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Science after Communism: Structural Change, Peers, and Productivity in East German Science*

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Abstract

Using the German re-unification as a natural experiment, we analyze the role of increased competition in academic productivity. We employ a unique dataset on East and West German scientists' publications in fields of science, technology, engineering, and mathematics (STEM) before and after the German re-unification in 1990. We focus on East German scientists' connections to their peers, their scientific productivity and impact as measured by the number of publications, citation accumulation, and the quality of journals where they publish. East German scientists show a significant convergence to their West German peers in all productivity accounts. We use the overlap of each East German scientist's research portfolio with the West German research prior to re-unification as identification and find that the effects of losing a collaborator or having a Soviet collaboration prior to re-unification differ across individuals with respect to their research portfolios, their ability to adopt to a new field, and their complementarities to their peers.

JEL Classification: I23, J24, J61, O33

Key Words: Productivity; Peer Effects; Institutions; Migration; East Germany

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1 Introduction

Technology and innovation are the main drivers of sustained economic growth as they provide a significant edge in international competitiveness (Verpagen, 2006) and it is crucial to understand their complex dynamics. Although it is hard to pin down every single factor that goes into the production of new ideas (Jones, 2005), it has been shown that collaborative interactions (Jones et al., 2008, Singh, 2005, Wuchty et al., 2007) and institutional environment (Heinze and Kuhlmann, 2008, Kim et al., 2009) play a significant role in innovation above and beyond what can be explained by qualities of individuals alone.

Competitive pressures in the production of research have been increasing largely over decades. The high level of competition in academic research is a consequence of existing incentive mechanisms that arise, for instance, due to the structure of the academic labor market where a researcher's publication portfolio is an (if not *the most*) important component in hiring and promotion decisions (Heckman and Moktan, 2018); due to financial pressures on universities and research institutes which leads to intense competition for grants (Jacob and Lefgren, 2011, Tabakovic and Wollmann, 2019); and due to expectations of high returns to fast commercialization of research, especially when industry and university collaborations are concerned (Perkmann et al., 2013). The constantly increasing competitive pressures must certainly be affecting the production processes of research yet it is hard to establish this link as these pressures have been building up over long decades. In this paper, we investigate a unique event where the unexpected and sudden fall of the Berlin Wall leads to significant structural changes in the academic structure of East Germany over a short period of time. The East German academic system has been overhauled into a very competitive and market-oriented academic structure within a few years, which we exploit to investigate how East German scientists adapted to this large structural change and how increased competitiveness affected their productivity and peer relations.

Academic research in natural sciences and engineering provides a solid fundament for new technologies and thus fuels innovation. When the structural setting underlying scientific and academic endeavour is very competitive, then collaboration provides a way to cope with it. Collaborations help researchers to overcome constraints of individual expertise or institutional

capacities on the creation of impactful research (Jones, 2009, Larivière et al., 2015). Despite the evidence on the growing importance of collaboration, the literature on peer effects delivers findings that look contradicting at first. On the one hand, Borjas and Doran (2012) show that the influx of Soviet mathematicians in the US after 1992 had negative productivity effects for US mathematicians, and Waldinger (2011) finds no effect of Jewish scientists' emigration in 1930s on their remaining colleagues at German universities during that time. On the other hand, Azoulay et al. (2010) shows that the loss of a very productive peer significantly reduces the productivity of their collaborators; Ductor (2015) finds statistically significant and positive productivity effects of research collaboration; Azoulay et al. (2019) show that the death of a star scientist affects the productivity of their peers adversely while the productivity of their non-collaborators increases. These seemingly contradicting findings are put into context by Borjas and Doran (2015b) where the interaction of peers is shown to give rise to two competing forces, namely, having to compete against peers (such as faculty positions, funding, journal space, or simply the attention of the scientific community) puts a downward pressure on one's productivity whereas spillover of ideas increases productivity. Hence the sign of the net peer effect on productivity is determined by whichever of these two competing forces dominates the other.

We analyze the productivity effects of sudden and unexpected changes brought about by the fall of the Berlin Wall and the German re-unification on East German scientists who are active in fields of science, technology, engineering, and mathematics (STEM). The era from November 1989 until mid-1990s for East German scientists is best described by freedom of movement and communication as well as large scale institutional restructuring that brought new opportunities for collaboration but also job insecurity at the same time. A significant institutional re-structuring requires significant re-adjustment. Focusing on East German scientists who were active around this period, we investigate how East German scientists did adjust to western style academic structure, how this affected their productivity. Moreover, what impact was made by the sudden availability of potential peers and collaborators, not only as a result of East German scientists' freedom of movement and communication but also as a result of the large influx of West German scientists to East German universities and research institutes. East German scientists got the opportunity to freely collaborate

with Western scientists, that is, West Germans, West Europeans, and scientists from the US, after the fall of the Berlin Wall in November 1989 and more so at an institutional level after the German re-unification in October 1990. How did this affect the scientific productivity of East German scientists?

[Archambault et al. \(2017\)](#) analyze East and West German scientists' publication patterns from 1980 to 2000 and show a significant convergence (or rather catching up) of East German scientists with their West German peers. This is a significant achievement, especially considering [Kozak et al. \(2015\)](#) where members of the pre-1990 Eastern block, except for East Germany, are shown to have experienced no significant improvement compared to their productivity and impact levels under the communist regime. An important revival in the scientific productivity of most of the East European countries is shown be linked to interactions and collaborations with the European Union ([Jurajda et al., 2017](#)).

In addition, we investigate the cognitive mobility of East German scientists. Cognitive mobility is the switch of a researcher to a new subfield where they have not been active before. [Borjas and Doran \(2015a\)](#) show that US mathematicians who experienced a large influx of Soviet mathematicians into their specific research area in 1990s moved away from these areas to new research topics. Such mobility in the space of ideas can also be an optimal response by East German scientists to changes in the institutional setting after 1990. We document relations between East German scientists' expertise, qualities, collaborations, and their propensity to switch to a new subfield. Although East German scientists with a similar portfolio to West Germans are less likely to switch their field, those who lost a previous collaborator are more likely to do so.

Our contribution to the literature on scientific productivity is to open up the black box of East German convergence process and use this natural experiment to establish causal relations between collaboration, research portfolio, and productivity measured by the number of publications, citation accumulation, and the quality of journals where they publish. East German scientists show a significant convergence to their West German peers in all productivity accounts after re-unification. East German scientists with a high overlap to pre-1990 West German research portfolio publish in journals with high impact factors, but they do not diverge from their East German peers in terms of publication and citation counts. East Ger-

mans who collaborated with Soviet scientists on non-Western research fields during the 1980s are significantly more likely to re-wire their collaboration networks away from the (former) Soviet scientists and towards Western Europe and the US after 1990.

The remainder of this paper proceeds as follows. In Section 2, we describe the historical background of East and West German academic structures and the harmonization of the two German states' university systems post-Reunification. In Section 3, we describe the data, present descriptive findings on productivity differences of East and West German scientists, and we explain the identification strategy. We present our main analysis in Sections 4 and 5. In Section 4, we investigate East German scientists' productivity and collaborations, and in Section 5, we analyze their cognitive mobility between research fields. Section A focuses on a specific subset of East German scientists, namely those who hold a professorship in the East after 1990. Section 6 concludes.

2 Historical Context

Collaboration opportunities between East and West German scientists were very limited, which was primarily due to the political climate of the cold war. After the Berlin Wall was erected in 1961, East and West German scientists' collaborations came to a sudden halt (Sabel, 1993). East German scientists have been collaborating exclusively with scientists from their East European and Soviet allies from then on. An agreement that entered into force in 1975 made it *theoretically* possible for East German scientists to collaborate with West German scientists under extremely restricted conditions. The bilateral agreement of scientific and technological collaboration (*wissenschaftlich-technologische Zusammenarbeit - WTZ*) of September 1987 between East Germany and West Germany aimed at easing some of the extreme restrictions of the 1975 agreement and make interactions between East and West German scientists on major research projects more of a practical possibility (Wissenschaftsrat, 1990). According to Wissenschaftsrat (1990) the WTZ agreement has given rise to collaborations on about 60 projects between East and West German scientists until July 1990. Considering that the intra-German border opened in November 1989, it is plausible to

expect that a non-negligible share of the above mentioned 60 collaborations as of July 1990 contains interactions that are formed thereafter.

The WTZ agreement continued to provide the main guideline for collaborations between East and West German scientists until the official re-unification in October 1990 which brought about the heavy task of unifying academic systems of the two countries. This process caused great disruption in the scientific environment of East Germany as the process involved an enormous amount of reshaping and rescaling of East German science as well as a thorough re-evaluation of East German scientists.

The academic system in the post-war West Germany was based on that of the Weimar Republic before 1933 which was rooted in the *Humboldtian* ideal of the unity of higher education and academic research (Günther and Schmerbach, 2010). This structure was considered *essentially healthy*¹ and thus, apart from de-Nazification and infrastructural rebuilding, a return to the traditional federal education system was deemed appropriate where universities became the responsibility of *Bundesländer*, the German federal states. A science council that exists until today was formed in 1957, consisting of representatives from the federal states and the federal government. The following decades saw different dynamics of reconstruction, expansion, some reforms as a result of the 1970 student movement and, in the 1980s, rising student numbers and stagnant numbers of academic personnel (Kehm, 1999).

In contrast to West Germany's federally structured and *Humboldtian* academic system, the post-war East Germany replaced the traditional institutional autonomy of higher education with a central education system run by the state secretary office and introduced Marxism-Leninism as a mandatory part of every higher education curriculum in 1960s (Kehm, 1999). East Germany followed the Soviet system to introduce a clear separation between higher education and research. Universities were primarily oriented towards training of students to accommodate the needs of the East German centralized economy. For this aim, the industry and universities worked closely together, the size of university programs was adapted to economic needs and alumni were centrally placed into the job market. The institutes

¹The phrase *essentially healthy* is our own translation of *im Kern gesund*, a phrase coined by the Prussian minister of education Carl Heinrich Becker with respect to the university system after the First World War and widely re-used, e.g. by Kehm (1999), in describing the university system after the Second World War in West Germany.

of the *Academy of Sciences -Akademie der Wissenschaften (AdW)* were mainly responsible for research and development, including the administration of doctorate and *habilitation* processes and even (although not exclusively) the appointment of professors (Kocka, 1994, Wissenschaftsrat, 1990).

The re-unification process started with travel freedom between East and West Germany in November 1989 and East Germany officially ceased to exist in October 1990. The first years of the re-unified Germany witnessed a great deal of academic restructuring in the former East Germany. After the re-unification in October 1990, the structure of West German university system was largely applied to East German universities. The division of subjects and disciplines of East German universities was adapted to West German standards and there was a substantial reform in the personnel structure. All university personnel and personnel of research institutes within the *AdW* were reviewed and evaluated politically as well as scientifically (Kocka, 1994, Sabel, 1993). If the outcome of staff reviews were negative, as was the case in most subjects that were politically involved, the academic in question was dismissed. It is possible that the outcomes of political and scientific reviews were somewhat linked, since some of the ruling party (SED) members were appointed for their political loyalty instead of relevant qualifications. This link could also give a possible explanation as to why the share of SED members was 63% among the university staff and only 13% among East German total population (Schattenfroh, 1993). It must also be noted that East German scientists were held up to very different standards before the re-unification where competition and mobility was discouraged, publication opportunities in Western journals were either restricted or even not possible at all as was in case of social sciences (Günther and Schmerbach, 2010), meaning that a politically positive evaluated scientist might fail the scientific review simply because the measure of good quality is now much different than what it used to be just a couple of years ago.

The academic staff in social science departments, who were evaluated positively, often had difficulties to adapt to the substantial changes in their disciplines and to the orientation towards the Western academic paradigm. While adjustment in relatively ideology-neutral subjects like natural sciences and engineering was not as difficult, East German academics in these subjects had different problems since many of them had been unable to publish

their work in Western journals and follow academic discourse outside of the Eastern block in the past. Especially older members of the academic staff therefore often could not adapt to the expected volume of publications and thus were left behind in international academic discourse (Günther and Schmerbach, 2010). In case of a positive outcome of the above mentioned evaluation, the academic could apply to open tenders for their old or similar positions. However, a significant downsizing of the former East German academia was taking place at the same time (Kocka, 1994) and a positive evaluation was necessary but by no means sufficient to secure an academic position. As it was common to see an abrupt end to one's academic career after a lengthy and even positive evaluation, some academic staff especially those who constitute the middle section (ranked higher than graduate students/assistants and lower than professors, *Mittelbau* in German) left the academia to take up jobs in the industry (Günther and Schmerbach, 2010). Despite the downsizing of East German universities, this struggle opened up vacancies even in natural sciences and engineering departments to be filled by West German scientists. Many West German scientists were able to obtain academic positions in the former East German universities and in re-structured or newly established research institutes during 1990-1995, which are the years of most intense re-structuring in East German academia according to Burkhardt (1997) as the initial evaluation of East German professorships was completed by 1995.

3 Data and Descriptive Findings on Scientific Output, Mobility, and Professorship

We obtain publication records of West German and East German scientists who publish in biology, physics, chemistry, mathematics, engineering, or medical sciences between 1979 and 2006 from Thomson Reuter's Web of Science (WoS). As scientists' nationalities are not recorded, we make use of affiliations to classify a scientist as an East or West German scientist. We take a scientist's main affiliation to be the one which is their most used affiliation within a given time period. Scientists whose main affiliation is located in East Germany during 1979-1989 count as East German, those with a West German main affiliation during the same period count as West German. We construct East and West German scientists' research

Table 1: East German and West German scientists’ mobility after 1990

	<i>Total</i>	After 1995 in Germany		Abroad
		East States	West States	
<i>Active before 1990 in</i>				
East Germany	<i>1,136</i>	842	209	85
West Germany	<i>8,771</i>	458	7,027	1,286

portfolio from 1979 to 2006. We restrict our data to those who have at least two publications between 1979 and 1989 as well as between 1996 and 2006. Our dataset contains a total of 751,641 peer-reviewed publications by 8,771 West German and 1,136 East German scientists.

We observe the mobility of scientists based on changes in their affiliations, however not every change in the affiliation is an official move. A scientist may be visiting another institute without giving up their initial position at their home institute and yet publish using the affiliation of the host institute. When a scientist’s main affiliation changes, we take it that this scientist has moved, which is in line with the methodology proposed by [Robinson-Garcia et al. \(2019\)](#). Based on changes in scientists’ main affiliations after 1990, we tabulate their movement in Table 1. After 1995, there are 842 of 1,136 East German scientists who remained in the region of former East Germany, 209 moved to the former West Germany, 85 moved abroad.

Figure 1 depicts productivity and impact trends of East and West German scientists from 1979 to 2006 who remained within the territory of the former East and West Germany, respectively, after the re-unification. The upper left panel depicts the annual average number of publications, the upper right panel shows normalized citations, the lower left panel shows normalized and annually variable impact factors of journals where their work got published in that year.

East German scientists produced less publications and received less citations per publication compared to their West German peers throughout 1980s. In 1980s, West German scientists published about three papers and East Germans about two papers per year. We observe a catch-up process in 1990s. After 1995, the annual average increases to four papers for West Germans and to three papers for East Germans. East German scientists have been catching up with their West German peers also in terms of citations and journal quality

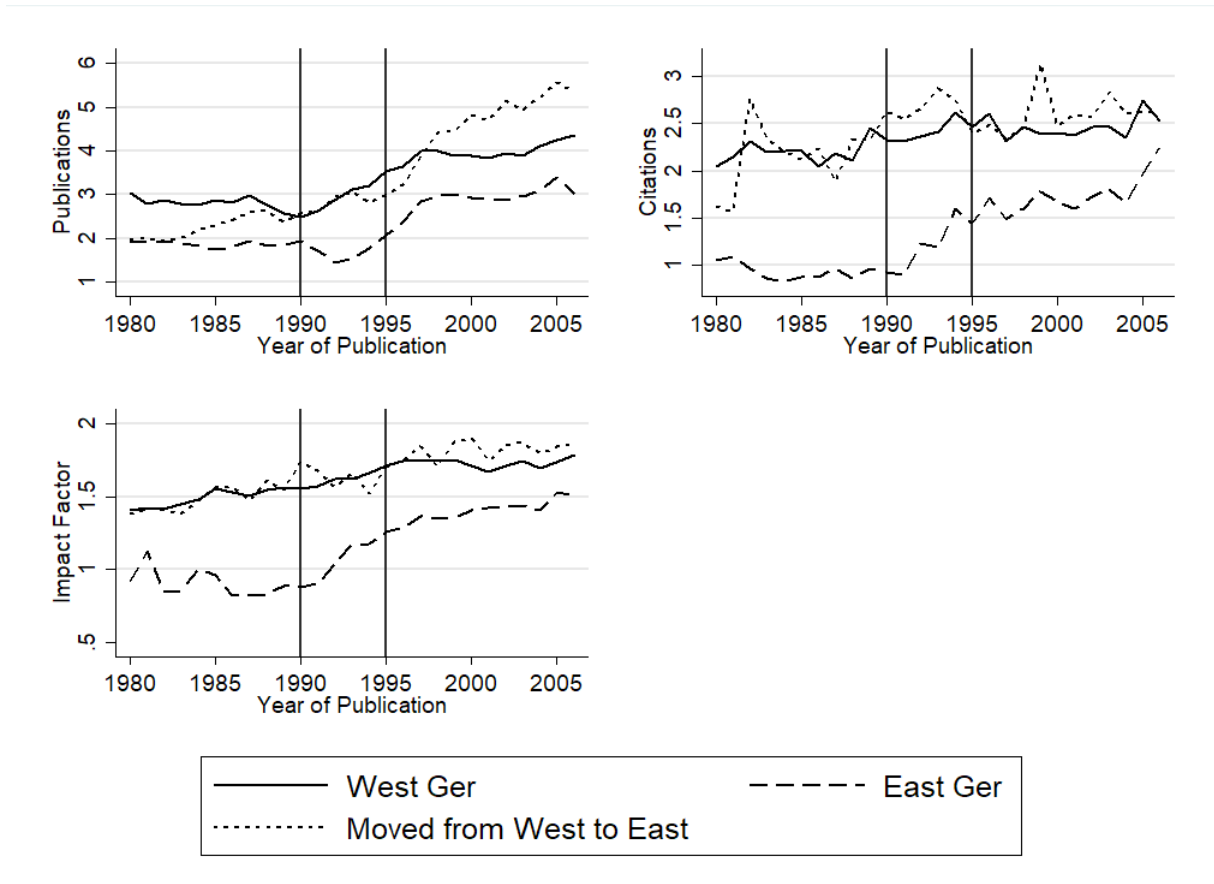


Figure 1: Productivity of stayers in West and East Germany compared to movers from West to East Germany (In-migrants)

(impact factor) after 1990. East Germans' average citation count increases from below one to above 1.5 from mid 1990s on and to 2 by 2004 whereas West Germans' citations remain within 2 to 2.5 for the whole period. This indicates an increase in the impact of East German science during this period as it starts to receive significantly more citations than it did before. Another important catch-up process is witnessed in the average impact factors of journals where East Germans publish. East Germans catching up with West Germans in terms of impact factor means that East Germans are publishing in better ranked journals starting from early 1990s on. This indicates a change in the publication culture of East Germans rather than a strict improvement in quality.

The dashed line in Figure 1 depicts the productivity of those West German scientists who moved to a former East German institution during 1990-1995. In terms of publications, they lack behind the West German average in 1980s. A possible explanation is that those

migrating from West to East Germany are younger than their West German peers. We do not have data about the actual age of scientists, but we confirm that the first publication of migrant scientists appears on average later than their non-migrating peers. The publication productivity of West-to-East migrating scientists soon catches up and surpasses their West German peers. In terms of citations and impact factors, migrating West Germans are indistinguishable from the other West Germans in 1980s and they look even better in these accounts in 1990s and thereafter.

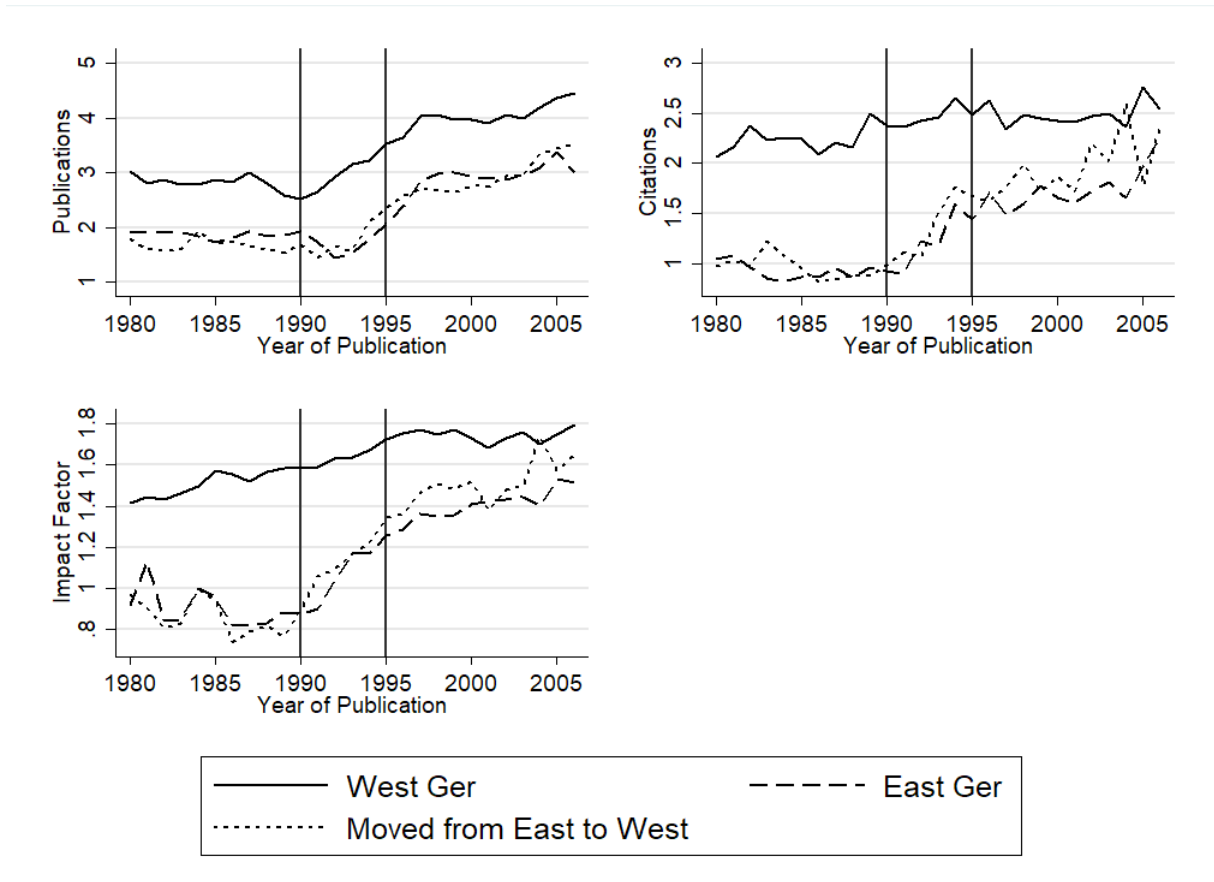


Figure 2: Productivity of stayers in West and East Germany compared to movers from East to West Germany (Out-migrants)

Figure 2 depicts the same East and West German stayers as in Figure 1 but the dashed line depicts those East Germans who migrated to former West Germany during 1990-1995. As shown in Table 1, about 18% of East German scientists who were active throughout 1980s moved to the West German territory during 1990-1995 and continued their scientific

activity there.² In terms of the annual number of publications, the East-to-West migrants are very similar to their non-migrating East German peers in 1980s and they remain so after 1990 as well. In terms of citations and journal quality, migrating and non-migrating East German scientists are fairly comparable in 1980s, but emigrating East Germans' annual average citations and journal quality are consistently above non-migrating East Germans from mid 1990s onwards. Hence both figures 1 and 2 reveal that migrants in either direction were fairly representative of their own group in terms of publication productivity and impact before re-unification. It is worth mentioning that both migrant groups perform consistently better than their initial peer groups after mid-1990s.

Publication data do not show scientists' academic rank which can be a useful dimension in the analysis of scientific productivity. For instance, professorship comes with job security and may lead to differences in research attitudes. We collect information on newly hired or re-hired (as a result of evaluations explained in the previous section) professors in sixteen East German universities³ between 1990 and 1995 using universities' online resources and records of the German National Library. A significant portion of academic re-structuring including the evaluation and either re-hiring or replacing of former East German professors was concluded mainly by 1995 (Burkhardt, 1997). Although professors make up a small share in our data, they provide useful insight into the academic re-unification process. In Table 2, we document the share of West German and East German scientists who were appointed as professors in natural sciences, engineering, and social sciences in the above mentioned sixteen East German universities between 1990 and 1995. Professors with a West German doctoral degree make up about half of all hired professors in East German universities in natural sciences and engineering, whereas this ratio is 86% in social sciences. We suspect that the observed displacement of East German professorships in social sciences may have also been reflected in other academic ranks so that a meaningful analysis of East German

²The actual amount of movement is larger than what we observe in our data. Many East German scientists with an academic post in 1980s chose to move to the West to take industry jobs shortly after re-unification and did not wait for the result of their re-evaluation of their initial academic post. Our data contain only those migrants who take up positions where they are expected to publish research, as they are the ones relevant for the aim of this paper.

³BTU Cottbus-Senftenberg, Bauhaus U Weimar, Europa U Frankfurt, U Jena, Humboldt U, U Halle-Wittenberg, U Magdeburg, TU Bergakademie Freiberg, TU Chemnitz, TU Dresden, TU Ilmenau, U Erfurt, U Greifswald, U Leipzig, U Potsdam, and U Rostock

Table 2: Hiring of professors in East German universities 1990-1995

	Hired Professors		Percentage of West Ger hires
	Total	from West Ger	
<i>Natural Sci. & Eng.</i>	<i>351</i>	<i>175</i>	<i>49.9%</i>
Biological Sciences	32	23	71.9%
Physics	74	46	62.2%
Computer Sciences	39	23	59%
Mechanical Eng.	44	22	50%
Civil Engineering	19	9	47.4%
Chemistry	53	21	39.6%
Biochemistry	8	3	37.5%
Mathematics	69	25	36.2%
Electronics	13	3	23.1%
<i>Social Sciences</i>	<i>236</i>	<i>203</i>	<i>86%</i>
Political Sci.	22	22	100%
Philosophy	17	17	100%
Economics	51	47	92.2%
Sociology	30	25	83.3%
History	52	43	82.7%
Management	39	30	76.9%
Psychology	25	19	76%

social scientists' post re-unification productivity levels becomes a very challenging task as the exit rate of East German social scientists is very large. Hence our analysis in this paper is focused on scientists in natural sciences and engineering.

While professors who obtained their PhD in East Germany began their tenure at the universities on average 17.8 years after obtaining their PhDs, the average time span for professors who obtained their PhD in the former West Germany was at only 14.7 years. This difference reinforces the theory that primarily inexperienced West German professors were hired at the East German universities. However, it could also be caused by the fact that those East German professors hired in the post-reunification period were usually the ones deemed ideologically untainted and perhaps were stuck as non-professorial staff for a longer time in East Germany as result of their ideological insubordination.

3.1 Identification and East German Activity in West German Fields

Since there was no or very little academic interaction between East and West Germany during the cold war, the two countries' scientific communities developed their research agenda and expertise in different areas. A research topic that was deemed important in the West German science and got a lot of attention by West German scientists may have been considered the same way by East German scientists only to the extent that this topic has a great intrinsic importance or coincides with industrial ambitions of the centrally planned East German economy. Other than that, it is reasonable to assume that East German academics had no incentive to treat any given research area with the same enthusiasm as their West German peers. East German scientists could not have imagined collaborating freely with West German, West European or American peers before the end of 1980s except under very extraordinary circumstances, and they could not have developed a career with an explicit aim to cope with the academic standards of West German universities, because East German academics were held up to very different standards before the re-unification as explained in Section 2. This provides a useful identification to isolate the causal effects of East German scientists' complementarities with West German research prior to re-unification on their post 1990 productivity and formation of collaborations.

In Table 3 we document the share of top specialized fields (*specialization* in the WoS database) in all publications of West German and East German scientists between 1979 and 1989. Although *general chemistry* and *biochemistry and molecular biology* are ranked very high in both sides' research activity, there is little overlap in the ranking of most of the fields listed in Table 3, for instance nearly 5% of West German publications is on *cardiovascular system* yet this field is not among the top fields in East German publications. *Veterinary medicine* receives a lot of attention in the East German science but this field has no comparable share in the West.

When political obstacles that prevent interactions with the West are lifted, a reasonable expectation is that those East German scientists whose research overlaps with dominant fields of the West German research may find themselves endowed with better chances to adopt to Western style research, enjoy higher levels of productivity due to access to more relevant resources as well as peers, and hence gain significant ground in their newly re-structured

Table 3: Most popular research fields in West and East Germany 1979-1989

Field (within main discipline)	Share of field in all publications
<i>West German scientists</i>	
Biochemistry & Molecular Biology (Biomedical Research)	7.8%
General & Internal Medicine (Clinical Medicine)	5.13%
General Chemistry (Chemistry)	5.1%
General Physics (Physics)	4.9%
Cardiovascular System (Clinical Medicine)	4.7%
Nuclear & Particle Physics (Physics)	4.6%
Immunology (Clinical Medicine)	3.11%
Neurology & Neurosurgery (Clinical Medicine)	3.05%
Gastroenterology (Clinical Medicine)	2.7%
<i>East German scientists</i>	
General Chemistry (Chemistry)	12.2%
Physical Chemistry (Chemistry)	8.5%
Biochemistry & Molecular Biology (Biomedical Research)	8.3%
Veterinary Medicine (Clinical Medicine)	3.7%
Applied Physics (Physics)	3.6%
General & Internal Medicine (Clinical Medicine)	3.5%
Solid State Physics (Physics)	3.22%
Endocrinology (Clinical Medicine)	3.19%
Pharmacy (Clinical Medicine)	3.16%
General Physics (Physics)	3.1%
Inorganic & Nuclear Chemistry (Chemistry)	2.9%
Dairy & Animal Science (Biology)	2.7%

academic environment overall. The unpredictability of the fall of the Berlin Wall, lifting of the iron curtain, and the re-unification of Germany support our claim that an East German scientist would have no reason or motivation to developed a research portfolio in 1980s with the hope of having job security in the Western academic world in the next decade, or surviving an overtake of East German academia by West German structures for that matter. The overlap of an East German scientist’s research portfolio to West German science of 1980s is the main identification that we employ in our analysis.

We measure the overlap between an East German scientist’s portfolio and the West German scientific agenda of 1980s using three indices that have been well established in the literature. The correlation coefficient of fields’ shares in research portfolios is a textbook measure of overlap (for instance in Newman (2010)) and was also employed in the analysis of Borjas and Doran (2012). The *correlation coefficient* between field shares of publications of any scientist s and West German scientists is defined by

$$C_s = \frac{\sum a_{sf} w_f}{\sum a_{sf}^2 \sum w_f^2} \quad (1)$$

where a_{sf} is the share of field f in publications of scientist s between 1979 and 1989; w_f is the share of field f in West Germans’ publications between 1979 and 1989. This measure takes values from zero to one and a greater overlap between fields of activity yields a larger correlation coefficient.

The *intensity* is an alternative useful index of research overlap which was also used in the analysis of Borjas and Doran (2012) and calculated by

$$I_s = \frac{\sum a_{sf} W_f}{\max W_f} \quad (2)$$

where a_{sf} is defined the same as above, W_f is West German scientists’ total number of publications in field f between 1979 and 1989. If a scientist s published only in fields where there has been no West German publications at all, then the intensity of her portfolio is zero. If s published in that field where West German scientists published most, then the intensity is one.

The index of *similarity* is another measure of research overlap between a scientist s and the overall West German research that has previously been used by Cutler and Glaeser (1997) and Borjas and Doran (2012). Similarity is based on the vector distance of portfolios and it is defined by

$$D_s = 1 - \frac{1}{2} \sum |a_{sf} - w_f| \quad (3)$$

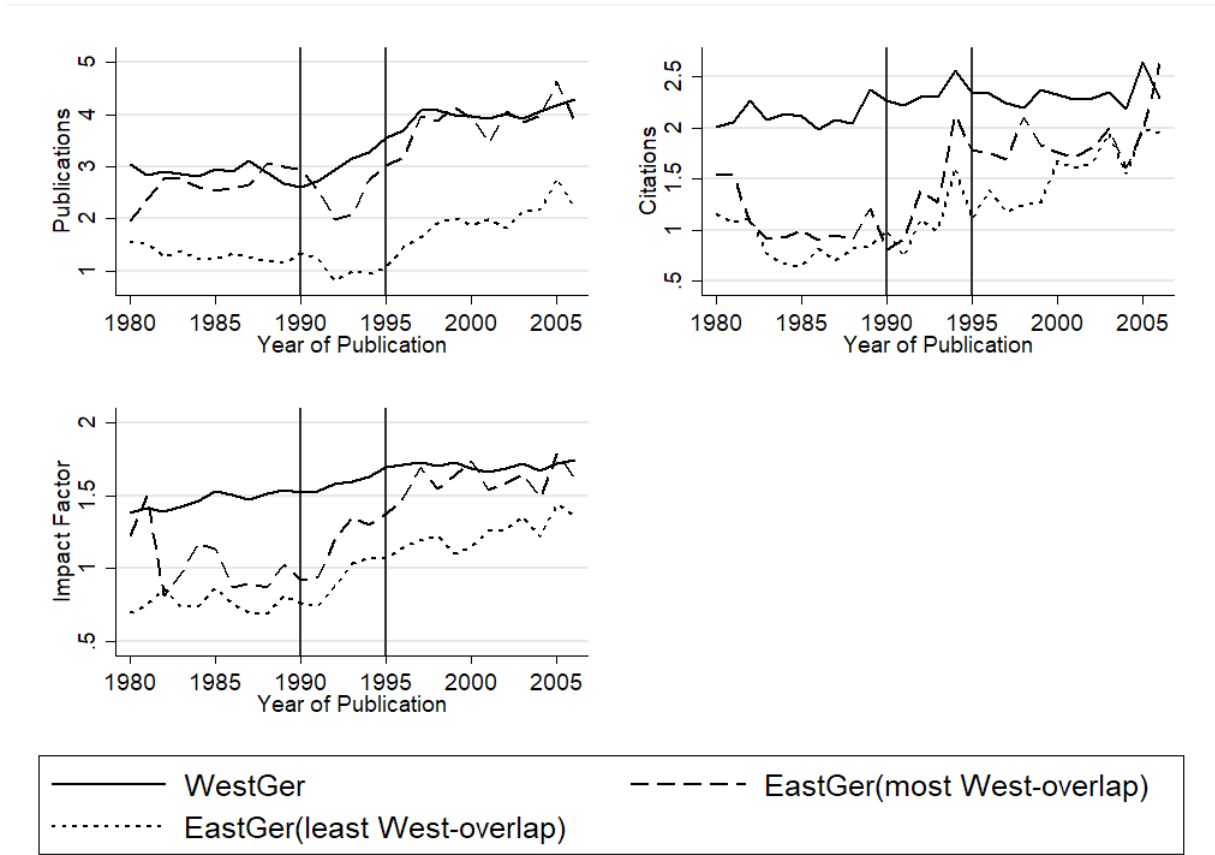


Figure 3: Productivity of East German scientists and the overlap of their research with the pre-1990 West German research

In Figure 3, we divide East German scientists into two groups based on how much their research portfolios overlap with the pre-1990 West German research. Those in the top quartile of the correlation coefficient are labeled as the *most West-overlap*, and those in the bottom quartile are labeled as the *least West-overlap*. The most West-overlapping East German scientists publish more than their least West-overlapping peers and are fairly comparable to West German scientists in this regard, especially after 1995. In terms of citations and impact factor, the gap between the most and the least West-overlapping East Germans is

less obvious before 1990, however the most West-overlapping ones have the upper hand. The gap widens in favor of the most West-overlapping group after 1995, especially when impact factors of their outlets are considered. This indicates that East German scientists whose research overlaps largely with West German research find their way into high impact Western journals relatively easier than their peers after the structural overhaul of the East German academia.

4 Productivity and Collaborations of East German Scientists

We start by exploring how scientific productivity differences among East German scientists have evolved after the re-unification. Scientific output is measured in three different ways: number of publications, count of field-normalized citations, and annually variable field-normalized journal impact factor. We regress the scientific output of scientist s in year t on standard controls, quartic life cycle controls, and their overlap with the West German research during 1979-1989. Years from 1990 to 1994 are left out of the analysis because these were years of stark transition. We estimate

$$Output_{st} = \beta X_{st} + \alpha(Post1990 \times Overlap_s) + \phi_s + \phi_t + \epsilon_{st} \quad (4)$$

where ϕ_s and ϕ_t are individual and year fixed effects, respectively, and α is the coefficient of main interest. Any statistically significant difference in the post re-unification scientific output of East German scientists who have a larger overlap with the pre re-unification West German research compared to their East German peers will reveal itself as a significant and positive point estimate of α . A non significant α would mean that there is no significant change in how East Germans with more West-overlapping and less West-overlapping research differ before and after the re-unification. It is important to emphasize that this analysis does not pay attention to the absolute productivity so that both groups' productivity may be increasing or decreasing together.

The first three columns of Table 4 lists coefficient estimates for α . Panels A, B, and C of Table 4 are based on three alternative measures for the overlap in research topics, as explained in Section 3.1. Those East German scientists whose research topics overlap more with West Germans’ topics publish less than their other East German peers. Their papers, however, are published in journals that have higher impact factors. Individually clustered standard errors are smaller than the point estimates of the post re-unification productivity difference of more West-overlapping and less West-overlapping East Germans, which yields statistically significant differences in two of three overlap definitions in Table 4. When citations are used for capturing productivity, we obtain negative point estimates for the research overlap, but these estimates come with large standard errors no matter which definition of research overlap is used.

Next, we explore if and how the scientific output of East German scientists is catching up with that of the West Germans after the re-unification by pooling East and West German scientists’ output to estimate the following specification

$$\begin{aligned} Output_{st} = & \beta X_{st} + \alpha(Post1990 \times Overlap_s) + \gamma(Post1990 \times East_s) \\ & + \theta(Post1990 \times East_s \times Overlap_s) + \phi_s + \phi_t + \epsilon_{st} \quad (5) \end{aligned}$$

where $Overlap_s$ applies to all scientists in this sample. A West German scientist’s research overlap with West German research areas measures whether and to what extent this person has been active in a West Germany-dominated field during 1979-1989. The point estimate of γ shows whether the descriptively illustrated productivity trends of East and West German scientists in Figure 1 are statistically significantly converging or diverging when controlled for research quality, common time trends, and individual effects. A positive and significant θ would reveal possible source of the descriptively observed catch-up between East and West German scientists and this coefficient is reported in the last three columns of Table 4.

The last three columns of Table 4 are based on pooled regression results using East and West Germans and the point estimates of α , γ , and θ in equation 5 are listet for three different productivity measures in each column and three different calculations of research overlap in panels A, B, and C. When the research overlap is calculated using the correlation coefficient or

Table 4: Differences in the productivity of East and West German scientists after 1990

	East Germans only			East and West Germans		
	Papers	Cites	IF	Papers	Cites	IF
<i>Panel A: Overlap based on corr. coef.</i>						
Post1990*Overlap	-0.296 ^b	-0.0290	0.427 ^b	-0.439 ^a	-0.192 ^a	-0.335 ^a
	[0.134]	[0.109]	[0.177]	[0.0504]	[0.0444]	[0.0473]
Post1990*East				0.121 ^a	0.171 ^a	0.259 ^a
				[0.0333]	[0.0290]	[0.0442]
Post1990*Overlap*East				0.127	0.183	0.702 ^a
				[0.140]	[0.124]	[0.177]
<i>Panel B: Overlap based on intensity</i>						
Post1990*Overlap	-0.0903	-0.0154	0.344 ^a	-0.211 ^a	-0.0902 ^a	-0.163 ^a
	[0.0854]	[0.0663]	[0.120]	[0.0321]	[0.0301]	[0.0315]
Post1990*East				0.119 ^a	0.186 ^a	0.259 ^a
				[0.0335]	[0.0287]	[0.0450]
Post1990*Overlap*East				0.106	0.0806	0.479 ^a
				[0.0897]	[0.0761]	[0.122]
<i>Panel C: Overlap based on similarity</i>						
Post1990*Overlap	-2.535 ^a	-0.260	1.259	-3.273 ^a	-0.636 ^a	-1.272 ^a
	[0.794]	[0.671]	[0.915]	[0.274]	[0.228]	[0.237]
Post1990*East				-0.259	-0.125	-0.735
				[0.429]	[0.390]	[0.474]
Post1990*Overlap*East				0.728	0.621	2.122 ^b
				[0.807]	[0.734]	[0.879]
<i>Observations</i>	14793	10780	10761	136500	107871	107714

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Restricted to East and West Germans who did not leave their pre-1990 territory.

All regressions include age and quality controls, individual and year FE.

the intensity measure, we find that East German scientists catch up with their West German peers significantly in all three productivity accounts. When the overlap is based on the similarity definition (panel C), however, we do not find a statistically significant difference in difference between East and West German scientists after the re-unification. Point estimates of θ are positive for all three productivity measures and in all three panels. Clustered standard errors are smaller than estimates of θ in most cases, and statistical significance based on p-value is obtained only for the journal quality in all three panels. Hence East Germans whose research overlaps with the top West German topics of pre re-unification era are publishing their research in journals with higher impact factors compared to their East German peers after the re-unification.

Negative point estimates of α in the East and West German pooled regressions in Table 4 (last three columns) reveal that West Germans who have been active in top West German fields experience a decline in their relative productivity after the re-unification. This may be due to several reasons, for instance, large fields of 1980s may have produced a lot of researchers in West German universities and research institutions that had not been able to produce as much and quality research after their junior career anymore; top research fields of pre re-unification era may have been saturated in personnel and research output so that they experience strong decline in marginal productivity; or the changing academic culture pushes researchers in all research fields for more publications so that smaller fields catch up with larger fields in productivity. It is plausible to ask whether there are any field specific or field and year specific trends that affect the above mentioned finding. Specific fields may have been subject to different trends over some particular years as they may have been subject to different academic labor market shocks or treated differently as a result of specific science and innovation policies of Germany after the re-unification. Following the analysis of arbitrary field specific trends in [Borjas and Doran \(2012\)](#), we include field fixed effects as well as field and year interactions in our pooled estimation and hence the initial estimation equation 5 becomes

$$\begin{aligned}
 Output_{st} = & \beta X_{st} + \alpha(Post1990 \times Overlap_s) + \gamma(Post1990 \times East_s) \\
 & + \theta(Post1990 \times East_s \times Overlap_s) + \phi_s + \phi_t + \phi_f + \phi_{tf} + \epsilon_{st} \quad (6)
 \end{aligned}$$

where ϕ_f are field fixed effects, ϕ_{tf} are field-year fixed effects. We rearrange our sample so that each observation is at scientist-year-field level. Coefficient estimates are shown in Table B.1 in the Appendix. Results are qualitatively comparable to East and West German scientists' pooled estimation results shown in Table 4, hence field and year specific interactions do not play a major role in the observed difference in differences after the re-unification.

4.1 Collaborations

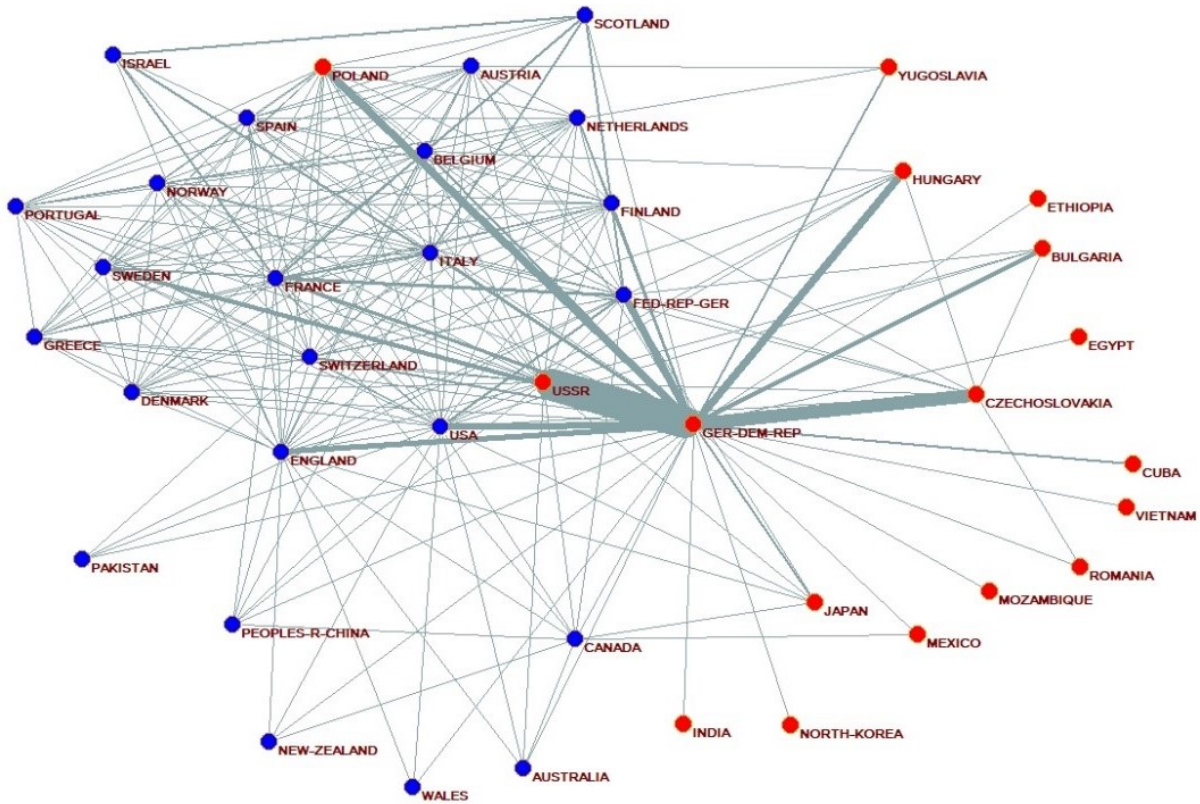


Figure 4: Collaboration networks of East German scientists 1979-1989 (More frequent collaborations are shown by thicker links; collaborating countries are found to form two communities marked blue and red by applying the Louvain partitioning method)

Figure 4 shows international collaborations of East German scientists between 1979 and 1989. Each link represents at least one collaboration of an East German scientist with sci-

tists from the respective country that led to publication of an article. The more the number of collaborations the thicker are links. The Soviet Union stands out as the most heavily collaborated partner during 1979-1989. Connections between countries other than East Germany in Figure 4 show that East German scientists collaborated with a team of scientists from those countries in the same publication. A tightly connected subnetwork of West European countries is observed in Figure 4, which indicates that East German scientists' collaborations with any West European country mostly involved international teams of scientists from several West European countries. Collaborations with East European countries do not seem to create such a clique, most likely because such collaboration could be formed at will whereas collaborations with West Europeans required more formalities and could be justified only if East German scientists are part of large international projects.

Using a simple community detection method such as the Louvain partitioning, we identify two communities that can be separated to maximize the modularity of the network shown in Figure 4. Red and blue nodes belong to these two separate communities. It is important to note that these two communities may or may not be statistically significantly different subnetworks, as the aim of the community detection is simply to maximize the modularity of the collaboration network. For instance, USA, England, and West Germany are among *blue* countries whereas USSR, Hungary, Poland, and Cuba are among *red* countries in Figure 4. Some of these countries may end up in the other camp if we were to re-wire this network at random while preserving linking probabilities. Nevertheless, even using a very simple community detection algorithm, the international collaboration network of East German scientists reveals an interesting division that lines up with the political background of the 1980s.

Figure 5 captures East German scientists' international collaboration network between 1996 and 2006. As collaborations become increasingly important, we observe a larger and denser collaboration network this time. Similar to Figure 4, we observe a densely webbed collaboration structure among most European countries, however the divide between East and West European countries is not as clear during 1996-2006 as 1979-1989. Using Louvain partitioning, we detect again two communities that maximize the modularity, identified by blue and red nodes. There is, however, no obvious and easy explanation for this division

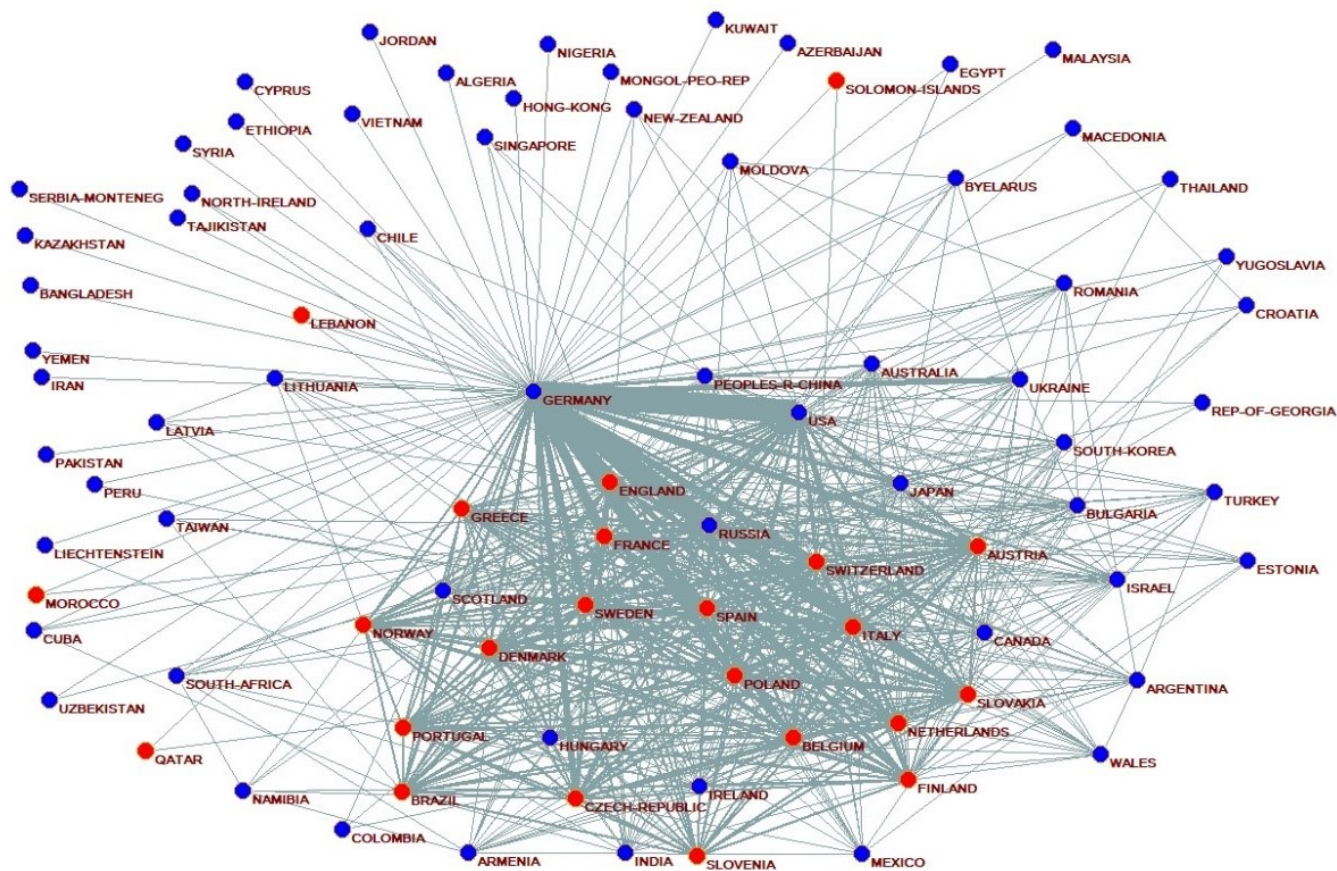


Figure 5: Collaboration networks of East German scientists 1996-2006 (*Germany* in this figure refers to East German scientists who remained in the former East German territory after reunification. More frequent collaborations are shown by thicker links; collaborating countries are found to form two communities marked blue and red by applying the Louvain partitioning method)

except for technical reasons. Poland is in the same community as England and France, whereas East German scientists are now put into the same community as the USA. The aim of this brief and descriptive documentation is to draw attention to overall patterns and macro-level traits of East German scientists' international collaborations during 1979-1989 and 1996-2006.

In order to analyze East German scientists' micro-level collaborations, who remained in the former East German territory after the re-unification, we employ a linear probability model of collaboration with West Germans who remained in the former West Germany

territory, West Germans who migrated from the former West to the former East Germany after re-unification (denoted *Inmigrants*), East Germans who migrated from the former East to the former West Germany after re-unification (denoted *Outmigrants*), West European, US, and Soviet scientists. We estimate

$$E(Collab_{st} | Publication_{st} > 0) = \beta^c X_{st} + \alpha^c (Post1990 \times Overlap_s) + \phi_s^c + \phi_t^c + \epsilon_{st}^c \quad (7)$$

where $Collab_{st}^j$ is one if the scientist s has co-authored with another scientist belonging to a specific group j in year t , and zero otherwise. Groups of co-authors that we are particularly interested in are as follows: A co-author can be a West German who remained in the former West Germany territory, West German who migrated from the former West to the former East Germany after re-unification (denoted *Inmigrants*), an East German who migrated from the former East to the former West Germany after re-unification (denoted *Outmigrants*), a West European, a US, or a Soviet⁴ scientist. We use a linear probability model to estimate how likely it is that an East German scientist s collaborates with a scientist from the above mentioned groups in year t , given that s has published at least one paper in that year.

In the first five columns of Table 5, we focus on the collaboration patterns of East German scientists. This analysis documents a significant change in collaboration patterns of East German scientists. East German scientists who stayed in former East Germany and whose research overlaps with West German research portfolio switch to increased collaborations with West Germans and divert from their collaborations with the former Soviet scientists. They are more likely to engage in collaborations with West German scientists after 1990 whether these West Germans are located in the former West Germany or moved to the former East German territory to take up academic positions there. There is, however, no statistically significant difference regarding establishing connections to West European or US scientists between East Germans that have a large overlap with West German research and those who do not. East Germans with large research overlap with West Germans tend to collaborate significantly less with outmigrating East Germans compared to other East Germans. All

⁴All countries that were once within the USSR prior to 1990 and became independent thereafter are considered to be the former USSR for purposes of this analysis.

Table 5: Differences in collaborations of East German scientists after 1990

	West Ger	Inmig.	Outmig.	West/US	USSR	East/West Ger with West/US	USSR
<i>Panel A: Overlap based on Corr. Coef.</i>							
Post1990*Overlap	0.166 ^a [0.0566]	0.127 ^a [0.0479]	-0.153 ^a [0.0496]	-0.0487 [0.0832]	-0.133 ^c [0.0704]	-0.0460 [0.0285]	0.135 ^a [0.0196]
Post1990*East						0.0613 ^a [0.0199]	0.0274 ^c [0.0160]
Post1990*Overlap*East						0.0239 [0.0879]	-0.256 ^a [0.0722]
<i>Panel B: Overlap based on Intensity</i>							
Post1990*Overlap	0.0744 ^b [0.0364]	0.0928 ^a [0.0345]	-0.0981 ^a [0.0365]	-0.00676 [0.0532]	-0.0671 [0.0435]	-0.0224 [0.0191]	0.116 ^a [0.0139]
Post1990*East						0.0572 ^a [0.0198]	0.0278 ^c [0.0158]
Post1990*Overlap*East						0.0304 [0.0567]	-0.174 ^a [0.0459]
<i>Panel C: Overlap based on Similarity</i>							
Post1990*Overlap	0.936 ^a [0.331]	0.748 ^a [0.275]	-0.736 ^a [0.278]	-0.228 [0.455]	-0.770 ^b [0.385]	-0.297 ^b [0.147]	0.155 [0.0982]
Post1990*East						-0.0711 [0.255]	0.461 ^b [0.200]
Post1990*Overlap*East						0.253 [0.479]	-0.911 ^b [0.377]
<i>Observations</i>	10780	10780	10780	10780	10780	107871	107871

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Restricted to East Germans who did not leave their pre-1990 territory.

All regressions include age and quality controls, individual and year FE.

three measures of research overlap (correlation coefficient, intensity, and similarity) yield qualitatively very similar results.

Next, we estimate

$$E(Collab_{st} | Publication_{st} > 0) = \beta^c X_{st} + \alpha^c (Post1990 \times Overlap_s) + \gamma^c (Post1990 \times East_s) + \theta^c (Post1990 \times East_s \times Overlap_s) + \phi_s^c + \phi_t^c + \epsilon_{st}^c \quad (8)$$

by pooling West and East German scientists together. In the last two columns of Table 5 we show that the likelihood of East Germans to collaborate with West European or US scientists as well as with the former Soviet scientists is significantly larger than their West German peers. East Germans whose research largely overlaps with West German research are significantly less likely to collaborate with former Soviet scientists after re-unification. When it comes to collaborating with Western European or US scientists, however, there is no significant difference in difference between East and West German scientists working in predominantly West German fields. Interestingly, East Germans who have a large overlap with West German research are losing their connections to former Soviet scientists so that the difference in difference between them and their West German peers with a comparable portfolio turns out significant and negative after re-unification. This can be explained by the freedom to establish connections to parts of the world that used to be out of reach to either side of Germany prior to 1990. The connection of West Germans to Soviet researchers much faster than East Germans is thus plausible. The same effect is, however, not found as a mirror image between East German scientists and West European and American scientists.

4.2 Emigrating Collaborators and former Soviet Collaborations

In this subsection, we focus on two particular subsets of East German scientists, namely those who have seen some of their pre 1990 collaborators emigrate after re-unification, and those who collaborated with Soviet scientists before 1990. There are some East German scientists who emigrated elsewhere after the German re-unification, may it be former West Germany, Western Europe, or anywhere else in the world. Although there are official barriers to prevent them from collaborating with their former East German peers, such a collaboration might

Table 6: East German scientists who remained in East Germany after re-unification and who collaborated with emigrant or Soviet scientists during 1979-1989

	At least one Soviet collab.	No Soviet collab.	Total
At least one emigrant collab.	70 (24)*	96	166
No emigrant collaborator	115	561	676
Total	185	657	

*24 East German scientists have an emigrant East German scientist in their collaboration with Soviets.

have become difficult due to practical reasons or emigrant East German scientists might be more interested to collaborate locally within their new environment. Either way, many East German scientists who chose to remain in former East Germany after the re-unification may have lost their connections to those collaborators who chose to emigrate. Losing connection to a co-author is a significant challenge for scientists as collaborations significantly affect scientists' productivity (Azoulay et al., 2019, Ductor et al., 2014).

Another interesting subset of East German scientists are those who have been collaborating with Soviet scientists before the re-unification. Although collaborations with Soviet scientists were not restricted like collaborations with scientists from the West back then, an international collaboration is always costly and its benefits must justify its costs, meaning that collaborations with Soviet scientists may be taken as a signal of rather high quality (if not frontier) research and involved scientists may well be expected to be rather good (if not outstanding) scientists. Hence one may expect to find positive selection of East German scientists when their collaborations with Soviet scientists are considered.

Figure 6 shows citations of East German scientists who have an emigrant co-author before re-unification in panel (a), and citations of East German scientists who have been collaborating with Soviet scientists in panel (b). They are compared against East Germans who did not have any emigrant co-authors (panel a), or did not collaborate with Soviet (panel b). Both subsets are more productive in terms of citations than their comparison group. Those who have had emigrating co-authors lost their edge after 1995, whereas those with Soviet collaborations maintain their position against their comparison group through 2000s.

In Table 6, we document the exact numbers of the above mentioned collaborations. 561 East German scientists have neither an emigrating collaborator from their publications prior

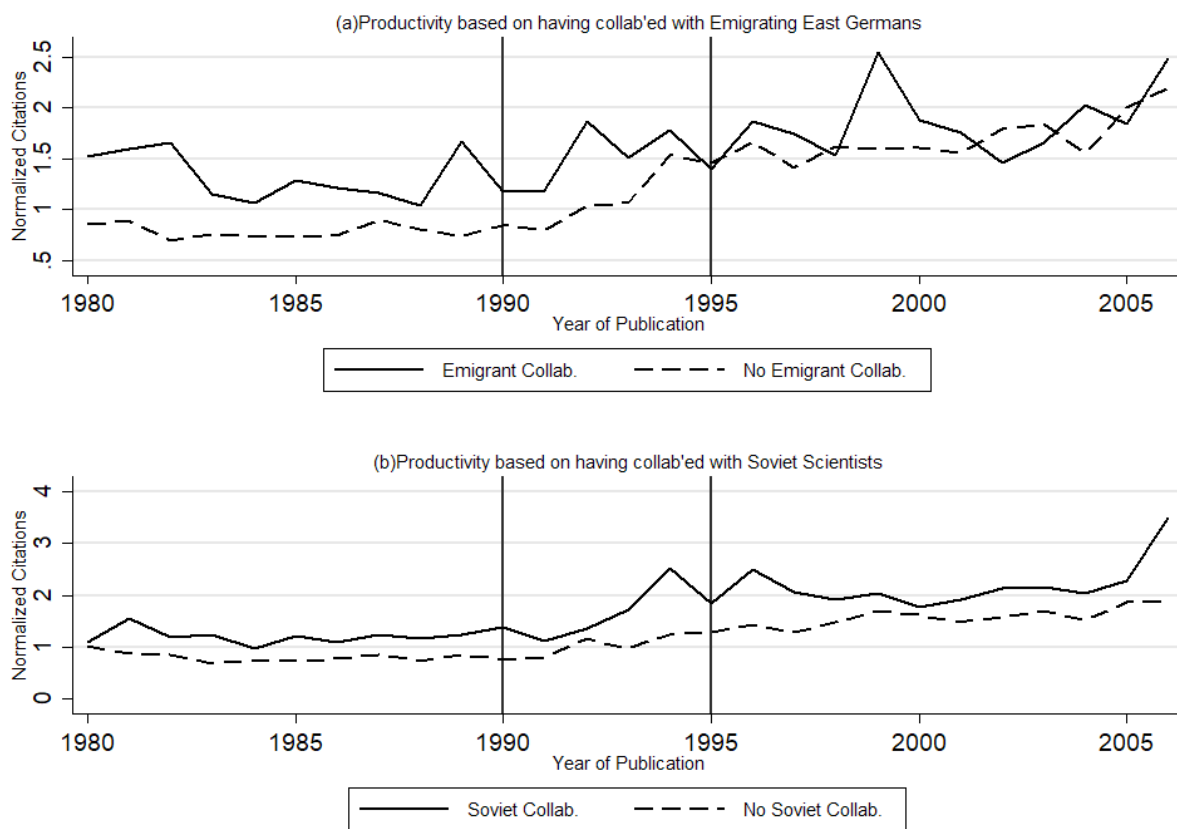


Figure 6: Citations of East German scientists based on their pre-unification collaborations

to 1990 nor did they collaborate with any Soviet scientist back then. 115 East German scientists do not have an emigrant East German collaborator but they did have at least one collaboration with Soviet scientists. 96 East German scientists did not have a Soviet collaboration but they have at least one emigrating co-author. 70 East German scientists have at least one Soviet and also one emigrating co-author. It is possible that an emigrant East German co-author was actually in the same paper that embodies a Soviet collaboration. This can mean that the East German scientist may have lost their connection to the Soviet scientist due to the emigration of this one East German co-author. There are 24 East German scientists who have been collaborating with Soviet scientists on a paper where another East German co-author from that paper ended up emigrating after the re-unification. We will treat these two group of Soviet collaborations separately in our analysis for robustness purposes.

Table 7: Differences in collaboration and productivity of East German scientists after 1990 based on their past collaborations with emigrating East German and Soviet scientists (Overlap is measured by *correlation coefficient*)

[Panel A]	Collaboration				Productivity			
	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Emigrant	0.208 ^c [0.112]	0.0549 [0.0977]	-0.775 ^a [0.128]	0.291 ^c [0.166]	0.128 [0.147]	-0.205 [0.298]	-0.288 [0.193]	-0.354 [0.257]
Post1990*Emigrant*Overlap	-0.686 ^b [0.299]	-0.0140 [0.288]	-0.527 [0.363]	-0.775 [0.506]	-0.513 [0.354]	0.313 [0.788]	0.435 [0.582]	1.063 [0.896]
Post1990*Soviet	-0.0305 [0.142]	0.133 [0.131]	0.0261 [0.0743]	0.339 ^c [0.191]	-0.792 ^a [0.195]	0.557 ^c [0.321]	0.660 ^a [0.244]	0.519 [0.356]
Post1990*Soviet*Overlap	0.293 [0.528]	-0.609 [0.404]	0.0207 [0.262]	-0.192 [0.635]	-0.0155 [0.763]	-0.167 [1.156]	-1.456 ^c [0.846]	-1.835 [1.240]
[Panel B]	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Soviet(without Emigrants)	-0.0784 [0.141]	0.158 [0.136]	0.0343 [0.0719]	0.343 ^c [0.196]	-0.850 ^a [0.205]	0.506 [0.331]	0.758 ^a [0.244]	0.376 [0.363]
Post1990*Soviet*Overlap (without Emigrants)	0.324 [0.538]	-0.637 [0.418]	-0.0191 [0.244]	-0.151 [0.652]	0.182 [0.798]	-0.000495 [1.184]	-1.522 ^c [0.832]	-1.303 [1.228]
<i>Observations</i>	10780	10780	10780	10780	10780	14793	10780	10761

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Emigrant is the share of East German co-authors who left East German territory after 1990.

Soviet is the share of Soviet co-authors before 1990.

Restricted to East Germans who did not leave their pre-1990 territory.

All regressions include age and quality controls, individual and year FE.

We repeat the analysis presented in Table 5 focusing on the effects of having had co-authors in 1980s who emigrated after the re-unification or having had Soviet collaborators during the 1980s. Results are shown in Table 7. We find that those East German scientists who have an emigrating co-author get significantly less citations for their work compared to other East Germans who did not have an emigrating collaborator after re-unification. They tend to connect to West Germans who are located in former West Germany as well as to West European and American scientists significantly more than their peers who have not had an emigrating co-author. East German scientists who have had an emigrating co-author suffer loss in their citations⁵ after re-unification but those whose research agenda overlaps largely with the pre-1990 West German research topics do not have significantly less citations than their peers after the re-unification. They, however, have a significantly less tendency to connect to West Germans, West Europeans, or Americans.

East German scientists who have been collaborating with Soviet scientists before the re-unification produce more papers, publish those papers in high impact outlets, and receive more citations after the re-unification. They get connected to West European and US scientists, at the same time they are being less connected to former Soviet scientists compared to their East German peers. It is plausible to think that those who collaborated with Soviet scientists before the re-unification might have done so because they worked on highly significant topics on which western scientists were also working back then, so that these East Germans would have a huge advantage over their East German peers after re-unification in terms of scientific visibility and impact. When the Soviet collaboration is interacted with the West German research overlap, we actually find the opposite, namely these subset of East German scientists do not necessarily publish more than their peers, receive significantly less citations, and publish in less prestigious journals.

Panel B of Table 7 shows the last two rows of panel A above using only those Soviet collaborations that do not include an East German co-author who emigrated after the re-unification. Results are qualitatively similar to those in panel A. We provide additional results using two alternative measures to capture East Germans' research overlap with the

⁵Although not significant at $p=0.1$, one should note that the coefficient estimate is negative and larger than the standard error in absolute value.

West German agenda of 1980s, namely *intensity* and *similarity*, in the Appendix in Tables B.2 and B.3, respectively. When alternative measures are used, coefficients' significance and signs turn out fairly comparable to those shown in Table 7.

4.3 Research Proximity and Collaborations

Research proximity⁶ of research portfolios between two scientists is linked to the likelihood of these scientists engaging in collaboration with another as well as the quality of such collaboration (Ductor, 2015, Fafchamps et al., 2010, Önder et al., 2021). We measure the research proximity of two scientists s_1 and s_2 using the cosine of the angle between vectors representing their field profiles denoted by \vec{s}_1 and \vec{s}_2 , respectively. Hence we calculate $Research\ Proximity(s_1, s_2) = \frac{\vec{s}_1 \cdot \vec{s}_2}{\|\vec{s}_1\| \|\vec{s}_2\|} \in [0, 1]$. Although the analysis in this subsection has a descriptive nature, it provides important insight into East German scientists' collaborations with other German (East or West) scientists.

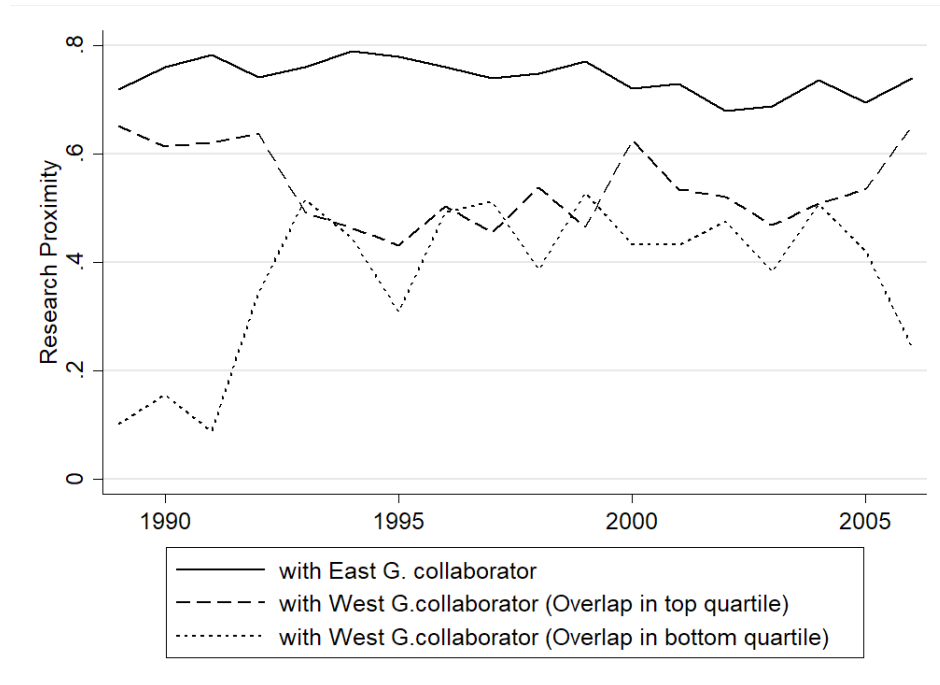


Figure 7: Research proximity of East German scientists to their collaborators (1989-2006)

⁶Compatibility of researchers' background and fields is also called the cognitive distance in the literature (Rousseau et al., 2017).

Figure 7 depicts the average research proximity of East German scientists to their collaborators between 1989 and 2006. Collaborations between East German peers have high research proximity whereas collaboration between East and West German peers have a considerably lower research proximity. We divide East Germans' collaborations with West Germans into two groups, namely collaborations of East Germans who are in the top quartile or in the bottom quartile of research overlap with West German research before re-unification. East Germans who are in the top quartile have a greater research proximity to their West German collaborators compared to East Germans who are in the bottom quartile. This difference is very large during the early 1990s. Although the research proximity of these two groups with their West German peers converge around 1995, those who have a large overlap with the strongest West German topics in their research, tend to have a closer research proximity to their West German collaborators compared to other East Germans who did not overlap much with West German research in 1980s.

We regress research proximity of East German scientists with their collaborators on time interactions of their characteristics from previous sections. In Table 8, the first column reveals that East Germans who have a large overlap with the West German topics from before the re-unification have a lower research proximity to their collaborators in the aftermath of the re-unification. If they have been collaborating with Soviet scientists before 1990, they have an even lower research proximity in their collaborations after 1990. However, East Germans who collaborated with Soviet scientists and do not have much overlap with pre-1990 West German topics have a significantly greater research proximity to their collaborators. In second and third columns of Table 8, we investigate how research proximity and its interactions with location and collaborator controls are related to the probability of engaging in a collaboration. We estimate

$$\begin{aligned}
Collab_{s_1,s_2,t} = & \beta^p X_{s_1,s_2,t} + \alpha_1^p(ResearchProx_{s_1,s_2,t}) + \alpha_2^p(ResearchProx_{s_1,s_2,t}^2) \\
& + \alpha_3^p(ResearchProx_{s_1,s_2,t} \times Location_{s_1,s_2,t}) + \alpha_4^p(Location_{s_1,s_2,t} \times WestGerman_{s_2}) \\
& + \alpha_5^p(ResearchProx_{s_1,s_2,t} \times WestGerman_{s_2} \times Location_{s_1,s_2,t}) + \phi_{s_1,s_2}^p + \phi_t^p + \epsilon_{s_1,s_2,t}^p \quad (9)
\end{aligned}$$

Table 8: Research proximity and collaborations of East German scientists with East and West German scientists

	Research Proximity	Collaboration	Citation weighted Collaboration
Post1990*Overlap	-0.186 ^c [0.101]		
Post1990*Emigrant	-0.0646 [0.0627]		
Ports1990*Emigrant*Overlap	0.379 ^c [0.212]		
Post1990*Soviet	0.299 ^c [0.162]		
Post1990*Soviet*Overlap	-1.229 ^b [0.514]		
Research Proximity		-0.00777 [0.0288]	-0.0440 ^c [0.0233]
Res.Proximity*Location		0.294 ^a [0.0191]	0.0948 ^a [0.0101]
Res.Proximity*West German CA		0.0815 ^a [0.0190]	0.0651 ^a [0.0129]
Res.Prox.*Location*WestG CA		0.146 [0.102]	-0.0417 [0.0403]
<i>Observations</i>	11347	104295	104295

Clustered standard errors at the individual level are in brackets in the first column.

Clustered standard errors at the pair level are in brackets in the second and third columns.

^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Emigrant is the share of East German co-authors who left East German territory after 1990.

Soviet is the share of Soviet co-authors before 1990.

Location is one if collaborators are located in the same city at the time of collaboration.

West German CA is one if the collaborator is a West German scientist.

All regressions include age controls, quality controls, and year FE.

Research proximity regression includes individual FE, collaboration regressions include pair FE.

where $X_{s_1, s_2, t}$ is a vector of time-dependent characteristics of s_1 and s_2 such as the quantity and quality of their individual as well as their joint publications in year t , $Location_{s_1, s_2, t}$ is a binary variable that equals one if both collaborators are located in the same city at time t and zero otherwise, ϕ_{s_1, s_2}^p and ϕ_t^p are pair and time fixed effects, respectively. $Collab_{s_1, s_2, t}$ is one if s_1 and s_2 collaborated in year t and zero otherwise. We take all collaborators of any given East German scientist and create annual collaboration vector starting from the earliest possible year to the latest possible year in which these two scientists could have collaborated. As we are using pair fixed effects, we do not include potential collaborators who never actually collaborated during the years covered in our analysis as their collaboration vector will be all zeros. Although research proximity between researchers is not significant in the second column in Table 8, its interactions with West German collaborator and with location have positive coefficients, meaning that for any given research proximity level, scientists located in the same city are more likely to engage in collaboration. Moreover, at any given research proximity level, an East German scientist is more likely to engage in collaboration with a West German scientist, which is in line with what is observed in Figure 7. In the third column of Table 8, we weigh collaborations of scientists by citations received for those collaborations and obtain qualitatively similar coefficients as in case of unweighted collaborations. Research proximity turns out negative, which is intriguing as this suggests that scientists who are not close in their research portfolios are getting more cited, most likely driven by the citation gap of all-East German collaborations and East-West German collaborations. It is important to note the square term of research proximity is positive with a large standard error and it is not reported here.

5 Cognitive Mobility of East German Scientists

Scientists can respond to changing conditions in the academic environment by changing the field of their activity, which is referred to as cognitive migration (Borjas and Doran, 2015a). Figure 8 shows the movement of East German scientists between top research fields of East and West German scientific agenda from 1979-1989 to 1996-2006 where we calculate the outflow of East German scientists from any given field using fractional counting approach. For

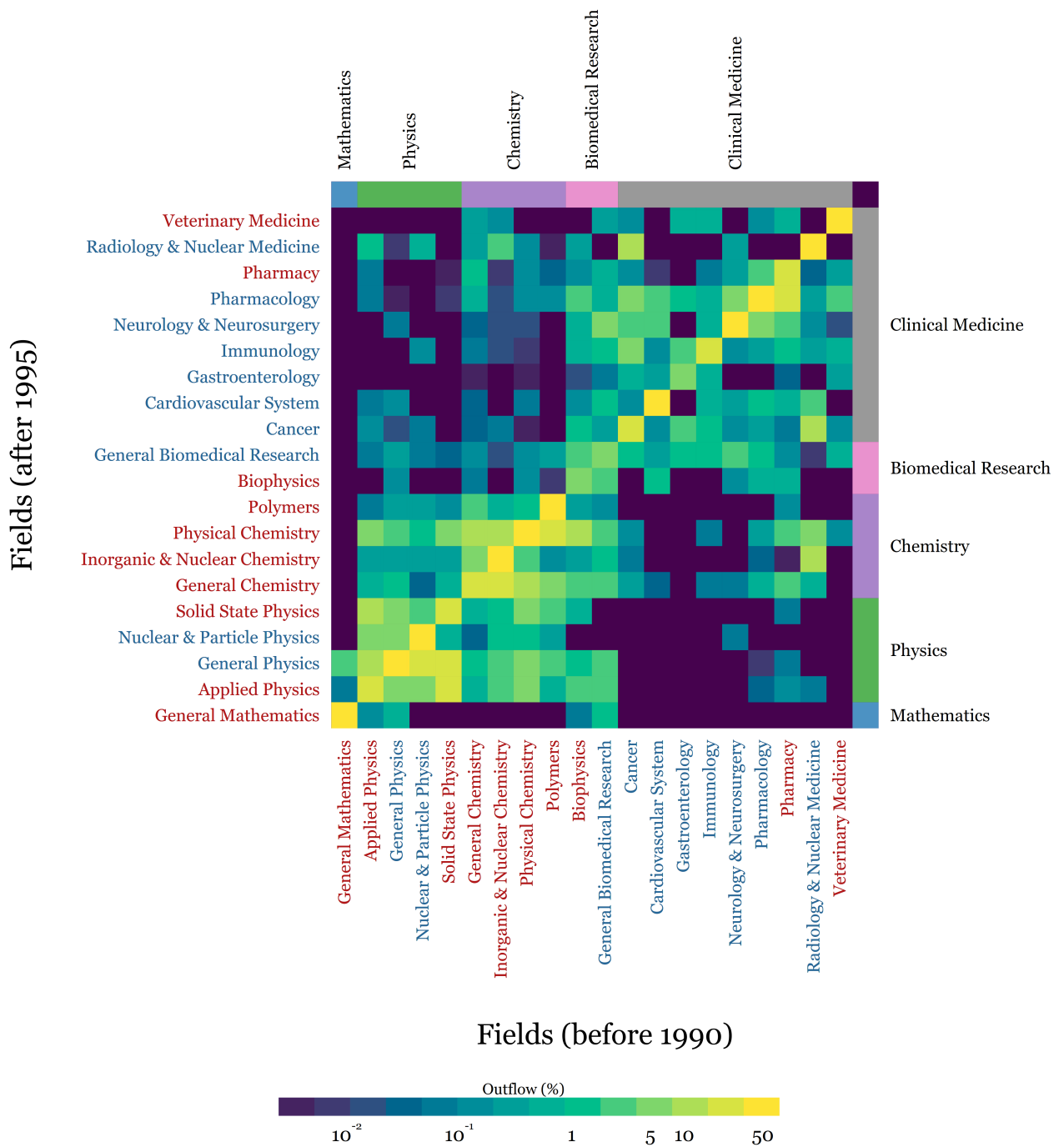


Figure 8: Cognitive mobility of East German scientists across top fields of East and West German science from 1979-1989 to 1996-2006

each East German scientists who stayed in East Germany after 1990, we calculate the share of publications they have in each field in the two periods. Then, for each field, we calculate the weighted average of outflow from pre-1990 to post-1995 by $Outflow_{fg} = \sum_{s=1}^S w_{sf}w_{sg}$ where f denotes fields before 1990, g denotes fields after 1995, w_{sf} is the share of publications of scientist s in field f before 1990, w_{sg} is that in field g after 1995. Research fields are listed on the x and y axes, broader disciplines which contain these individual fields are listed across axes. We calculate for each research field the relative East-West dominance by taking the difference of the average share of pre-1990 publications in each field between West and East German scientists. That is, for General Chemistry, it accounts for 8.62% of all East Germans pre-1990 publications compared to only 3.65% for West Germans (difference of 4.97pp), whereas for Nuclear Particle Physics, West Germans devote 3.89% of publication effort compared to 1.21% of East Germans (difference of 2.68pp). The 10 fields with the largest WestEast and EastWest difference is shown in Blue and Red, respectively.

Table 3 in Section 3.1 documents that 8.5% of all peer-reviewed science and engineering publications was in physical chemistry in East Germany during 1979-1989. Figure 8 here reveals that most scientists whose main field is physical chemistry before 1990 still have their most publications in that field after 1995. Some East German scientists switched from physical chemistry to other fields in physics, chemistry, and to a smaller extent biomedical research. About 5% to 10% of physical chemists ended up publishing more either in the field of applied physics or in solid state physics after 1995 compared to how much they publish in physical chemistry during the same period. There is, however, very little transition observed between physical chemistry and fields of clinical medicine, as revealed by darker colors of the heat map in Figure 8. We further observe that East German scientists who publish in a West German top field before 1990 tend to remain in that field.

Definition of a scientist’s main field over a time window of ten years is necessarily a vague concept and we lose significant amount of information when aggregating data in this way. In Figure 9, we graph the probability that an East German scientist publishes in a new field in a given year. This new field does not need to dominate this scientist’s research agenda or it does not need to embody a permanent shift in the research focus of this scientist. In panel (a) of Figure 9, we compare the share of new fields in East German scientists’ publications

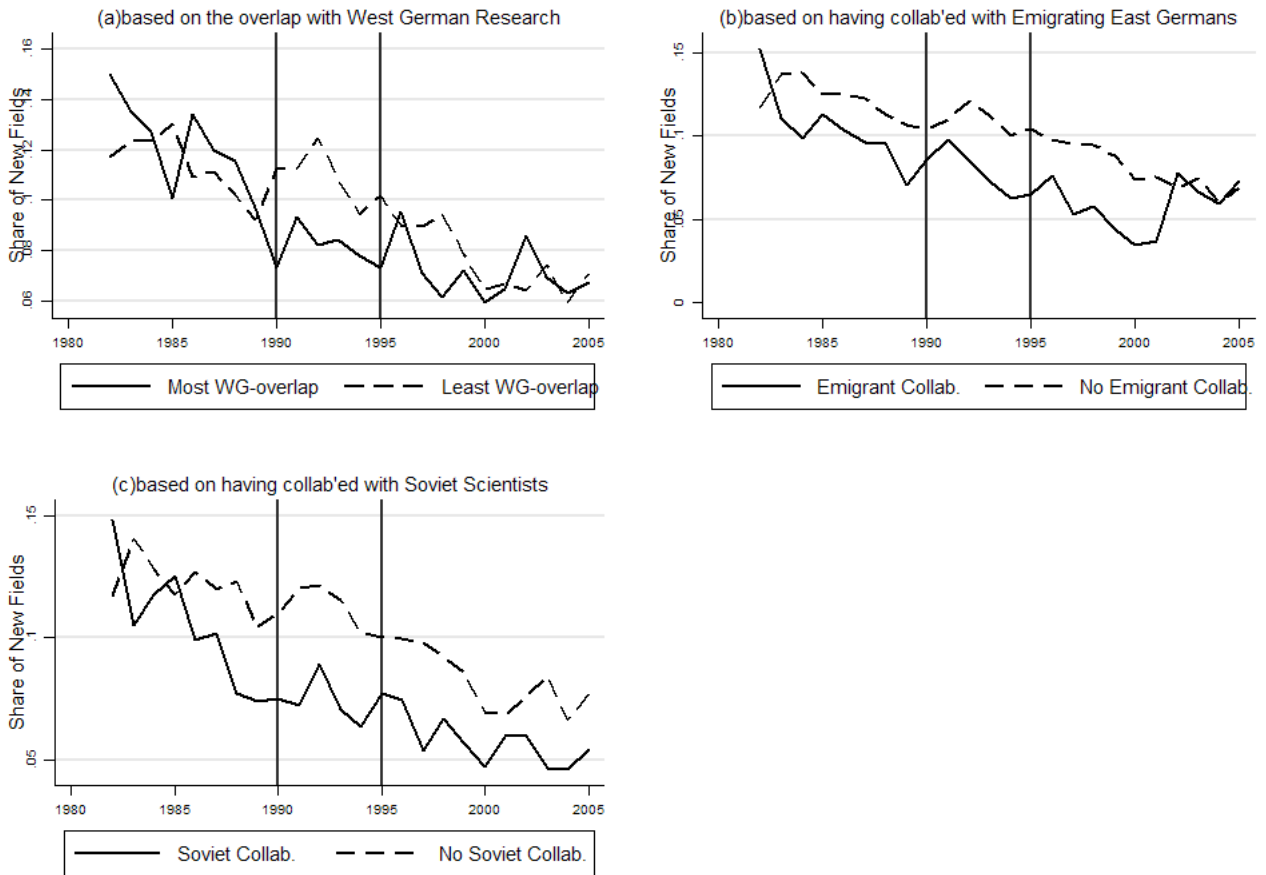


Figure 9: Share of new fields in East German scientists' publications

whose research portfolio overlaps more (first quartile when ranked according to the degree of overlap) and less (bottom quartile), respectively, with the West German research during 1979-1989. East German scientists whose research overlaps less with West German research show a larger tendency to switch to a new field after 1989 compared to their peers whose research overlaps more. East Germans who had publications with another peer who emigrated after re-unification have a less likelihood to switch to a new field compared to other East German scientists who didn't have an emigrant co-author, as shown in panel (b) of Figure 9. Interestingly, East Germans who had at least one publication where they collaborated with a Soviet scientist before 1990 are less likely to publish in a new field.

In order to test for statistical significance of the above mentioned observations when controlled for various characteristics, we run difference-in-difference estimations including

standard controls for research quality, academic age as well as individual and year fixed effects. We estimate the following linear probability model:

$$NewField_{st} = \beta X_{st} + \gamma_1(Post1990 \times Overlap_s) + \gamma_2(Post1990 \times Soviet_s) + \gamma_3(Post1990 \times Overlap_s \times Soviet_s) + \phi_s + \phi_t + \epsilon_{st} \quad (10)$$

where the vector X_{st} includes quality and age controls. In Table 9, we present three sets of results where each set corresponds to a particular definition of the research overlap. Coefficients for the above specification are shown in columns (1), (3), and (5) in Table 9. When controlled for the overlap with the pre-1990 West German research, the stock of Soviet collaborations from pre re-unification has no significantly different effect on the likelihood of publishing in a new field after 1995. When the overlap is defined using correlation coefficient (column (1)) or similarity (column (5)), its interaction with the post re-unification period turns up negative, implying that East Germans whose research overlaps with the pre-1990 West German research are less likely to publish in a new field after 1995. When the overlap is defined in terms of intensity, this coefficient is positive yet not very different from its standard error and hence statistically insignificant.

East German scientists had the liberty to collaborate with other East German scientists as well as with Soviet scientists before the German re-unification, and we investigate how the likelihood of switching to a new field changes across these collaborations after the re-unification. We estimate

$$NewField_{spt} = \beta^{ca} X_{st} + \gamma_1^{ca}(Post1990 \times EastGermanCA_{spt}) + \gamma_2^{ca}(Post1990 \times EastGermanCA_{spt} \times Overlap_s) + \gamma_3^{ca}(Post1990 \times SovietCA_{spt}) + \gamma_4^{ca}(Post1990 \times SovietCA_{spt} \times Overlap_s) + \phi_s^{ca} + \phi_t^{ca} + \epsilon_{st}^{ca} \quad (11)$$

where the observations are at publication level and $NewField_{spt}$ is one if East German scientist s has a publication p in a new field in year t , zero otherwise. $EastGermanCA_{spt}$ ($SovietCA_{spt}$) is one if s collaborated with another East German scientist (Soviet scientist) in publication p in year t , and zero otherwise.

Table 9: Research and collaboration characteristics and the propensity to switch to a new field by East German scientists

	[Correlation coeff.]		[Intensity]		[Similarity]	
	(1)	(2)	(3)	(4)	(5)	(6)
Post1990*Overlap	-0.123 ^a [0.0414]	-0.0657 [0.105]	0.0326 [0.0310]	0.0293 [0.0772]	-1.165 ^a [0.215]	-1.013 ^a [0.375]
Post1990*Soviet			-0.0889 [0.0887]		-0.0497 [0.886]	
Post1990*Overlap*Soviet	0.141 [0.278]		0.149 [0.206]		0.0673 [1.631]	
Post1990*East German CA		1.506 ^a [0.0431]		1.014 ^a [0.0351]		21.26 ^a [0.542]
Post1990*Overlap*EastG CA		-4.755 ^a [0.147]		-2.160 ^a [0.0876]		-38.20 ^a [0.978]
Post1990*Soviet CA		0.0799 ^b [0.0322]		0.0746 ^b [0.0353]		0.407 [0.309]
Post1990*Overlap*Soviet CA		-0.239 ^b [0.113]		-0.159 ^c [0.0854]		-0.706 [0.563]
<i>Observations</i>	35809	35809	35809	35809	35809	35809

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Dependent variable is one if publication is in a new field for the scientist, zero otherwise.

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Soviet is the share of Soviet co-authors before 1990.

East German CA is one if the collaborator is an East German scientist.

Soviet CA is one if the collaborator is a Soviet scientist.

All regressions include age and quality controls, individual and year FE.

Columns (2), (4), and (6) in Table 9 display coefficient estimates for the above linear probability model. Those East Germans whose research overlaps largely with the pre-1990 West German research tend not to embark on a new field in their post-1990 collaborations with East German scientists or Soviet scientists. Those whose research does not overlap, however, are highly likely to publish in a new field with these collaborations. These finding remains fairly robust through all three definitions of the research overlap. Collaborations with other East German scientists obtain larger point estimates in absolute terms compared to those obtained for the engagement with Soviet co-authors. A co-authored publication with another East German after 1990 is highly likely to signal a new field, whereas a large degree of overlap with the pre-1990 West German research reverses this and makes such a switch less likely. The same tendency exists also for post-1990 co-authorship with (ex) Soviet scientists yet smaller point estimates and smaller divergence from the estimated standard error signals a weaker tendency in either direction.

6 Conclusion

The re-unification of East and West Germany brought many structural reforms for universities and research institutes in the former East Germany. This provides a unique opportunity to open up the black box of complex mechanisms that drive the scientific productivity. Making use of the 1990 German re-unification's direct effects on German citizens' mobility and on the former East German academic structure, we investigate changes in East German STEM scientists' production of peer reviewed journal articles to establish causal effects between scientific productivity, peers, and cognitive mobility.

A difference-in-difference analysis of East German scientists' connections to their peers, their scientific productivity and impact as measured by the number of publications, citation accumulation, and the quality of journals where they publish reveal intriguing findings reveals that East German scientists who remained in former East Germany after re-unification show a significant convergence to their West German peers in all productivity accounts. East German scientists' complementarities with the newly established institutional structure of East German academia has a detrimental effect on their productivity. Although the degree

of overlap of an East German scientist's research portfolio to the West German research prior to 1990 may be expected to yield a significant edge for the survival during the restructuring of the East German academia, we find that the main leap forward came from those East German scientists who have been working with Soviet scientists on topics that were not necessarily a significant part of the West German research agenda before the re-unification.

Scientists are said to be cognitively mobile when they switch their field of scientific activity, which may be a permanent or a temporary switch. Cognitive mobility provides an important strategy to cope with shocks in the academic labor market (Borjas and Doran, 2015a) as it allows scientists to sustain their productivity by channeling their intellectual input to fields that they have not published in previously but may yield a higher marginal return under current circumstances. We find that East German scientists who collaborated with Soviet scientists on non-Western research fields before the re-unification are not only more likely to collaborate with West European and US scientists after the re-unification but they are also less likely to switch their field of research compared to their peers who collaborated with Soviet scientists and had a large overlap with Western research topics. Those who collaborate with (former) Soviet scientists after re-unification tend to do so in a new field if their overlap with the pre-1990 West German research is small. If, on the other hand, their overlap is large, then they collaborate with Soviet scientists as well as with their East German peers in fields where they have published before.

These findings contribute to institutional change and peer effects literature as they show that complementarities of research expertise between scientists or between scientists and governing structures and institutions of science policy, such as the academic labor market structure or structures of incentive and promotion, are significant drivers of scientific productivity. Although loss of collaborators has adverse effects on scientists' productivity, formation of new collaborations and cognitive mobility make up for this loss if scientists are able to complement the process of knowledge production in plausible ways.

It must be noted that our analysis is based on the survivors of the academic restructuring process in East Germany, which is likely to lead to underestimation rather than overestimation of the true size of the effects documented in this study. Assuming that characteristics needed to survive and to thrive during a large-scale academic restructuring are not completely

different skill sets, the inclusion of those who either retired and moved out of scientific careers after the re-unification would emphasize those characteristics that are shown to embody a behavioral adjustment in scientists' careers in our current analysis even more as more variation would be introduced that way. For instance, in the Appendix A, we provide an analysis of the productivity differences within East German university professors only, and we do not obtain much difference among this highly specific subgroup of scientists in how they coped with the structural changes after the re-unification.

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Appendices

A Productivity and Collaborations of University Professors in East German Universities

In this subsection we focus on a specific subset of East German scientists, namely those who have held a chaired professorship in a former East German university after the reunification. Appointment of a professor is a long and tedious procedure in the German university system and the winner of such a process will have many academic merits. Moreover, tenured appointment brings life long job security, which can allow scientists to engage in more long term and high-risk high-return projects. Hence, we provide here a close glimpse into collaboration and productivity patterns of this specific group.

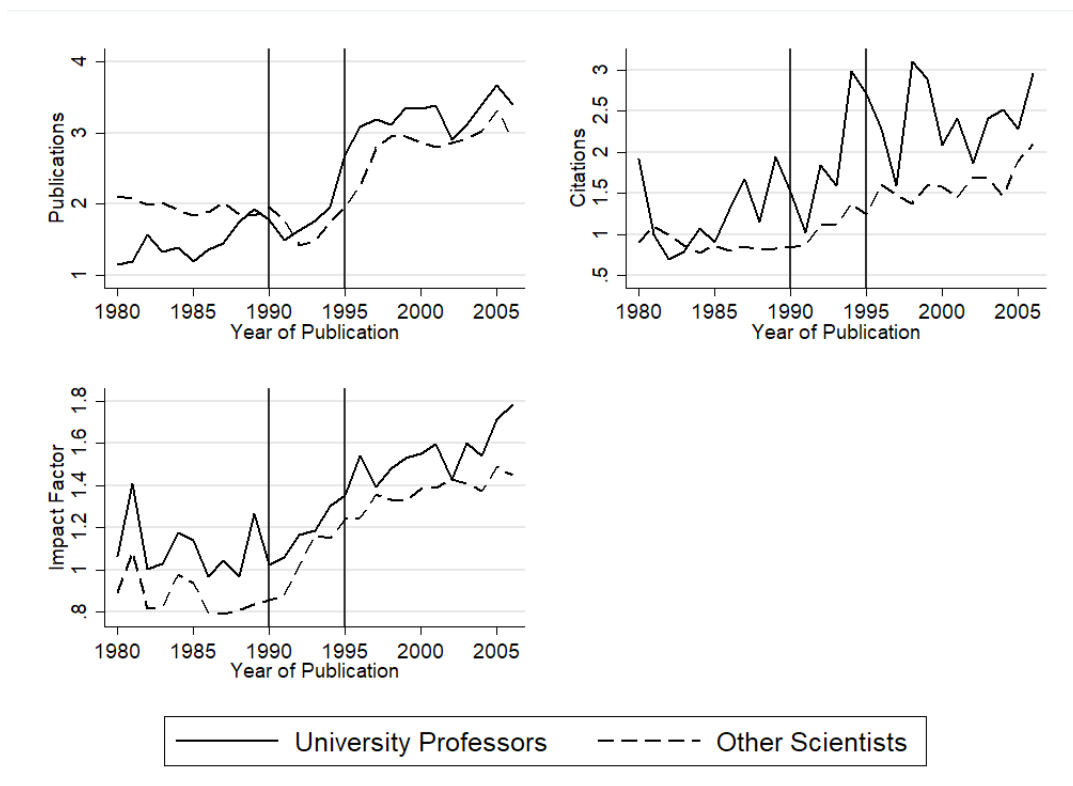


Figure A.1: Productivity of East German professors and other scientists

In Figure A.1, we show East German professors' publication numbers, citations, and impact factors of their outlets against the rest of the pool of East German scientists. Professors

Table A.1: Differences in collaboration and productivity of professors in East German universities after 1990

	West Ger	Collaboration			Production		
		Inmig.	West/US	USSR	Pubs.	Cites	IF
<i>[Panel A: Overlap based on corr. coeff.]</i>							
Post1990*Overlap	0.129 [0.187]	0.00297 [0.116]	0.0403 [0.252]	-0.218 [0.219]	-0.175 [0.322]	0.207 [0.374]	-0.117 [0.571]
Post1990*Soviet	-0.560 [0.472]	-0.293 [0.228]	0.872 [0.577]	-1.686 ^a [0.618]	0.437 [0.664]	0.622 [0.589]	0.906 [0.888]
Post1990*Soviet*Overlap	0.744 [2.974]	3.761 ^c [2.126]	-4.954 [3.734]	4.125 [3.692]	-5.885 [4.851]	0.849 [4.844]	-2.634 [6.019]
<i>[Panel B: Overlap based on intensity]</i>							
Post1990*Overlap	0.0315 [0.114]	-0.00845 [0.0774]	-0.0431 [0.152]	-0.204 [0.135]	-0.196 [0.207]	0.00533 [0.181]	0.0517 [0.385]
Post1990*Soviet	-0.528 [0.482]	-0.272 [0.288]	0.330 [0.619]	-1.785 ^a [0.627]	0.166 [0.753]	0.323 [0.615]	0.526 [0.880]
Post1990*Soviet*Overlap	0.259 [1.724]	2.156 [1.518]	-0.704 [2.442]	2.958 [2.193]	-2.208 [3.147]	1.681 [2.787]	0.0675 [3.709]
<i>[Panel C: Overlap based on similarity]</i>							
Post1990*Overlap	0.492 [1.203]	-0.178 [0.677]	0.218 [1.336]	-0.578 [0.961]	-1.731 [1.522]	0.749 [2.438]	-0.620 [2.142]
Post1990*Soviet	4.470 [8.974]	-11.84 ^a [4.436]	23.24 ^a [8.861]	-3.089 [9.443]	3.794 [14.34]	-6.130 [11.79]	15.58 [13.62]
Post1990*Soviet*Overlap	-9.374 [17.57]	22.99 ^a [8.612]	-43.90 ^b [16.78]	3.806 [18.40]	-7.871 [27.59]	13.07 [22.62]	-28.64 [25.87]
<i>Observations</i>	1557	1557	1557	1557	2428	1557	1552

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Soviet is the share of Soviet co-authors before 1990.

Restricted to East German scientists who became professor in an East German university before 2000.

All regressions include age and quality controls, individual and year FE.

constitute a productive group in all productivity measures, with the exception of publication numbers in 1980s. This can be due to the fact that most professors are young and it is their first time appointment so that their publication volume was very unripe, especially during the first half of the 1980s.

In Table A.1, we re-run the analysis that has been presented in Table 7 based solely on this specific subset of East German scientists, namely professors. It is important to note that professors are compared against professors in this analysis using this subsample, and they are not compared against the rest of East German scientists who were active during that time. We do not find dramatic changes after the re-unification in productivity measures of professors, which is not surprising as this group is not only the survivor but the winner of the whole post re-unification restructuring process. Professors who had Soviet collaborations before the re-unification tend to have less collaboration with (ex) Soviet scientists after 1995, and at the same time, those whose research overlaps with the West German research and had Soviet collaboration previously tend to collaborate more with those West Germans who arrived in (former) East German universities and newly established research institutes. This should not be surprise either, as they may be collaborating with younger researchers hired East German institutes, or even in very their own institute.

B Additional Tables

Table B.1: Differences in the productivity of East and West German scientists after 1990 (including field and field-year FE)

	<i>Overlap based on corr. coef.</i>			<i>Overlap based on intensity</i>			<i>Overlap based on similarity</i>		
	Papers	Cites	IF	Papers	Cites	IF	Papers	Cites	IF
Post1990*Overlap	-0.0250 ^a [0.00106]	-0.137 ^a [0.0360]	-0.140 ^a [0.0186]	-0.00824 ^a [0.000651]	-0.141 ^a [0.0248]	-0.0979 ^a [0.0133]	-0.187 ^a [0.00600]	-0.0752 [0.170]	-0.344 ^a [0.0864]
Post1990*East	0.00271 ^a [0.000556]	0.217 ^a [0.0222]	0.145 ^a [0.0126]	0.00414 ^a [0.000593]	0.206 ^a [0.0223]	0.142 ^a [0.0125]	-0.0283 ^a [0.00834]	0.378 [0.259]	-0.135 [0.133]
Post1990*Overlap*East	0.00899 ^a [0.00273]	0.0263 [0.0882]	0.188 ^a [0.0513]	0.00262 [0.00175]	0.0520 [0.0567]	0.144 ^a [0.0337]	0.0594 ^a [0.0158]	-0.281 [0.483]	0.596 ^b [0.247]
<i>Observations</i>	14469000	215109	213954	14469000	215109	213954	14469000	215109	213954

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Restricted to East and West Germans who did not leave their pre-1990 territory.

All regressions include age and quality controls, individual, year, field, and fieldXyear FE.

Table B.2: Differences in collaboration and productivity of East German scientists after 1990 based on their past collaborations with emigrating East German and Soviet scientists (Overlap is based on *Intensity*)

[Panel A]	Collaboration				Productivity			
	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Emigrant	0.206 ^c [0.105]	0.0344 [0.0895]	-0.815 ^a [0.111]	0.0820 [0.149]	0.00143 [0.118]	-0.382 [0.267]	-0.282 [0.180]	-0.252 [0.240]
Post1990*Emigrant*Overlap	-0.431 ^a [0.154]	0.0369 [0.152]	-0.253 [0.176]	0.00262 [0.268]	-0.0259 [0.174]	0.570 [0.466]	0.275 [0.288]	0.406 [0.511]
Post1990*Soviet	0.0932 [0.150]	0.115 [0.140]	0.0328 [0.0782]	0.277 [0.199]	-0.982 ^a [0.206]	0.439 [0.327]	0.529 ^b [0.262]	0.480 [0.359]
Post1990*Soviet*Overlap	-0.120 [0.306]	-0.347 [0.274]	-0.00196 [0.157]	0.0545 [0.427]	0.478 [0.520]	0.195 [0.734]	-0.588 [0.573]	-1.125 [0.737]
[Panel B]	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Soviet(without Emigrants)	0.0280 [0.147]	0.159 [0.148]	0.0554 [0.0777]	0.304 [0.210]	-1.045 ^a [0.221]	0.395 [0.347]	0.653 ^b [0.268]	0.303 [0.380]
Post1990*Soviet*Overlap (without Emigrants)	-0.0548 [0.313]	-0.409 [0.292]	-0.0656 [0.148]	0.0167 [0.452]	0.604 [0.557]	0.278 [0.789]	-0.688 [0.592]	-0.702 [0.763]
<i>Observations</i>	10780	10780	10780	10780	10780	14793	10780	10761

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Emigrant is the share of East German co-authors who left East German territory after 1990.

Soviet is the share of Soviet co-authors before 1990.

Restricted to East Germans who did not leave their pre-1990 territory.

All regressions include age and quality controls, individual and year FE.

Table B.3: Differences in collaboration and productivity of East German scientists after 1990 based on their past collaborations with emigrating East German and Soviet scientists (Overlap is based on *Similarity*)

[Panel A]	Collaboration				Productivity			
	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Emigrant	0.740 [1.145]	-0.164 [1.056]	0.00635 [1.176]	3.002 ^b [1.479]	2.923 ^b [1.195]	-1.519 [2.736]	-2.828 [2.201]	-4.005 ^c [2.387]
Post1990*Emigrant*Overlap	-1.319 [2.160]	0.402 [1.956]	-1.693 [2.184]	-5.363 ^b [2.704]	-5.374 ^b [2.141]	2.627 [4.976]	4.908 [4.149]	7.315 ^c [4.421]
Post1990*Soviet	-1.992 [2.259]	2.342 ^c [1.289]	-0.512 [1.378]	1.612 [2.470]	2.849 [2.722]	3.328 [4.240]	5.282 [3.406]	7.430 [4.571]
Post1990*Soviet*Overlap	3.796 [4.232]	-4.366 ^c [2.374]	1.013 [2.577]	-2.444 [4.576]	-6.748 [5.050]	-5.224 [7.905]	-9.242 [6.364]	-13.62 [8.449]
[Panel B]	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Soviet(without Emigrants)	-0.945 [2.307]	1.794 [1.282]	-0.632 [1.339]	0.481 [2.529]	1.750 [2.886]	2.507 [4.324]	4.664 [3.378]	6.857 [4.683]
Post1990*Soviet*Overlap (without Emigrants)	1.783 [4.316]	-3.321 [2.361]	1.231 [2.507]	-0.331 [4.692]	-4.742 [5.363]	-3.725 [8.073]	-7.958 [6.319]	-12.58 [8.661]
<i>Observations</i>	10780	10780	10780	10780	10780	14793	10780	10761

Clustered standard errors at the individual level are in brackets. ^c $p < 0.10$, ^b $p < 0.05$, ^a $p < 0.01$

Overlap is based on the share of publications in pre-1990 West German specialization fields.

Emigrant is the share of East German co-authors who left East German territory after 1990.

Soviet is the share of Soviet co-authors before 1990.

Restricted to East Germans who did not leave their pre-1990 territory.

All regressions include age and quality controls, individual and year FE.