenured position is to accept an offer from another university. As a result, all junior researchers in Germany move between universities at least once. Also, a senior researcher who wants a higher salary must have at least one outside offer to be able to renegotiate her current contract. As universities often do not renegotiate or the hiring university has more funding, many outside offers are taken. Many researchers move 3 or 4 times in their career as a result.

These legal restrictions have two advantages for our study: First, the selection of movers is not very different from the selection of non-movers as everyone is obliged to move. Thus we can measure the effect of labor mobility for the whole population. In the US system this would be much more challenging, because moving researcher are a selected sample - either superstars or assistant professors who did not receive tenure. Second, mobility is due to the system much higher, there is frequent reshuffling of professors within Germany increasing the size of our sample.

Data

For our study, we have access to all short lists of candidates of one German university from 1950 to 2005. The university under consideration offers a wide range of subjects from humanities to natural sciences and medicine. In total we have access to 1,609 ranked lists for professorships containing 4,572 researchers (2.84 per list). We match all researchers on the lists with their academic publications from Scopus, their patents from Patstat and the year of their move to the university from historical course catalogs. For all articles and patents, we collect all citations by other articles and patents. Finally, we use Open Streetmap to geo-locate all citing companies and researchers to identify which citations are from the area around the university. As citations are at the moment only available from 1980s onward, this leaves us with 855 short lists with 2,543 scientists, 55,372 publications and 1.1 million geo-located citations.

We also construct an alternative dataset from publicly available sources. The magazine "Forschung and Lehre" of the association of German professors reports offers for appointments for every month since 2001. The data is reported by the universities or by the scientists receiving the offer. By repeatedly observing the same position being offered, we can reconstruct candidates on a short-list whenever the highest ranked candidate declined. In total we can reconstruct at least two candidates for 164 lists from 47 universities in Germany.

III. Empirical strategy

Ideally, we would like to compare how much local researchers around the destination university use the knowledge of the researcher after she moves to the situation when she does not move. This is not possible because we cannot observe the use of ideas directly and we cannot observe both, the world with and without a move. We thus must find a way to measure the use of knowledge and to construct a counterfactual for moving scientists.

To adress the measurement problem, we use citations in scientific articles and patents as a measure for the use of a researcher's knowledge. Journal articles are the main output of a researchers in Germany. Citations to articles of a researcher are the accepted way within the scientific community to acknowledge that own work benefited from the work of someone else. We use article-to-article (AtA) citations, citations of other scientific and peer-reviewed articles to the articles of the moving scientist, as a measure for knowledge flows within academia.

To measure knowledge flows to the private sector, we use the number of citations an article receives in patents of the private sector. Patents cite academic articles to give credit to the researcher who contributed to the disclosed technology of the patent.[9] In contrast to patent-to-patent citations, they have no legal meaning but are also not added by the examiner. Thus they reflect the assessment of the inventor which scientific article is prior art. Agrawal and Henderson (2002) and Roach and Cohen (2013) show that patent-to-article (PtA) citations seem to genuinely reflect knowledge flows from academia to the private sector.

We only consider citations to research articles that were published before the move to estimate knowledge spillovers. Articles of the moving professor published afterwards might have benefited from knowledge flows *coming from* researchers in close proximity of the moving university. As a consequence, these articles might be different from articles of the non-moving researchers.

Constructing a control group for moving researchers from a sample of non-moving researchers is challenging because researchers move for a reason. In particular, they might move to the vicinity of academic or corporate researchers who are interested in the same type of research. For example, a university might work towards establishing a cluster in a certain technology or private companies might provide additional funding for fields related to their production technology. Such an endogenous sorting would confound any measurement leading to an overestimation of spillover effects.

To address this identification problem, we exploit the particularities of the German university system to construct a control group. We use all non-moving researchers on the same short-list of candidates for the same position as a close control group for the moving researcher. All candidates on the short list applied for the

9. PtA citations are not a mechanic result from university researcher patenting their own technology as it is not possible in Europe to patent inventions which were already disclosed in an article. This requirement of "absolute novelty" is thus much more stringent than the application of a grace period in the US.

position, were extensively vetted and accepted by the university as potential new hires. Therefore, all of them might have been appointed to the university. Using this group of non-moving researchers, we are able to control for the endogenous selection of researchers to jobs because the non-moving researchers give us an estimate of how much local researchers would have cited the moving professor in the absence of the move.

The validity of our approach hinges on the assumption that in the absence of the move, citations to the pre-move work of all ranked candidates would have followed the same trend. This assumption is by definition untestable. In the latter part of the paper, we provide a series of checks to show that the assumption is plausible.

IV. Results: Hiring a scientists increases the use of her knowledge

If (personal) communication is important for research and innovation, the labor mobility of scientists may lead to an increase in the use of the moving researcher's knowledge in the destination area and a change in the direction of follow-on innovation. The reason is that when a researcher comes to a new university, she can more easily communicate with other academic researchers working at the same university or in the private companies in the same area. In this section we estimate whether these local spillovers exist and how large they are.

IV.A. Local knowledge flows increase in response to the move

In this subsection, we first look at the raw number of citations to articles of the moving and the non-moving researchers over time. Next, we use a regression model with time-varying coefficients to trace out the time path of excess citations.

In Figure II we compare the average number of citations to articles published before the scientist's move for treatment and control scientists and for both article-to-article and patent-to-article citations. To identify regional spillovers, we only consider citations within a 50 km range of the university. In the graphs, years are relative to the year of the move of the appointed professor.

For both types of citations, the average number of citations is very similar for treatment and control professors prior to the move. Starting with the second year after the move, articles of the moving professor receive substantially more citations from researchers in and around the destination university: Citations increase by 50%. This result points to a strong effect of localization on regional knowledge flows.

The picture is similar for patent-to-article citations. Starting in the third year after the move, the average number of patent-to-article citations diverges for moving and non-moving researchers. The impact appears to be a bit slower than for AtA citations, achieves its peak four to five years after the move and recedes again to baseline. With an increase of around 100% in years three and four, the peak impact on the number of citations from patents is even larger than for article-to-article citations.

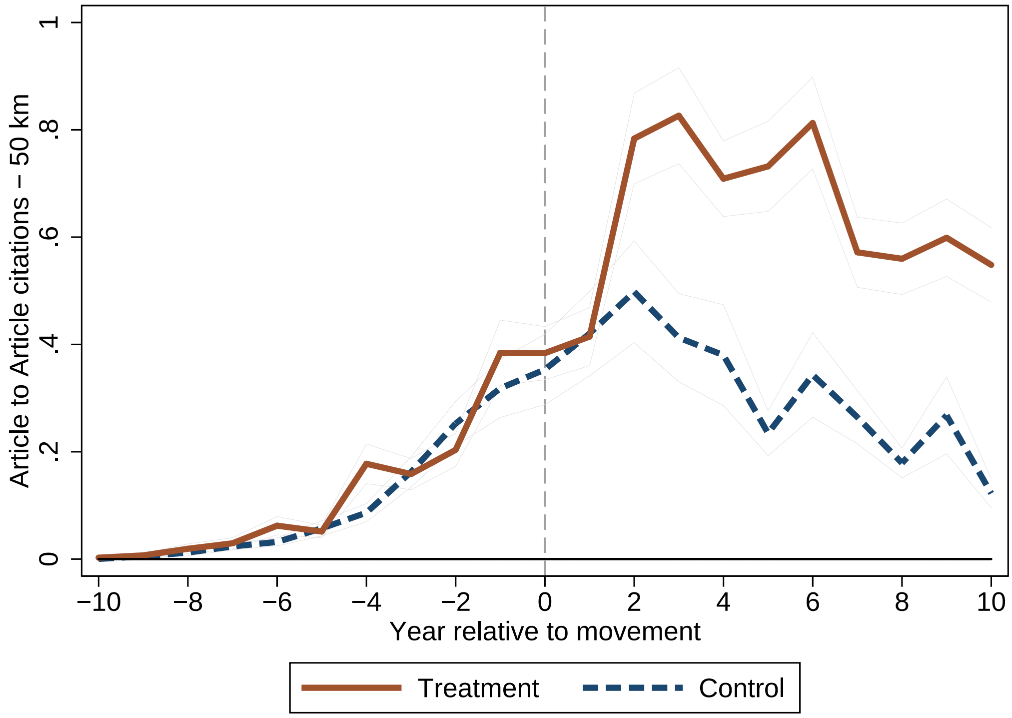
To show that these effects are not driven by other observable factors, we use the following difference-in-differences specification to estimate time-varying treatment effects:

$$\#Citations_{i,t} = \beta_t \cdot Move_i + Controls_{i,t} + \epsilon_{i,t} \tag{1}$$

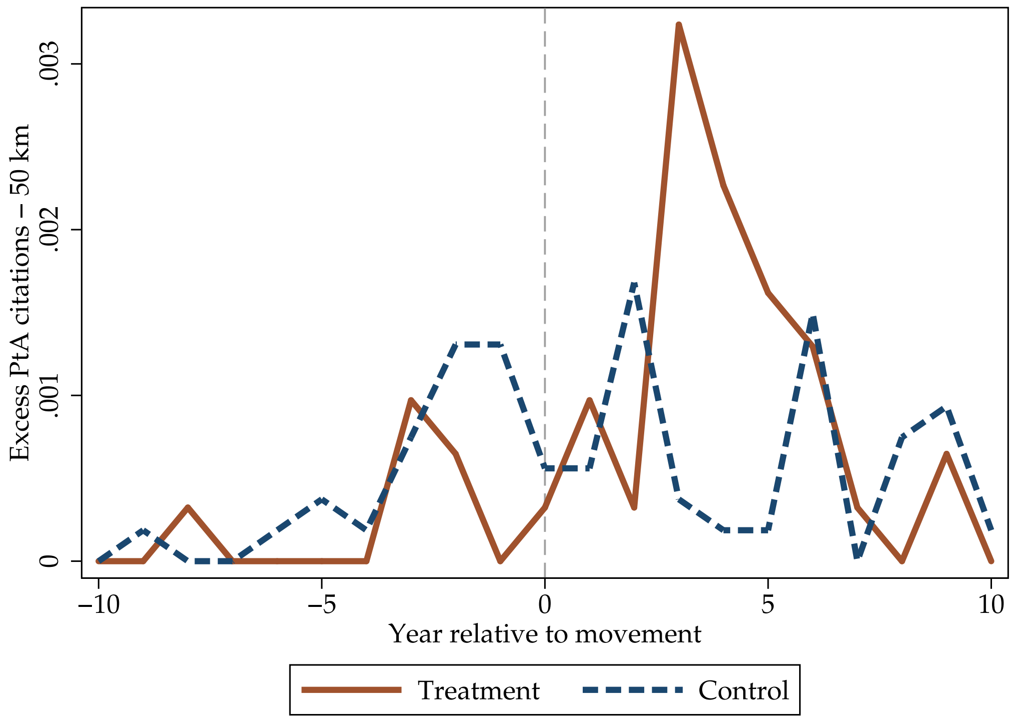
where the dependent variable $\#Citations_{i,t}$ are yearly article-to-article or patent-to-article citations within 50 km of the university. The main independent variable, $Move_i$, is an indicator whether or not the author of the article is appointed as a professor at the university. The estimate for β_t measures the average number of yearly excess citations to articles of the moving relative to citations to articles of the non-moving researchers on the same short-list. We control for the total number of citations prior to the move to adjust for the fact that some articles might be

Figure II: Mean # Citations to articles published before the move

(a) Article-to-article citations



(b) Patent-to-article citations



Note: Panel (a) plots the yearly average number of article-to-article citations for treatment and control articles that were published before the move. In panel (b) we plot the bi-yearly average number of patent-to-article citations. On the x-axis the years are given relative to the year of the move.

either of higher quality or in higher demand in the region under consideration. We include fixed effects for the publication year and the year of the appointment as additional controls. To compare only researcher that are on the same list we add an list fixed effects.

In Figure III we show the estimates for β_t in Equation ((1)) measuring the number of excess article-to-article and patent-to-article citations within a distance of 50 km. Prior to the appointment of the professor, there are no differences in citations between articles of treatment and control scientists. Starting with the move, both types of citations start to increase for articles of the moving researcher relative to those of the non-moving researchers. Article-to-article citations turn significant in year 3, while the estimated coefficients for patent-to-article citations become significantly different from zero in years 4 and 5. Again, both graphs suggest that scientists produce large local spillovers, both within the academic community as well as to the private sector.

IV.B. Citations to the articles of the mover increase by more than 50% after the move

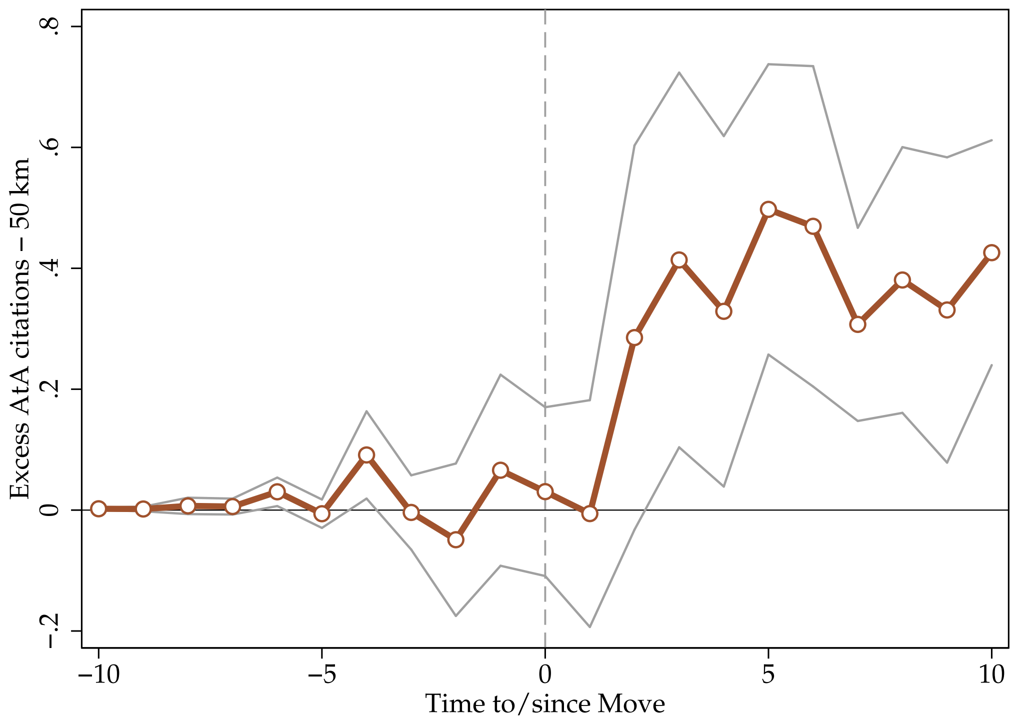
In order to quantify the effect, we estimate the average excess citations per year following a professor appointment using the following difference-in-differences specification

$$\#Citations_{i,t} = \alpha \cdot Move_i + \beta \cdot Post_t + \gamma \cdot Move_i \cdot Post_t + Controls_i + \epsilon_{i,t} \quad (2)$$

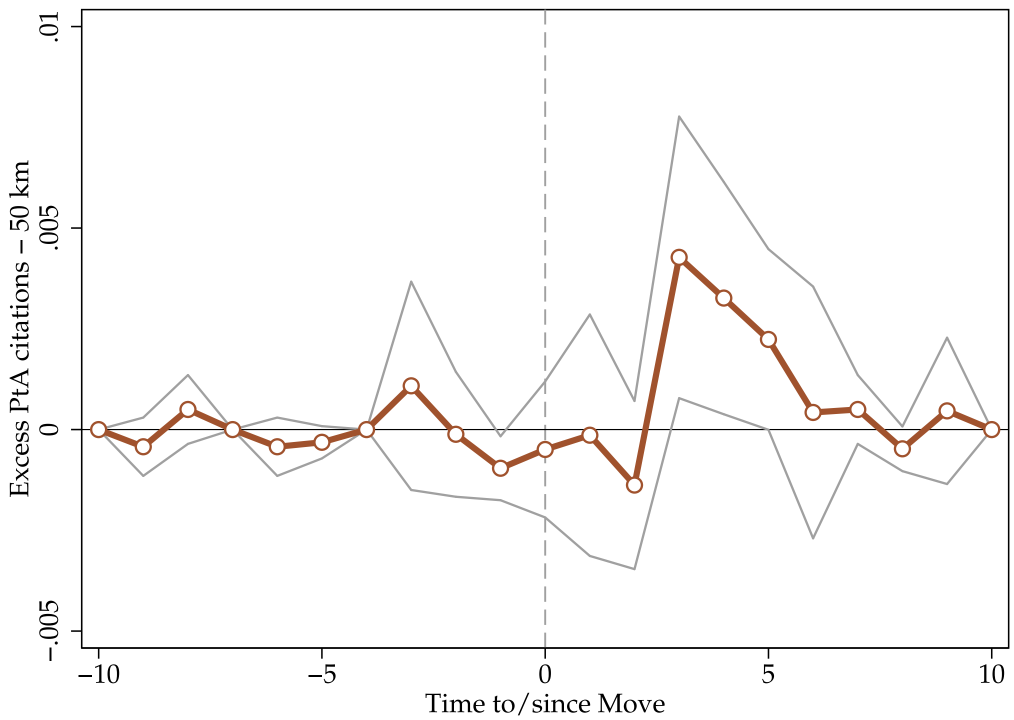
where $Move_i$ is an indicator for an article of an appointed professor and $Post_t$ is an indicator for the years one to ten after the move. The coefficient of interest is γ, the average increase in citations to movers after the move relative to non-movers. As controls, we use the number of citations to the patent prior to the move and list fixed

Figure III: Compare treatment and control articles

(a) Article-to-Article Citations



(b) Patent-to-Article Citations



Note: Panel (a) plots the regression coefficient β_t and 90% confidence intervals obtained by estimating equation ((1)) via repeated cross-section using article-to-article citations as dependent variable. In panel (b) we use patent-to-article citations as dependent variable. Standard-errors are clustered on the researcher level.

Table I: Impact of professor appointment on local spillovers

	Article-to-Article					Patent-to-Article				
		Quality		Fields			Quality		Fields	
	<50 km	Low	High	Humanities	Science	<50 km	Low	High	Humanities	Science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Move	-0.3	1.8	-2.6	-2.6	-0.0	-4.1	-5.9	-3.9	-17.8	-3.6
	(5.4)	(4.2)	(8.0)	(4.7)	(6.2)	(2.9)	(5.3)	(3.5)	(13.0)	(3.0)
Post	17.9***	8.7***	21.6***	4.3***	20.3***	-0.7	5.3	-1.5	-4.3	-0.4
	(5.3)	(2.4)	(7.3)	(1.2)	(6.2)	(3.0)	(10.4)	(3.4)	(12.8)	(3.1)
Post x Move	27.3***	15.9	35.9**	24.2*	27.9**	18.0***	6.5	20.8**	40.7	17.2**
	(10.4)	(11.9)	(14.7)	(12.4)	(12.1)	(6.8)	(12.0)	(8.3)	(32.7)	(7.0)
R2	0.04	0.07	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.00
N	246070	73381	168135	36883	209187	74536	9207	60357	4004	70532

Notes: This table shows OLS regressions on the article level. The data comprises the 5 years before and 5 years after the appointment. All articles are published prior to the appointment of the researcher under consideration. The dependent variable is the number of citation of this article from academic articles (columns 1-5) and patents (columns 6-10). In column (1) and (6) we use the citations up to the radius of 50 km as dependent variable. In the following two columns we split the sample at the median of the average number of article-to-article citations of the short list. In the last two columns we split the sample by researchers in the sciences and the humanities. The independent variables of interest are dummies. $Move$ is an indicator if the article was written by the appointed professor, $Post$ is an indicator for the post-move period and the indicator of interest $Post\,x\,Move$ is the interaction for the period after the move of treated articles. In every regression we control for fixed effects for the appointment list under consideration. Standard-errors clustered on the researcher level are in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively. To improve the readability of the table we multiply the number of article-to-article citations by 100 and the number of patent-to-article citations by 10,000.

effects. Therefore, we only identify from variation within lists, using non-movers as the control group for movers.

The results are reported in Table I. In columns (1) and (6) we show the baseline specification with citations up to 50 km around the university for AtA and PtA citations, respectively. The average effect per year is around 0.273 additional article-to-article and 0.0018 additional patent-to-article citations. The coefficients are statistically different from zero on conventional levels.

In the following two columns, we split the effects by the field of the researcher into list in the sciences and the humanities.[10] The effect of spillovers within the academic community is about the same size for all fields. For patent-to-article citations the effect is only significant for the sciences. This is true even though we drop all lists with no patent-to-article citations. Thus we exclude researchers working on topics that are never used in the private sector.

IV.C. Local knowledge flows increase more for researchers of high academic quality

We split the lists by academic quality in the final two columns. To measure the academic quality of a short list, we use the average number of article-to-article citations the articles of the researchers on the list received before the year of appointment. Then we split the short lists at the median of these averages separately for each faculty. By calculating the number of citations per list we make sure that we have a counterfactual for every moving researcher. By calculating the splitting value separately for each department we make sure that we do not classify all lists of a field with many citations as high quality.

For the article to article citations, the effect is similar in size for the high- and

10. We classify the fields Biology, Chemistry, Computer Science, Engineering, Mathematics, Medicine, Physics, Pharmacy and Statistics as science and all other fields as humanities and social sciences.

the low quality lists. Yet, only the coefficient for the high quality lists is statistically significant. As researchers on low quality lists have fewer articles prior to the move, the effect might just be imprecisely measured for the low quality lists.

In contrast, for the patent to article citations the effect is statistically larger for lists with highly cited researchers. The effect for low quality lists is much smaller and not statistically different from zero. This suggests that academic stars have a larger impact on innovation in the private sector than researchers of lower quality.

This result is not obvious because our estimate does not compare better with worse researchers but it compares a high-quality researcher who is moving with a non-moving high quality researcher on the same list. Thus the difference might go either way.

Gone but not forgotten? Move redistributes local spillovers

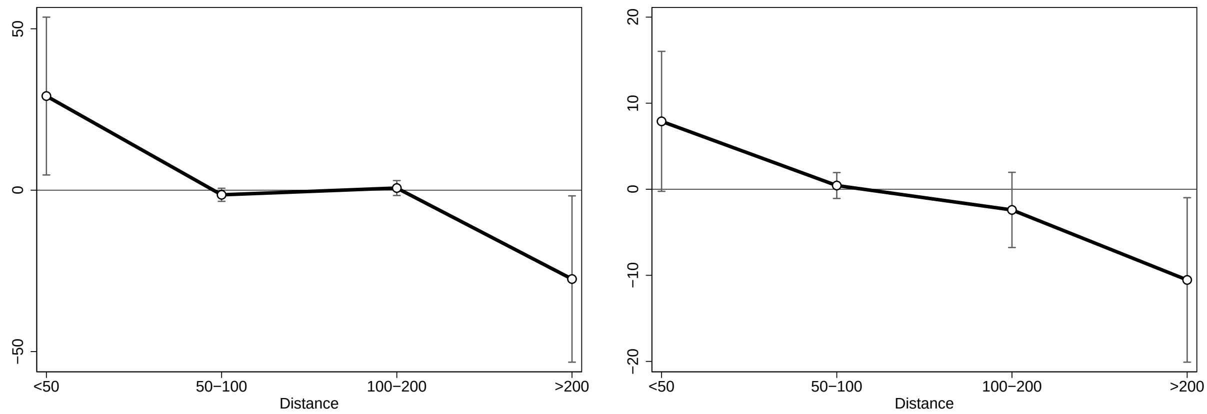
How local are the measured effects? In Figure IV we change the dependent variable to citations within 50 km radius around the university, between 50 and 100 km, between 100 and 200 km and more than 200 km and plot the resulting coefficient for the interaction of interest, γ. For both, PtA and AtA citations, we find a strong regional concentration of the effect. The effect is positive within 50 km, not measurable between 50 and 200 km and negative for more than 200 km. The negative effect measures the effect of researchers moving away from another university. The movement of a researcher thus results in a redistribution of knowledge flows speaking in favor of personal interaction as the causal mechanism.

Falsification & Plausibility Checks

There are three potential problems for the identification of the effect of the mobility of scientists: First, the hiring committee might decide to place researchers with more expected local spillovers on a higher rank of the short list such that they are more likely to receive and accept an offer. In Table II we show that this

Figure IV: Changing the radius

(a) Article-to-Article (b) Patent-to-Article



Note: Panel (a) plots the regression coefficient β_t and 90% confidence intervals obtained by estimating equation ((2)) using article-to-article citations within various distances as dependent. In panel (b) we use patent-to-article citations as dependent. For the first regression coefficient we use citations up to 50 km around the university, for the second we use citations between 50 km and 100 km, for the third between 100 km and 200 km and for the fourth all citations localized further away than 200 km. Standard-errors are clustered on the researcher level.

is not the case. In columns (1) and (6) we repeat the baseline specification. In columns (2) and (7) we use the total number of citations irrespective of distance as dependent variable. We do not find a significant result. This suggests that appointed researchers do not have systematically more total citations after the move than their runners-up. In (3) and (8) we compare the highest ranked non-mover as placebo treatment to a lower ranked non-mover. In this specification we also do not find any effect. Thus, there does not seem to be a different local trend by rank at the destination. Both results speak in favor of parallel trends.

A second problem might be that researchers with more expected future spillovers around the university might be more likely to accept, conditional on receiving an offer. If this is the case, selection might drive the results. In columns (4) and (9) we re-define professors with rank 1 as treated. This is an intention-to-treat analysis, so we compare the local spillovers of professors with different propensities to be treated. For AtA citations, the effects are pronounced and large. This suggests that there is no endogenous selection based on future knowledge flows within academia. For

Table II: Placebo and Plausibility Checks

	Article-to-Article					Patent-to-Article				
	<50 km	All	Non-Mover	ITT	F&L	<50 km	All	Non-Mover	ITT	F&L
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Move	2.0	-0.4	1.5	1.2	-0.0	-0.3	-0.9*	-0.6*	-0.1	-0.9
	(1.4)	(0.9)	(1.4)	(1.4)	(2.7)	(0.2)	(0.5)	(0.3)	(0.2)	(0.9)
Post	13.9***	23.8***	19.9***	16.1***	-0.1	0.3	1.3	-0.1	0.6	-2.8**
	(3.2)	(1.3)	(7.3)	(3.2)	(3.1)	(0.4)	(1.0)	(0.7)	(0.4)	(1.2)
Post x Move	21.9***	2.5	-9.6	16.3**	26.2**	1.3*	0.3	0.9	0.4	3.1**
	(8.0)	(1.9)	(7.7)	(8.3)	(13.0)	(0.7)	(1.1)	(0.8)	(0.7)	(1.3)
R2	0.08	0.17	0.10	0.08	0.04	0.02	0.03	0.02	0.02	0.04
N	629076	629076	388500	629076	375501	921102	921102	479304	921102	27930

Notes: This table shows OLS regressions on the article level. The data comprises the ten years before and after the potential move. All articles are published prior to the potential move of the researcher under consideration. The dependent variable is the number of citation of this article from academic article (column 1-6) and patents (column 7-12). In column (1) and (6) we use the citations up to the radius of 50 km as dependent. In column (2) and (7) we use all citations as dependent. In column (3) and (8) we only consider non-mover and assign a placebo treatment to the higher-ranked non-mover. In column (4) and (9) we do an intention-to-treat analysis with the treatment assigned to the highest ranked researcher. In column (5) and (10) we use an alternative dataset for rejected offers in all of Germany. The independent variables of interest are dummies. $Move$ is an indicator if the article was written by the appointed professor, $Post$ is an indicator for the post-move period and the indicator of interest $PostxMove$ is for the period after the potential move of treated articles. In every regression we control for the number of citations prior to the move, and fixed effects for the publication year and the year of the list. Standard-errors clustered on the researcher level are in parentheses. ***, **, * indicate statistical significance at the 1%, 5%, and 10% level, respectively. To improve the readability of the table we multiply the number of article-to-article citations by 100 and the number of patent-to-article citations by 10000.

patent-to-article citations, the estimate is in the right direction but the coefficient is not significant.

Lastly, as we are considering only one particular university, the effect might be driven by peculiarities in the area of this university. In this case, our results would not be externally valid. To see if this is the case, we collected additional data about academic hiring from the journal "Forschung & Lehre". Published monthly since 1994, it offers articles and interviews concerned with universities and science policies, a large job market section for academics and a section listing habilitations (a German degree indicating readiness for senior faculty positions) and offers and appointments to professorships in Germany.

This allows us to track the movements of a set of researchers in Germany and to match researchers that accepted an appointment to a university to other researchers who received and rejected an appointment for the exact same position. All these researchers went through the whole selection process of the German appointment system and ended up on the same short list. Compiling the announcements extracted from the publications of the F&L magazine, accessed December 12, 2015, from 1996 (earliest year available) to 2012 results in a dataset consisting of 533 researchers grouped in 230 short lists. In column (5) and (10) of Table II we show the results for this sample. The estimated coefficient for both types of citations are in line with the findings from our main sample.

V. Conclusion

We use data on newly hired university scientists to provide evidence on the impact of labor mobility on the diffusion of ideas across space. We do so by analyzing the impact of movements of scientists to one university in Germany on local innovation. Our identification strategy leverages the legal constraints on university hiring procedures in Germany that require universities to draw up a list of acceptable researchers (runners-up) for the position of every appointed professor. We show that these runners-up are not just acceptable, but in fact very similar to moving researchers and use them as a close control group for moving researchers.

Our results draw a nuanced picture of the trade-offs involved in designing university systems. We find that regional spillovers between scientists and to the private sector as measured through citations to the mover's pre-move work vastly increase at the destination location after the researcher's move. However, overall citations do not increase, pointing to a shift in regional spillovers from the origin to the destination location. This is in contrast to much of the previous literature whose results largely followed the idea that scientists were "gone but not forgotten", but which had difficulties isolating the exogenous geographic component of scientist moves.

The heterogeneity in the impact of scientist moves on regional spillovers uncovers interesting patterns. Regional spillovers to the patenting activity of the private sector arise only in hard sciences such as physics, chemistry or the life sciences while citations from other academics also increase in the humanities and social sciences. Furthermore, regional spillovers both within academia and to the private sector are exclusively driven by high-quality researchers, as indicated by article-to-article citations. Finally, university spillovers are measurable only up to a distance of 50 kilometers, suggesting that proximity indeed matters. As we only analyze citations to articles published before the move, our results emphasize the importance of tacit knowledge for regional spillovers.

Taken together, this paper provides evidence that regional spillovers from universities to the private sector and within academia are large, and that labor mobility shifts rather than exacerbates spillovers of scientists. Our findings therefore do not support previous findings that mobility is per se conducive to the spread of ideas. However, they do suggest that in industry-related scientific fields, cluster policies and university policies should be determined hand-in-hand to maximize the benefit from university funding.

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