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The return on scientific mobility: An econometric analysis based on CV data

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Abstract

The intensification of international mobility of researchers and related policy action pose the question whether mobility activities have an impact on scientific productivity. Although the benefits of mobility are usually assumed, empirical evidence is rare. Moreover, the operationalisation of mobility and productivity as well as the problem of two-sided causal effects are challenging and explains the differences in existing findings. This study focuses on mobility activities of researchers at the University of Vienna and their effect of publications and citations. Curricula vitae (CV) and publication lists of post-docs and professors were collected to gain information on the complex phenomenon of mobility pattern. CV data were systematically standardised and prepared on a cross-section data set for quantitative analysis. Econometric models show that mobility has a positive effect on the number of foreign-language publication. Yet, possible identification problems have to be taken into account.

Jelcodes:J61,O31

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1. Introduction

The international mobility of researchers has received increasing attention in the last years from a scientific and political point of view. Although it is not a new phenomenon the magnitude has increased substantially. The global competition for talent and the complexity of the mobility phenomenon is mirrored by several policy actions. International mobility has been acknowledged by policy makers, especially in Europe, who for example reflected in their green paper of the European Research Area (ERA): "*Researchers should be stimulated by a single labour market [...] involving the absence of financial or administrative obstacles to trans-national mobility. There should be full opening of academic position and national research programmes across Europe, with a strong drive to recruit researchers internationally, [...].- such mobility becoming a standard feature of a successful research career.*" (Commission of the European Communities 2007, p 8). One of the most important pillars in the 7th Framework Programme is the "people" programme. Its main objective is to make Europe more attractive for the best researchers of the world. The Marie-Curie Fellowships explicitly fund incoming and outgoing mobility. For the "people" programme 4.7 billion Euro are foreseen. This is about 10% of the total framework programme budget.

However, empirical data does not reliably support the positive effect of international mobility to the extent policy makers pay attention to it. There is insufficient data on mobility flows and only a few empirical studies analysing the impact of researchers' mobility (Van Heeringen und Dijkwel 1987, Canibano et al. 2008, OECD 2008). In most European countries data collection on researchers' mobility is difficult and longitudinal data sets that follow the mobility trajectory of researchers are hardly available. This has initiated a debate on a consistent methodological framework that encounters the problems of data lack and data standardisation. Canibano et al. (2008, S. 22) noticed: „*Although the benefits of mobility in terms of research performance are usually assumed, they have rarely been assessed. (...) However, as in the case of collaboration (Lee and Bozeman, 2005) the relationship between mobility and research performance is more a perception than an empirical studied fact.*"

The paper is based on the analysis of Curricula Vitae (CV) as an innovative approach to follow the career trajectory of researchers. CV include data to build indicators mirroring the complexity of mobility event and therefore enhance the understanding of mobility activities and their impact. CV data are gained from researchers at the University of Vienna. The University of Vienna is the largest university in Austria with about 85,000 students and over 300 professors. About one quarter of the students and PhD students have a foreign nationality and about one third of the professors (2010). After the collection of CV, we prepared indicators to finally estimate the effect of mobility using a regression approach.

This paper aims to empirically study the impact of international mobility of researchers on their scientific performance. It expands the rare body of empirical studies and provides a contribution to the debate on the returns on mobility. The paper analyses mobility events and their returns operationalised on publication outputs of researchers. It specifically addresses effects of long-stays abroad (three months or more) and distinguishes between mobility events to German-speaking countries vs. other countries. Furthermore, the effects on publications are measured in terms of quantity and quality (citations) indicators. The econometric implications and challenges of estimation are discussed.

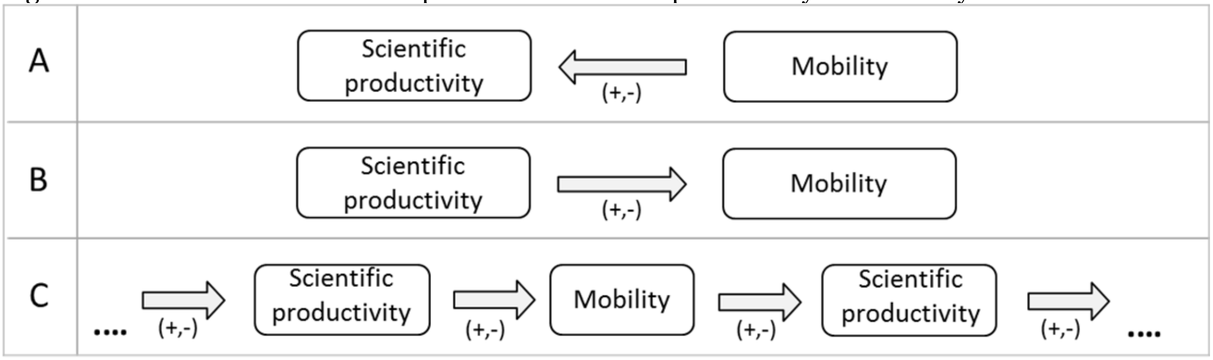
We show a significant relation between long-stay mobility events and the number of foreign-language publications. This effect even increases when researchers spent time in a non-German speaking country. Our findings may provide policy makers with more realistic expectations on the effects of international mobility activities of researchers.

The paper is structured as follows: Section 2 provides a literature overview. In Section 3 we present our CV-based approach of data-collection. Section 4 is devoted to the econometric analysis and the discussion of the empirical findings. Section 5 concludes.

2. Literature overview

The relationship between international mobility and scientific productivity is complex. Neither the direction nor the sign of the causal link between these variables is clear cut. Theoretical arguments and empirical findings support several assumptions on the causal relationship. Figure 1 summarises possible constellations regarding the influence of mobility on productivity and/ or the other way around.

Figure 1: Possible causal relationships between scientific productivity and mobility



Source: Own figure

The first case in Figure 1 (A) shows a causal impact of mobility on scientific productivity. Yet, the influence can be positive or negative. From a neoclassical economic point of view it can be argued that mobility has a positive impact on scientific productivity. The human capital migration theory proposes that mobility represents a human capital investment which is only undertaken if the expected and discounted costs are smaller than expected and discounted gains (Sjaastad 1962). The work of Topel and Ward (1992) suggests that mobility triggers a better matching between employer and employee. This reallocation is a very important mechanism with possibly high efficiency gains. Empirical findings from the US-labour market show that an American worker who makes a job-to-job move receives on average an 8% higher wage in the new job (The Economist, 11.02.2012). Part of this can be attributed to higher productivity as a result of an improved matching. Considering the case of scientists, the argument can be extended to international mobility because the high specialisation in certain research fields makes it unlikely that the best match is found in the home region or country of the researcher. Furthermore, moving to the location where the best researchers in the field reside is a very attractive opportunity for young researchers to benefit from positive external effects mediated by spatial and institutional proximity. An empirical finding which corroborates the positive causal impact of mobility on productivity (measured by citations per patent) is provided by Hoisl (2009) on the basis of a sample of German inventors. Based on CV-data on young Spanish scientists and structural equation modeling, Canibano et al. (2008) find no impact of mobility on productivity.

A negative impact of mobility on scientific productivity can also be argued. Several effects can induce such a negative impact. For example, transaction costs related do language barriers, different social systems and administrative regulations can be high, especially when the researcher moves together with his/her family. Additionally, the loss of social capital might decrease the career prospects in the home country. For the family the loss of support from relatives can be costly and change the opportunity costs of work compared to leisure or reproductive work. In a comment on an editorial in the Reports of the European Molecular Biology Organization " (Gannon 2007), Boyan Garvalov (2007, 422), states that "Together, these hindrances can be dramatically vexing to the travelling scientist, to the point of seriously impeding his or her research productivity and career development – the officially proclaimed raison d être for mobility."

The situation B in Figure 1 shows the causality the other way around: productivity impacts on mobility. While a negative sign of this relationship is rather unlikely, a positive impact of productivity on mobility is also a well-established stylized fact in migration studies and labour economics (Borjas 2010, Chiswick 1999). However, scientists are already a highly selected subpopulation and it is not clear, if the same mechanisms apply even in this case. For example, Hunter et al. (2009) find no significant productivity differences between stayers and movers in field of (highly cited) physicists and (highly-cited) bio scientists. One possible explanation for selectivity among scientists is the allocation of mobility grants for young researchers. Generally, this grants are allocated according to the hitherto publication record and the quality of a research proposal. In so far as these policy instruments follow a picking the winner strategy, this will induce a positive impact of productivity on mobility. Based on survey data, Dutch scientists Van Heeringen and Dijkwel (1987) infer that mobility is a characteristic of productive scientists and not a mechanism to increase productivity.

Situation C in Figure 1 proposes a circular-cumulative causation pattern between the two variables. Probably this is the most realistic but also most complex assumption on the relationship between international mobility and scientific productivity. This model of causation finding is empirically established by Hoisl (2007).

Taken together, theoretical arguments and empirical work gives no clear indication on the expected direction or sign of the causal relationship between international mobility and scientific productivity. Of course, the potentially complex pattern of causality presents a challenge for the econometric identification of causal effects.

3. Data – a CV based approach

Vienna as the largest city and capital of Austria hosts nine public universities with about 160.000 students in 2010. 23% of students and 25% of PhD students have a foreign nationality. According to OECD (2011) statistics, Austria successfully attracts international students and researchers, it closely follows Australia and Great Britain. Although, regions of origin are in spatial, cultural and historical proximity - Germany, Eastern Europe, Turkey and Italy – Austria, especially Vienna, proves to have a good position in the competition for talents. Over the last ten years, the number of international students and researchers and their ethnic diversity has increased enormously in Vienna. Vienna is an attractive city for internationally mobile researchers. The University of Vienna – with about 85.000 students and over 300 professors (2010) - is the largest university in Austria. It is a classical public university covering major scientific areas like natural sciences, humanities, economic/social sciences and law. We therefore focused in this study on researchers at the University of Vienna to investigate how their mobility activity affects their scientific productivity. We selected researchers in their academic career after their PhD graduation as the relation of mobility events and publication record can be hardly seen in a very early phase of the academic career.

Researchers' mobility is a very complex phenomenon without a consistent conceptual definition and a comprehensive analytical framework. Methodological approaches vary according to available data and research questions addressed. As mobility research is in an explorative stage, different concepts and methodologies still add to the understanding of the field. Analysis of CV is one approach to encounter the complex structures of mobility, because CV provide the individual trajectory of researchers. Independently of nationality or institutional framework, researchers rely on their CV as a currency for different purposes (grant application, job positions etc.), therefore they are mainly up-to-date. CV reflect researchers' scientific positions, mobility events, outcomes and specific features (Cañibano et al. 2008). Therefore CV analysis has become an innovative methodology to follow mobility trajectories and their impact on the scientific output. However, it is important to realise that CV analysis still entails many challenges. First, the operationalisation of mobility events of researchers and scientific output is already subject to discussion. E.g. Cañibano et al. (2008) distinguish short- and long stays abroad. As a matter of course, scientific output differs according to scientific area. Second, the structure of CV differs in length and information density. CV analysis is limited to information available. Some information can be provided by additional sources (Cañibano and Bozeman 2009), but not all desired information is available. Third, standardisation of qualitative data (CV) is challenging. And although information is digitalised in a more or less standard format a comparison to other CV analyses is difficult due to inconsistent methodological frameworks. But despite the conceptual and methodological difficulties, the intensification of mobility flows – also reflected in public policy making – encourages to accept the limitations of CV analyses.

As there is no databank in Austria that systematically makes the appropriate CV data available, we manually collected and analysed CV. The alternative – conducting a survey – appeared less appropriate to cover the complex and highly individual pattern of mobility events. Therefore, in close cooperation with the Vice Chancellor and the Human Resources Department of the University of Vienna, an electronic mailing was prepared to request post-docs and professors to make their CV and publication list available for us. In September 2011 this e-mail approached 1,315 researchers. After one month we received 211 (16%) CV and publication lists. We did not work with reminders or telephone follow ups to increase the return rate due to recommendation of University of Vienna.

Table 1 Comparison sample and population

	Sample			Population		
	Professor[2]	**Post-Doc[3]**	**Total**	**Professor**	**Post-Doc**	**Total**
Number[1]	157	54	211	376	939	1,315
Share	74%	26%	100%	29%	71%	100%
Humanities	39%	38%	38%	44%	37%	39%
National Sciences	37%	36%	37%	31%	42%	39%
Economic and Social Sciences	11%	15%	14%	15%	11%	12%
Law	13%	11%	11%	10%	9%	10%

[1]There is a significant difference on the 1% level between the distribution of professors and post-docs in the sample and population according to chi^2-significance test.

[2]There is a significant difference on the 5% level between the distribution of professors over the scientific areas the sample and the population according to chi^2-significance test.

[3]There is no significant difference between the distribution of post-docs over the scientific areas in the sample and the population according to chi^2-significance test.

Source: Own calculations, Data University of Vienna

Table 1 shows a comparison between sample and population. Out of 1,315 researchers 71% are officially in a post-doc position and 29% are professors. We defined a researcher to be in a post-doc position if he/she has graduated as a PhD, but has not yet reached a professorship. In Austria there a many researchers with permanent contracts in a post-doc position. Officially they aim for a professorship, but in fact they are involved in teaching or contract research with no hard ambition to reach a professorship. In our sample we have 74% professors and 26% post-docs. The sample is skewed towards professors. The number of post-docs who replied is extremely low. We assume that only post-docs followed the request who indeed aim for a professorship. The distribution of post-docs over the scientific areas in the sample and population do not differ significantly. For the professors there is a significant difference on the 5% level due to higher shares of professors in law and lower shares in economic and social sciences in the sample in comparison to the population.

In a next phase, the CV data have been digitalised according to a standard format:

- Individual data: sex, place of birth, year or birth

- Scientific area of expertise
- Mobility activities: Number of long (>=3 months) stays abroad during study period, PhD period, post-doc phase and professor phase, locations and institutions
- General publication information: Number of publications according to CV, number of foreign-language publication

According to Cañibano and Bozeman (2009) information of other sources is often a useful supplement to gained information from CVs. Therefore the dataset was enhanced by the following information: Specific information on the TOP 3 publications: identification of the three "TOP" publications meaning the three most frequently cited publications in Google Scholar: year of publication, language of publication, number of citations, number of co-authors, country of origin of co-authors. Information on the TOP 3 publications enables us to prove whether mobility influences the quality of publication. Publication data are not limited to refereed journals, but contain information on all relevant publications in the researchers' view. Scientific areas are therefore equally treated. Other information, e.g. relevant data on the family status of researchers, was not systematically included in the CV structure and could not be added using additional sources. This is a clear limitation of the dataset.

4. Empirical findings and discussion

4.1 Descriptive statistics

To prepare data for regression analysis, we developed a mobility variable summarising the number of long-stays/positions (>=3 months) abroad since the PhD period has started. We selected a period of three months because it is a realistic period to do research and establish relations to a level that results in joint publications. Because researchers in Austria tend to have intensive exchange with Germany, we distinguished two mobility variables: number of mobility events including Germany (mobil_ig) and number of mobility events excluding Germany (mobil_i). We assume that the two variables have different effects on productivity due to proximity in language and scientific system to Germany. Table 2 revealed that 28,4% of the researchers in the sample did not record a stay abroad longer than 3 months in their entire research career. If we exclude research visits to Germany, the share climbs to 46%.

Table 2 Descriptive statistics to the mobility variables

	Absolute frequency	Percent	Relative cumulative frequency	Absolute frequency	Percent	Relative cumulative frequency
		mobil_ig			*mobil_i*	
0	60	28.4%	28.4%	97	46.0%	46.0%
1	45	21.3%	49.8%	53	25.1%	71.1%
2	27	12.8%	62.6%	40	19.0%	90.1%
3	33	15.6%	78.2%	9	4.3%	94.3%
4	17	8.1%	86.3%	5	2.4%	96.7%
5	11	5.2%	91.5%	3	1.4%	98.1%
6	6	2.8%	94.3%	4	1.9%	100.0%
7	8	3.8%	98.1%			
8	3	1.4%	99.5%			
11	1	0.5%	100.0%			
Total	211	100.0%		211	100.0%	

Source: Calculation based on own data collection

Scientific productivity is operationalised in three variables: number of total publications, number of foreign-language publications and sum of the citations of the three most frequently cited publications – TOP 3. The first variables are a quantity measure for scientific output, the last variable mirrors a quality measure. The number of foreign-language publications is a measure of publication quantity, but is also contains a qualitative aspect assuming that publishing in a foreign language, mainly in English, means that authors faced higher competition. This corresponds to Cañibano et al. (2008) call to study the mobility effect on the quality of scientific performance. In Figure 2 and Figure 1 density functions for the three variables are shown. We observe right skewed curves. Many researchers have only a few publications whereas very few researchers are responsible for a lot of publications. This skewness increases, if we concentrate on foreign-language publications only. The same finding turned out for the citation variable. A short summary of the descriptive statistics of all dependent and independent variables is displayed in Table 3.

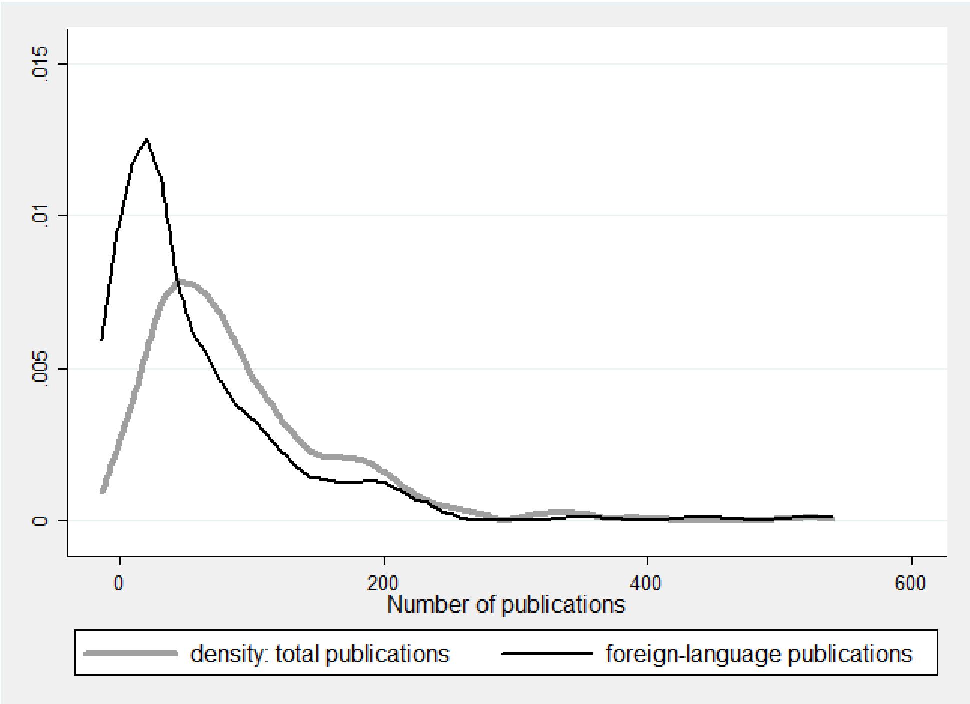


Figure 1 Density function of the number of publications

Source: Calculation based on own data collection

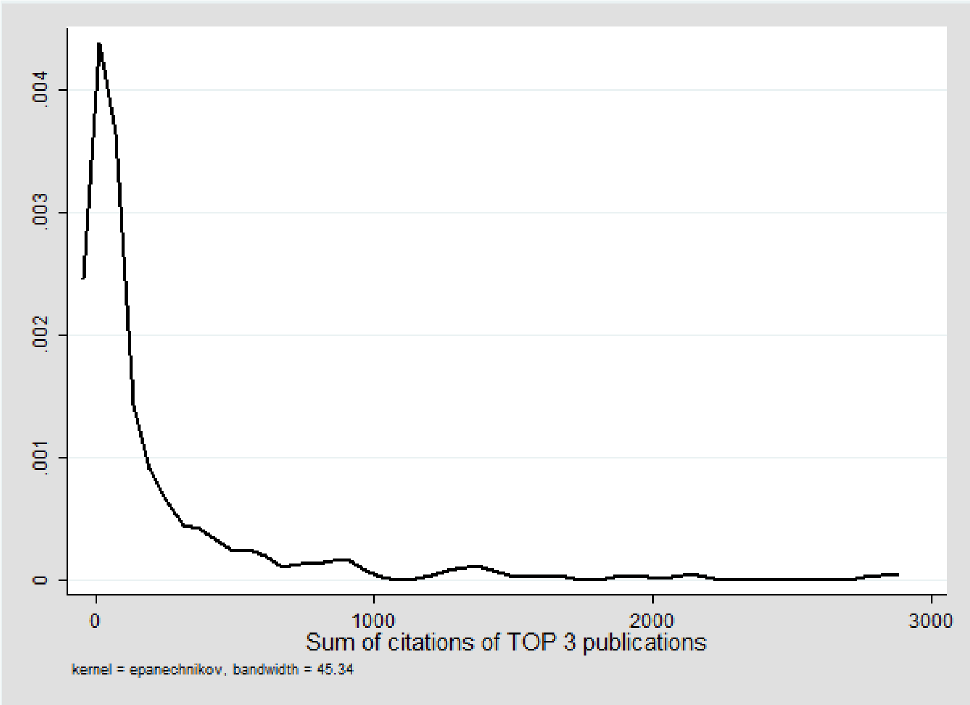


Figure 2 Density function of sum of citation of Top 3 publications

Source: Calculation based on own data collection

Table 3 Descriptive statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Dependent Variables						
lnpub	number of publications	211	4.20	0.84	1.10	6.26
lnpub_for	number of foreign-language publications	211	2.94	1.62	0	6.10
lncit_top3	sum of citations of the three most frequently cited publications according to google scholar (10/2011)	211	3.59	2.18	0	7.95
Mobility Variables						
mobil_ig	research stays abroad (outside Austria) >= 3 months	211	2.12	2.15	0	11
mobil_i	research stays abroad (outside Austria and Germany) >= 3 months	211	1.04	1.32	0	6
mobilprof_i	interaction variable of mobil_i and prof_d	211	0.85	1.28	0	6
Control Variables						
c_age	career age = 2011-year of PhD graduation	211	24.28	9.67	1	45
c_age2	(career age)² = (2011-year of PhD graduation)²	211	682.85	476.82	1	2025
sex	dummy sex, male=1, female=0	211	0.71	0.45	0	1
birth_place1	Place of birth in Austria	207	0.66	0.47	0	1
birth_place2	Place of birth in Germany or Switzerland	207	0.23	0.42	0	1
birth_place3	Place of birth outside Austria, Germany and Switzerland (=Rest of the world, ROW)	207	0.11	0.31	0	1
hum	dummy humanities	211	0.38	0.49	0	1

nature	dummy natural science	211	0.36	0.48	0	1
law	dummy law	211	0.14	0.35	0	1
ecso	dummy economic and social sciences	211	0.11	0.32	0	1
phd_at	dummy country of PhD Austria	203	0.74	0.44	0	1
phd_dech	dummy country of PhD Germany or Switzerland	203	0.20	0.40	0	1
phd_row	dummy country of PhD graduation is outside Austria, Germany and Switzerland (=Rest of the world, ROW)	203	0.06	0.24	0	1
prof_d	dummy professor	211	0.74	0.44	0	1
spub_for	share foreign-language publication/total publication	210	0.53	0.40	0	1
top3_for	number foreign-language publication of TOP 3 publication	211	1.65	1.33	0	3
inbreeding	University of Vienna as location for master graduation, PhD graduation, post-doc „graduation“ (habilitation) and first professorship	211	0.24	0.43	0	1
r_phduni	ranking of university of PhD graduation according to Shanghai-Ranking	209	0.08	0.27	0	1

Source: Calculation based on own data collection

4.2 Regression results (OLS)

The aim of the empirical analysis is to estimate the impact of mobility on scientific productivity. Table 4 displays the estimated equations and the respective dependent and independent variables of interest as described above. Productivity variables enter in logs to account for their skewed distribution as well as for possible outliers. Hence, the equations can be interpreted as constant semi-elasticity models. Canibano et al. (2008) and Van Heeringen and Dijkwel (1987) use annually adjusted productivity indicators. Yet, estimating the models with our data and publications normalised with career age as dependent variables does not change the main results. The numbers in parentheses correspond to the numbers in the first row of the regression output in Table 6 Table 7 and Table 8. In a first step we estimate these equations with OLS. Hence, we have to make an identification assumption on the direction of causality. We assume that mobility (x) impacts on scientific productivity (y) and not the other way around. Later on, we will discuss the case for a causal interpretation and try to relax some of the identifying assumptions.

Table 4: Dependent variables, independet variables and estimated equations

	(lnpub)	(lnpub_for)	(lncit_top3)
mobil_ig	(1), (2)	(5),(6)	(9), (10)
mobil_i	(3), (4)	(7), (8)	(11), (12)

Source: Calculation based on own data collection

Our estimation strategy rests on the “specific-to-general approach” (Verbeek 2008). Several specification tests (e.g. RESET-test) and criteria (e.g. AIC) were applied. Firstly, we estimate a “short model”, which includes control variables for age, sex and scientific area using the two different mobility variables. The variable age enters the equations in level and in a squared form. This follows from the work on life-cycle effects on research productivity. For example, Levin and Stephan (1991) show that research productivity diminishes as scientists become older. Indeed, all specifications show an inverted u-shaped relationship between age and productivity. The reference category for the dummies on scientific area is humanities. Secondly, a fully specified model is presented. The added set of control variables varies with the respective dependent variable. For the fully specified models the results of a RESET-test are presented. They indicate that none of the models is miss-specified.

The main results of the OLS-estimates for the fully specified models are summarised in Table 5. All significant coefficients have a positive sign. International mobility including Germany as destination (mobil_ig) has a positive impact on the number of publications (lnpub). Both mobility variables (mobil_ig, mobil_i) have a positive impact on the number of foreign-language publications (inpub_for). The citation variable (lncit_top3) is only influenced via an interaction term between mobility_i and prof_d. Regarding the interpretation of the significance level, one should keep in mind the rather small sample size of 211 observations. In the "short models", the mobility variables are all significant with a positive sign with the exception of an insignificant coefficient of mobility in equation (3). The R-square of the fully specified models is about 0.48. In the following, the detailed results are discussed and the interpreted.

Table 5 Main results of OLS-estimations

	(lnpub)	(lnpub_for)	(lncit_top3)
mobil_ig	(+)**	(+)***	-
mobil_i	-	(+)***	-
mobilprof_i	not included	not included	(+)*

*** p<0.01, ** p<0.05, * p<0.1
Source: Calculation based on own data collection

coefficients are quite similar.

Table 6 shows the regression of mobility on the number of publications (lnpub). Mobility including Germany as a destination triggers an increase in research productivity. Similarities in language and scientific system and networks might ease publication outputs. After controlling for additional variables, equation (2) displays a larger and more significant coefficient compared to the short model (1). Interpreting the results as correlations, we can infer that a researcher with an additional mobility event and the same observed characteristics compared to another arbitrary chosen researchers displays an 6.1% higher expected number of publications. A causal interpretation would be as follows: An arbitrary scientist deciding to make an additional spatial movement experiences an increase in the number of publications of the magnitude of 6.1%. Equation (4) shows, that international mobility outside Germany is not statistically significant. Researchers do not profit from the natural similarities to Germany and publication output cannot be significantly increased. However, the signs and magnitudes of the coefficients are quite similar.

Table 6: The impact of mobility on the number of publications (lnpub) (OLS, robust standard errors)

VARIABLES	(1) lnpub	(2) lnpub	(3) lnpub	(4) lnpub
mobil_ig	0.0353*	0.0606**		
	(0.0975)	(0.0288)		
mobil_i			0.0398	0.0605
			(0.334)	(0.176)
c_age	0.105***	0.0697**	0.107***	0.0729**
	(2.02e-05)	(0.0147)	(1.02e-05)	(0.0129)
c_age2	-0.00117**	-0.000651	-0.00121**	-0.000697
	(0.0163)	(0.242)	(0.0119)	(0.221)
sex	0.282***	0.217**	0.286***	0.206**
	(0.00359)	(0.0223)	(0.00317)	(0.0309)
nature	0.150	0.228*	0.140	0.233*
	(0.127)	(0.0623)	(0.154)	(0.0562)
law	0.168	0.121	0.150	0.129
	(0.239)	(0.410)	(0.292)	(0.399)
ecso	-0.250	-0.199	-0.268	-0.210
	(0.136)	(0.232)	(0.117)	(0.216)
phd_at		0.0473		-0.0381
		(0.811)		(0.837)
phd_dech		-0.184		-0.0761
		(0.382)		(0.699)
spub_for		-0.0978		-0.115
		(0.539)		(0.484)
prof_d		0.375***		0.382***
		(0.00497)		(0.00429)
Constant	2.118***	2.378***	2.133***	2.449***
	(0.000)	(8.55e-10)	(0.000)	(2.36e-10)
RESET-test		1.13		1.07
F-statistics	26.12	16.00	25.00	15.20
R-squared	0.473	0.480	0.469	0.474
Observations	211	202	211	202

Robust pval in parentheses

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

Source: Calculation based on own data collection

The impact of mobility on the number of foreign-language publications is presented in Table 7. All mobility variables have a positive sign and are highly statistically significant in all four specifications. However, the coefficient of mobil_i is approximately double the size of the coefficient of mobil_ig. Not surprisingly, the coefficient for researchers in law is negative. Law is still dominated by national issues, which are only of limited importance or interest to foreign scientists. A professor is also considerable more productive than non-professors with a coefficient of about 0.7.

Table 7: The impact of mobility on the number of publications in foreign language (lnpub_for) (OLS, robust standard errors)

VARIABLES	(5) lnpub_for	(6) lnpub_for	(7) lnpub_for	(8) lnpub_for
mobil_ig	0.153***	0.179***		
	(0.000516)	(0.00918)		
mobil_i			0.294***	0.304***
			(0.000545)	(0.00303)
c_age	0.117***	0.0743*	0.118***	0.0784*
	(0.00241)	(0.0779)	(0.00194)	(0.0556)
c_age2	-0.00180**	-0.00129	-0.00184**	-0.00132
	(0.0263)	(0.127)	(0.0211)	(0.106)
sex	-0.0945	-0.134	-0.0792	-0.181
	(0.632)	(0.498)	(0.683)	(0.357)
nature	1.542***	1.621***	1.448***	1.562***
	(0.000)	(0.000)	(0.000)	(0.000)
law	-1.133***	-1.120***	-1.157***	-1.046***
	(0.000706)	(0.000616)	(0.000410)	(0.00145)
ecso	0.551*	0.619**	0.407	0.538*
	(0.0597)	(0.0378)	(0.175)	(0.0705)
phd_at		-0.0776		-0.192
		(0.874)		(0.669)
phd_dech		-0.545		-0.0562
		(0.208)		(0.900)
r_phduni		-0.0644		-0.0766
		(0.847)		(0.822)
inbreeding		-0.0459		0.0167
		(0.860)		(0.949)
prof_d		0.653***		0.624**
		(0.00978)		(0.0172)
Constant	0.608	0.919	0.674	0.953
	(0.167)	(0.170)	(0.123)	(0.134)
RESET-test		1.11		1.72
F-statistics	34.08	21.39	33.75	23.58
R-squared	0.475	0.499	0.489	0.514
Observations	211	202	211	202

Robust pval in parentheses

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

Source: Calculation based on own data collection

Table 8 displays the regression results for the number of citations of the three most frequently cited publications according to Google Scholar. The short models (9) and (11) show a positive and significant impact of mobility. Similar to the results presented in Table 7, the size of the mobile variable mobil_i is about double the size of mobil_ig. An additional mobility event is associated with an increase in citations of 14%, this number rises to 26% if the destination is outside of Austria or Germany. Again, this is a quite huge effect in an economic sense. Yet, adding additional control variables, the mobility variables become insignificant. Regression (12) shows a slightly different specification. Several specification tests suggest the inclusion on an interaction term of mobil_i with prof_d. The respective variable is significant at the 10% level. Even though the p-value is only slightly smaller than 0.1, the small sample size suggests that the effect might be correct. Professors with a mobility history reach higher cited papers. However, a word of caution is needed regarding equation (12). Without mobilprof_i the coefficient of mobil_i would be positive, insignificant with the size of 0.028. This would be similar to the results of equation (10). Additionally, the significance of the interaction term rests crucially on the inclusion of the two dummy variables phd_at and phd_dech, indicating where the scientists received his/her PhD. This group of dummy variables is neither individually nor jointly [F (2,188)=0,69] statistically significant. Yet, the inclusion is justified by two arguments. Firstly, the Akaike Information Criterion is strongly affected by their inclusion. It decreases from 770.17 to 743.33. Secondly, the variance inflation factor of the mobility variables (which is about 6) is not infected by their inclusion, which suggests that multicollinearity is no problem. Nevertheless, the results should be interpreted with caution and further investigations are warranted.

Table 8: The impact of mobility on the number of citations of the three, most frequently cited publications (lncit_top3) (OLS, robust standard errors)

	(9)	(10)	(11)	(12)
VARIABLES	lncit_top3	lncit_top3	lncit_top3	lncit_top3
mobil_ig	0.140**	0.0420		
	(0.0144)	(0.464)		
mobil_i			0.261***	-0.237
			(0.00417)	(0.204)
mobilprof_i				0.343*
				(0.0995)
c_age	0.140**	0.0904	0.141**	0.0896
	(0.0160)	(0.215)	(0.0135)	(0.234)
c_age2	-0.00207*	-0.00114	-0.00211*	-0.00112
	(0.0821)	(0.435)	(0.0724)	(0.454)
sex	-0.247	0.0384	-0.233	0.0430
	(0.354)	(0.882)	(0.385)	(0.868)
nature	2.342***	0.649*	2.258***	0.650*
	(0.000)	(0.0968)	(0.000)	(0.0960)
law	-0.697*	-0.609*	-0.722*	-0.585*
	(0.0678)	(0.0625)	(0.0503)	(0.0748)
ecso	1.409***	0.569	1.281***	0.459
	(0.000281)	(0.107)	(0.000989)	(0.195)
phd_at		-0.342		-0.408
		(0.488)		(0.379)
phd_dech		-0.556		-0.539
		(0.206)		(0.245)
prof_d		0.711**		0.442
		(0.0330)		(0.214)
top3_for		0.918***		0.919***
		(0)		(1.49e-10)
r_phduni		0.466		0.576
		(0.276)		(0.184)
Constant	0.573	0.160	0.633	0.458
	(0.358)	(0.858)	(0.304)	(0.616)
RESET-test		0.50		0.25
F-statistics	22.81***	35.13***	22.48***	32.52***
R-squared	0.395	0.574	0.400	0.579
Observations	211	202	211	202

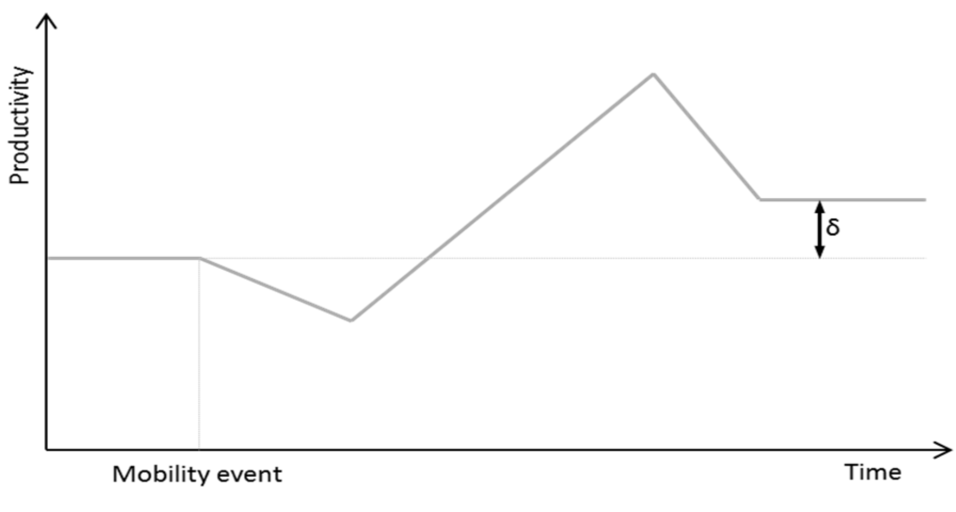
Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Calculation based on own data collection

Our results show that there is some positive relationship between mobility and scientific productivity. The number of publications is affected by the international mobility including Germany but not by international mobility outside Germany. Taking into account the quality of the indicator, this result seems plausible. Interpreting the results in a causal way it can be argued that staying at home triggers a relative penalty on productivity but it is not necessary to move to countries with a foreign language. The most robust finding of the OLS estimates is the impact of mobility on the number of foreign publications. Note that this result is not merely a reflection of language proficiency, since the place of dissertation is controlled for. The finding that the coefficient of mobility excluding Germany is double the size of mobility including Germany is also plausible. While additional language proficiency might be one explanation, network and pure productivity effects as a result of mobility might be further explanations. Interestingly, citations are more or less unexplained by mobility, beside a positive impact of an interaction term between mobil_i and prof_d.

Comparing our results with the literature, we provide some evidence on a positive impact of mobility on scientific productivity. Canibano et al. (2008), which is the most similar available study, find no evidence of a positive relationship for a sample of scientists with an average age of 35. On the contrary, the average age in our study is about 50. About 75% scientists of our sample are professors. The large, positive and highly significant coefficient of the dummy variable indicating if a scientist is professor reveals that there is an important effect of the career stage on productivity. In so far as stage of career and age are correlated, there is also an age effect. How can this be reconciled with the stylized fact, that older scientists face a decrease in productivity? A possible explanation can be derived from the migration literature. In a seminal article Sjaastad (1962) treated migration as an investment in human capital. Typically, investments are characterized by initial outlays, i.e. costs, and subsequent periods with interest payments. As a result, a time lag arises between the mobility decision and the subsequent pay off in terms of higher scientific productivity. Further explanations may refer to resource-effects as a result of a professorship increasing research productivity or to a more complex interaction between mobility and professorship. Mobility can be conceived as an important signaling effect in academic job applications. The proposed arguments were already conceptualized by Van Heeringen and Dijkwel (1987). Figure 3 shows that in the period after a mobility investment occurred, productivity decreases because of e.g. transaction costs and forgone social capital etc. This negative effect is generally not visible in our data but the negative sign of the coefficient of the mobility variable after including an interaction of mobility with prof_d in equation (12) might reflect this time period of decreasing productivity. However, after some time productivity increases and the final outcome is a productivity gain of magnitude δ.

Figure 3: Stylized, possible effects of mobility on productivity



Source: Adapted from Van Heeringen and Dijkwel (1987)

In summary, our results seem to complement the findings of Canibano et al. (2008), reflecting the time lag between the migration investment and the interest payments in terms of publications and citations.

4.3 Beyond OLS

The preceding section is based on OLS and the associated identification assumptions. Two issues need to be addressed, while the second one is much more important. Firstly, specification of an equation is always and inevitably somewhat arbitrary. Hence, the robustness of our estimates should be checked using alternative techniques. This will be done for the equations which regress mobility on the number of foreign-language publications via the application of a matching estimator.

Secondly, the other natural question that arises is: do our estimates reflect correlation or causality? In other words, are the mobility variables exogenous or are they plagued by endogeneity? Several arguments suggest the latter one. (1) Reverse causality is probably the most important point of concern. (2) Selection bias might be present, leading to the selection of scientists with a higher innate mobility into mobility. (3) Our data do not contain certain variables (e.g. family status) which might lead to an omitted variable bias. The only possible solution which addresses these problems simultaneously is the instrumental variable (IV) estimator. As far as we know, there is no other paper published so far which has tried to estimate the impact of international mobility on research productivity. However, IV is applied in similar situations. For example, Lee and Bozeman (2005) try to estimate the causal effect of research collaboration. The recognize the possibility for reverse causality and apply an IV estimator based on cosmopolitan scale as instrumental variable.

Matching estimators are widely used in determining the causal impact of policies on certain outcome variables. However, the technique of matching is not restricted to policy analysis. For an overview see Wooldridge (2010). The main advantage over OLS is that the assumptions regarding functional form are much more limited compared to OLS. In the terminology of policy evaluation, the mobile population represents the treatment group while the non-mobile scientists are the control group. Two identifying assumptions are necessary. The first one is referred to as conditional independence assumption, which implies that the uptake of the programme, i.e. the decision to become mobile is entirely based on observed characteristics:

$$Y^T, Y^C \perp M_i \parallel X \,, \qquad (1)$$

where Y^T denotes the productivity of the mobile scientists, whereas Y^C refers to the productivity of the non-mobile scientists; M is the mobility variable and the X are the observed characteristics what determine M (selection upon observables). Obviously, if self-selection of scientists on innate mobility is present, than (1) will not be satisfied. The second assumption is the assumption of common support, which demands that for every mobile scientist there is a non-mobile scientist "nearby". Formally:

$$0 < P(M = 1 \parallel X) < 1 \,. \qquad (2)$$

Since matching is based on a binary treatment variable, the mobility variable mobil_i, i.e. international mobility outside Germany, is recoded in a binary dummy variable (mobil_ih), indicating if a scientist is mobile or not.

Table 9 shows the distribution of our "treatment" variable. Accordingly, approximately half of the scientists were international mobile.

Table 9: Mobile or non-mobile?

mobil_ih	Frequency	Percent	Cum.
0	97	45.97	45.97
1	114	54.03	100
	211	100	

Source: Calculation based on own data collection

Technically our matching estimator utilises the propensity score matching estimator which is implemented in Stata by Becker and Ichino (2002). The first stage comprises the estimation of the propensity to belong to the treatment group. This probit estimation is shown in Table 10. We included the year and place of birth as well as scientific area of expertise as dummies.

Table 10: Participation equation (estimating the propensity score)

VARIABLES	mobil_ih
geb_jahr	-0.00322
	(0.736)
nature	0.437**
	(0.0374)
law	-0.795**
	(0.0101)
ecso	0.0738
	(0.807)
birth_place2	0.0254
	(0.907)
birth_place3	1.079***
	(0.00243)
Constant	6.236
	(0.739)
Likelihood-ratio-chi2	30.04***
Observations	207

pval in parentheses

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

Source: Calculation based on own data collection

Based on the estimated propensity scores, scientists are matched on the basis of several matching estimators. We applied the two most popular ones, nearest-neighbour and kernel matching. Whereas the former one compares on mobile scientist with the most similar non-mobile scientist, kernel matching compares mobile scientists to a weighted average of all non-mobile scientists. Table 11 shows the results of the impact of mobility on the number of foreign-language publications. First of all, the last columns displays the t-statistics based on the comparison of mean values between mobile and non-mobile scientists. Both matching estimators are statistically significant. The fourth column reports the evaluation parameter “average treatment effect on the treated” (ATT). The coefficients are not directly comparable to the coefficients of the regression, because our mobility variable is now a discrete binary variable. The coefficients are somewhat larger compared to OLS in equation (8) (see Table 11). Taken together, the matching estimators confirm our OLS results based on less restrictive assumptions regarding functional form. However, the direction of causality and the problem of possible self-selection remain open questions.

Table 11: Results of the matching technique (Y=number of foreign-language publications)

	Treatment (mobile_ih=1)	Control (mobile_ih=0)	ATT[a]	Standard error[b]	t-statistics
Nearest-neighbour matching	111	56	0.729	0.254	2.867**
Kernel matching	111	95	0.561	0.201	2.792**

[a] Average traetment effect on the treated

[b]Bootstraped standard errors (r=200)

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

Source: Calculation based on own data collection

In order to address the potential endogeneity of the mobility variable we apply an IV estimator and regress international mobility on the number of citations of the three most frequently cited publications. An IV estimator rests on two identification assumptions. Firstly, the instrument has to be exogenous or valid, i.e. uncorrelated with the error term in the structural equation:

$$Cov(Z, \nu) = 0, \quad (3)$$

where Z denotes the instrument and ν the error term of the structural equation. Secondly, the instrument has to be relevant, i.e. the correlation between the instrument and the endogenous variable (X_1) should be strong:

$$Cov(Z, X_1) \neq 0. \quad (4)$$

Of course, finding an instrument which satisfies (3) and (4) is the main challenge of the IV-approach. Given our data set there is only one possible instrumental variable, the place of birth. Regarding the exogeneity assumption (3) it can be argued that the place of birth has no partial effect on productivity, once other, observed and unobserved variables are controlled for. Probably more problematic is the question on the relevance of this instrument. The argument is that those scientists who were not born in Austria display at least one mobility event due to their move from the foreign location to Vienna. Furthermore and even more important, the probability of further mobility events increases if a person was already mobile (Borjas 2010). As a result, the place of birth could be a valid and relevant instrument for the mobility variable mobil_i.

The variable which indicates the place of birth is a dummy variable with three values: (1) Austria, (2) Germany and Switzerland and (3) ROW. Hence, we have two instruments. The IV estimator is implemented via 2SLS. The results are presented together with OLS estimates in Table 12. Both estimates are insignificant, while the size of the coefficient differs substantially with the IV-estimator being much larger than OLS.

The crucial question is whether the IV-estimates are consistent. Beside the not testable validity assumption, the issue of weak instruments has to be addressed. Individually, Adkins and Hill suggest that the t-values should exceed the value of 3.3. Yet, the t-values of our instrumental variables are 4.15 and -1.16 respectively. Another rule of thumb to establish the weakness of an instrument states that the value of an F-test on joint significance should be larger than 10. Again, our instruments fail to fulfil this criterion; the F-statistic is 5.77541. As a result, we should interpret the IV estimates with caution.

Table 12: The impact of mobility on the number of citations of the three, most frequently cited publications (OLS, IV, robust standard errors)

VARIABLES	OLS lncit_top3	IV lncit_top3
mobil_i	0.0137	0.303
	(0.854)	(0.293)
c_age	0.130*	0.0881
	(0.0620)	(0.226)
c_age2	-0.00194	-0.00118
	(0.158)	(0.415)
sex	0.0514	0.0757
	(0.839)	(0.772)
nature	0.855**	0.876**
	(0.0220)	(0.0216)
law	-0.520	-0.504*
	(0.103)	(0.0977)
ecso	0.701**	0.591*
	(0.0384)	(0.0954)
r_phduni	0.220	0.159
	(0.482)	(0.656)
prof_d	0.705**	0.634**
	(0.0314)	(0.0498)
top3_for	0.858***	0.741***
	(4.32e-10)	(2.48e-05)
Constant	-0.578	-0.133
	(0.421)	(0.855)
F-statistics	39.78***	-
Wald-test	-	393.82***
R-squared	0.560	0.534
Observations	209	205

Robust pval in parentheses

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

Source: Calculation based on own data collection

A Durbin-Wu-Hausman test on endogeneity fails to reject the null hypothesis. As a result, we can assume that mobil_i is exogenous. On the one hand, taking into account our weak instruments and the huge difference between the size of the IV and the OLS coefficient for the mobility variable, this result may be taken with a grain of salt. One the other hand, Canibano et al. (2008) find also no evidence for reverse causality of productivity on mobility. Van Heeringen and Dijkwel (1987) detect a causal impact of productivity on mobility and not the other way around. Yet, they do not consider international mobility but job mobility and their sample is restricted to physics, chemistry and economics. But perhaps even more important is that their sample reflects the situation in the middle of the 1980s. A simple model of Hunter et al. (2009) investigates the impact of costs of migration on the talent distribution of mobile scientists. With high mobility costs, only the most talented scientists will move. Decreasing migration costs broadens the talent distribution from which the mobile scientists come from. Probably the labour market for scientists experienced a structural break in the meantime and mobility has become an event which is not restricted to the more productive scientists any more. This might hold especially for our mobility variable, which counts every foreign sty longer than 3 months as a mobility event.

Taken together, analysis beyond OLS shows that our OLS results on the impact of mobility on foreign-language publications are not sensitive to the model specification. The matching estimators are also positive and statistically significant. An IV estimator was applied to address the potential endogeneity of the mobility variable. Yet, the impact of mobility on citations remains insignificant and the instruments turn out to be weak. Therefore, we cannot reject the case nor solve the problem of endogeneity unambiguously.

5. Conclusions

The international mobility of researchers has received increasing attention in the last years from a scientific and political point of view. However, empirical data does not reliably support the positive effect of international mobility to the extent policy makers pay attention to it. There is insufficient data on mobility flows and only a few empirical studies address the causal impact of researchers' mobility on productivity. The benefits of mobility in terms of research performance are usually rather assumed than fact based. This paper aimed to empirically study the impact of international mobility of researchers at the University of Vienna (Austria) on their scientific performance using CV data. It specifically addresses effects of long-stays abroad (three months or more) distinguishing mobility events to German-speaking countries vs. other countries. Furthermore, the effects on publications are measured in terms of quantity and quality aspects.

Results from regression analysis suggest that there is some positive relationship between mobility and scientific productivity. The number of publications is positively affected by the international mobility including Germany but not by international mobility outside Germany. Additionally, we find a strong and highly significant positive effect of mobility on the number of foreign publications. Note that this result is not merely a reflection of language proficiency, since the place of dissertation is controlled for. The finding that the coefficient of mobility excluding Germany is double the size of mobility including Germany is also plausible. While additional language proficiency might be one explanation, network and pure productivity effects as a result of mobility might be further explanations. Interestingly, citations are more or less unexplained by mobility. Our results complement the findings of Canibano et al. (2008), reflecting the time lag between the migration investment and the interest payments in terms of publications and citations.

Analysis beyond OLS due to matching estimators shows that our OLS results on the impact of mobility on foreign-language publications are not sensitive to the model specification. An econometric model with (relatively weak) instrumental variables corroborates the finding that mobility has no impact on citations.

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