Science after Communism: Why does Westernization Correlate with Productivity?*

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Abstract

How do institutional structures affect the productivity in innovative sectors? Using German re-unification as a natural experiment, we analyze the effect of institutional change in the East German academic system on the scientific productivity of East German scientists in the research fields of science, technology, engineering, mathematics, and medicine (STEMM). We find a strong correlation between restructuring of the East German academic system and the productivity of East German scientists. To identify the causal effects that yield this correlation, we investigate to what extent the observed productivity is brought about by efficiency gains and to what extent by reallocation. We analyze difference-in-differences in productivity, collaboration, field switching behavior, and attrition of the treatment and non-treatment groups of East German scientists. We find reallocation between fields or attrition to be the dominant feature that underlies East German scientists' productivity differences when institutional effects are isolated. Our findings have implications for the effects of increased competition in today's academic environment.

JEL Classification: D24, I23, J24, O32, O33

Key Words: Productivity; Peer Effects; Institutions; Competition; Reallocation; East Germany

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1 Introduction

Whether institutional structures affect productivity is an important question with immediate policy implications. We investigate the source of the correlation between today's highly competitive Western-style academic structures and the productivity of scientists. Today's academic structures are the result of what has built up over a very long time. They have been reshaped over the past several decades by constantly increasing competitive pressures in the academic labor market (Azoulay et al., 2011, Heckman and Moktan, 2020), in finance of research activities (Jacob and Lefgren, 2011, Tabakovic and Wollmann, 2019), and in commercialization (Bikard and Marx, 2020, Buchbinder, 1993, Perkmann et al., 2013). In this paper, we specifically ask: How do competitive pressures affect the productivity of scientists?

We make use of a unique natural experiment to pinpoint the productivity effects, by focusing on the large-scale institutional change that occurred in East German academia over a very short period of time following German re-unification in 1990. We investigate the causal effects of the introduction of a Western-style academic structure on the productivity of East German scientists. 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 scientific productivity in today's highly competitive academic environment. Making use of German re-unification's direct effects on German citizens' mobility and on the former East German academic structure, we investigate changes in East German scientists' production of peer-reviewed journal articles in the research fields of science, technology, engineering, mathematics, and medicine (STEMM) to establish causal effects between their productivity and the Westernization of the East German academic structure. The East German academic system was overhauled into a highly competitive and market-oriented Western-style academic structure within just a few years following German re-unification. We exploit this to investigate the productivity of East German scientists working in STEMM fields who were effectively catapulted into the competition-driven Western-style academic world. We focus on STEMM, not only because STEMM is directly related to large-scale innovation (Fager-

berg et al., 2012, Li et al., 2017, Merigó et al., 2016) and East German technology had a very prominent place within the Eastern bloc (Augustine, 2007), but also because STEMM fields were relatively more immune to political influences compared to social sciences in East Germany (Jessen, 1999).

The era starting with the fall of the Berlin Wall in November 1989 and lasting until the mid-1990s witnessed a large-scale institutional restructuring of the East German research establishment that constituted an exogenous demand shock for East German scientists' expertise. Some topics that were deemed important in East Germany might not have been considered that way under the new regime, and some other topics may have gained importance, meaning a whole new world as far as publishing and promotion opportunities were concerned. An important consequence of this restructuring was to introduce East German scientists to Western-style competition, where publication success (quantitatively and qualitatively) holds the key to survival and career success in academia (hence *publish-or-perish*). We refer to the restructuring of East German academia during the first half of the 1990s as *Westernization* hereinafter.

Archambault et al. (2017) descriptively document 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 in terms of their publication output. Such convergence is a significant achievement, especially considering the findings of Kozak et al. (2015) that members of the pre-1990 Eastern bloc, except for East Germany, experienced no significant improvement compared to their productivity and impact under the communist regime. We analyze the adjustment mechanisms that fueled the convergence documented in Archambault et al. (2017) to establish causal links between the new institutional environment that East German scientists found themselves in and their productivity. Using East German scientists' research overlap with West German research topics during the 1980s as the identification for exogenous variation, we employ a difference-in-differences framework to investigate the effects of the Westernization of East German academia on the research productivity of East German scientists who remained in East German institutions after re-

unification. We analyze their mobility between collaborators and research topics[1] as well as their propensity to exit research production altogether. Unveiling these mechanisms allows us to draw lessons about the costs and benefits of Westernization (i.e., the *Westernization effect*) for East German science, which most likely embodies a different mode of production of research output than what they were used to.

It is hard to pin down every single factor that goes into the production of new ideas (Jones, 2005). However, it has been shown that collaborative interactions (Jones et al., 2008, Singh, 2005, Wuchty et al., 2007), as well as the institutional environment (Heinze and Kuhlmann, 2008, Kim et al., 2009), play a significant role in innovation above and beyond what can be explained by the qualities of individual scientists alone. The Westernization of East German academia did not happen in isolation; it arrived at the same time as an opportunity for East German scientists to access a whole new group of peers in the West, which was impossible before the fall of the Berlin Wall. Having access to a new and large peer group is advantageous, as peers may help overcome individual or institutional constraints on the creation of impactful research (Jones, 2009, Larivière et al., 2015). Supporting this argument, Azoulay et al. (2019, 2010) find positive peer effects of star scientists on their collaborators; Ductor (2015) finds statistically significant and positive productivity effects of research collaboration. We refer to the productivity effect borne by connecting to peers who would not have been accessible before re-unification as the *West-peer effect*. This differs slightly from the usual terminology of peer effects, as peer effects would also be at work for East German scientists who decide to collaborate more intensely with their East German peers in response to Westernization. In that case, however, we capture this response as part of the *Westernization effect* as the scientist could have done so before re-unification, and the decision to team up more intensely with other East Germans or Eastern bloc scientists should be seen as an effect of the changing institutional setting.

Our identification strategy allows us to separate the *West-peer effect* and the *Westernization effect*. If one is to take the findings of Archambault et al. (2017) at face value, one might be tempted to jump to the conclusion that German re-unification is beneficial for East

[1]Scientists' mobility across different research fields or topics is referred to as *cognitive mobility* (Borjas and Doran, 2015).

German scientists as their productivity levels increase. There are two problems with this conclusion. First, it is not clear to what extent the observed convergence is driven by the West-peer effect (access to new peers due to opening of borders) and by the Westernization effect. Second, even when one rules out the West-peer effect (which one should not), what remains is a positive correlation between competition and productivity, which does not necessarily imply causation. The observation of such a correlation is common across many sectors regionally and internationally as evident in the literature (Holmes and Schmitz, 2010) but the source of this correlation may be due to reallocation and selection of the fittest in more competitive markets and not necessarily because competition enters the production function as an input (Backus, 2020, Collard-Wexler and Loecker, 2015). The aim of this study is to investigate to what extent the observed productivity gains arise due to efficiency gains or other direct effects on the scientific production (production of paper publications) function and to what extent this is the result of reallocation of the productive capacities.

We show that although East German scientists' productivity catches up on all accounts (publication number, citation counts, and the field-normalized impact factors of journals where they publish) with West German scientists, research overlap with pre-1990 West German research does not explicitly give an edge to that subset of East German scientists, except for publishing in high impact factor journals. Research overlap with West German topics drives significant differences in how East Germans establish collaborations with their peers. Those with large overlaps collaborate significantly more with West Germans compared to how their East German peers collaborate after re-unification. The structure of the post-1990 collaborations yields significant differences based on the structure of the pre-1990 collaborations of individual scientists and their overlap with West German topics, indicating that the underlying mechanism of how peers open the doors of new and productive ideas is not uniform and that a high degree of overlap with West German topics does not guarantee a productive match between collaborators. Nevertheless, East Germans with less overlap with West German topics are significantly more likely to reallocate their research activities to different fields or exit research-active careers altogether.

Overall, the Westernization effect leads to reallocation in the form of cognitive mobility across fields or exit from the sector. The West-peer effect, on the other hand, offers alternative

mechanisms for East German scientists to dampen the need for reallocation. We find that the observed correlation between Westernization and improved productivity does not arise from efficiency gains in scientific production; rather, it is the result of the reallocation of productive capacities. Reallocation is the dominant feature that underlies East German scientists' productivity differences when the West-peer effect is removed. Hence the observed productivity improvements are most likely to be generated not by efficiency gains but by reallocation and selection. Our contribution to the literature is to open up the black box of the links between competitive pressures in research-intensive sectors and scientific productivity using the restructuring of East German academia as a natural experiment. This analysis indirectly draws lessons about the costs and benefits of the publish-or-perish era overall that we are currently living in. The highly popular *publish-or-perish* mantra of the contemporary research community should be taken to be more of a manifestation of a selection mechanism rather than a productivity-enhancing input.

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 following re-unification. In Section 3, we describe our 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 as well as their attrition rates. Section 6 concludes.

2 Historical Context

The academic system in 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 system was considered *essentially healthy*[2]. Therefore, apart from denazification and infrastructural rebuilding, a return to the traditional federal education structure, in which universities were the responsibility of the

[2]The 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

German federal states, *Bundesländer*, was deemed appropriate. A science council consisting of representatives from the federal states and the federal government was formed in 1957. This body still exists. The following decades saw reconstruction, expansion, some reforms as a result of the 1970s student movement and, in the 1980s, rising student numbers and stagnant numbers of academic staff (Kehm, 1999).

In contrast to West Germany's federally structured and *Humboldtian* academic system, post-war East Germany replaced the traditional institutional autonomy of higher education with a central system run by the state secretary's office. East Germany also introduced Marxism-Leninism as a mandatory part of every curriculum in 1960s (Kehm, 1999). Furthermore, East Germany followed the Soviet system in introducing a clear separation between higher education and research. The institutes of the *Academy of Sciences -Akademie der Wissenschaften (AdW)* were mainly responsible for research and development; universities' primary aim was to train individuals to meet the needs of the East German centralized economy. For this reason, industry and universities worked closely together, the size of university programs was adapted to economic needs, and alumni were centrally placed in the job market. For our analysis, a particularly important feature of the organization of STEMM research in East Germany is that East German policy makers understood early on that technology and innovation were the main drivers of sustained economic growth. They thus offered various levels of preferential treatment to STEMM scientists in order to align their interests with the needs of the centrally planned economy (Augustine, 2007). This policy provided a rather protective environment for STEMM scientists as opposed to the highly competitive academic environment of the West.

It is crucial to understand that the activities and career evaluations of East German scientists followed very different rules compared to those in the West. Neither mobility across institutions nor competitiveness was encouraged by the existing rules (Günther and Schmerbach, 2010). As a result, although collaborations among East German scientists were not explicitly forbidden, they remained very uncommon before re-unification. Opportunities for cooperation with West German scientists or those from the wider West were extremely

and widely re-used, e.g. by Kehm (1999), in describing the university system after the Second World War in West Germany.

limited due to the political climate of the cold war. After the Berlin Wall was erected in 1961, collaborations between East and West German scientists came to a sudden halt (Sabel, 1993). From then on, East German scientists collaborated exclusively with colleagues from their East European and Soviet allies. An agreement that entered into force in 1975 made it *theoretically* possible for East German scientists to cooperate with West German scientists under extremely restrictive conditions. The bilateral agreement of scientific and technological collaboration (*wissenschaftlich-technologische Zusammenarbeit -WTZ*) of September 1987 aimed at easing some of the restrictions of the 1975 arrangement and making interaction on major research projects more of a practical possibility (Wissenschaftsrat, 1990). According to Wissenschaftsrat (1990), the WTZ agreement gave rise to about 60 projects until July 1990. Considering that the intra-German border opened in November 1989, it is reasonable to presume that a non-negligible share of these 60 projects consisted of interactions that were formed after this event.

The WTZ agreement continued to provide the main guideline for collaborations between East and West German scientists until the country's official re-unification in October 1990, which brought about the substantial task of unifying the academic systems of East and West Germany. This process caused great disruption in the East German scientific community, as it involved an enormous amount of reshaping and rescaling as well as a thorough re-evaluation of staff. Westernization introduced East German scientists to a new set of academic rules, regulations, and norms such as increased competition for positions and funding. Scientists' publications plays a key role in this new system, as had already been the case in Western-style academia for several decades. Thus, East German scientists, especially in STEMM fields, suddenly found themselves in an academic world where they had to publish to achieve satisfactory metrics (may these be the number of publications or citations etc.) or perish.

The re-unification process started in November 1989 with the freedom to travel between East and West Germany. In October 1990, the East officially ceased to exist. During the first years after re-unification, a great deal of academic restructuring took place in former East Germany. In essence, the structure of West German universities was applied to East German ones. As described by Hechler and Pasternack (2014): *"The official narrative tells a story of normalisation of the academic system during the process of German unification. This is*

often labelled as renewal [...]. While the use of the term renewal inside academia originally described a process of transformation, it was quickly adopted by external political actors to label a process of transfer of West German higher education structures to the territory of the former [East Germay].” (p.208).

The division of subjects and disciplines of East German universities was adapted to West German standards; there was also a substantial reform in the personnel structure. All university and research institutes staff in the *AdW* were reviewed and evaluated scientifically as well as politically (Kocka, 1994, Sabel, 1993). If the outcome of the review was negative, as was the case in most subjects that were politically involved, the academic in question was dismissed. The outcomes of scientific and political reviews might have been linked since some of the ruling party (SED) members were appointed for their political loyalty rather than their qualifications. This link might explain why the share of SED members was 63% among university staff and only 13% among the East German population (Schattenfroh, 1993). It must also be noted that before re-unification, East German scientists followed the standards of a system where competition and mobility were discouraged and publication opportunities in Western journals were either restricted or absent, as was the case for the social sciences (Günther and Schmerbach, 2010). This meant that a scientist who was evaluated positively politically might fail the scientific review because the measure of good quality had changed radically compared to only a few years prior.

Academic staff in social science departments who were evaluated positively often faced difficulties in adapting to the Western academic paradigm. Adjustment in relatively politically neutral subjects such as the natural sciences and engineering was less challenging. However, academics in these subjects also faced problems, since many of them had been unable to publish in Western journals and follow the academic discourse outside the Eastern bloc. In particular, older members of staff often could not adapt to the new expected volume of publications and were thus left behind (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 position or a similar one. However, due to the significant downsizing of East German academia after re-unification, a positive evaluation was necessary but by no means sufficient to secure a position (Kocka, 1994). 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 constituted the middle section (ranked higher than graduate students/assistants and lower than professors, *Mittelbau* in German) left academia to take up jobs in industry (Günther and Schmerbach, 2010). Despite the downsizing of East German universities, this trend created vacancies not only in social sciences but also in natural sciences and engineering departments. Between 1990 and 1995, many West German scientists were able to obtain positions in the former East German universities and in re-structured or newly established research institutes. According to Burkhardt (1997), the period in question corresponds to the years of most intense re-structuring in East German academia as the initial evaluation of East German professorships was completed in 1995. We thus take the first decade of Westernization to run from 1996 to 2006, and we investigate differences in the productivity of East German scientists compared to the decade before re-unification (1979-1989).

3 Data Description and Identification

We obtain the publication records of West German and East German scientists who published in biology, physics, chemistry, mathematics, engineering, and the medical sciences from Clarivate Analytics' Web of Science (WoS) dating back to 1970. The Web of Science and its predecessor, the Science Citation Index, emerged in the United States and are thus generally considered to prioritize English publications from Western countries (Archambault et al., 2006, Mongeon and Paul-Hus, 2016). However, when the Science Citation Index was created in the 1960s, there was a strong interest and a genuine effort to index research from the USSR and other Eastern countries (Garfield, 1972, 1979). As a consequence, the Web of Science coverage of pre-1990s research in East European countries is surprisingly adequate (Vladutz and Pendlebury, 1989), especially for the natural sciences and engineering (Carpenter and Narin, 1981, Vlachý, 1986).

As scientists' nationalities are not recorded in the data, we make use of affiliations to classify a scientist as East German or West German. We take a scientist's main affiliation to be their most used affiliation in a given period. Scientists whose main affiliation was located in East Germany during 1979-1989 are considered East German, while those with

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

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

a West German main affiliation during the same period are considered West German. We construct East and West German scientists' research portfolios based on their publications from 1979 to 2006. We restrict our sample to those scientists who published at least once between 1979 and 1989, as well as between 1996 and 2006. Our final dataset consists of a total of 751,641 peer-reviewed publications by 8,771 West German STEMM scientists and 1,136 East German ones whose main affiliations were with universities or research institutes.

We observe the mobility of scientists based on changes in their affiliations. However, not every change in affiliation is an official move. A scientist may have been visiting another institute without giving up their initial position at their home institution, but may have published using the affiliation of the host. When a scientist's main affiliation changes, we interpret this as the scientist having moved, which is in line with the methodology proposed by Robinson-Garcia et al. (2019). Scientists' movements are documented in Table 1 based on changes in main affiliations after 1990. After 1995, of the original 1,136 East German scientists, 842 remained in former East Germany, 209 moved to former West Germany, and 85 went abroad[3]. In the 1990s, 458 West German scientists moved to East German institutions.

Figure 1 shows the productivity and impact trends from 1979 to 2006 of East and West German scientists who remained within the territories of their respective former countries after re-unification. The upper-left panel depicts the annual average number of publications, the upper-right panel shows field-normalized citations, and the lower-left panel displays the field-normalized and annually variable impact factors of the journals where they published

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

their research[4]. The dotted line in Figure 1 captures those West German scientists who moved to the former East.

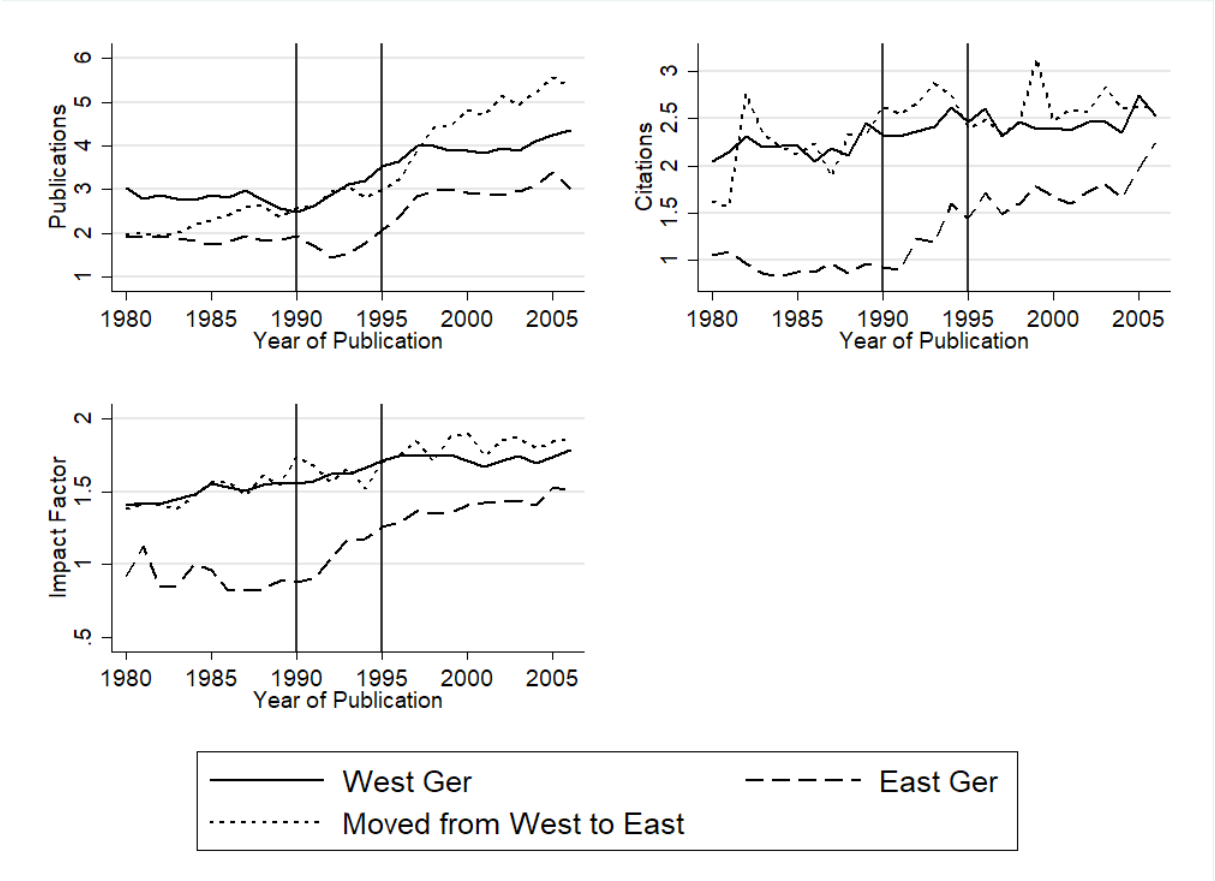

Figure 1: Productivity of stayers in West and East Germany compared to movers from West to East Germany (In-migrants)

Throughout the 1980s, East German scientists produced fewer publications and received fewer citations per publication compared to their West German peers. During this decade, West German scientists published about three papers per year, while East Germans published about two papers yearly. A catch-up process took place in the 1990s. After 1995, the annual average increased to four papers for West Germans and three papers for East Germans. Around this time, East German scientists started catching up to their West German peers also in terms of citations and journal quality (i.e., impact factor). During the mid-1990s, East Germans' average citation count increased from below 1 to above 1.5; it reached 2 by 2004. In contrast, West Germans' citation count remains between 2 and 2.5 for the whole

[4]Field-normalized versions of citations and impact factors allow us to make direct comparisons of productivity and quality across different fields.

period. This indicates an increase in the impact of East German science. Another important catch-up process took place in the average impact factors of the journals in which East Germans published. Starting in the early 1990s, East Germans published in better-ranked journals compared to before. This indicates an overall change in the publication culture of East German scientists rather than a strict improvement in quality.

The dotted line in Figure 1 depicts the productivity of those West German scientists who moved to an East German institution during the 1990s. In terms of publications, they lagged behind the West German average in the 1980s. A possible explanation for this evidence is that those who went East were younger scientists. Although we do not have data about scientists' ages, the first publication of the scientists who migrated appears in the publication data on average later than that of their non-migrating peers. The publication productivity of migrating scientists soon caught up and surpassed that of West German peers. In the 1980s, migrating West German scientists were indistinguishable from their West Germans peers in terms of citations and impact factors. Their productivity improved even more in the 1990s and afterward.

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 thus collect information on newly hired or re-hired (as a result of scientific and political evaluations) professors in 16 East German universities[5] between 1990 and 1995 using universities' online resources and records in the German National Library. A significant portion of academic restructuring, including the evaluation and re-hiring or replacing of former East German professors, ended mainly by 1995 (Burkhardt, 1997). Table 2 shows the share of West German and East German scientists who were appointed as professors in faculties of natural sciences, engineering, and social sciences in the above mentioned 16 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' natural sciences and engineering faculties, whereas this ratio is 86% in the social sciences. We suspect that the observed displacement of East German

[5]BTU 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
	Total	from West Ger	West Ger hires
Natural Sciences & Engineering	*351*	*175*	*49.9%*
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%
Social Sciences	*236*	*203*	*86%*
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%

professorships in the social sciences may have also been reflected in other academic ranks; this means that a meaningful analysis of East German social scientists' post-re-unification productivity levels is a challenging task as their attrition rate is very high. This problem is another important reason to focus solely on STEMM scientists and not on social scientists in our analysis.

While professors who obtained their PhD in East Germany began their tenure on average 17.8 years after obtaining their doctorate, the average time for professors who obtained their PhD in former West Germany was 14.7 years. This difference reinforces the theory that inexperienced West German scientists were primarily hired as professors at East German universities during the restructuring. However, the difference could be caused by the fact that the East German professors hired in the post-re-unification period were usually the ones deemed ideologically untainted, who were perhaps stuck as non-professorial staff in East Germany due to their ideological insubordination.

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

Field (within main discipline)	Share of field in all publications
West German scientists	
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%
East German scientists	
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%

3.1 Identification and East German Activity in West German Fields

Table 3 shows the share of top specialized fields in all the 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 the research activity of both sides, there is little overlap in the ranking of most of the fields listed in Table 3. For instance, nearly 5% of West German publications are on the *cardiovascular system*, yet this topic is not found among the top fields in East German publications. *Veterinary medicine* receives considerable attention in East German science, but this is not the case in the West.

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 West German science and got a lot of attention by West German scientists may have been considered in the same way by East German scientists only if it was a topic of great intrinsic value or if it coincided with the industrial ambitions of the centrally planned East German economy. Otherwise, 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 the 1980s, except under very extraordinary circumstances. They could also not have developed a career with the explicit aim of adhering to the academic standards of West German universities, because East German academics were held up to very different standards before re-unification as discussed in Section 2. The unpredictability of the fall of the Berlin Wall, the lifting of the iron curtain, and re-unification of Germany suggests that an East German scientist would have had no reason or motivation to develop a research portfolio suitable for the Western academic world or for surviving an overtake of East German academia by West German research structures.

The degree of overlap between an East German scientist's research agenda prior to re-unification and West German research topics during the 1980s provides a useful identification to separate peer effects from the Westernization effect. When the political obstacles that prevented interactions with the West were lifted, a reasonable expectation is that those East German scientists whose research overlapped with the dominant fields in West German research may have found themselves in a better position to adopt a Western-style research practice, enjoy higher levels of productivity due to access to more relevant resources and peers, and gain significant ground overall during the Westernization process. We thus measure the overlap between an East German scientist's portfolio and West German research in the 1980s using three well-established indices in the literature. These three indices deliver continuous measures of the overlap between the research portfolio of individual scientists and the overall West German research output. In the remainder of this article, when referring to East German scientists who are placed in the upper and lower sections of these measures, we

use the terms ***West-overlapping*** and ***non-West-overlapping*** East German scientists, respectively. The *correlation coefficient* between field shares of publications of any scientist s and West German scientists is defined by

$$C_s = \frac{\sum a_{sf} w_f}{\sqrt{\sum a_{sf}^2 \sum w_f^2}} \tag{1}$$

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 is a textbook measure of overlap (for instance in Newman (2010)) and was also employed in the analysis of Borjas and Doran (2012). 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

$$I_s = \frac{\sum a_{sf} W_f}{\max W_f} \tag{2}$$

where a_{sf} is defined in the same way 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 widely used measure of research overlap between a scientist s and the overall West German research, it has previously been used by Cutler and Glaeser (1997) and Borjas and Doran (2012) to analyze similar contexts. The metric is based on the vector distance of portfolios, defined by

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

Figure 2 shows the total publications, field-normalized citations, and impact factors of West-overlapping (top quartile according to the correlation coefficient) and non-West-overlapping (bottom quartile) East German scientists. Especially after 1995, West-overlapping

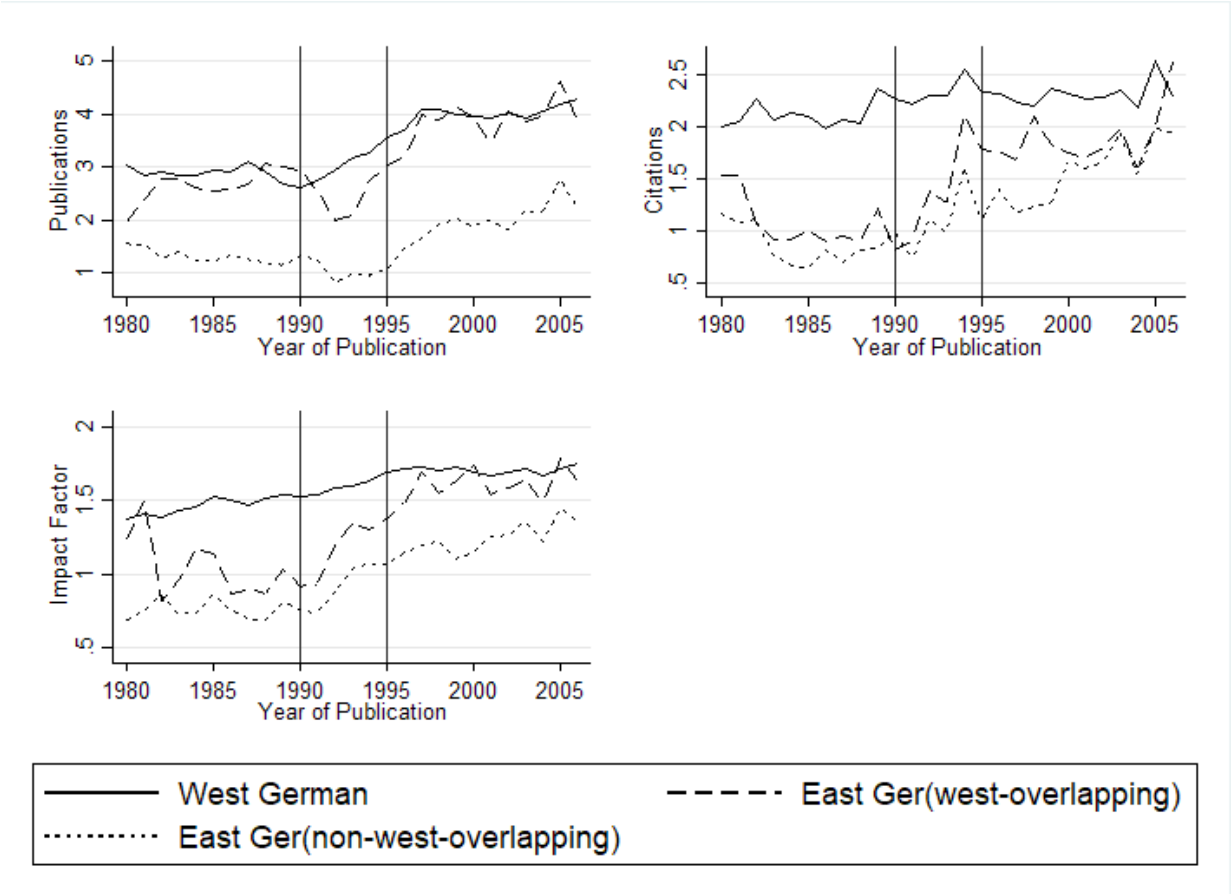

Figure 2: Productivity of East German scientists and the overlap of their research with the pre-1990 West German research

East German scientists publish more than non-West-overlapping ones and are fairly comparable to West Germans in this regard. In terms of citations and impact factors, the gap between West-overlapping and non-West-overlapping East Germans is less obvious before 1990. However, after 1995, the gap widens in favor of West-overlapping scientists, especially when the 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 more easily than their peers during and after the Westernization of East German academia.

4 Productivity and Collaborations

Scientific output is measured in three different ways: number of publications, count of field-normalized citations, and annually variable field-normalized journal impact factor. Throughout this paper, we restrict our attention to those East German scientists who remained in the territory of the former East Germany after re-unification. We regress the scientific output of an East German scientist s in year t on her overlap with the West German research during 1979-1989 as well as standard controls and quartic life cycle controls. Years from 1990 to 1995 are left out of the analysis because these were years of stark transition. We estimate

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

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.

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 other East Germans. Their papers, however, are published in journals that have significantly higher impact factors as individually clustered standard errors are smaller than the point estimates of α in this particular specification. When citations are considered, we obtain negative point estimates for the research overlap, but these estimates come with large standard errors no matter which overlap definition is used.

Since the above analysis does not focus on the absolute productivity so that both groups' productivity may be increasing or decreasing together, we explore if and how the scientific output of East German scientists is catching up with that of the West Germans after re-

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
Panel A:Overlap based on corr.coef.						
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]
Panel B:Overlap based on intensity						
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]
Panel C:Overlap based on similarity						
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]
Observations	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.

unification by pooling East and West Germans' output to estimate

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

where $Overlap_s$ applies to all scientists in this sample so that a West German scientist's research overlap with West German research areas measures to what extent this person has been active in a West German-dominated field during 1979-1989. A positive and significant γ would imply that the descriptively illustrated productivity trends of East and West German scientists in Figure 1 are indeed statistically significantly converging even when controlled for research quality, common time trends, and individual effects. A positive and significant θ would reveal East Germans' research overlap with West Germans as a possible source of catch-up.

The last three columns of Table 4 report the point estimates of α, γ, and θ in equation 5. When the research overlap is calculated using the correlation coefficient or 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 differences between East and West German scientists after 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. West-overlapping East Germans are publishing their research in journals with higher impact factors and gaining on everybody else but they are not necessarily catching up in terms of publication numbers or citations.

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 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

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

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 A.1 in the Appendix. Results are qualitatively comparable to the last three columns of Table 4, hence field and year specific interactions do not play a major role in the observed difference in differences after re-unification.

Table A.2 in the Appendix is the reproduction of Table 4 excluding professors in East German universities. Professors may have different motivations in their research activities or they are affected by the Westernization as well as the availability of potential new peers very differently compared to other scientists. After all, Westernization brings an the immense competition to the scientific landscape of East German science and although professors are not protected from competitive pressures in a Western-style university system, they may be affected in different ways. Results shown in Table A.2 are similar to those in Table 4.

4.1 Collaborations

Figure 3 shows international collaborations of East German scientists between 1979 and 1989. Each link represents at least one collaboration in a peer-reviewed publication of an East German scientist with scientists from the respective country. The more the number of collaborations between East German scientists and scientists of a country the thicker are links between East Germany and that country. The Soviet Union stands out as the most heavily collaborated partner during 1979-1989. Connections between countries other than East Germany in Figure 3 indicate 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 in Figure 3 means that East German collaborations with West European countries mostly involved large international teams of scientists from several countries. Collaborations with East European countries do not seem to create such a clique, most

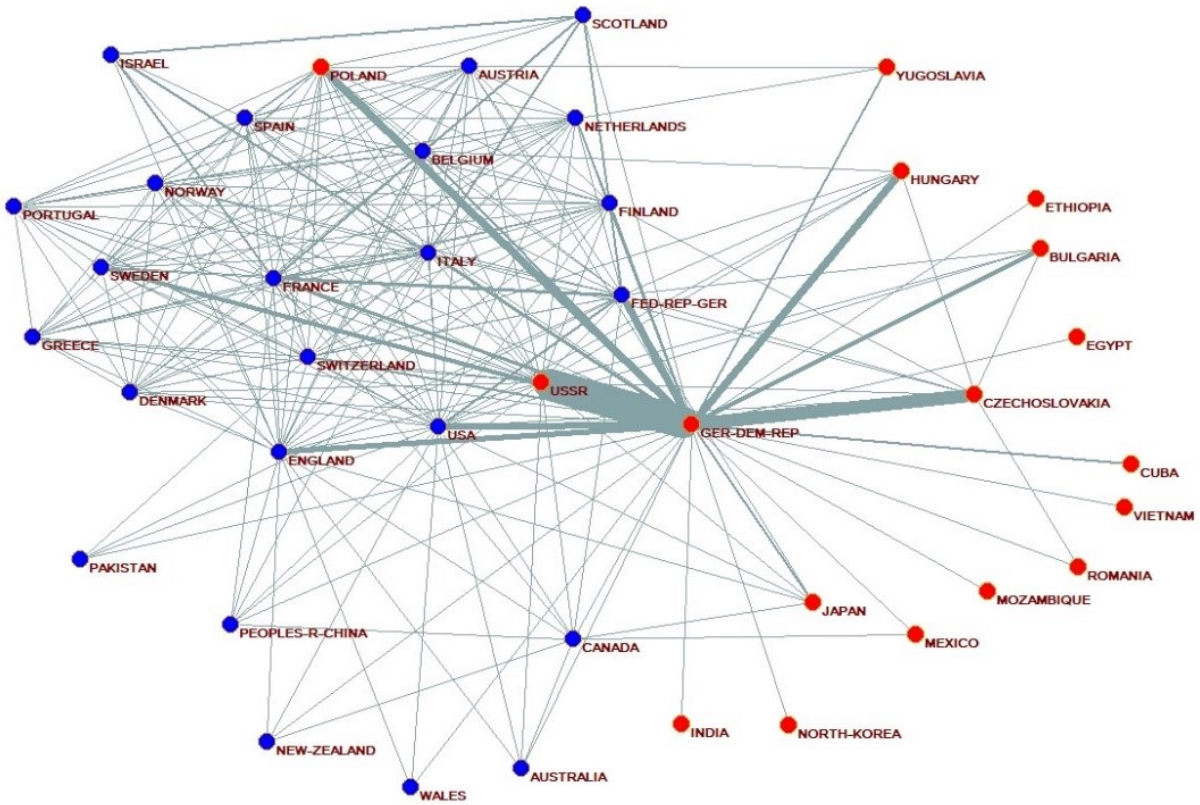

Figure 3: Collaboration networks of East German scientists 1979-1989 (More frequent collaborations are shown by thicker links; collaborating countries are found to form two communities marked blue and red by applying the Louvain partitioning method)

likely because such collaboration could be formed at will whereas collaborations with West Europeans required more formalities and could politically 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 3. 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 3. 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 this simple community detection algorithm reveals a division of the East German collaboration network that lines up almost perfectly with the political background of the 1980s.

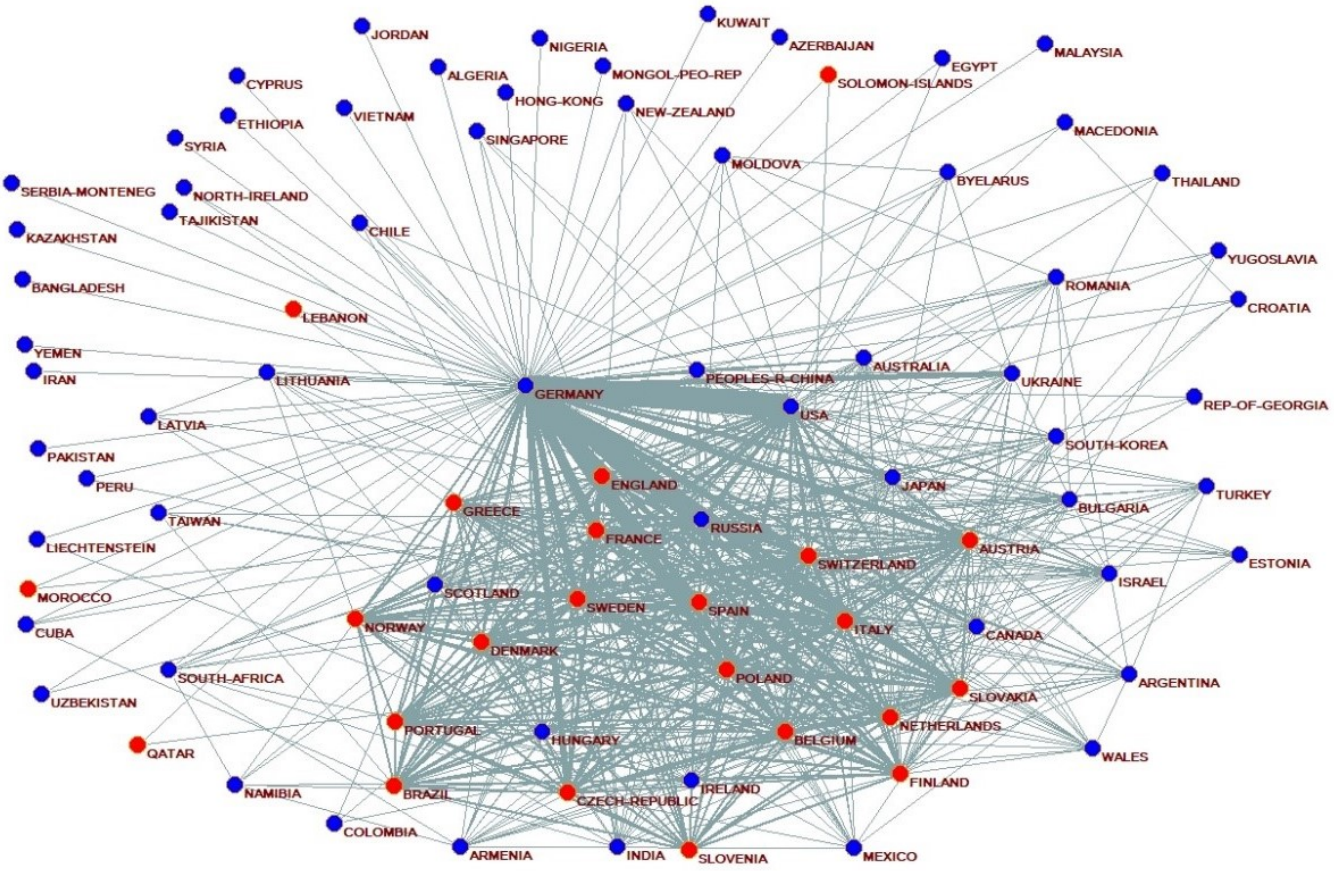

Figure 4: Collaboration networks of East German scientists 1996-2006 (*Germany* in this figure refers to East German scientists who remained in the former East German territory after re-unification. More frequent collaborations are shown by thicker links; collaborating countries are found to form two communities marked blue and red by applying the Louvain partitioning method)

Figure 4 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 3, we observe a densely webbed

collaboration structure among most European countries, however the divide between East and West European countries is not as clear as it was during the 1980s. Using Louvain partitioning, we detect again two communities that maximize the modularity, identified by blue and red nodes. There is, however, no obvious explanation for this division 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.

We employ a linear probability model to analyze East German scientists' (remaining in the former East German territory after re-unification) individual level collaborations. We analyze differences in their propensity to collaborate 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[6] scientists. We 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 using the following specification

$$E(Collab^{j}_{st}|Publication_{st} > 0) = \beta^{c} X_{st} + \alpha^{c}(Post1990 \times Overlap_{s}) + \phi^{c}_{s} + \phi^{c}_{t} + \epsilon^{c}_{st} \qquad (7)$$

where $Collab^{j}_{st}$ is one if the scientist s has co-authored with another scientist belonging to a specific group j in year t, and zero otherwise.

In the first five columns of Table 5, collaboration patterns of East German scientists are shown and this indicates a significant change. West-overlapping East Germans 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. There is, however, no statistically significant difference regarding establishing connections to West European or US scientists

[6]All 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

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

between West-overlapping and non-West-overlapping East Germans[7]. West-overlapping East Germans tend to collaborate significantly less with outmigrating East Germans than other East Germans do. All three measures of research overlap (correlation coefficient, intensity, and similarity) yield qualitatively very similar results.

The last two columns of Table 5 are based on the specification

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

where East and West German scientists are pooled together to compare differences in their tendencies to collaborate internationally. 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. West-overlapping East Germans 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 differences between East and West German scientists working in predominantly West German fields. Soviet scientists are losing their relative prominence for West-overlapping East Germans, which may be a result of 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. West Germans establishing connections to Soviet researchers after 1995 much faster than East Germans do is thus plausible. The mirror image of this occurrence would be East Germans who work on West German topics connecting to West European and American scientists, however we detect no significant difference in differences. When professors are excluded from the analysis, we obtain qualitatively similar results as shown in Table A.3 in the appendix. Section B in the Appendix provides a further discussion on the productivity and collaboration differences among East German professors.

[7]Collaborations with West European countries during 1990s are linked to significant increase in the scientific productivity in the East European countries (Jurajda et al., 2017), and this might be the reason why we don't find any difference in differences between West-overlapping and non-West-overlapping East German scientists, as these collaborations are crucial for either group.

The main finding of this subsection is that connections to West German scientists are not the main driving force behind the three productivity measures of the East German science documented in the previous subsection. West-overlapping East Germans collaborate with West German peers significantly more than other East Germans do (Table 5), which is expected, nevertheless these connections do not necessarily lead to more publications or citations compared to other East Germans, just publications in higher impact factor journals. Westernization of East German academia pushes for more productivity, leading to significant catch up with West Germans but the access to new peers does not seem to give an edge to East German scientists as one would have hoped. Moreover, connection to Soviet scientists seem to play an important role in this process too for East Germans who have not been working in West German topics before re-unification. We open this black box in the next subsection.

4.2 Emigrating Collaborators and Soviet Collaborators

West-overlapping East German scientists lost their relatively high difference in connections to *outmigrants* and former Soviet scientists after re-unification, as shown in Table 5. These are two groups of collaborators with whom collaboration was possible also before re-unification, and we investigate collaboration and productivity differences after re-unification focusing on pre-1990 collaboration with these two groups. Some East German scientists left the former East German territory after German re-unification and emigrated elsewhere, may it be former West Germany, Western Europe, or anywhere else in the world. Although there are no official barriers to prevent them from collaborating with their East German peers back home, such a collaboration might have become difficult due to preference or practical reasons. As a result, many East German scientists who chose to remain in former East Germany after re-unification would have lost their connections to those peers who chose to emigrate, which we label as emigrant co-authors. 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 re-unification. Although collaborations with Soviet scientists

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.

were not explicitly restricted, 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. As a result, pre-1990 Soviet collaborations may be used as an additional proxy for the research strength of East German scientists in case these qualities fail to be picked up by our productivity measures explicitly. Although WoS is a comprehensive source of pre-1990 research activities in the East bloc (as discussed in Section 3) the number of citations may be affected by several factors of the non-Western research culture, for instance, low number of publications may be affecting citations going out to previous research, as there is less opportunity to get cited. Hence one may expect to find positive selection of East German scientists when their collaborations with Soviet scientists are considered. A Soviet collaboration may potentially signal high productivity and high quality research, but the argument for the exogeneity of being West-overlapping still holds.

In Table 6, we document the exact numbers of the above mentioned collaborations. 561 East German scientists have neither an emigrant nor a Soviet collaborator prior to 1990. 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 emigrant co-author. 70 East German scientists have at least one Soviet and also one emigrant 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

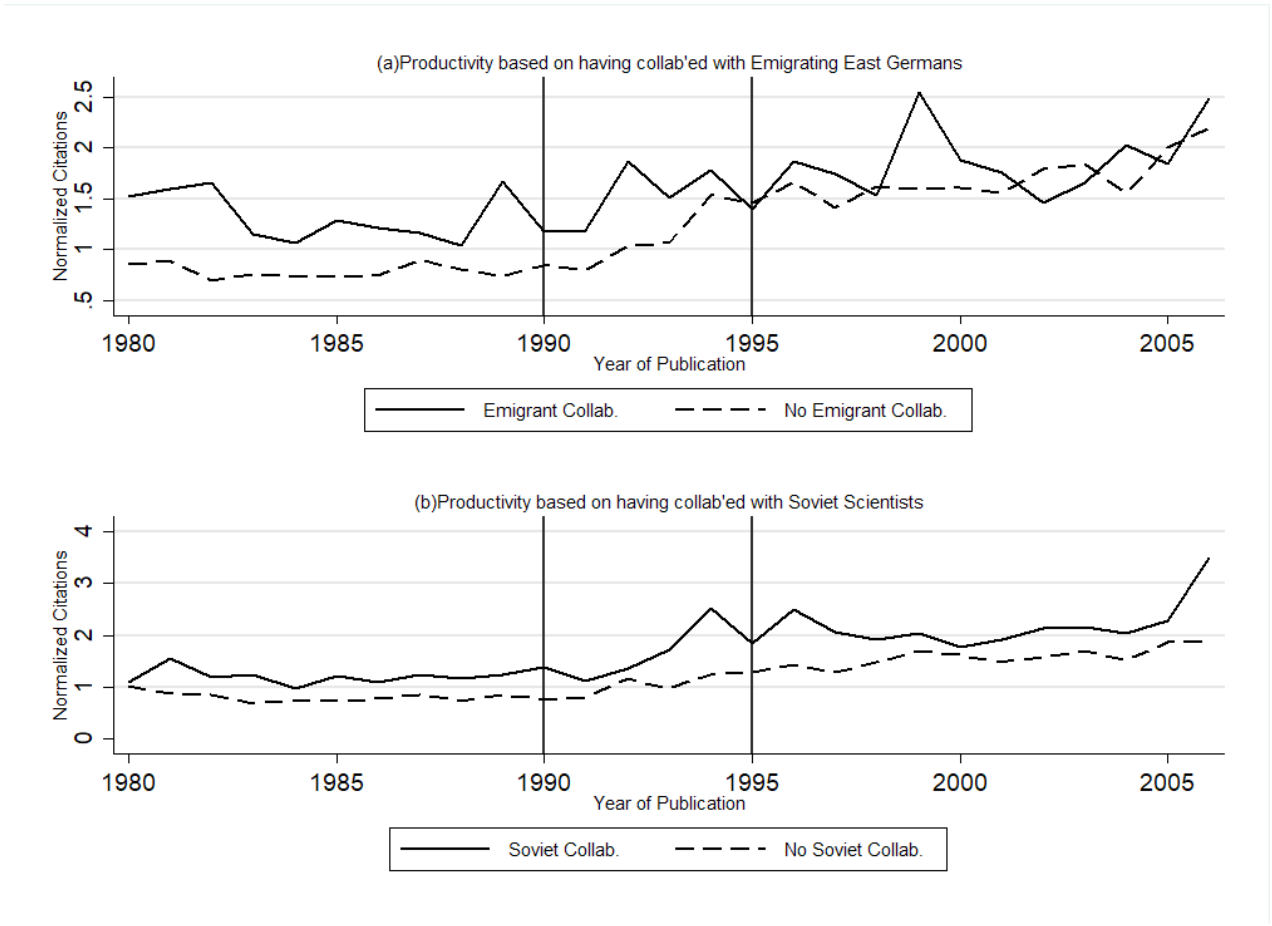

Figure 5: Citations of East German scientists based on their pre-unification collaborations

scientists who have been collaborating with Soviet scientists on a paper where another East German co-author from that paper ended up emigrating after re-unification. We will treat these two group of Soviet collaborations separately in our analysis for robustness purposes.

Figure 5 shows citations of East German scientists who did collaborate at least once with another East German peer before 1990 who chose to emigrate after 1990 (Panel a); and at least once with a Soviet scientist before 1990 (Panel b). They are compared against East Germans who did not have any emigrant or Soviet co-authors, respectively. Both subsets have higher citations throughout the 80s. Those who have had emigrating co-authors start losing their edge as early as 1994, whereas those with Soviet collaborations maintain their lead against their comparison group through 2000s.

East Germans who had an emigrant or a Soviet collaborator differ from their peers in their research productivity and quality but the argument that their overlap with the pre-1990

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*)

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

West German research is exogenous still holds and we make use of this exogeneity. In Table 7, we show difference-in-differences for collaboration tendencies and productivity measures across East German scientists who had an emigrant or a Soviet collaborator during the 1980s. We find that those East German scientists who had an emigrant co-author tend to connect to West German, West European, and American scientists significantly more than their peers do. They lost ground against their peers in terms of citations and the impact factor of journals where they publish.[8] Those whose research overlaps largely with the pre-1990 West German research do not have such loss in their relative productivity, however, they 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 re-unification produce more papers, publish those papers in high impact outlets, and receive more citations after re-unification compared to their East German peers. They get connected to West European and American scientists, at the same time they are being less connected to former Soviet scientists compared to their peers. When further interacted with the West German research overlap, we find that those who have had Soviet collaborators lose ground after re-unification in all accounts especially in citations.

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 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 West German agenda of 1980s, namely *intensity* and *similarity*, in the Appendix in Tables A.4 and A.5, respectively, and obtain fairly comparable to those shown in Table 7.

4.3 Research Proximity in Collaborations

Although West-overlapping East Germans are shown to collaborate relatively more with West Germans after re-unification (Table 5), difference-in-differences vary depending on whether they have had an emigrant or a Soviet collaboration as well (Table 7). Why is this happening and how does this relate to productivity outcomes? To find out, we investigate in

[8] Although not significant at p=0.1, one should note that both coefficient estimates are negative and larger than absolute value of their standard errors.

this subsection how an East German scientist's expertise in the field compares to that of her collaborators. Research proximity[9] of any two scientists' research portfolios affects the likelihood of these scientists engaging in collaboration with another as well as the quality of research generated by 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. 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.

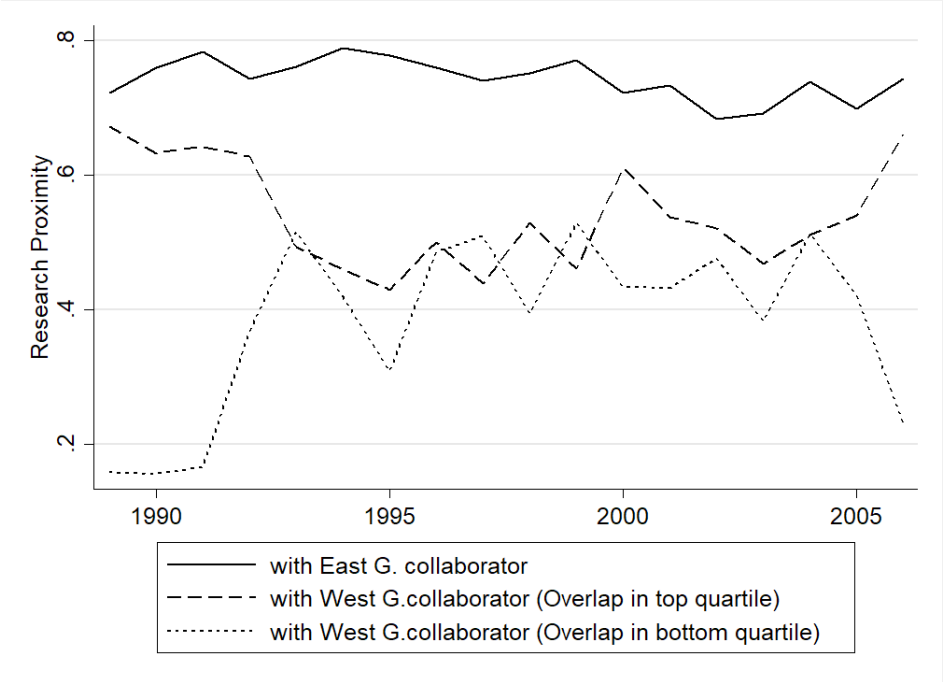

Figure 6: Research proximity of East German scientists to their collaborators (1989-2006)

Figure 6 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 West-overlapping (top quartile) and West-

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

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

	(1) Research Proximity
Post1990*Overlap	-0.182^{c}
	[0.100]
Post1990*Soviet	0.303^{c}
	[0.162]
Post1990*Soviet*Overlap	-1.249^{b}
	[0.514]
Post1990*Emigrant	-0.0541
	[0.0620]
Post1990*Emigrant*Overlap	0.352^{c}
	[0.210]
Observations	11418

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.
Regression includes age controls, quality controls, as well as year and individual FE.

non-overlapping (bottom quartile) East Germans. Those in the top quartile have a greater research proximity to their West German collaborators compared to those in the bottom quartile. This difference is large during the early 1990s, then it shrinks but still remains throughout the entire period.

We regress the research proximity of East German scientists with their collaborators on time interactions listed in Table 8, quality and life cycle controls, year and individual fixed effects. Results shown in Table 5 reveal that West-overlapping ones tend to have a lower research proximity to their collaborators after re-unification. Combining these findings with those from the Table 5, West-overlapping East Germans collaborate with West German scientists after 1990 who are further away to their expertise profile than their pre-1990 collaborators. Moreover, if they have been collaborating with Soviet scientists before re-unification, then this effect becomes even stronger. Non-West-overlapping East Germans, however, have a greater proximity to their collaborators, especially those who have had a Soviet collaboration pre-1990. This proximity correlates with a significant relative increase

in their publications and citations following the Westernization period. In this respect, West-overlapping East Germans engage in more field-distant collaborations that bring them high impact-factor journal publications but neither more publications nor higher citations. A possible consequence of collaborations that have a low research proximity is to switch into a new field, namely into the field of the collaborator if the collaborative work is mainly focused on collaborator's field. Field-switching behavior, also referred to as the *cognitive mobility*, is a plausible strategy for scientists to cope with an institutional restructuring or any other large scale exogenous demand shock (Borjas and Doran, 2015). Cognitive mobility of East German scientists is analyzed in the next section.

5 Cognitive Mobility of East German Scientists

As the Westernized academic and scientific setting forces East German scientists to be as productive as possible, some may find it optimal to shift their productive capacities into research areas where they enjoy higher marginal productivities. Figure 7 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 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. Twenty research fields are listed on the x and y axes in Figure 7, ten each for East and West Germany (shown in red and blue, respectively) where they dominated[10] the most during the 80s. Broader disciplines where these individual fields belong to are listed across axes.

Table 3 in Section 3.1 documents that 8.5% of all peer-reviewed science and engineering publications of East Germans was in physical chemistry during 1979-1989. Figure 7 here reveals that most scientists whose main field is physical chemistry before 1990 still have

[10]We calculate for each research field the relative East or West dominance by taking the difference of the average share of pre-1990 publications in each field between West and East German scientists.

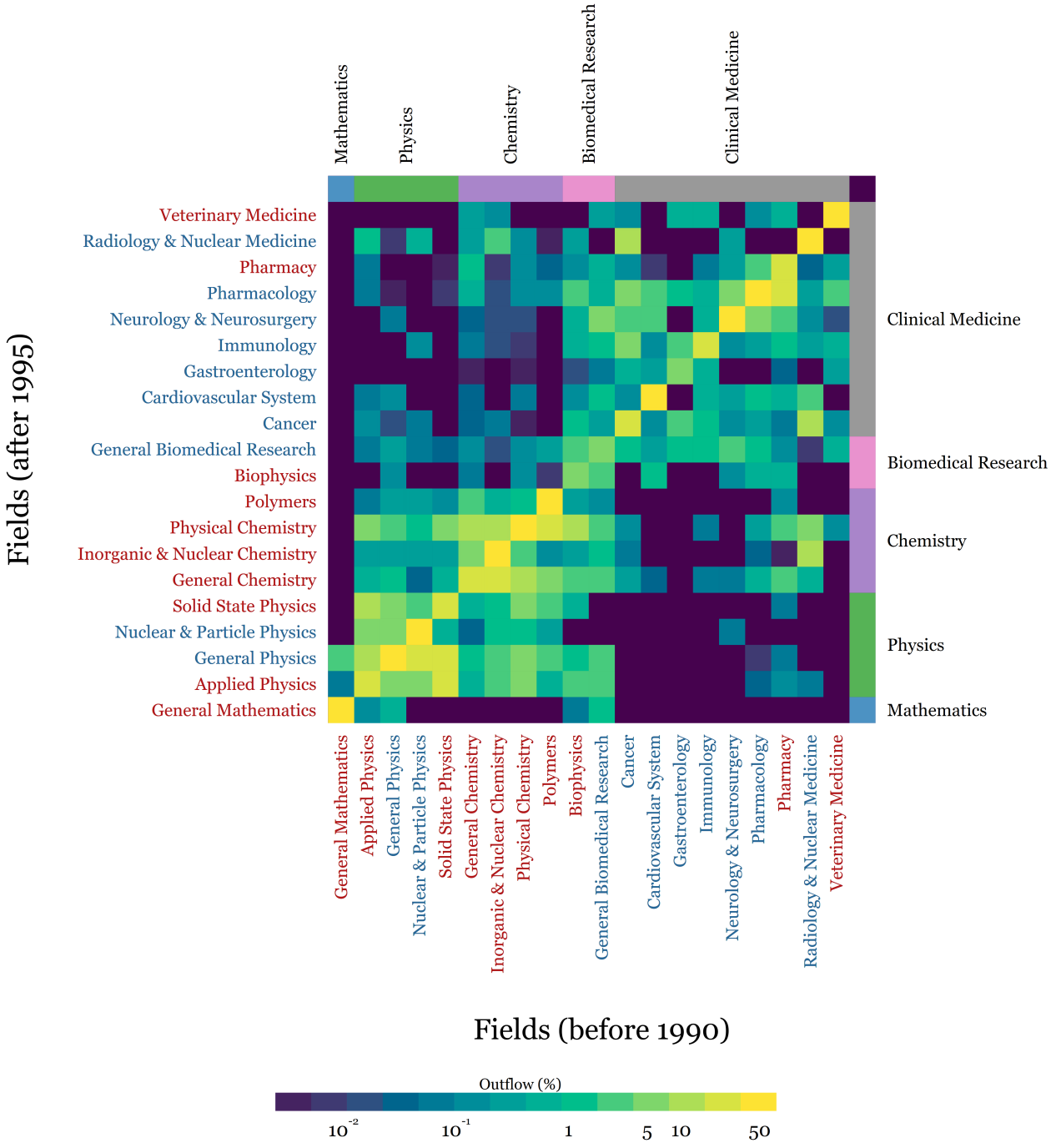

Figure 7: Cognitive mobility of East German scientists across top fields of East and West German science from 1979-1989 to 1996-2006

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. There is, however, very little transition observed between physical chemistry and fields of clinical medicine, as revealed by darker colors of the heat map. We further observe that East German scientists who publish in a West German top field before 1990 tend to remain in that field. This observation, however, needs further investigation which follows below.

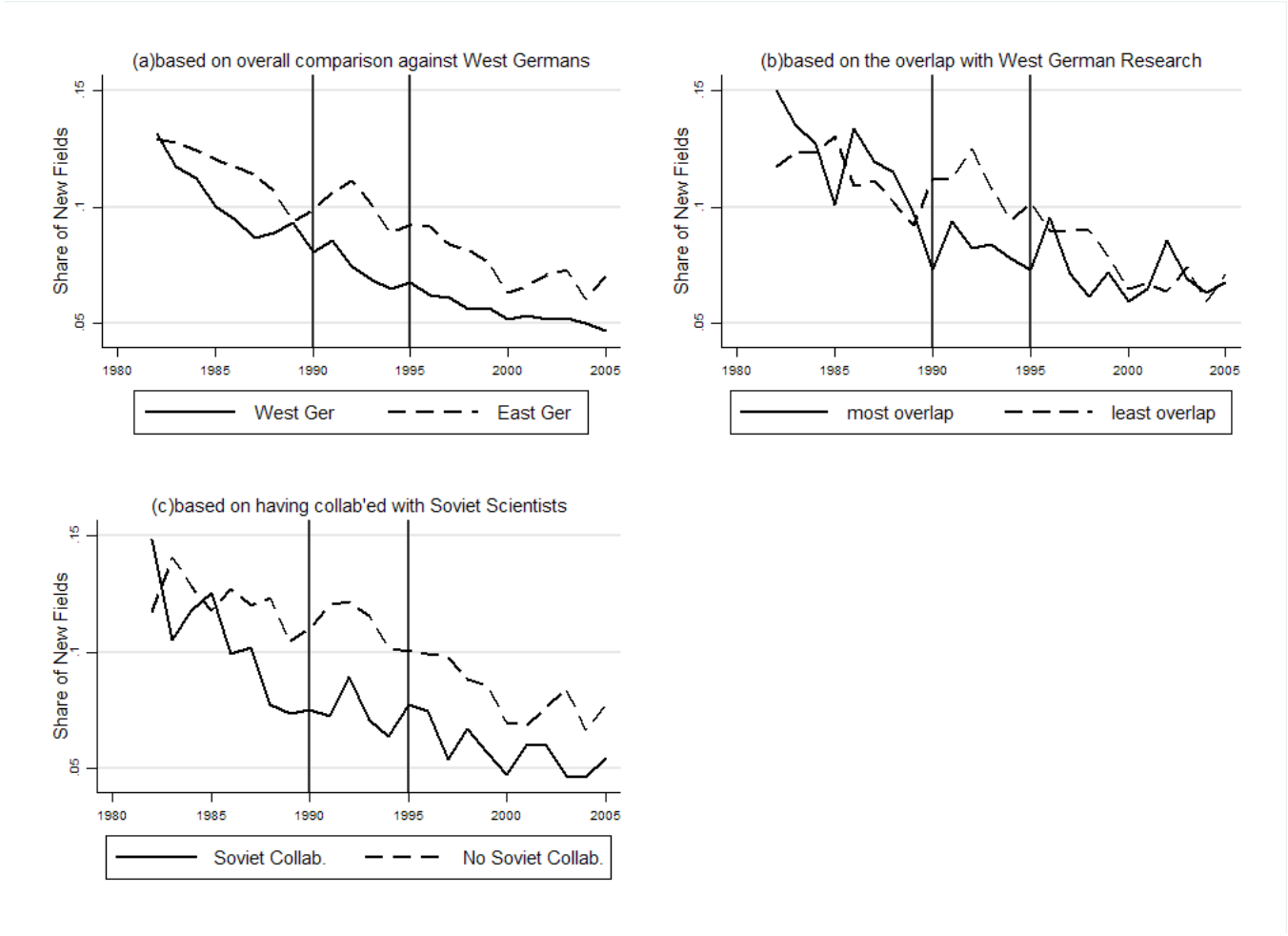

Figure 8: Share of new fields in East German scientists' publications

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 8, 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, it just needs to show up in at least one publication of this scientist. In panel (a) of Figure 8, we compare the share of new fields in East and West German scientists' publications and observe that this share is higher for East Germans consistently from the mid 1980s to mid 2000s. We compare West-overlapping (top quartile) and non-West-overlapping (bottom quartile) East German scientists in panel (b). Non-West-overlapping East Germans show a larger tendency to switch to a new field after 1989 compared to their peers. Interestingly, East Germans who collaborated at least once with a Soviet scientist before 1990 are less likely to publish in a new field, as shown in panel (c).

We estimate difference-in-differences including standard controls for research quality, academic age as well as individual and year fixed effects using the following linear probability model:

$$NewField_{st} = \beta X_{st} + \gamma_1(Post1990 \times Overlap_s) + \gamma_2(Post1990 \times Soviet_s) + \gamma_3(Post1990 \times Overlap_s \times Soviet_s) + \phi_s + \phi_t + \epsilon_{st} \quad (9)$$

where the vector X_{st} includes quality and age controls, $Soviet_s$ is the share of Soviet collaborations in pre-1990 publications of scientist s. 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). 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 West-overlapping East Germans are less likely to publish in a new field after 1995. When controlled for the overlap with the pre-1990 West German research, the stock of pre-1990 Soviet collaborations has no significant on difference-in-differences of the likelihood of publishing in a new field after 1995.

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

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	-0.0657	0.0326	0.0293	-1.165^a	-1.013^a
	[0.0414]	[0.105]	[0.0310]	[0.0772]	[0.215]	[0.375]
Post1990*Soviet	-0.0502		-0.0889		-0.0497	
	[0.0759]		[0.0887]		[0.886]	
Post1990*Overlap*Soviet	0.141		0.149		0.0673	
	[0.278]		[0.206]		[1.631]	
Post1990*East German CA		1.506^a		1.014^a		21.26^a
		[0.0431]		[0.0351]		[0.542]
Post1990*Overlap*EastG CA		-4.755^a		-2.160^a		-38.20^a
		[0.147]		[0.0876]		[0.978]
Post1990*Soviet CA		0.0799^b		0.0746^b		0.407
		[0.0322]		[0.0353]		[0.309]
Post1990*Overlap*Soviet CA		-0.239^b		-0.159^c		-0.706
		[0.113]		[0.0854]		[0.563]
Observations	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.

We estimate

$$NewField_{spt} = \beta^{ca} X_{st} + \gamma_1^{ca}(Post1990 \times EastGermanCA_{spt}) + \gamma_2^{ca}(Post1990 \times EastGermanCA_{spt} \times Overlap_s) + \gamma_3^{ca}(Post1990 \times SovietCA_{spt}) + \gamma_4^{ca}(Post1990 \times SovietCA_{spt} \times Overlap_s) + \phi_s^{ca} + \phi_t^{ca} + \epsilon_{st}^{ca} \quad (10)$$

where the observations are at publication level. $NewField_{spt}$ is one if publication p of an East German scientist s in year t is in a new field, and 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.

Columns (2), (4), and (6) in Table 9 display coefficient estimates for the above linear probability model. West-overlapping East Germans tend not to embark on a new field in their post-1990 collaborations with East German scientists or Soviet scientists. Non-West-overlapping ones, however, are highly likely to publish in a new field when collaborating with them. 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 Soviet scientists yet smaller point estimates and smaller divergence from the estimated standard error signals a weaker tendency in either direction.

5.1 Attrition

Another possibility for scientists who see their marginal productivity level to not live up to their (or their employers') expectations is, to leave research-active careers altogether to take up other positions where they are not required to publish scientific peer-reviewed research. Our dataset does not explicitly indicate if and when a scientist leaves a research active position, but we use the last publication of a scientist in our dataset as the date they leave. Our analysis in this study covers years up to 2006, but we trace all individuals in our dataset

up to 2018 so that one can credibly claim that a scientist left the sector if there is no publication to be found for them from whenever they have their last publication in our analysis to 2018. We refer to the year where a scientist published their last publication as the year they exit their research-active career.

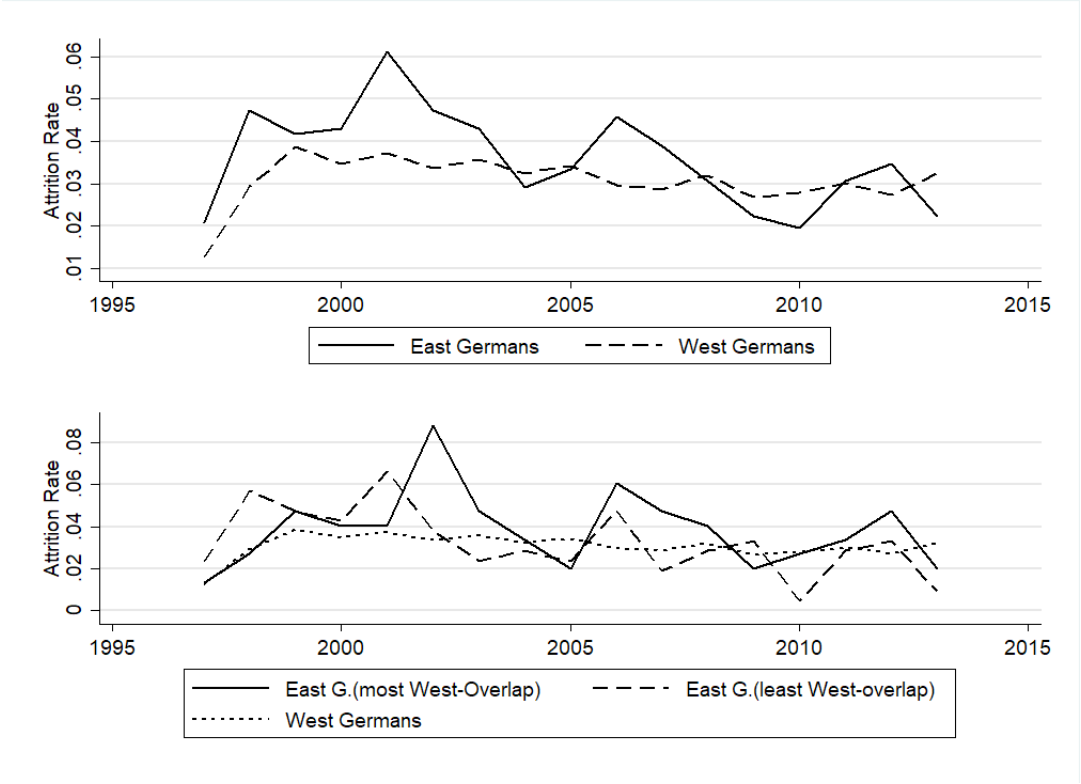

Figure 9: Attrition rates of East and West German Scientists based on publication data

Figure 9 documents the rate at which East and West German scientists (excluding professors) exit research active careers. In 1998, the attrition rate of West German scientists in our data is 3% whereas this ratio is almost 5% for East Germans. Attrition rate of East Germans reached its annual peak at 6% in 2001; West Germans' attrition rate was less than 4% the same year. In the lower panel of Figure 9, East German scientists with the most (top quartile) and the least (bottom quartile) West German research overlap are depicted. The annual attrition rate of those in the top quartile reaches as high as 6% in 1998. Although East German scientists in the bottom quartile experience such high attrition rates in 1990s, those in the top quartile experience also high annual attrition rates from early 2000s on.

We create a binary variable *attrition*, which becomes one in the year of an individual's last publication and zero in all other years before that, to regress it on interactions of reunification with the research overlap. Results are shown in Table 10. The structure of *attrition* has a strict time trend for the dependent variable, as it is always zero for each individual-year pair and is one only for the final observation. Although this pattern of the dependent variable may potentially create an identification problem, we are solely interested in interactions of time-invariant variables in this model. Most of our control variables (such as life cycle productivity controls), on the other hand, may have a time trend and we detrend them by regressing each of them on individual fixed effects and a time trend to use their residuals as detrended controls in our analysis.

The first six columns of Table 10 are restricted to East German scientists only. When the sample time is restricted to 1996-2001, all three definitions that we use to capture research overlap imply a relatively lower probability of attrition for West-overlapping East Germans. When the sample is extended to 2006, this relation becomes ambiguous. Furthermore, we find no significant difference in the attrition rate when pre-1990 Soviet collaborations are controlled for neither in the shorter time sample nor in the full sample.

The last three columns of Table 10 pull East and West Germans together. East German scientists are significantly more likely to exit research-active careers compared to West German scientists. When interacted, research overlap has a negative coefficient, which is larger than its standard error in case of intensity. These results reveal that the descriptive observations of Figure 9 are robust and statistically significant when controlled for productivity and life cycle effects. Hence East German scientists have a larger propensity to leave research-active sectors. Although West-overlapping East Germans seem to be immune to higher attrition rates in the early years following the Westernization, their seemingly advantageous topical orientations do not necessarily provide a safe harbor either.

Table 10: Differences in attrition rates after re-unification

	East Germans only						East and West Germans		
	Corr.Coef.		Intensity		Similarity		Corr.Coef.	Intensity	Similarity
	to 2001	to 2005	to 2001	to 2005	to 2001	to 2005			
Post1990*Overlap	-0.0443^{c}	-0.00174	-0.0183	0.00120	-0.252^{c}	0.0160	0.0171^{a}	0.0164^{a}	0.0314
	[0.0249]	[0.0244]	[0.0161]	[0.0159]	[0.140]	[0.137]	[0.00646]	[0.00439]	[0.0324]
Post1990*East							0.0149^{b}	0.0163^{a}	0.0108
							[0.00620]	[0.00614]	[0.0691]
Post1990*East*Overlap							-0.0191	-0.0173	0.000196
							[0.0240]	[0.0159]	[0.128]
Observations	9830	12365	9830	12365	9830	12365	134072	134072	134072

Dependent variable is *attrition* that becomes one at the year of the last observation for an individual and zero in all years before that.

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.

6 Discussion and Conclusion

We investigate changes in East German STEMM scientists' production of peer-reviewed journal articles to establish causal effects between their productivity and the Westernization of the East German academic structure. We find a strong correlation between Westernization and productivity: East German scientists catch up with their West German peers on major productivity measures following the Westernization of East German academia. To identify the driving mechanisms underlying this observation, we investigate the differences between East Germans arising from the overlap of their pre-1990 research with West German research. Those with West-overlapping research publish in journals with higher (field-adjusted) impact factors after re-unification, but interestingly, their West-oriented research agenda does not seem to provide any particular advantage as far as their productivity in terms of the number of publications or citations is compared to other East German scientists.

Although West-overlapping East Germans collaborate increasingly more with West German peers (who may be located in former West Germany or may have relocated to the former East Germany) after re-unification, it is not them for whom significant differences in publication numbers and citations are observed. It is the non-West-overlapping scientists with Soviet collaborators who experience a significant difference in publication numbers and citations after re-unification. It is also exactly this subset of East German scientists who engage in collaborations involving very high research proximity with their peers. West-overlapping East Germans collaborate more with West Germans and such collaborations come with less proximity compared to those with other East Germans. Less research proximity does not necessarily mean that they are switching research fields, as West-overlapping East Germans are significantly less likely to embark on a new research field than non-West-overlapping East Germans. East German scientists are significantly more likely to exit research-active careers. Although non-West-overlapping East Germans are more likely to do so in the short-run, we find no significant difference between the exit rates of West-overlapping and non-West-overlapping East Germans in the first decade following Westernization.

Our findings show to what extent the observed correlation between Westernization and improved productivity arises due to efficiency gains in scientific production and to what ex-

tent this is the result of the reallocation of productive capacities across sectors. Although the West-peer effect does not manifest itself in two of the three major productivity measures that we employ in our analysis, it shows up in East German scientists' collaboration patterns and field-switching behavior. Non-West-overlapping East Germans have higher research proximity to their post-re-unification collaborators, meaning that they collaborate, on average, more with collaborators whose research background and expertise are very similar to their own. Interestingly, however, they tend to switch fields significantly more than West-overlapping East Germans, although they collaborate with more similar collaborators. This can possibly be interpreted as a sign of desperation. If the aim is to embark on a new field, then it would be more reasonable to collaborate with experts from that field so that collaborators' research proximity would be larger, almost by construction. We take this as a strong indication of the need to reallocate productivity across cognitive space.

Reallocation takes place across scientific fields or, in the extreme case, via exiting a research-active career altogether. This is the dominant feature that underlies East German scientists' productivity differences when the West-peer effect is removed. Hence, the observed productivity improvements are most likely to be generated not by efficiency gain but by the selection (or most likely self-selection) of more productive East German scientists. East German scientists in our sample are those who actually *survived* the initial phase of the Westernization process and had been approved to be politically untainted and scientifically sound, yet the observed productivity gains of Westernization follow mainly from the reallocation of productive activity. That our sample consists of survivors of the initial phase of Westernization is likely to lead to underestimation rather than overestimation of the true size of reallocation, which would have been more pronounced if those who moved out of (or were removed from) scientific careers from 1991 to 1995 were included.

Our findings draw lessons about the costs and benefits of the publish-or-perish era that we are currently living in and hence have immediate implications for science and innovation policy. Scientific activities are being undertaken in a world where competitive pressures are growing exponentially. As more universities, research institutes, and scientific bodies enter the stage of science and innovation, the rules of the *publish-or-perish* game are being inflicted on faculty members or researchers by administrators of aspiring universities or

research establishments. Although research administrators might be motivated to impose more competitive standards to make their faculty members or researchers more productive, it is crucial to understand that academic productivity in transition to a highly competitive environment is generated through reallocation rather than efficiency gain. One way to avoid this problem is to open up significant opportunities for new collaborations for staff; however, this will have unequal effects on large or well-established fields and rather small and niche fields.

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Appendices

A Additional Tables

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

	Overlap based on corr.coef.			*Overlap based on intensity*			*Overlap based on similarity*		
	Papers	Cites	IF	Papers	Cites	IF	Papers	Cites	IF
Post1990*Overlap	-0.0250^a	-0.137^a	-0.140^a	-0.00824^a	-0.141^a	-0.0979^a	-0.187^a	-0.0752	-0.344^a
	[0.00106]	[0.0360]	[0.0186]	[0.000651]	[0.0248]	[0.0133]	[0.00600]	[0.170]	[0.0864]
Post1990*East	0.00271^a	0.217^a	0.145^a	0.00414^a	0.206^a	0.142^a	-0.0283^a	0.378	-0.135
	[0.000556]	[0.0222]	[0.0126]	[0.000593]	[0.0223]	[0.0125]	[0.00834]	[0.259]	[0.133]
Post1990*Overlap*East	0.00899^a	0.0263	0.188^a	0.00262	0.0520	0.144^a	0.0594^a	-0.281	0.596^b
	[0.00273]	[0.0882]	[0.0513]	[0.00175]	[0.0567]	[0.0337]	[0.0158]	[0.483]	[0.247]
Observations	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 A.2: Differences in the productivity of East and West German scientists after 1990 -excluding Professors

	East Germans only			East and West Germans		
	Papers	Cites	IF	Papers	Cites	IF
Panel A:Overlap based on corr.coef.						
Post1990*Overlap	-0.173	-0.0275	0.520^{a}	-0.430^{a}	-0.185^{a}	-0.335^{a}
	[0.150]	[0.117]	[0.184]	[0.0504]	[0.0445]	[0.0473]
Post1990*East				0.0592	0.154^{a}	0.243^{a}
				[0.0379]	[0.0311]	[0.0457]
Post1990*Overlap*East				0.195	0.138	0.794^{a}
				[0.153]	[0.129]	[0.184]
Panel B:Overlap based on intensity						
Post1990*Overlap	-0.000319	-0.0107	0.390^{a}	-0.207^{a}	-0.0870^{a}	-0.163^{a}
	[0.0962]	[0.0729]	[0.126]	[0.0321]	[0.0301]	[0.0315]
Post1990*East				0.0460	0.165^{a}	0.247^{a}
				[0.0381]	[0.0309]	[0.0467]
Post1990*Overlap*East				0.181^{c}	0.0629	0.526^{a}
				[0.100]	[0.0816]	[0.127]
Panel C:Overlap based on similarity						
Post1990*Overlap	-1.764^{c}	-0.198	1.754^{c}	-3.194^{a}	-0.589^{b}	-1.275^{a}
	[0.933]	[0.684]	[1.012]	[0.275]	[0.229]	[0.238]
Post1990*East				-0.377	0.0175	-0.960^{c}
				[0.482]	[0.384]	[0.516]
Post1990*Overlap*East				0.867	0.308	2.547^{a}
				[0.904]	[0.721]	[0.959]
Observations	12365	9223	9209	134072	106314	106162

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.

Table A.3: Differences in collaborations of East German scientists after 1990 -excluding Professors

		East Germans with				East/West Ger with	
	West Ger	Inmig.	Outmig.	West/US	USSR	West/US	USSR
Panel A:Overlap based on Corr.Coef.							
Post1990*Overlap	0.157^{b}	0.124^{b}	-0.139^{b}	0.000122	-0.121^{c}	-0.0415	0.137^{a}
	[0.0612]	[0.0525]	[0.0546]	[0.0882]	[0.0732]	[0.0285]	[0.0196]
Post1990*East						0.0361^{c}	0.0199
						[0.0208]	[0.0163]
Post1990*Overlap*East						0.0430	-0.272^{a}
						[0.0928]	[0.0754]
Panel B:Overlap based on Intensity							
Post1990*Overlap	0.0742^{c}	0.0913^{b}	-0.0968^{b}	0.0237	-0.0526	-0.0204	0.117^{a}
	[0.0394]	[0.0375]	[0.0407]	[0.0575]	[0.0453]	[0.0191]	[0.0139]
Post1990*East						0.0300	0.0158
						[0.0209]	[0.0161]
Post1990*Overlap*East						0.0487	-0.170^{a}
						[0.0610]	[0.0483]
Panel C:Overlap based on Similarity							
Post1990*Overlap	1.004^{a}	0.842^{a}	-0.784^{b}	0.157	-0.636	-0.266^{c}	0.168^{c}
	[0.349]	[0.307]	[0.314]	[0.480]	[0.429]	[0.148]	[0.0983]
Post1990*East						-0.147	0.518^{b}
						[0.261]	[0.219]
Post1990*Overlap*East						0.356	-1.035^{b}
						[0.490]	[0.413]
Observations	9223	9223	9223	9223	9223	106314	106314

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.

Table A.4: 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*)

	Collaboration					Productivity		
[Panel A]	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Soviet	0.0932	0.115	0.0328	0.277	-0.982^{a}	0.439	0.529^{b}	0.480
	[0.150]	[0.140]	[0.0782]	[0.199]	[0.206]	[0.327]	[0.262]	[0.359]
Post1990*Soviet*Overlap	-0.120	-0.347	-0.00196	0.0545	0.478	0.195	-0.588	-1.125
	[0.306]	[0.274]	[0.157]	[0.427]	[0.520]	[0.734]	[0.573]	[0.737]
Post1990*Emigrant	0.206^{c}	0.0344	-0.815^{a}	0.0820	0.00143	-0.382	-0.282	-0.252
	[0.105]	[0.0895]	[0.111]	[0.149]	[0.118]	[0.267]	[0.180]	[0.240]
Post1990*Emigrant*Overlap	-0.431^{a}	0.0369	-0.253	0.00262	-0.0259	0.570	0.275	0.406
	[0.154]	[0.152]	[0.176]	[0.268]	[0.174]	[0.466]	[0.288]	[0.511]
[Panel B]	West Ger	Inmig.	Outmig.	West/US	USSR	Pubs.	Cites	IF
Post1990*Soviet(without	0.0280	0.159	0.0554	0.304	-1.045^{a}	0.395	0.653^{b}	0.303
Emigrants)	[0.147]	[0.148]	[0.0777]	[0.210]	[0.221]	[0.347]	[0.268]	[0.380]
Post1990*Soviet*Overlap	-0.0548	-0.409	-0.0656	0.0167	0.604	0.278	-0.688	-0.702
(without Emigrants)	[0.313]	[0.292]	[0.148]	[0.452]	[0.557]	[0.789]	[0.592]	[0.763]
Observations	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 A.5: 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*)

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

B 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 re-unification. 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.

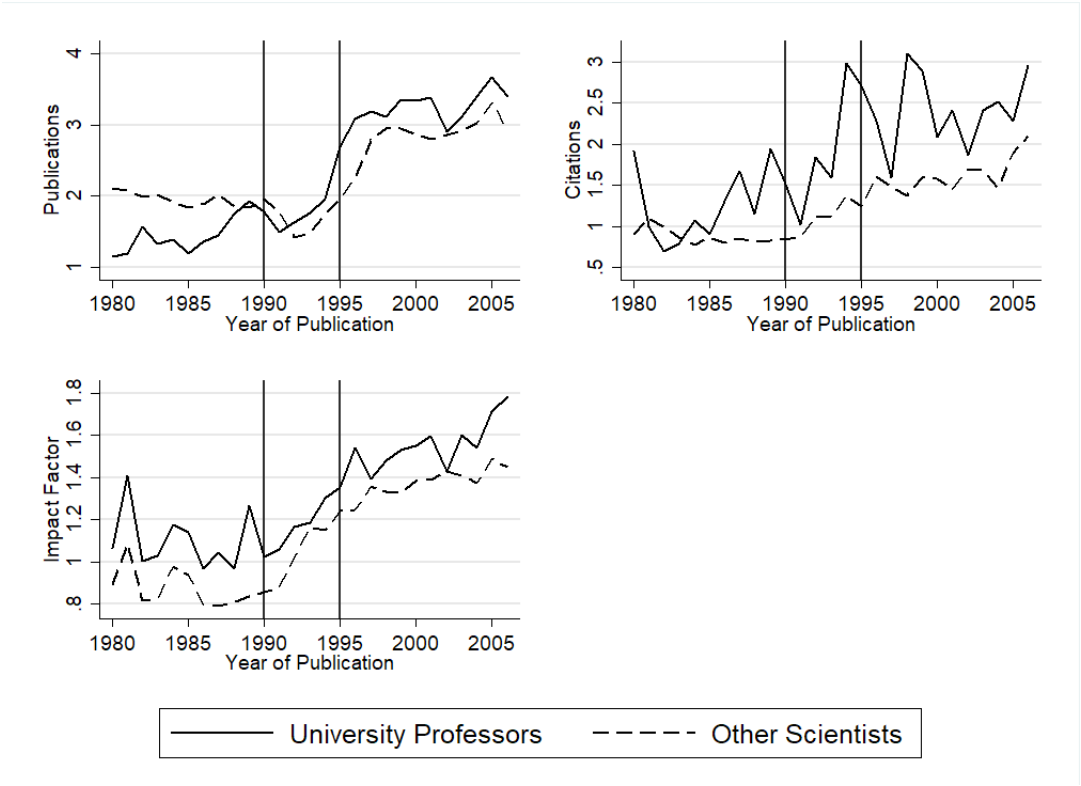

Figure B.1: Productivity of East German professors and other scientists

In Figure B.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 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 B.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 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 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.

Table B.1: Differences in collaboration and productivity among professors in East German universities after 1990

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