
Knowledge Flows in Science and Innovation

From the Embryonic Internet to the German Reunification

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All knowledge is connected to all other knowledge.

The fun is in making the connections.

— Arthur Aufderheide

Preface

Our world is profoundly shaped by ideas. Throughout history, inquisitive minds have contributed to economic and societal well-being by generating new knowledge. However, societies would not have advanced to their current state if people had kept their ideas secret. Instead, for knowledge to accumulate it has to be shared and reused by others. Economists have long perceived this cumulative process as a key determinant of economic growth (e.g., Romer, 1990; Weitzman, 1998). Given the pivotal role of knowledge, it is crucial to understand its movement and dissemination within the economy.

Knowledge is preserved and shared in various ways: it may be transmitted through written work, disseminated through modern communication channels such as mass media, or embedded in individuals, who share it through personal interaction. Using quantitative evidence, this dissertation sheds light on various ways in which knowledge circulates within society. In line with the famous saying of George Santayana (1905) “Those who cannot remember the past are condemned to repeat it”, all three chapters of this dissertation draw on historical settings to gain insights into contemporary questions.

Each chapter is self-contained and examines a different channel of knowledge transmission. In the first part of this thesis, I provide evidence on knowledge exchange in written form. In the second part, I investigate knowledge transmission via mass media, and in the third part, I examine knowledge flows through people. While Chapters 1 and 2 focus on the impact on patenting, Chapter 3 assesses the effect on researchers’ publications.

Chapter 1 of this dissertation, which is based on joint work with Markus Nagler and Martin Watzinger (Wernsdorf et al., 2022), provides evidence on how the rise of information and communication technologies (ICT) has shaped innovation. Governments across the globe spend significant resources on ICT, believing that this would spur innovation and ultimately economic growth. This is reflected, for example, in the U.S. president’s budget submission report for the fiscal year 2025, which states that spending on these technologies “has evolved from a minor component of the President’s annual budget submission to a dedicated chapter over the past two decades” (Fiorentino, 2024). These policy choices are consistent with current theories of endogenous growth, which highlight the cumulative idea creation process as key

In the preface, the grammar and the wording of several paragraphs were refined using ChatGPT.

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determinant of economic growth (e.g., Romer, 1990; Weitzman, 1998). Taking these theories at face value, ICT could foster innovation by reducing barriers to knowledge exchange and collaboration. However, whether the desired effects will materialize is not straightforward. Much of the knowledge involved is difficult to codify, making it challenging to transfer it. Additionally, innovation is frequently characterized by secrecy, which may cause inventors to hesitate in sharing valuable information. Finally, for collaborations to take place, the benefits must outweigh the costs.

Does access to ICT increase local innovation? This chapter addresses this question by exploiting the staggered introduction of BITNET, an early version of the internet. Upon its introduction in the U.S. in 1981, it merely connected three U.S. universities. However, the network quickly expanded to institutions worldwide until 1991. BITNET significantly reduced the costs for communication in written form by introducing e-mail service, real-time messaging, and online discussion groups. With the rise of the World Wide Web, the network was discontinued in 1996.

Due to BITNET being an academic network, we focus our analysis on patents assigned to universities (“university patents”). Using a differences-in-differences approach, we compare changes in the number of patents in a region before and after the local university’s connection to BITNET with changes in the number of patents in regions around universities that have not yet connected to the network.

In response to the introduction of BITNET, patenting in regions surrounding BITNET-adopting universities increases on average by 0.3 university patents per 100,000 population. While we find an increase in citation-weighted patents per 100,000 population of 1.4, the average university patent receives fewer citations. The resulting patents are primarily filed by inventors in non-urban regions and reflect an increased use of prior art from other connected universities. Most importantly, the new patents are closely linked to science, either by directly citing scientific research articles or by indirectly citing them through another patent. In line with facilitated knowledge transmission in written form, these patents use novel words to the U.S. or the region. Further, these patents are longer, use more figures, and are more similar to existing patents, suggesting a decrease in novelty.

Collaboration appears to be the key driver of the observed effects. In particular, new inventor teams, i.e., teams involving individuals who have not patented together before, increase their patenting most in response to the introduction of BITNET. Further, collaboration between inventors at BITNET-connected universities increases. These results confirm the notion that BITNET has facilitated the exchange of knowledge among otherwise unconnected individuals, thereby fostering new collaborations.

The findings of this chapter contribute to a growing literature on ICT and knowledge production by showing a large positive effect of ICT on patenting. Most importantly, our results highlight

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that ICT can facilitate the translation of science to patents. This is particularly relevant because patents closely connected to science are on average more valuable (Poege et al., 2019; Krieger et al., 2024). At the same time, this translation process faces many barriers, such as the tacit nature of scientific knowledge (Polanyi, 1958, p. 57) or the limited attention of inventors (Bikard, 2018). ICT has the potential to foster collaborations that can bridge the gap between science and patenting.

We further contribute to the literature studying the effect of BITNET on scientists' outcomes and collaborations (e.g., Agrawal and Goldfarb, 2008; Winkler et al., 2010; Ding et al., 2010). We extend this evidence to inventors and show that patenting and collaboration increased as well. Most importantly, we show that the collaborations created through BITNET serve to translate scientific insights into innovation. Finally, the findings of this chapter extend the literature on the impact of ICT on productivity and growth to innovation. This extension is particularly important because innovation, and especially innovation closely related to science, is a key driver of economic growth and long-run productivity.

For a long time, the storage and transmission of knowledge relied on written records as the dominant medium, apart from oral transmission. The advent of television revolutionized knowledge transmission by accelerating the speed of knowledge transfer and its reach. Mass media, such as television, have the power to influence many aspects of daily life. Among them are political outcomes, e.g., vote shares, the rise of extreme nationalist parties, and political attitudes of the population (e.g., Enikolopov et al., 2011; DellaVigna and Kaplan, 2007). Further, social outcomes such as women's status, and fertility can be impacted (e.g., Jensen and Oster, 2009; La Ferrara et al., 2012). However, the impact of mass media on innovation – a key determinant of economic growth – has largely been neglected in the literature. While studies have demonstrated positive effects of exposure to television on children's cognitive development and learning abilities (e.g., Wright et al., 2001; Omi et al., 2010; Calvert and Valkenburg, 2013), it is less clear whether inventors can leverage knowledge transferred via television programs for innovation.

Chapter 2 of this dissertation, which is based on joint work with Dietmar Harhoff and David Heller, investigates the impact of inventors' exposure to media on fostering technological change. Literature on this topic has debated the factors contributing to technological change for ages. Classics highlight the role of both demand-pull reasons and technology-push reasons, and point out that both of them must coexist to spur innovation (Schmookler, 1962; Mowery and Rosenberg, 1979). In recent years, the focus of the literature has moved on to labor-saving and labor-augmenting technologies, and factors influencing green innovation (Acemoglu, 2002; Jones, 2005; Hassler et al., 2021; Acemoglu, 2023). This chapter contributes to this debate by providing evidence on another, so far neglected, determinant of technological change: publicly available information transmitted via television.

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To examine the impact of knowledge transmitted through television programs on inventive activity, we leverage a unique setting which allows a causal identification of the effect. In particular, we analyze the German Democratic Republic (GDR), a socialist economy. During the 1960s, economic policies under Walter Ulbricht prioritized industrial production and automation technology at the expense of consumer goods production, which led to increasing dissatisfaction within the population. In 1971, Walter Ulbricht resigned, and his successor, Erich Honecker, redirected economic policy towards increased consumer goods production. Further, he pursued reconciliation with West Germany, which expanded access to Western media, including television.

We hypothesize that the changes in politics as of 1972 significantly impacted both the supply and direction of innovation in the consumer goods sector. With the East German government emphasizing the development and production of consumer goods, inventors were directed to prioritize consumer goods inventions. At the same time, reconciliation with West Germany increased the propensity of inventors to watch and learn from West German television. Western TV programs thus became a key channel for gathering information about the design and functionality of West German products.

To test this hypothesis, we combine the shift in government policy with geographic variation in the access to West German television. Within the GDR, a municipality's access to West German television depended on the strength of the TV signal, which was exogenously determined by geographic barriers (see Bursztyn and Cantoni, 2016). Using a difference-in-differences approach, we then compare patenting in municipalities with access to West German television before and after the shift in government policy to patenting in municipalities unable to watch West German television before and after the change in policy.

In line with our hypothesis, our analysis reveals that municipalities with access to West German television raise the amount of household goods-related patents. In particular, patenting in IPC A increases by 25%. This increase is driven by consumer goods patents, while patents in other categories remain unaffected. We conduct several additional analyses to test the robustness of our findings.

The contributions of this chapter are threefold. First, our study adds to the historical account of GDR policy. We are first in studying the shift in the direction of technological change from industrial products to household products. We further contribute to the literature on determinants of technological change, which has so far mainly examined knowledge transmission through personal communication and written sources (e.g., Catalini, 2018; Furman et al., 2021; Wernsdorf et al., 2022). Our study focuses on the transmission of knowledge via media. While the effects of mass media have been studied in other contexts, such as political outcomes, women's status, social capital, and fertility (e.g., Enikolopov et al., 2011; DellaVigna and Kaplan,

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2007; Jensen and Oster, 2009; La Ferrara et al., 2012), its impact on inventive activity has been largely neglected. We can provide causal evidence of a sizable effect of this transmission channel on inventive activity.

Finally, our study informs the debate on demand-pull–technology-push factors by highlighting another important determinant of technological change. While the literature has identified spillovers from written work, such as patents or books, and knowledge transfer via personal interaction (e.g., Giuri et al., 2007; Furman et al., 2021; Wernsdorf et al., 2022) as important factors, the informative role of mass media has remained unstudied. We close this gap by showing positive spillover effects of watching television on inventive activity.

The previous chapters have highlighted the importance of knowledge transfer through written sources and mass media. However, some forms of knowledge can neither be codified in writing nor expressed through visual images in any way. One of those is tacit knowledge, which is gained through experience, trial and error, and contextual understanding, amongst others. It is widely acknowledged that this type of knowledge is deeply embedded in individuals and can hardly be transferred, except through interactions with the person possessing it (e.g., Ganguli, 2015). Further, social capital, in particular the network an individual has access to, is crucial. Individuals may derive substantial benefits from engaging with well-connected peers, such as enhanced knowledge flows and increased collaboration opportunities (e.g., Fry, 2022).

In Chapter 3 of this dissertation, I turn towards these uncodified types of knowledge and examine how the particular knowledge embodied in a researcher influences the integration of recipients into the global science system. Being well-integrated into the global science system becomes increasingly important because the expanding stock of knowledge makes it ever more difficult for individuals to stay fully informed (Jones, 2009). Achieving such integration can be facilitated by established researchers who can share their professional networks and their system-specific tacit knowledge. These individuals may be particularly important in the context of large-scale disruptions to research systems, where the interruption of existing scientific networks requires a swift and sustained reintegration.

In light of this, this chapter investigates the East German academic sector following the reunification. In the first part, I conduct a descriptive analysis of the East German academic sector before and after the reunification. In the second part, I examine the influx of West German researchers into East German university departments during the German reunification, aiming to provide insights on how well-integrated researchers can facilitate the integration of East German researchers into the global science system.

Following the reunification, East German university departments, which previously operated within a science system characterized by central planning, lack of resources, limited international exchange and absence of competition, were required to swiftly adjust to the international and

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competitive Western system. This transition was accompanied by a wave of dismissals of scientific staff, and the recruitment of new researchers, especially from West Germany. These newly appointed West German individuals were familiar with the Western-style science system, including information about publication processes, trending research topics and the necessary professional networks, and brought this knowledge with them to their new East German departments.

However, not all departments hired a West German colleague. More importantly, and a particular feature of my setting, hiring decisions followed a strictly regulated procedure in which the East German department had virtually no influence over the hiring decision. I exploit this exogenous variation to causally identify the impact of West German researchers on the publication behavior and international integration of East German stayers, i.e., researchers who remain employed in the same department before and after the German reunification. Using a difference-in-differences approach, I compare publication quantity and quality of East German stayers at departments with West German colleagues before and after 1990 to publication quantity and quality of East German stayers at departments without a West German appointment.

Following the influx of West German researchers into a department, I observe a field-specific tradeoff between publication quantity and quality. Medicine departments experience a pronounced decrease of publications per East German stayer, whereas publication quantity is unaffected in the remaining fields. However, the opposite pattern emerges for publication quality: in response to the influx of West German researchers, publication quality in Medicine departments increases, while it decreases in the remaining disciplines. In further analyses I show that Medicine departments benefit from an improved internationalization in terms of English-language publications. Finally, departments in all disciplines increase the amount of third-party funding following the influx of West German researchers.

My findings suggest that West German researchers facilitated the international integration of East German researchers through various forms of knowledge transfer. The analysis of collaboration patterns indicates that West Germans primarily acted as knowledge brokers in Medicine by sharing their professional networks with their East German colleagues. In the other disciplines, however, this network-expanding effect played a subordinate role. Instead, West Germans engaged with East German researchers either through direct co-authorship or through sharing system-specific knowledge. These interactions facilitated a transition of East German researchers across all disciplines towards a more Western-oriented publication behavior. This is confirmed by a shift towards publication outlets preferred in West German universities in departments with West German researchers compared to those without.

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The findings of this chapter contribute to the literature examining the effects of the German reunification. Despite the reunification having passed 30 years ago, the effects are still highly debated in German society, but comprehensive quantitative evidence is still largely absent. The majority of studies in this field is purely descriptive and consists of case studies (e.g., Burkhardt, 1997; Archambault et al., 2017; Pasternack, 2015). I contribute to this literature by causally identifying the impact of West German researchers onto East German researchers' publication behavior. I show a field-specific tradeoff between research quality and quantity that is driven by an adjustment of East Germans' publication behavior towards a more Western-oriented publication style following the arrival of West German researchers in the department. The extensive descriptive evidence quantifies the magnitude of job losses among East German researchers and shows, amongst others, that the widely noted high share of female employment in East Germany did not extend to the scientific sector. I further refute the commonly made claim that West German switchers to East Germany were only those unable to build a successful career in West Germany.

This chapter further contributes to the literature on knowledge brokers by showing that brokerage can still be effective despite an ex-ante hostile environment. However, the effects are field-specific. Finally, the evidence of this chapter demonstrates that the arrival of researchers with system-specific knowledge and established networks can mitigate the adverse consequences of large-scale disruptions of scientific systems. The knowledge embodied in these individuals can contribute to improved professional networks and higher success in applications for third-party funding, both of which is deemed important by the literature to build resilient scientific communities (e.g., Ganguli and Waldinger, 2023; Ganguli, 2017).

In summary, this dissertation sheds light on different ways of knowledge transfer within the economy and its impact on innovation and science. It enhances our understanding of factors contributing to knowledge sharing, such as ICT, highlights the role of media in knowledge dissemination, and underscores the importance of individuals in transmitting knowledge. In light of the ongoing crises and disruptions to scientific systems, this dissertation provides guidance on measures to promote knowledge exchange and dissemination, and the role of individuals in mitigating the adverse effects of such crises. It is hoped that policy makers will draw on these insights to develop policies that encourage knowledge exchange and ultimately pave the way for greater resilience of scientific systems.

1

ICT, Collaboration, and Innovation

Evidence from BITNET

1.1 Introduction

Scientific and technological advances are thought to be critical drivers of economic growth. Modern theories put cumulative innovation, i.e., that inventors stand on the proverbial shoulders of prior innovations, and collaboration at the heart of the ideas production function (Romer, 1990; Jones, 2009). If these theories are true, information and communication technologies (ICTs) could supercharge the innovation process as they greatly facilitate collaborating with other researchers and learning from and building on the knowledge of others. ICT could thus provide governments with a tool to boost regional development and innovation. For example, President Biden has made it a priority to “ensure that science and technology hubs flourish in every part of the country” (Office of the President-Elect, 2021).

Does access to ICT increase local innovation? Answering this question is important as significant economic resources are spent to extend access to ICT to every region in the developed world. However, it is far from obvious that there should be strong effects of ICT on innovation. On the one hand, ICT gives inventors easier access to a wider range of ideas and potential collaborators,

This chapter is based on joint work with Markus Nagler and Martin Watzinger, which is published in the *Journal of Public Economics* (Wernsdorf et al. (2022)).

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which can potentially lead to new inventions. On the other hand, ICT might have no effect at all because relevant information for inventions is difficult to codify, people are reluctant to share valuable information, or because collaborations are costly.

This study exploits the staggered adoption of BITNET, an early version of the Internet, among U.S. universities between 1981 and 1990 to provide evidence whether access to ICT affects local innovation. BITNET was initiated in 1981 with the aim of setting up a messaging network for students. At its start, it only connected three universities, but it quickly became the most widely adopted network in academic institutions worldwide, with about 1,400 member organizations in 1991. BITNET greatly facilitated the exchange of knowledge by reducing communication costs. It allowed written communication through e-mail, real-time messages, and featured e-mail lists and discussion groups. Because of these characteristics, our results largely speak towards other ICTs or policies reducing the costs of communication in written form. In contrast, other features of modern ICT such as access to large databases or real-time video telephony as well as other effects of lower communication costs in face-to-face settings are not part of BITNET (Catalini, 2018; Furman et al., 2021). BITNET was only discontinued in 1996, when the World Wide Web became dominant.

To estimate the impact of BITNET adoption on innovation in a region, we focus on patents assigned to universities (“university patents”) as only university affiliates had access to BITNET. In our empirical specification, we compare the change in the number of university patents in a region before and after the local university adopted BITNET with changes in the number of university patents around universities that are not yet connected to BITNET. Thus, we compare the change in innovative activity around treated universities to the change in not-yet-treated universities that eventually adopt BITNET in later periods. Our analysis focuses on the years between 1981 and 1990, the time period during which the network was rolled out.

We find that the introduction of BITNET results in an average increase of 0.3 university patents per 100,000 population relative to control universities, a sizable effect. If we weight each patent with its forward citations to account for quality, we find an increase of around 1.4 citation-weighted university patents per 100,000 population. However, we also find that the average university patent receives fewer citations after BITNET introduction. In line with the idea that ICT can facilitate communication and improves the transmission of knowledge that is otherwise unavailable locally, we find that the impact is entirely driven by universities in non-urban areas. After BITNET adoption, universities also use more prior art from universities that themselves are already connected to BITNET. The effects are robust to a wide range of robustness and plausibility checks. For instance, there is no significant impact of BITNET on patents by non-university corporate inventors.

In additional analyses, we provide evidence that collaboration among new inventor teams is

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the mechanism behind our effects. We first show that our results are driven by inventor teams (Agrawal and Goldfarb, 2008). Second, investigating this result further we show that new inventor teams, i.e., those that had not yet collaborated before BITNET adoption, increase their patenting most. Third, we show that collaboration between inventors at different BITNET-connected universities is increasing the most in relative terms. These results are in line with the notion that BITNET facilitated the exchange of knowledge among collaborators with access to BITNET.

We then show that the patents induced by BITNET are closely related to science. Using data on patent-to-article citations by Ahmadpoor and Jones (2017), we show that the effect is entirely driven by patents that either directly cite research articles or that cite other patents that directly cite research articles. In contrast, patents that are not closely related to science are unaffected by the adoption of BITNET. In line with the transmission of scientific information as mechanism behind our result, we show that the excess patents induced by ICT use words that are either completely new (i.e., used for the first time in a U.S. patent) or are new in the region around the university. Patents that do not contain words in either of these two categories again show no change after BITNET adoption. However, we also find that patents become longer, use more figures, and are more similar to already existing patents. Thus, the marginal patents induced by BITNET may be less novel than the average patent that is closely related to science.

Our findings contribute to the literature on ICT and knowledge production by showing a large positive effect of ICT on the translation of science to patents. The most closely related paper is Forman and van Zeebroeck (2012) that analyzes the effect of basic internet on the productivity of inventors in firms. In contrast to our results, they do not find any effect. In line with our results, Kleis et al. (2012) find a positive effect of general IT investments on firm innovation. We provide new evidence for a positive impact of a specific form of ICT on the productivity of inventors in a setting where the change in communication costs due to the ICT is likely larger than in the later years studied in Forman and van Zeebroeck (2012).

Our work is also related to several studies that look at the effect of BITNET on scientific publications. For example, Winkler et al. (2010) and Ding et al. (2010) focus on academic life scientists and find some evidence that BITNET increased the publication rates of life scientists. We provide evidence that not only scientific publications but also patenting increased after the introduction of BITNET at a university. Agrawal and Goldfarb (2008) examine the effect of BITNET on collaboration among university scientists in top electrical engineering journals between 1981 and 1991 and find a positive impact. Complementing their paper, we show that collaborations also increased among inventors. Most importantly, we show that these new collaborations seem to translate scientific insights into innovation. Patents close to science are particularly valuable on average (Poege et al., 2019; Watzinger et al., 2021; Arora et al., 2022) and we do not yet understand well under which circumstances they emerge (e.g., Bikard, 2018;

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Bikard and Marx, 2020).

This study also extends the literature on the effect of ICT on productivity and growth to innovation. Recently, there have been contributions on the impacts of ICT on knowledge spillovers, firm productivity, and firm organization (Huang et al., 2022; Saunders and Brynjolfsson, 2016; Forman and McElheran, 2019; Forman and van Zeebroeck, 2019). On the macro level, Czernich et al. (2011) show that increases in broadband penetration raise annual per capita growth in OECD countries.¹ Extending this literature to innovation is important since innovation, and especially innovation closely related to science, is a key driver of economic growth and long-run productivity.

The remainder of this chapter proceeds as follows. Section 1.2 provides the institutional background on BITNET. In Section 1.3 we describe our data sources and our empirical setup. Section 1.4 presents the results on patenting. In Section 1.5, we investigate the mechanism behind the observed effects. Section 1.6 concludes.

1.2 Institutional Background: BITNET

Ira H. Fuchs and Greydon Freeman initiated BITNET (“Because It’s There NETwork”) in 1981 as a communication network between students of different universities.² BITNET became the most widely used network for communication in scientific research. The network featured e-mail communication, real-time messages, transmission of text files and programs. The most popular feature was mailing lists on almost 3,000 different topics. For example, BITNET featured an Organic Chemistry mailing list. It was intended “[t]o facilitate the interchange of ideas, information, computer programs, papers, to announce opportunities for doing collaborative efforts (teaching and/or research activities) between specialists in Organic Chemistry and related areas.” (NetMonth, 1987).³ Besides e-mail lists, BITNET also featured other collaboration tools, such as *LifeSci*, a computer program intended “to enhance interaction and cooperation among researchers and scientists working far from each other” (Zakai, 1988).⁴ These ways of communicating permitted active discussions and knowledge exchange even among geographically separated scientists.

In the beginning, Ira H. Fuchs and Greydon Freeman directly approached IT administrators

¹See also Andersen et al. (2012). Other strands of the literature on the impacts of ICT, for example, study the impacts of internet access on education and labor market outcomes (e.g., Akerman et al., 2015; Dettling et al., 2018; Bhuller et al., 2021), on political outcomes (e.g., Falck et al., 2014; Campante et al., 2018; Gavazza et al., 2019; Zhuravskaya et al., 2020), and on social capital (e.g., Bauernschuster et al., 2014; Geraci et al., 2022).

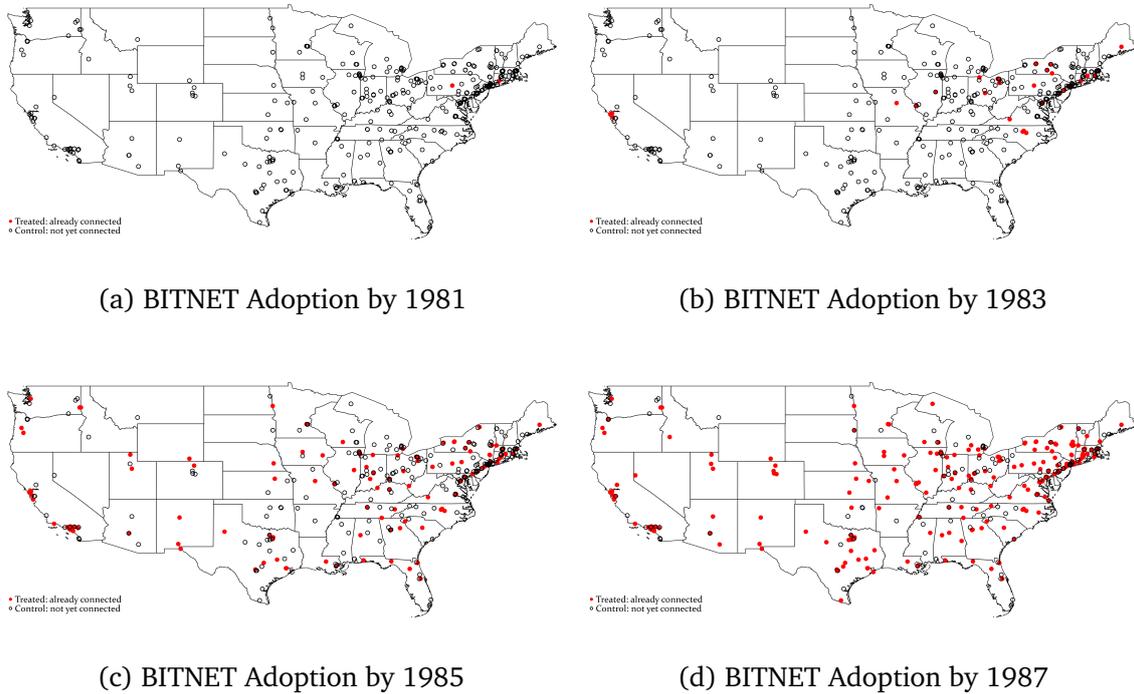
²The information summarized in this paragraph is based on Gale Encyclopedia of E-Commerce (2019), Ramirez (2014), Gurbaxani (1990), Agrawal and Goldfarb (2008), CREN (1997), Living Internet (2000).

³See https://ia803109.us.archive.org/10/items/bitnet_documents/nm8711.txt, last accessed February 11th, 2022.

⁴See https://ia803109.us.archive.org/10/items/bitnet_documents/nm8802.txt, last accessed February 11th, 2022.

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Figure 1.1: Location of Treated and Control Universities



Note: Universities connecting to BITNET prior to or in the respective year are displayed by red dots and constitute the treatment group in our analysis. Universities adopting BITNET later than the considered year are depicted by black hollow circles and constitute the control group. Universities located in Hawaii and Alaska are omitted from the figure for better visibility.

via letters and phone calls to outline the benefits of joining the network. Institutions could join BITNET if they fulfilled several requirements: First, they had to lease a phone line which allowed them to connect to the network. Second, each institution had to serve as entry point for a new potential member. Third, each institution contributed intermediate storage and computer processing power. Membership was initially free. Yet, each institution had to lease the phone lines to connect to the network. Leasing these lines could be quite costly, depending on the distance between the potential new member and the already existing members of the network. In 1986, a membership fee was implemented which was dependent on the annual budget of the institution.

BITNET spread quickly across the United States and around the world. The first connection was established between the City University of New York and Yale University in May 1981. Figure 1.1 displays the geographical dissemination of BITNET in the continental United States for the years 1981, 1983, 1985, and 1987. Universities which adopted BITNET up until the respective year are shown as red dots. Universities connecting to BITNET that were not yet connected are shown in black hollow circles.

In 1981 only three universities were connected to the network. In 1983 the number of members was 36, 133 in 1985, and 248 in 1987. By 1990, 365 U.S. universities had joined the network.

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In 1991, at the peak of its popularity, the network had connected about 1,400 organizations in almost 50 countries. BITNET was discontinued in 1996 as the number of BITNET members declined due to the rise of the internet.⁵

1.3 Empirical Setup and Data

In the empirical analysis we aim to estimate the impact of adopting BITNET at a university on university patenting in proximity to the institution. To do this, we need an estimate of how patenting activity in that region would have evolved had the university not received BITNET access. To construct an estimate of this counterfactual, we exploit the staggered adoption of BITNET between 1981 and 1990. Our control group consists of regions around universities that received BITNET at a later point in time. Figure 1.1 therefore shows the treatment and control universities for the years 1981, 1983, 1985, and 1987.

Regions that have not yet connected to BITNET are a useful control group if patenting in these regions follows the same trend as patenting in regions with BITNET access would have, had the institution not connected to BITNET.⁶ Although we cannot verify the validity of this assumption, historical evidence suggests that the time of connection to BITNET was probably not systematically related to any factor that could also influence changes in patenting. In particular, the decision to adopt BITNET was the responsibility of the directors of university computing centers and not undertaken by individual scientists (Agrawal and Goldfarb, 2008).⁷ In line with this, we show below that prior to the actual adoption of BITNET, regions around treatment and around control universities are on parallel trends in terms of per-capita patenting. Because the network spread fast, it is also unlikely that adopting BITNET was part of a strategic plan that involved investments into innovation capabilities that would have generated higher patenting even in the absence of BITNET adoption. In line with this, we show in the Appendix that there do not seem to be concurrent funding shocks or effects of the Bayh-Dole Act that can plausibly explain our results.

In our main specification, we estimate an event-study difference-in-differences specification. Specifically, we quantify the impact of adopting BITNET on patenting by estimating the following equation:

$$y_{j\tau}^i = \beta_1 \cdot Post_{\tau}^i + \beta_2 \cdot BITNET_j^i \cdot Post_{\tau}^i + \mu_t + \gamma_j^i + \varepsilon_{j\tau}^i \quad (1.1)$$

where superscript i denotes the group of universities, each including one treated university

⁵The network formation has been studied by Kellerman (1986).

⁶Note that, for the validity of the control group, it is fine that those universities with a higher treatment effect join BITNET first, as long as the parallel trends assumption holds.

⁷For that reason, Ira H. Fuchs, one of the founders of the network, targeted IT administrators by sending out letters and by advocacy in public forums of IT professionals to persuade new member institutions to join.

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along with several associated control universities assigned to the treated university.⁸ j denotes the university under consideration, τ indexes the time relative to the BITNET adoption of university i in years, and t are the calendar years. Thus, ij is our unit of observation, observed over t . $y_{j\tau}^i$ corresponds to the outcome of interest, $Post_{\tau}^i$ is an indicator which equals one in the years after BITNET was introduced and $BITNET_j^i$ is an indicator equal to one for the treated university (i.e., $i = j$) and zero otherwise. In all specifications, we include calendar year fixed effects (μ_t) and a separate fixed effect for each combination of university j and treated university i . We adjust for the different number of control observations for each treated university by using weights (Iacus et al., 2012). The standard errors allow for clustering at the treated university i level. β_2 measures the average increase in the outcome variable in the year of BITNET introduction and in the four years thereafter for treated universities.⁹ Given our estimation equation, our approach is simply a difference-in-differences approach around treatment adoption using stacked datasets. The advantage of this approach is that it takes care of recent issues around staggered treatment designs since in each university group, there is only one treated university.¹⁰

In our main analysis, the outcome of interest is the number and quality of university-assigned patents. We capture patent quantity by the yearly overall number of patents assigned to a university and filed by inventors within 15 miles around the university.¹¹ For patents with multiple inventors, we allocate an equal share of the patent to each inventor. If there are multiple universities less than 15 miles from an inventor, we divide the inventor's patent share equally among them to avoid double counting. To factor in quality differences between patents, we use the number of citation-weighted patents. To this end, we determine for each patent the number of forward citations received within 5 years of the filing date (including the year of filing). To account for regionally varying population, in all analyses we divide the number of patents and citation-weighted patents by the population within 15 miles of the university.¹² We use *university patents with an inventor localized in the region of the university* instead of

⁸Note that, given the design of our control group, many universities appear more than once in the sample since they serve as control group for initial adopters and then adopt BITNET at a later point in time.

⁹Note that, upon BITNET adoption, some universities drop from the control group. This does not drive our effects: In Appendix A.1.2, we show that an approach similar to our approach, but leveraging only control universities that adopt BITNET after the treatment period of the focal universities (Deshpande and Li, 2019; Gengiz et al., 2019) provides similar results.

¹⁰The reason why standard difference-in-difference approaches would be problematic here is that the effect of BITNET on patenting likely builds over time and universities that recently adopted BITNET would thus depress the estimate of BITNET on patenting for adopting universities (de Chaisemartin and D'Haultfœuille, 2020). In Appendix A.1.3, we additionally show that alternative difference-in-differences specifications such as those suggested by Callaway and Sant'Anna (2021) and Borusyak et al. (2021) provide qualitatively similar results.

¹¹This distance approximately corresponds to the average commuting distance in the United States, which is roughly 15 miles according to polls (ABC News, 2005). Rapino and Fields (2013) find a mean commuting distance of around 19 miles (including extreme commutes).

¹²In Figure A.3 in Appendix A.1.4, we show the treatment effects around BITNET adoption using the number of patents as the dependent variable. The results are qualitatively similar to our time-varying results in the main specification, but larger by around the average population in the data. In the same Appendix, we also show that scaling university patents per faculty yields qualitatively similar results.

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patents assigned to the university because from the name of the assignee it is often unclear which university is meant. For example, patents of all universities in the University of California System are assigned to “The Regents of the University of California” and not to the individual universities.¹³

For our empirical analysis, we combine data from various sources. The information on universities and their BITNET status is from the Atlas of Cybergeography.¹⁴ The data covers 1,054 institutions worldwide, among them universities, government institutions and companies, which connected to BITNET between 1981 and 1990. It includes the exact adoption date as well as information on the number of connections (nodes) to other institutions. Of these institutions, we keep only U.S. universities. The exact university geolocations are from the Integrated Postsecondary Education Data System (U.S. Department of Education, 2019). Finally, the U.S. Census in 2010 provides information on the population within a certain region around each university (NBER, 2010). The patent data is from PATSTAT (European Patent Office, 2016). To obtain the geographic location of the inventors, we use the geolocated patent data from Morrison et al. (2017).

Table A.1 in Appendix A.1.1 shows summary statistics for the universities in our sample in the year before their respective BITNET adoption. The average university has around 0.39 university patents and 1.35 citation-weighted patents per 100,000 population in the year before BITNET adoption.

1.4 The Impact of BITNET on Patenting

We start our examination of the innovation effects of BITNET by estimating a variant of equation (1.1) with time-varying treatment effects. Figure 1.2 displays the yearly treatment effects for the number of university patents per 100,000 persons in the 15 miles region around a university. We use the year before BITNET adoption as baseline period. The estimates are very small and statistically insignificant prior to BITNET adoption. This speaks in favor of the parallel trends assumption. After BITNET adoption, the number of patents increases around treated universities relative to universities that have not yet adopted BITNET. The impact starts in the year after BITNET adoption and increases over time.¹⁵

Table 1.1 presents the difference-in-differences estimation results for Equation (1.1). In line with the figure, column (1) shows a positive impact of BITNET on the number of patents per 100,000 population relative to universities that gain access to BITNET later. On average, the number

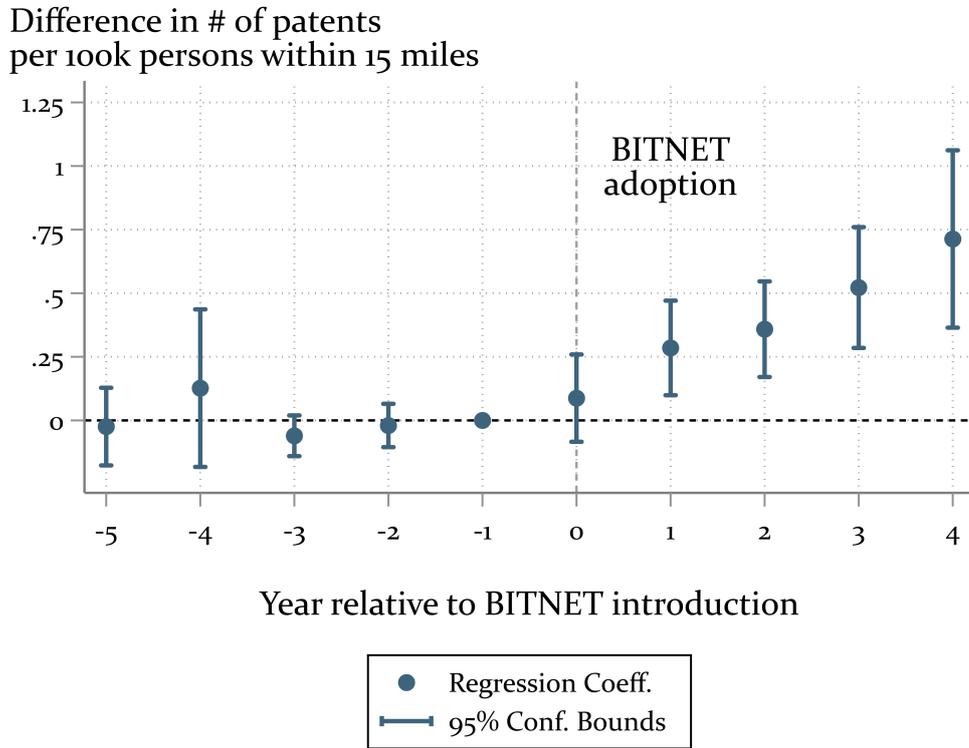
¹³Similar problems appear with patents assigned to universities throughout the United States.

¹⁴The file including information on BITNET institutions is available at https://personalpages.manchester.ac.uk/staff/m.dodge/cybergeography/atlas/bitnet_topology.txt, last accessed February 10th, 2022.

¹⁵This increase over time is consistent with several explanations. For instance, effects may take time to develop, for example because producing the invention takes time. However, it could also be driven by network effects with more and more universities connecting to BITNET and the network thus becoming more useful over time.

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Figure 1.2: Effects of BITNET on Local Patenting Relative to the Connection Date



Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the number of university patents per 100,000 population within 15 miles of universities adopting BITNET relative to universities that only adopt BITNET later. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

of patents increases by 0.3. This is around 34% of the average number of university patents around treated universities in the post period.¹⁶ Summing up over all treated universities over the post period and taking this main effect at face value, the effect of BITNET amounts to almost 1,000 additional university patents. These results suggest that BITNET spurred local innovation close to adopting universities. In column (2), we use citation-weighted patents as the dependent variable and find a positive and significant effect on citation-weighted patents. This suggests that the patents resulting from the adoption of BITNET are useful. However, when we analyze the impact of BITNET on the number of forward-citations per patent, we find that the average patent around treated universities receives around 13% fewer citations after BITNET introduction, relative to the average of the outcome variable among treated universities in the post period.¹⁷ Thus, the marginal patents induced by the adoption of BITNET seem to be of somewhat lower quality than an average patent in the control group. Figure A.6 in Appendix

¹⁶Note that this large effect is also due to many universities not patenting much. This is illustrated when estimating our main model with a Poisson maximum likelihood model following Correia et al. (2020). Using this approach, we obtain an estimate for the increase in local per capita patenting after BITNET adoption of around 11%.

¹⁷This result also only appears after BITNET adoption, as Figure A.5 in Appendix A.1.5 shows.

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A.1.5 shows that this is independent of the exact measure of patent quality that we use.

Because BITNET lowered the cost of communicating with other universities, we would expect the impact of BITNET to be greater in remote, non-urban areas. In columns (4) and (5), we thus split the sample by population density. We find that universities with below-median population densities (labeled “non-urban”) largely drive the effect.¹⁸ For universities in urban environments, we only find a small effect of BITNET on local innovation. This is in line with the idea that ICT facilitates communication and collaboration in particular in non-urban regions. In Table A.4 in Appendix A.1.6, we show further heterogeneity analyses for our results. We find that the effect is driven by universities that already showed above-median patenting levels before the introduction of BITNET. This could point to a complementarity between ICT and local inventive capacity. We also show a split by adoption year and find that the effect is larger for early adopters (until 1984), but is also substantial for late adopters. We show time-varying treatment effects of all of the above heterogeneities in Figure A.7 in Appendix A.1.6.¹⁹

Do these effects plausibly stem from BITNET? We investigate this question directly by leveraging the “paper trail of ideas” embedded in citations. We weight all university patents around treatment and control universities by whether they cited inventors at other already connected BITNET universities or inventors that are not close to a BITNET-connected university. That is, we use backward citations to BITNET-connected or non-BITNET-connected universities as our dependent variable.²⁰ Columns (6) to (9) show the results of this analysis. Column (6) uses the patents’ total backward citations per 100,000 population as dependent variable. Relative to baseline, inventors around BITNET-adopting universities start citing more prior art than inventors around control group universities. Columns (7) and (8) then show that this is largely due to patents citing inventors close to other BITNET-connected universities. This suggests that BITNET primarily increased patenting based on inputs from other BITNET universities. This is true both in absolute terms and relative to baseline citation rates to both sets of universities. In addition, this is not driven by increased self-citations, as column (9) shows.

So far, our analysis has focused on patents filed by universities. This is because BITNET was designed as an academic network and consisted almost entirely of academic institutions. If the parallel trends assumption holds, it is reasonable to expect effects on university patenting but less so on the patenting of other inventors. In contrast, if unobservable regional shocks were driving our effects, we would expect to see similar productivity effects for other inventors as

¹⁸When we split the sample by quartiles of population densities, we find that the effect is strongest for the bottom quartile and decreases subsequently, with no effect in the most populated regions. Results are available on request.

¹⁹In unreported regressions, we estimate interaction effects to formalize inference. We find that non-urban universities experience significantly higher treatment effects than urban universities. In contrast, the results on above- vs. below-median patenting universities as well as on early vs. late adopters are not significant at conventional levels.

²⁰This exercise is similar in spirit to recent approaches in the literature such as by Wasserman and Frakes (2021), who find that patent examiners’ peer effects and knowledge flows are stronger when examiners work at the office, rather than working from home.

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well. To test this, we rerun our analysis using patents filed by company inventors unconnected to universities as the dependent variable. Column (10) shows the result from this analysis. The impact of BITNET on company inventors unconnected to universities is very small (less than 1% of the variable mean in 1980) and statistically not significantly different from zero. We acknowledge, however, that the standard errors are wide such that the 95% confidence bounds of this analysis include the effect on university patents.

Further Analyses in the Appendix

In Appendix A.1 we show the results from several auxiliary analyses. Using data from Hausman (2021), from Fleming et al. (2019), and from Microsoft Academic, we provide evidence that it is not likely that concurrent funding shocks can fully explain our results in Appendix A.1.7. In Appendix A.1.8 we provide evidence that we do not confound the impact of BITNET with the impact of the 1980 Bayh-Dole Act and the subsequent establishment of technology transfer offices (TTOs) by universities (see, e.g., Henderson et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002). BITNET seems to have an independent effect on local innovation, which also appears at universities without TTOs. However, we do find that universities with TTOs benefit more from BITNET than universities without and that TTOs are directly associated with more university patenting.²¹ We also use data from Ouellette and Tutt (2020) to investigate whether the introduction of royalty payments biases our estimates of the BITNET effect. This does not seem to be the case.

²¹We thank Arvids Ziedonis for providing us with data on TTOs.

Table 1.1: Main Results

Dep. Var.:	Univ. patents p.c.	Cit.-wght. patents p.c.	univ. citations	University patents p.c.		Backward citations		Company patents p.c.		
				Non-urban	Urban	All	BITNET		Other	Self
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
BITNET x Post	0.30*** (0.08)	1.43*** (0.35)	-0.62*** (0.13)	0.58*** (0.15)	0.05*** (0.01)	2.44*** (0.49)	1.74*** (0.37)	0.70*** (0.23)	0.04 (0.04)	0.08 (0.27)
Mean Dep.	0.30	1.01	4.17	0.48	0.12	1.78	0.66	1.12	0.09	9.28
R2 (within)	0.00	0.01	0.05	0.00	0.15	0.01	0.02	0.01	0.00	0.05
Obs.	531063	531063	307858	125306	139950	531063	531063	531063	531063	531063

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. Column (1) as well as columns (4) and (5) use patents by university-connected inventors adjusted by the population in the 15 miles region around the university as the dependent variable. Column (2) uses forward citations to these patents per population as the dependent variable and column (3) uses average 5-year forward citations per patent among university-connected inventors as the dependent variable. Columns (4) and (5) split the sample by median local population density. Columns (6) to (9) use backward citations per capita as the dependent variable. Columns (7) and (8) distinguish between citations to patents where at least one inventor is around a BITNET-connected university vs. not. Column (9) uses patents with self-citations as the dependent variable, a subset of BITNET-connected patents. Column (10) uses patents per 100,000 population by company inventors (not connected to universities) as the dependent variable. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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In Appendix A.1.9 we show that results are not driven by a particular university. In Appendices A.1.10 we show the results of alternative control groups that rely on more stringent matching strategies and find similar results. In Appendix A.1.11, we estimate different plausible alternative versions of the main specification, accounting for the skewed nature of patenting, and find similar results. In Appendix A.1.12 we show that results are not driven by a particular region.

Finally, in Appendix A.1.13, we find that the effect of BITNET is largely proportional to baseline patenting levels across fields. We show that the largest absolute effects occur in Chemistry and in Instruments, followed by Electrical Engineering. The largest relative results are in Electrical Engineering, however, in line with the impact of BITNET on collaboration in this category reported by Agrawal and Goldfarb (2008).

1.5 Mechanism: Collaboration and Patenting Closely Related to Science

1.5.1 Effects are Driven by Collaborative Patents by New Inventor Teams

One reason why BITNET may lead to more patenting is easier team formation (Agrawal and Goldfarb, 2008; Ding et al., 2010; Forman and van Zeebroeck, 2012). For example, e-mail and discussion forums made it easier to identify potential collaborators with complementary capabilities.

Table 1.2 shows the results of our analysis. Column (1) repeats our baseline estimate for comparison. In columns (2) and (3), we split the dependent variable by whether the patent was filed by multiple inventors (“collaborative patents”) or whether the patent was single-authored. Both in absolute and in relative terms, the impact on collaborative patents is substantially stronger. This is in line with prior research that found impacts of BITNET on collaboration among academics (Agrawal and Goldfarb, 2008). Columns (4) and (5) investigate this result further. In this analysis, we split the result on collaborative patents by whether the inventor team is newly formed (i.e., has at least one new team member) or whether the inventor team has patented before.

We find that the effect on collaborative patents is larger both in absolute and in relative terms among new inventor teams. These results point to a leading role of new collaborations in explaining the effect of BITNET on patenting. Incumbent inventor teams are less affected, but still benefit from the adoption of BITNET. In combination with column (2), this suggests that ICT may also have productivity effects that go beyond its impact on collaboration and new team formation. In columns (6) and (7), we split the collaborative patents into those that were filed with other inventors around universities that already adopted BITNET (labeled “BITNET collaborations”) and into all other team patents. Both BITNET collaborations and other

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collaborative patents contribute to our finding that BITNET positively impacts collaborative patents, with the latter contributing more in absolute terms. However, relative to baseline levels, collaborations that are joint with inventors close to universities that already connected to BITNET rise substantially more than other team patents. Relative to baseline levels, column (6) suggests that collaborative patents with other BITNET universities increase sevenfold. Finally, in column (8) we show only a small positive effect on team size, suggesting that our results rather reflect a change in team composition. We show time-varying treatment effects of these effects in Figure A.11 in Appendix A.2.1.²² Overall, while direct productivity effects may well be possible, our effects seem to largely be driven by increases in collaborative patents by new inventor teams.

1.5.2 BITNET Induced Patenting Closely Related to Science

What kind of patents were induced by BITNET? We investigate this question in Table 1.3. Column (1) repeats our baseline specification for comparison. We start by investigating how closely related to science the excess patents are. Columns (2) through (4) leverage the data on patent-to-article citations by Ahmadpoor and Jones (2017). We distinguish between patents that (i) directly cite scientific papers and patents that (ii) either do this or cite a patent directly citing an article. Thus, the latter is a superset of the former category. All other patents are interpreted as not being closely related to science. Column (2) shows that the effect is largely driven by increases in patents directly citing scientific articles. Columns (3) and (4) show that it is entirely driven by patents that at least indirectly cite scientific articles. In contrast, patents that are not closely related to science show no effect at all.

In Figure A.12 in Appendix A.2.2, we show the time-varying version of these results. In line with our identification assumption, patents of all types do not differ between treatment and control group before BITNET adoption. After BITNET adoption, patents that directly or indirectly cite research articles increase around treated universities. In contrast, patents that are not closely connected to science are unaffected. It seems plausible that patents closely connected to science are most affected by the introduction of BITNET, since BITNET was a communication system between scientists.

²²These figures again show that the impact on team size is small and hardly detectable, suggesting a change in team composition as the likely driver behind our results.

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Table 1.2: Impact on Collaboration

Dep. Var.:	University patents p.c.			Collaborative univ. patents p.c.				Average team size
	Baseline	Single-authored	Collab-orative	New Team	Old	BITNET Collaboration	Other	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
BITNET x Post	0.30*** (0.08)	0.07** (0.03)	0.23*** (0.06)	0.18*** (0.04)	0.05** (0.02)	0.10*** (0.01)	0.13*** (0.05)	0.06* (0.03)
Mean Dep.	0.30	0.13	0.17	0.14	0.03	0.01	0.16	2.27
R2 (within)	0.00	0.00	0.01	0.01	0.00	0.03	0.00	0.05
Obs.	531063	531063	531063	531063	531063	531063	531063	307858

Note: This table shows difference-in-differences estimates of BITNET adoption on collaboration. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. Columns (1) to (5) use patents by university-connected inventors adjusted by the population in the 15 miles region around the university as the dependent variable. Columns (2) and (3) distinguish between patents involving only one inventor and patents involving multiple inventors. Columns (4) and (5) distinguish between teams involving some inventors that are new to the team and teams consisting only of inventors who patented together before. The results thus sum up to column (3). In column (6) we use the number of patents that involve inventors from different BITNET universities. In column (7) we use all patents of teams that are not included in (6) as outcome. This means inventor teams exclusively at one university or where inventors are at different non-BITNET universities. Column (8) uses the average number of inventors on a university-connected patent as the dependent variable. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In columns (5) through (7) we analyze the patent text of the affected patents further. We use the data of Arts et al. (2018) that gives us the set of words used in the abstract and title of each U.S. patent from 1976 to 2013 and add to this data all words of the first independent claim from the PatentsView database. We split patents into (i) those containing words that are new to the U.S. patent system (i.e., that were previously not used in any USPTO patent), (ii) those containing words that are not new, but new to the region around the treated university, and into those patents (iii) containing only words that do not fall in these two categories. As the results show, the effects are largely driven by patents containing words that are either entirely new or that are new to the region around the adopting university. The strongest relative effect of BITNET is on patents new to U.S. patenting. This is in line with the idea that patents that use novel concepts, such as concepts derived from science, are the most affected.²³

In Figure A.13 in Appendix A.2.3, we investigate this result further by analyzing more dimensions of patent content. We find that the patents driving our results, namely those closely connected to science, change in content. They increase in length, use more figures, show somewhat higher originality (Hall et al., 2001), and their text is more similar to existing patents

²³In unreported regressions, we estimate interaction effects on stacked datasets to formalize inference. We find that all differences that we report above are significant at conventional levels.

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using the measure of Kelly et al. (2021).

Overall, our findings show that BITNET induced more and different patenting. Our results are especially relevant since patents closely connected to science are particularly valuable on average (Poege et al., 2019; Watzinger et al., 2021), but there are many barriers to translating scientific insights to actual innovation (e.g., Bikard, 2018). The types of collaborations that BITNET induced seem to produce knowledge that directly translates research to patenting. At the same time, our additional results caution that the marginal patent translating scientific insights to actual innovation may be less novel than the average patent doing so.

Table 1.3: Types of Patents

Dep. Var.:	University patents p.c.				University patents p.c. with words...		
	Baseline	Close to Science	Not Close	to Science	new to	new to the region,	old
	(1)	Direct (2)	(In)direct (3)	to Science (4)	the world (5)	not the world (6)	words (7)
BITNET x Post	0.30*** (0.08)	0.14*** (0.03)	0.29*** (0.06)	0.01 (0.07)	0.11*** (0.03)	0.18*** (0.05)	0.00 (0.00)
Mean Dep.	0.30	0.06	0.10	0.20	0.09	0.21	0.01
R2 (within)	0.00	0.03	0.03	0.00	0.00	0.00	0.01
Obs.	531063	531063	531063	531063	531063	531063	531063

Note: This table shows difference-in-differences estimates of BITNET adoption on patent types. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. All columns use patents by university-connected inventors adjusted by the population in the 15 miles region around the university as the dependent variable. Column (2) estimates the effect for patents that directly cite scientific articles (“Direct”). The next two columns distinguish between patents that directly cite research articles or that cite patents based on scientific articles (“(In)direct”, column 3); and patents not closely connected to scientific articles (column 4). Column (5) uses patents that include words never used before in U.S. patenting as the dependent variable. Column (6) uses patents containing no new words, but containing words that are new to the region. Column (7) uses patents only containing words that have been used in U.S. patents and patents around the treated university before as the dependent variable. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

1.6 Conclusion

Many observers have argued that ICT facilitates the exchange of knowledge, which in turn improves productivity and inventive activity. While there exists some evidence that shows a research-enhancing role of information technology in academic research, evidence on the impacts of these technologies on innovation and patenting is scarce.

We exploit the staggered adoption of BITNET across U.S. universities between 1981 and 1990 to study whether access to specific ICTs affects (local) innovation. We document a strong effect

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of BITNET on patenting around adopting institutions. We provide evidence that this effect is driven by an increase in collaborative patents by new inventor teams. Our effect is larger among universities in non-urban areas and is linked to increased knowledge flows between universities already connected to BITNET. Patenting by assignees outside of universities is unaffected by BITNET. We finally show that the patents induced by ICT are closely connected to science. Thus, BITNET seems to have facilitated the translation of scientific insights to innovation by inducing productive collaborations.

Because BITNET largely reduced the costs of communication in written form, our results mainly speak towards related ICTs or policies. In contrast, the innovation impacts of modern ICTs that allow for more extensive communication as well as access to large scale databases and online search remain to be studied.

2

Learning by Watching

Western TV Access and Innovation Activity in the German Democratic Republic

2.1 Introduction

Innovation scholars have debated the direction of technological change for ages. In his classical work, Schmookler (1962) argued that demand pull factors were as salient in determining innovation as technology push factors – an argument that sparked an intense debate.¹ In recent years, the discussion around the direction of technological change has mostly focused on the choice between labor-saving and labor-augmenting technological change, e.g., in the context of artificial intelligence, as well as the presence of factors favoring or disfavoring green innovation.²

We study how the supply of information to inventors via media affects the direction of inventive

This chapter is based on joint work with Dietmar Harhoff and David Heller. In this chapter, the grammar and the wording of several paragraphs were refined using ChatGPT.

¹Freeman (1974) found in his own empirical work that successful innovations showed the ability to connect, or “couple” a technical opportunity with a market opportunity. Mowery and Rosenberg (1979) argued that demand-pull and technology-push are “necessary, but not sufficient, for innovation to result; both must exist simultaneously.”

²See Acemoglu (2002), Jones (2005), Hassler et al. (2021) and Acemoglu (2023) for contributions to the discussion.

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effort. This is a crucial channel since industrialized societies have been awash in an abundance of media information for many decades. Yet, the actual effects of media on the direction of innovation remain underexplored. Our analysis focuses on the role of television in impacting the direction of inventive activity and innovation. To examine this effect, we study inventive activities in the German Democratic Republic (GDR) between 1958 and 1986. We consider inventors' exposure to TV as a source of knowledge, as it was an increasingly important part of individuals' everyday life. The absence of online media in this period allows us to focus on one main channel of content delivery. In our historical setting, TV was the dominant medium and – contrary to radio – capable of communicating visual signals. This empirical setup thus provides a unique opportunity to examine the role of TV in steering the direction of technological change as evidenced by patent filings.

During the 1960s, economic policies developed under the chairman of the SED party, Walter Ulbricht, had led to growing dissatisfaction of the GDR population. Ulbricht's policies had favored industry products, equipment, and chemicals that could be sold in international markets to earn returns in Western currencies. In turn, the GDR could then use these reserves to purchase much needed advanced technologies that were in short supply in East Germany, as in many countries dominated by the Soviet Union. This policy focus came at the expense of other industries, such as consumption goods, substantially deterring the support by GDR citizens for the current regime.

In 1971, Walter Ulbricht had to resign over the failure of these policies. His successor, Erich Honecker, initiated a new direction of policies and entered into some reconciliation with West Germany. We exploit this regime shift in our empirical analysis as an exogenous event, affecting the direction of technological innovation. In this context, the Honecker takeover of 1971 and the subsequent restructuring of the economic system triggered two specific policy changes that proved to be particularly relevant for our purposes. First, the focus of production was shifted towards consumer goods, away from prioritizing heavy industry and production technology. The new objective emphasized product innovation in the consumer goods domain where East Germans had endured a long period of supply shortages and lack of innovation. Second, Honecker's political approach stipulated improving access to Western media, such as books, newspapers and television. This new approach stood in marked contrast to the repressive system pursued under the Ulbricht regime, in which the consumption of Western media was heavily sanctioned.

We hypothesize that the regime change in 1971 had a strong impact on the direction of innovation, towards a greater emphasis on the consumer goods domain. East German inventors were now "state-ordained" to pursue inventions in household and consumption goods. Information as to how such goods would look and how they would be used was flowing in via Western TV programs, which became a potent source of information spillovers.

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To identify the effect of Western TV on the direction of innovation in response to the Honecker takeover in 1971, we exploit cross-sectional variation on the municipality level in the quality of Western TV reception, which was contingent on geological features and very uneven across East German regions.³ We follow Bursztyn and Cantoni (2016) and utilize exogenously determined differences in the signal quality of West German TV. In our setting, these TV signals were the conduit through which East German inventors obtained information on advanced household goods. Combining the shift in economic policy with data on differences in TV reception in a difference-in-differences design, we are able to generate causal evidence that household inventions became more frequent in areas where TV signals from West Germany reached inventors. Due to low inventor mobility, the impact of this information was regionally restricted.

We quantify inventors' output using patent data. In general, the East German patent system was largely based on the pre-World War II unified German patent system and most of its features render it comparable to patent systems in a capitalist society. We obtain the full population of patents filed in the GDR between 1949 and 1990 from Hipp et al. (2024) and the German Patent Office (DPMA). Importantly, it comprises information on inventor locations, which allows us to assign TV signal strengths to individual inventor locations. Based on details about the patents' technology classes, we can track differential changes in the direction of technological inventions across municipalities in the GDR.

We obtain very robust and strong results, indicating that the number of inventions in municipalities with good TV reception was 25% to 30% higher than in the regions without high quality TV access. We probe these results in various ways, e.g., in a placebo test using distance to the East-West German border as placebo treatment. We also find that the results are not driven by particular municipalities, such as Berlin or Dresden. We further refine the robustness test by pairing cities with similar distance to the border, again with a positive differential change towards consumer goods technologies in high signal strength regions. In our most restrictive robustness test, we only maintain directly neighboring municipalities above and below the threshold that determines Western TV access in the spirit of a geographical regression discontinuity design. While this approach reduces the number of municipalities, it also provides the sharpest test with the strongest results. Here we find effect sizes of 30% to 36% for the TV signal treatment.

³Terrestrial TV signals have to be received line-of-sight from the transmitting tower. The main reason for heterogeneous reception was the presence of mountainous regions, such as the Harz and the Ore Mountains. Two regions were particularly affected by these geographical barriers – around Dresden in the Elbe valley and Greifswald in the northern GDR. They became known as the “Valley of the Clueless” as their inhabitants were not connected to developments in the West. The lack of access to West German TV information may not just have limited access to political information and advertising. For example, Bönisch and Hyll (2015) find that the birth rate in the “Valley of the Clueless” was higher than in other areas of the GDR, presumably because West German ideas of smaller families, visible on TV shows, had not been available as comprehensively as in other GDR regions.

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This chapter makes several contributions. First, in the economic historical account of GDR economic policy, the role of inventions has been studied (e.g., by Hipp et al., 2022, 2024). To the best of our knowledge, we are first to study shifts in the direction of technological change from mostly industrial products to household products in this historical setting. Our analysis of East German patent data reveals that patenting of household inventions rose after 1971 much stronger in regions with high-quality West German TV reception (our treatment group) than in low signal strength regions. In fact, regions without access to information from West German TV programs exhibit around 30% lower inventive activity in this technology group compared to regions enjoying the informational advantage.

Second, prior literature on the determinants of technological change mainly studies knowledge absorption through codified knowledge sources such as scientific publications and patents, or through more informal inter-personal communication, such as the internet (e.g., Catalini, 2018; Furman et al., 2021; Wernsdorf et al., 2022). In contrast, we focus on a rather passive form of knowledge absorption through media consumption in the form of watching TV and its advertisement content. Recent literature has shown that media, such as TV, has multiple effects on political outcomes, e.g., vote shares, the ascendancy of extreme national parties, and political attitudes in general. Similarly, social outcomes such as women's status, social capital, and even fertility may be affected by TV. For a brief survey of these literatures see Bursztyn and Cantoni (2016). We are not aware of any study that has shown causal evidence for an impact of TV on inventive activity.

We also add to the discussion on invention processes and the demand pull-technology push debate by demonstrating the crucial role that information spillovers had for informing East German inventors about advanced household goods technology. While the innovation literature has unearthed many results on codified sources, i.e., on how reading patents, scientific literature and discussions with colleagues inform invention processes (e.g., Levin et al., 1987; Catalini, 2018; Furman et al., 2021; Wernsdorf et al., 2022; Giuri et al., 2007; Torrisi et al., 2016), the role of mass media has been neglected. Our study contributes to filling this gap, and the exogenous nature of the quality of TV reception in our data lends our regression results a strong causal underpinning.

This chapter proceeds as follows. Section 2.2 provides details on economic policies in the GDR, and how they shifted in 1971. It also describes patterns of TV consumption in East Germany and regional restrictions on TV reception due to geological and technical reasons. Section 2.3 provides information on our data sources and descriptive statistics, including a discussion on the GDR patent system. In Section 2.4, we describe the empirical setup. Section 2.5 displays the main empirical findings from difference-in-differences specifications, including several robustness tests, and details on potential underlying mechanisms. We conclude in Section 2.6.

2.2 Institutional Framework

2.2.1 Historical Background and Political Landscape

After World War II, Germany was separated into four different occupation zones – the British, the French, the American and the Soviet occupation zone (Cassidy, 1994). The Western powers (Great Britain, France and the U.S.) differed strongly from the Soviet Union in terms of ideology and, consequently, also in their treatment of the respective occupation zone. These differences ultimately resulted in the foundation of two separate German states in 1949 – the Federal Republic of Germany (FRG, West Germany) and the German Democratic Republic (GDR, East Germany). West Germany's economy recovered swiftly from the destructions of World War II and the population's standard of living rose. Due to its substantial scale, this period of tremendous growth is also referred to as the "economic miracle" ("Wirtschaftswunder" in German). Massive U.S. economic development programs, like the Marshall Plan, and the introduction of the social market economy by Ludwig Erhardt mostly contributed to growth in West Germany during the first two decades after World War II.

In contrast, East Germany's economic development took a fundamentally different path. Unlike the U.S.-aided Western part, the GDR economy was restrained by large reparation payments from the start (Kimmel, 2005). Further, the governmental system of the GDR was based on a socialist dictatorship, in which only the ruling party, the SED, stipulated every aspect of political and economic activity. This implied the absence of decision-making power of the agents within the economy, especially companies. The resulting lack of flexibility in navigating changing economic circumstances hampered the economic development, ultimately causing the near-collapse of the East German economy (Eichberg, 2017). The unequal evolution of the two German states soon triggered frustration among East German citizens, resulting in a large emigration wave of East Germans to the West. Until 1961, 3.5 million citizens left East Germany (Eichberg, 2017).

The GDR's political leaders responded to these developments in multiple ways. Most visibly, the SED suppressed the free movement of citizens by installing physical barriers, such as the Berlin Wall, and psychological barriers led by the secret police, the so-called Stasi. Besides this, SED rulers reacted to the social issues by making significant adjustments to the economic system in an effort to spur market activity and regain confidence in the socialist system. At the fifth party congress of the SED in 1957, Walter Ulbricht, the General Secretary of the SED, announced to match West German living standards and consumption as the primary goal for the upcoming years (MDR Fernsehen, 2023). To achieve this goal, in 1963, the SED government introduced the largest reform package in GDR history, the "New Economic System of Planning and Management of the National Economy". As a key component, the reform asked for greater autonomy for companies by reducing central planning activities of the SED. Companies were allowed to generate profits which could then be used for necessary investments. The reform

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also supported pay-for-performance based wage schemes for workers (MDR Fernsehen, 2023; Eichberg, 2017).

However, despite these ambitious reform plans, its practical implementation was insufficient to overcome the increasingly visible economic problems. As part of the problem, the economic crisis in the Soviet Union in the mid-1960s worsened the conditions of limited resources as it led to a halt to the delivery of previously cheap mineral oil into the GDR (Eichberg, 2017). Further, companies struggled with a lack of skilled employees. To counteract this scarcity, the government invested heavily in automation technologies in an attempt to substitute for the missing workers. In this context, massive investment programs were launched to specific industries, such as electrical engineering and nuclear research. These investments came at the expense of other industries, such as consumption goods, which further deteriorated the support of the citizens for the socialist regime (Eichberg, 2017).

The growing dissatisfaction within the population and the leading party eventually led to the resignation of Walter Ulbricht in 1971 (Gruler and Wagner, n.d.). His successor, Erich Honecker, reversed most of the reforms of the New Economic System. Decision-making power now laid again with the leading party, the SED, and the large investment programs in automation and research were terminated. Further, there was a political rapprochement with West Germany following this change in government power. One milestone in this development was the signing of the Basic Treaty between East and West Germany in 1972 (Schwabe, 2016). This treaty intended to create “normal relationships” between the two German states and to foster collaboration in various economic areas (Deutscher Bundestag, 1973).

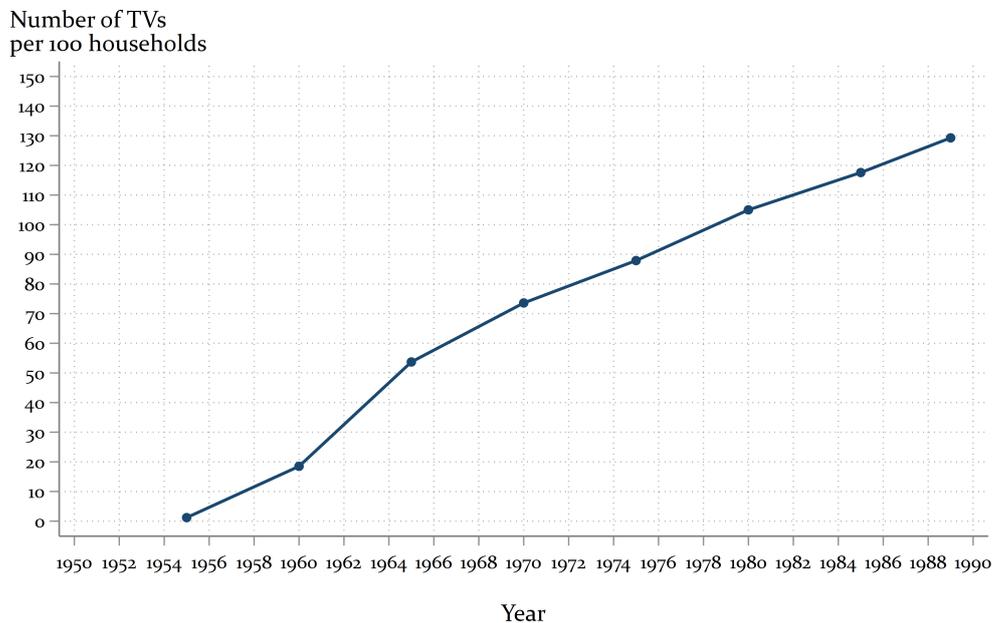
Most important in the context of our analysis are two significant changes triggered by the takeover of Erich Honecker and the subsequent restructuring of the economic system. First, the new focus of production was shifted towards consumer goods (Blum and Dudley, 2000). This focus stood in contrast to the final Ulbricht years, which were marked by massive investments into heavy industry and automation technology. Aligning with the Basic Treaty between East and West Germany, the GDR received substantial financial support from West Germany in the form of loans, intended to raise consumption good production. Second, Honecker’s political approach stipulated improving access to Western media. It allowed the consumption and dissemination of media content via books, newspapers and television. Importantly, the new doctrine enabled GDR citizens to freely observe Western consumer products via media. It stands in contrast to the repressive system pursued under the Ulbricht regime, in which the GDR citizens faced heavy sanctions for accessing West German media.

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2.2.2 TV Availability and Consumption in East Germany

This section provides details on TV consumption in East Germany and the resulting changes of the shift in political power. Media consumption, in one form or another, was part of everyday life for GDR citizens. Especially newspapers, and as of 1960, radio, were heavily used (Fiedler and Meyen, 2012; Fischer, n.d.). In 1952, East Germany launched a pilot run in the dissemination of television, initially starting with 75 TV sets (Fischer, n.d.). While in the mid-1950s only 1.2% of all East German households owned a TV, this percentage rose to approximately 55% within the next 10 years and by 1975 almost 90% of GDR households had a TV at home (see Figure 2.1).

Figure 2.1: Television Availability in the German Democratic Republic



Note: This figure shows the possession of television sets in the German Democratic Republic between 1950 and 1990 based on data from Statista Research Department (1990).

At the onset and similar to most areas of daily life, television in East Germany was centrally planned and supervised. This system impaired the freedom to broadcast and the SED regime stipulated the specific content available to GDR citizens. In particular, broadcasts criticizing the ruling party or the concept of socialism were banned, and those responsible were dismissed and faced additional sanctions (Bundeszentrale für politische Bildung (bpb), 2012). Instead, TV content in the GDR was intended to educate the citizens in accordance to the ruling system (Dittmar, 2010). As such, East German television almost exclusively covered news, movies, or other entertainment shows from the GDR and other socialist states. Advertising had been an integral component of watching TV in East Germany. For example, the GDR produced and broadcasted its own advertising program called “Tausend Tele-Tipps” (meaning “Thousand TV

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Hints”) from 1959 to 1976. It was similar to West German TV commercials but advertised only goods produced in East Germany or the Soviet bloc (WDR, 2020).

Despite the attempt to bind GDR citizens to East German television through entertainment programs, the leading party was increasingly confronted with greater interest of their citizens in Western television. The attractiveness of West German television was motivated by a strong desire of East German citizens for free and independent information (Richter, 2018). Initially, the GDR regime tried to keep citizens away from Western television by exerting pressure on workers in the companies to “voluntarily” refrain from watching Western TV (Wehinger, 2011). It also resorted to sanctioning people who watched Western television by denouncing the dissemination of Western television as morally questionable and endangering peace in the GDR (Wehinger, 2011). The demonization of West German television culminated in the “Ochsenkopf campaign” (“Aktion Ochsenkopf”) in 1961, in which party supporters dismantled antennas facing west (Scheida, 2022).

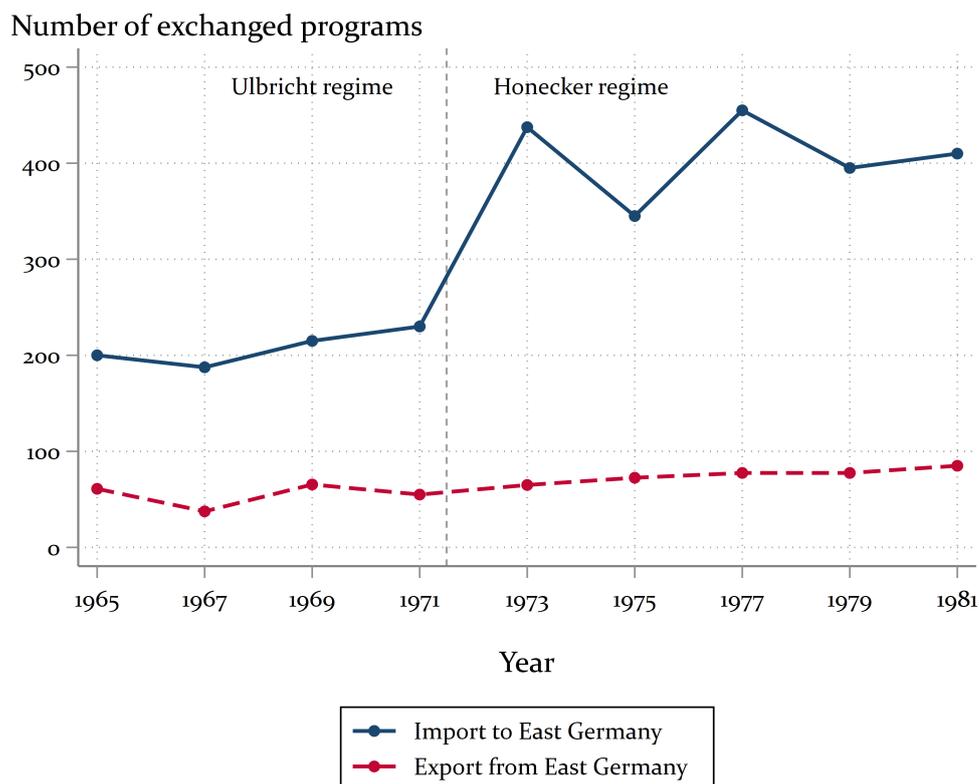
When Erich Honecker seized power, there was a general shift in the East German government towards improving relationships to West Germany. In particular, the Basic Treaty of 1972 served to ameliorate the previously tense political relationship by improving collaboration in various areas, amongst others the access to newspapers and television across German states (Deutscher Bundestag, 1973). Erich Honecker explicitly expressed greater tolerance for East Germans watching West German television by stating that “citizens could switch West German television on and off as they like” (Meyen, 2022). Later, during the 1980s, West German television was not only tolerated by the GDR government, but even actively supported. Together with private initiatives of citizens, the government promoted the expansion of antennas and reception amplifiers to give more East Germans access to West German television (Wissenschaftliche Dienste Deutscher Bundestag, 2016).

The regime shift and, specifically, the greater tolerance and access to West German TV in the GDR is documented in aggregate statistics. As such, Figure 2.2 displays statistics on the program exchange between the Intervision and Eurovision broadcasting networks. These authorized platforms coordinated the cooperation of radio and television organizations in the socialist community of states (Intervision) and the Western European countries (Eurovision), respectively. The GDR was a founding member of the Intervision distribution network in 1960. The graph plots the two-year moving averages of TV programs exchanged between the two networks between 1965 and 1981. Overall, the Eastern TV networks imported significantly more programs as compared to their Western peers. Most importantly for our empirical analysis, it shows a spike in the number of imported programs after 1971, when government power changed from Ulbricht to Honecker. The average number of imported Eurovision programs almost doubled after 1971, rising from about 201 to about 379 per year. These patterns are unlikely to reflect general shifts in the exchange of TV programs across borders at the time.

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As such, the levels of TV program exports from the GDR to West Germany did not change around 1971 and, overall, increased at a much lower pace across the observation period than imports. These statistics illustrate the government-led tolerance for East Germans watching West German television, triggered by the 1971 regime shift in the GDR.

Figure 2.2: Exchange of TV Programs Between East and West Germany



Note: This figure shows the exchange of TV programs between television organizations in the socialist community of states (Intervision) and the Western European countries (Eurovision). The blue solid line is the two-year moving average of the number of TV programs imported to East Germany from West Germany, and the red dashed line is the two-year moving average of the number of TV programs exported from East Germany to West Germany. The graph indicates also the change in government power from Ulbricht to Honecker in 1971. Own depiction based on data from Beutelschmidt (2019).

We exploit this policy shift in tolerance for West German television in the empirical section. In particular, we test whether and how this shift affected East German patenting activities. The key idea is that we can expect a relative increase in patenting activities in municipalities with access to West German TV, compared to municipalities without, if the policy change had an effect on information relevant for patenting that was transmitted via TV to local inventors. To confirm this general mechanism, the increase should be driven by patents protecting inventions in consumer goods, i.e., those products actually displayed on Western TV.⁴

⁴In Table B.1 of Appendix B.1, we show that most advertising on West German television between 1970 and 1973 was directed to industry sectors associated with consumer goods.

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As underlying channels for these effects, we posit that the regime shift in 1971 raised East German inventors' propensity to learn from West German TV. East German inventors became more likely to consume West German TV programs since the regime shift directly raised their supply (e.g., as illustrated in Figure 2.2). There are two specific channels how the sharp rise in access to Western television programs impacts inventive activities in the GDR. First, by raising inventors' exposure to Western TV, the policy shift increased their probability of absorbing knowledge about consumer products displayed on Western TV programs. Until 1971, the barriers to watching Western TV were significant and the variety of programs was small, limiting the potential spillover of knowledge through television. Second, the new tolerance of watching Western TV also raised inventors' propensity to seek patent protection for inventions that relate to Western products displayed on TV. As such, seeking patent protection for Western TV-inspired products resembles an implicit disclosure of exposure to respective TV programs. The regime change lifted inventors' fear of revealing potential TV consumption that could paint a negative picture of their loyalty towards the SED regime. Therefore, East German inventors were likely less hesitant to seek authorized protection for Western TV-inspired products after Honecker's takeover than before. In summary, the regime change in 1971 and the associated shift in access to West German TV programs raised the potential of knowledge spillovers from West to East, and it also raised GDR inventors' propensity to transform absorbed knowledge into patented inventions. For these reasons, both channels should foster the patenting activities in the GDR related to products displayed on Western television. We formally test the aforementioned implications of the GDR policy change in 1971 in Section 2.5.

2.3 Data and Descriptive Statistics

2.3.1 Patenting in the GDR: Context and Aggregate Statistics

We operationalize GDR inventors' inventive activities using patenting activities. In most aspects, the patent system in East Germany was similar to patent systems in Western economies. For better understanding, the following paragraphs provide an overview of the key characteristics of the GDR patent system and general patent trends at the time.

As of 1951, East Germany had been a member of the World Intellectual Property Organization (WIPO), which defines international standards for a patent. In general, East German patents were thus comparable in terms of quality to a patent from West Germany and other Western economies (Günther et al., 2020). A particularity of the East German patent system was the differentiation between exclusive patents and economic patents (Deutsches Patent- und Markenamt, 2024). Exclusive patents (so-called "Ausschlusspatente") granted their holders the right to exclusively use the invention for a limited period of time. These patents were equivalent to those in Western economies. However, most patents were granted as economic patents (so-called "Wirtschaftspatente") and allowed all state-owned enterprises to make use

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of the patented invention when paying a fee (Deutsches Patent- und Markenamt, 2024). This concept is comparable with a compulsory licensing scheme in which a person or company seeking to use another's patent can do so without seeking the rights holder's consent, and pays the rights holder a set fee for the use. Importantly, this particularity did not prevent GDR citizens from creating inventions. In fact, increases in per capita patenting in East Germany were almost as high as they were in West Germany throughout the entire existence of the GDR between the 1950s and 1980s (Günther et al., 2020). Against this background, we do not consider patents as a means of economic agents to exploit an invention commercially. Instead, we view patents as an expression of inventive activity in our empirical setting.

Just like in West Germany, inventions in the GDR resulted from scientists working in the institutes of the Academy of Sciences or other scientific institutions, research institutes and state-led companies. At the same time, there were virtually no entrepreneurs or market-oriented enterprises (Günther et al., 2020). Notwithstanding, to foster patent activity and to create incentives for inventors to innovate, the GDR government granted inventors a share of the revenue generated by the patent (Günther et al., 2020). For example, inventors could receive up to 200,000 Mark for their inventions (Rauner, 2010). Depending on the number of patents, inventors were honored with the medal of meritorious inventor, the so-called "Orden des verdienten Erfinders" (Rauner, 2010; Günther et al., 2020). Despite these efforts, the East German patent production was much smaller than the one in West Germany. The average number of patents per 100,000 inhabitants between 1950 and 1989 was 40.5 in the GDR and 75.1 in West Germany (Günther et al., 2020). Also due to differences in the sizes of the two states, these differences were manifested from the onset of the GDR's existence.

Importantly, in terms of dynamics and composition, patenting activities in East and West Germany were much more comparable. To illustrate, Figure 2.3 summarizes the evolution of overall patenting activities in the GDR between 1950 and 1988. It displays the total number of patent applications filed at the East German patent office each year (gray dashed line, left y-axis). It further shows the yearly number of patents in IPC A separately for the same time period (red solid line, right y-axis). This IPC section includes consumer goods-related patents and will be the focus of our empirical analysis.

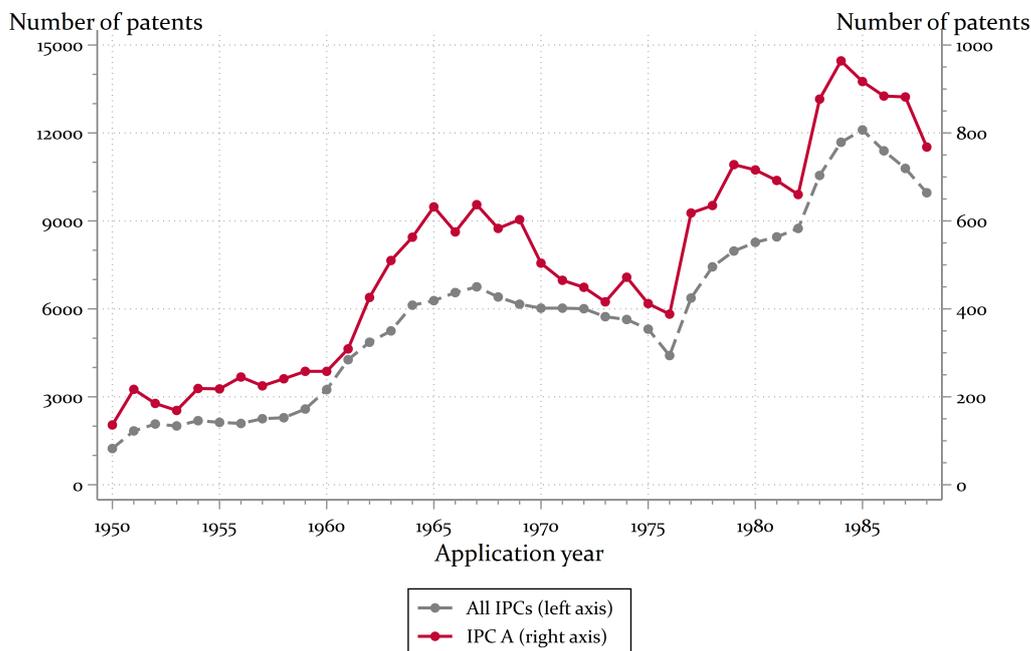
During the first decade, the total annual number of patents across all IPC sections was around 2,000, and it tripled by the mid-1960s. This rate remained fairly constant until a second wave of increasing patent applications between 1975 and 1985 further raised patenting activities, with a maximum of about 12,000 patents filed in 1985. As documented in Günther et al. (2020), the number of patents per 100,000 inhabitants in the GDR was, on average, 12.4 in the 1950s and it rose to 67.0 in the 1980s. The same figures are higher in absolute, but not in relative terms for West Germany, with 47.9 and 100.1 in the 1950s and 1980s. Hence, regarding the overall patenting dynamics, East and West German patenting activities increased at a comparable pace

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over the four decades, with a total increase of 54.6 and 52.2 patents per 100,000 inhabitants, respectively. Moreover, prior research shows that East German patenting activities were closely aligned with those in West Germany in terms of technological focus (Günther et al., 2020).

The trend in patenting in IPC A closely followed the trajectory of total patenting across all IPC sections. In the 1950s, around 200 patents were filed annually in IPC A. This number tripled by the mid-1960s. In the following decade, patenting in IPC A declined, and reached about 400 patents in 1976. From that point onward, patenting in IPC A gradually increased and peaked at 950 patents in 1984.

Figure 2.3: Yearly Patent Application Count in East Germany for All IPCs and for IPC A Separately



Note: This figure shows the number of patent applications to the East German patent office per year between 1950 and 1988. The gray dashed line represents the total number of patents across all IPC sections, measured on the left y-axis. The red solid line represents the number of patents in IPC A, measured on the right y-axis.

Overall, we observe fairly large disparities in total patent output between East and West Germany, which already existed for pre-defined reasons. Yet, there was a large overlap of technological clusters, and the dynamics in aggregate output were closely aligned. Thus, we can conclude that the GDR patent system was comparable to the patent system in Western economies at the time, even though East Germany followed a quite different economic regime.

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2.3.2 Sample Data Construction

The construction of our final data for estimation involves several steps and combines data from different sources. The basic data comes from Hipp et al. (2024). This data comprises all patents granted in the German Democratic Republic after the inception of the East German patent office in 1950. This data does not only include patents filed by East German inventors, but also patents filed by inventors from other countries, such as West Germany. As an important feature of our data, all patents are assigned in the patent office to technology classes using the International Patent Classification (IPC) system. This information allows us to assign specific technologies and categories, such as consumer goods-related inventions, to each patent. Details on the IPC classification are provided in Appendix B.2.1. In addition to this, each patent states the inventor names.

The main challenge in constructing our data set is to determine the location of the inventors of each patent and to ultimately assign them to high or low signal strength municipalities. We begin by obtaining a list of all potential cities in East Germany from Wikipedia.⁵ We then extract the location information of the inventors from the inventor and applicant variables, which are string variables that include individual names of inventors, companies, and their residencies. We assign the respective location information to East Germany based on the list of East German city names. We exclude patents filed by inventors from other countries than East or West Germany. In a first step, this leaves us with 142,759 patents labeled as GDR patents with any type of location information, out of which location information on inventors is directly available for 64,400 patents. The main reason for missing location information is that the physical appearance of GDR patent applications changed over time. In particular, as of the late 1960s and until the early 1980s, filed patents did not contain inventor location information. Retrieving these information is important, because the missing entries during the 1960s and 1970s could introduce systematic error in our data and estimation results.

To identify location information for these remaining inventors, we proceed in two steps. As a first step, we draw on information about the patent assignee if the assignee is a nationally-owned company or a combine (VEB). The general idea behind this is that inventors are likely to be located in proximity to their workplace. This step increases the number of patents with available location information for East German inventors to 126,020, which is a coverage of 88.3% of East German patents in our dataset.

As a next step to retrieve further inventor locations, we systematically impute location data from already known locations. More specifically, we impute disambiguate inventor names and resort to inventor location information from patents filed before or after the entry with missing data. The maximum duration for which we do so is 15 years, but for most imputations information

⁵Source: https://de.wikipedia.org/wiki/Liste_der_Stadte_der_DDR

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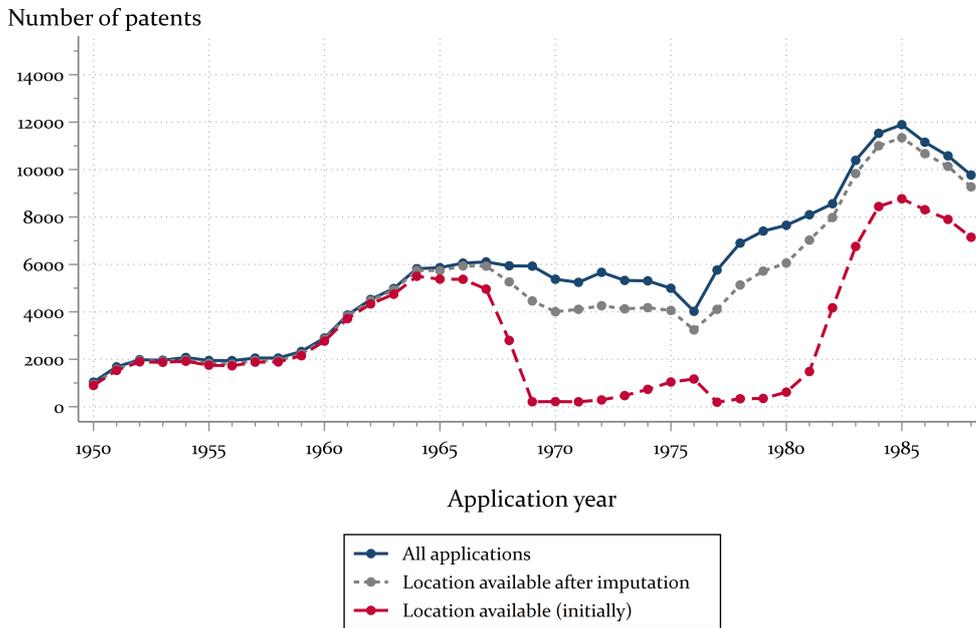
stems from within a five-year time span. In case such information is not available, we impute location information via the city given in co-inventor records. The main underlying assumption for this step is that inventor mobility in East Germany is low. This assumption is consistent with prior literature showing that labor mobility in the GDR was exceptionally low, since the East German state allocated production factors according to a central plan and housing supply was generally low (Kern and Hainmueller, 2009; Grünert, 1996). We provide details on the validity of this assumption by displaying inventor mobility patterns in the GDR using our sample data in Appendix B.2.2. To ultimately assign a location, we use the modal municipality from the backward and forward imputations. This leads us to an additional increase of patents with location information by 18,968, which results in 144,988 East German patents with known inventor location.⁶ Figure 2.4 shows the increase in coverage achieved by the two imputation steps.

To assess the availability of West German television within GDR municipalities, we use data on the ARD signal strength in each GDR municipality from Bursztyn and Cantoni (2016). ARD was the main public TV station in West Germany at the time. Bursztyn and Cantoni (2016) draw on information about the location of the antennas in use by ARD in 1989 and calculate the signal strength in each GDR municipality. We combine this data with the patent data including the location information of inventors listed on respective patents. We are able to assign signal strengths to 99% of East German patents with available location information.

⁶This number exceeds the initial count of 142,759 GDR patents, as some GDR patents were incorrectly labeled as West German patents.

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Figure 2.4: Availability of Location Information - Patent Level



Note: This figure shows the total number of patents filed in the GDR between 1950 and 1988 (blue line). Further, the red dashed line displays patents in the raw data for which inventor locations are directly available. The grey dotted line plots patents with locations available after the imputation step.

2.3.3 Descriptive Statistics

This section provides descriptive statistics on our data. The unit of analysis is the municipality level. Table 2.1 provides summary statistics for the main patenting dimensions. On average, we observe 15.7 patents across all municipalities, while the median municipality has 3 patents. These statistics reveal that the distribution of patents is right-skewed, consistent with other studies that use patenting activities to measure inventors' output (e.g., Scherer and Harhoff, 2000; Gill and Heller, 2024). Large municipalities have very high patent output, such as Berlin (2,242 patents) or Dresden (1,052 patents), which comprise 15.8 and 11.3% of overall GDR patenting. Still, in terms of overall regional patenting activities, most GDR municipalities exhibit some patenting activities, with the largest five regions only comprising 43.6% of total patenting output between 1958 and 1986. Transforming the patent variable using a log transformation strongly reduces the skewness of the distributions.

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Table 2.1: Summary Statistics

Variable	Mean	Std. dev.	Min.	Max.	Median	P25	P75
<i>Patenting</i>							
# patents	15.72	74.09	1.00	2242.00	3.00	1.00	8.00
# patents in IPC A	3.96	9.45	1.00	177.00	1.00	1.00	3.00
# patents in IPC B-H	15.51	71.35	1.00	2074.00	3.00	1.00	8.00
# consumer goods patents in IPC A	3.30	6.36	1.00	114.00	1.00	1.00	3.00
# other goods patents in IPC A	3.40	6.18	1.00	70.00	1.00	1.00	3.00
<i>Log-transformed patenting</i>							
log(1 + # patents)	1.66	1.11	0.69	7.72	1.39	0.69	2.20
log(1 + # patents in IPC A)	1.17	0.71	0.69	5.18	0.69	0.69	1.39
log(1 + # patents in IPC B-H)	1.66	1.11	0.69	7.64	1.39	0.69	2.20
log(1 + # consumer goods patents in IPC A)	1.13	0.65	0.69	4.74	0.69	0.69	1.39
log(1 + # other goods patents in IPC A)	1.13	0.68	0.69	4.26	0.69	0.69	1.39
<i>Other variables</i>							
Distance to border (hrs)	1.00	0.60	0.00	3.50	0.95	0.54	1.37
ARD signal strength	-61.70	19.97	-107.03	-12.49	-64.46	-77.66	-47.34

Note: This table displays summary statistics on the main sample. All variables are measured on the municipality level. In total, we observe 1,152 municipalities over the time period of 1958 – 1986.

In terms of technological distribution, the average number of patents in IPC A, which comprises all consumer goods technologies, amounts to 26% of the average number of patents in the remaining IPC sections.⁷ Consumer goods are defined as patents belonging to one of the following classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). The average number of consumer goods patents in IPC A is similar to the average number of IPC A patents related to other goods.

On average, municipalities are located about one hour away from the inner German border, albeit some municipalities are up to 3.5 hours away. Most municipalities have a signal strength around -61.70. Few municipalities, such as Potsdam, which are located very close to an ARD broadcasting antenna, have excellent signal strength close to -12.49. The more shielded a municipality is from the broadcasted signal, the lower the signal strength value. The lowest reception is on Rügen island, with signal strength values between -98.68 and -107.03.

2.4 Empirical Setup

In our empirical analysis, we explore the impact of West German TV access on the direction of patenting activity in the GDR. To do so, we need an estimate of how patenting activity in those

⁷Appendix Table B.3 provides summary statistics for each individual IPC section.

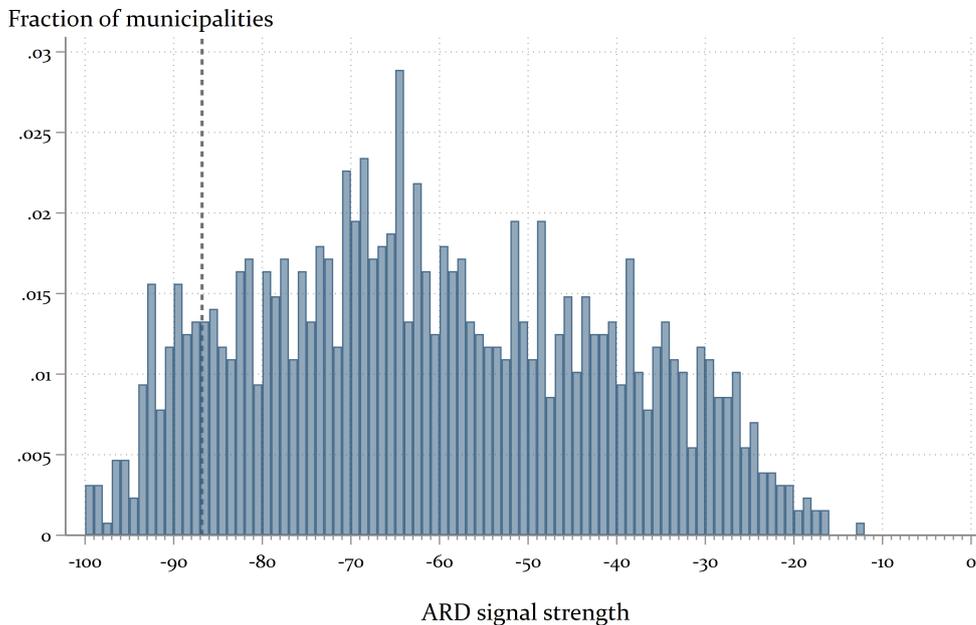
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municipalities would have evolved had access to West German TV been absent.

A key challenge in constructing this counterfactual is the fact, that watching TV is rarely random. In particular, people usually decide if they watch TV and what they watch. Our setting allows us to address this challenge by exploiting cross-sectional variation arising from exogenously determined access to West German TV. In particular, whether a municipality could watch West German television was determined by geographic factors, such as the existence of mountains blocking the TV signal or the location in a valley. Thus, we propose to use municipalities in which West German TV signal strength is too low to actually watch West German television as a counterfactual.

Figure 2.5 displays the distribution of municipalities across ARD signal strength values. It is evident, that the majority of cities is located around intermediate values of signal strength. We define cities receiving a signal strength smaller than -86.8 as the control group, whereas cities receiving a signal strength larger than -86.8 belong to the treatment group. As Bursztyn and Cantoni (2016) show, this threshold marks an important discontinuity at which watching TV becomes hardly possible. In Figure 2.5, the grey line marks the signal strength that separates the treatment group from the control group.

Figure 2.5: Distribution of Municipalities Across ARD Signal Strength Values



Note: This figure shows the distribution of municipalities across ARD signal strength values (measured in decibels). The grey dotted line marks the signal strength value that separates treatment and control group, which is equal to -86.8. This value corresponds to the average signal strength value in Dresden, which, according to historical evidence, is close to the discontinuity in signal strength values separating regions with sufficient signal strength to watch Western TV from those with insufficient signal strength (see Bursztyn and Cantoni (2016) for a more detailed explanation).

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To identify the effect of a change in the availability of Western TV, we combine this cross-sectional variation arising from the inventor locations with variation over time arising from the regime shift in 1971. This regime shift changed the propensity of watching West German television, but only for those municipalities with a signal strength high enough to actually watch Western TV.

We use a difference-in-differences specification according to the following equation:

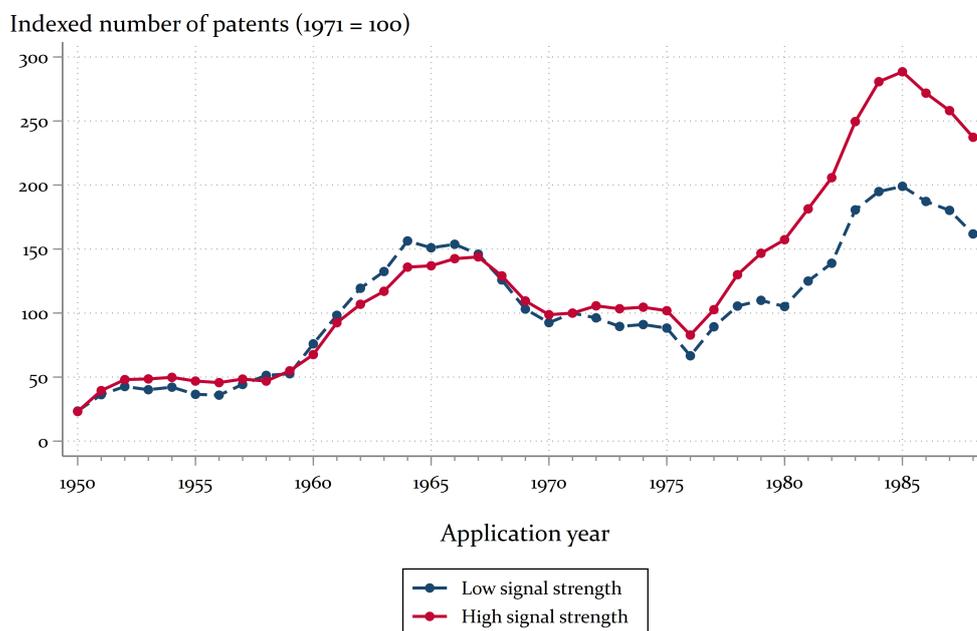
$$y_{it} = \beta_1 \cdot Post_t + \beta_2 \cdot Treated_i \cdot Post_t + \mu_t + \gamma_i + \varepsilon_{it} \quad (2.1)$$

where subscript i denotes the municipality and t indexes the time in calendar years. y_{it} corresponds to the number of patents in municipality i in year t , $Post_t$ is an indicator which equals one in the years after Erich Honecker succeeded Walter Ulbricht in 1971, and $Treated_i$ is an indicator equal to one for municipalities with West German TV access and zero otherwise. In all specifications, we include calendar year fixed effects (μ_t) and municipality fixed effects (γ_i). The standard errors allow for clustering at the municipality i level. β_2 measures the average increase in the number of patents in the years after the succession of Walter Ulbricht by Erich Honecker.

Municipalities with a signal strength too low to watch West German TV are a valid control group if their patenting trend is similar to municipalities with West German TV access, if those municipalities were unable to watch West German television. Although we cannot test this assumption directly, we can provide pieces of evidence supporting it. Figure 2.6 displays the yearly number of patents for high signal strength municipalities and low signal strength municipalities indexed to 1971. The red line displays patenting activity in high signal strength municipalities and the blue line shows patent application counts in low signal strength municipalities. It is evident that the two groups follow similar trends in the years prior to 1971, which is the year of a change of power from Ulbricht to Honecker in the GDR government. Appendix B.3.1 shows patenting activity in high and low signal strength municipalities without indexing to 1971.

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Figure 2.6: Overall Patenting in the GDR by TV Signal Strength (1971=100)



Note: This figure shows the yearly number of patents indexed to 1971 (=100) for high signal strength municipalities (red solid line) and low signal strength municipalities (blue dashed line).

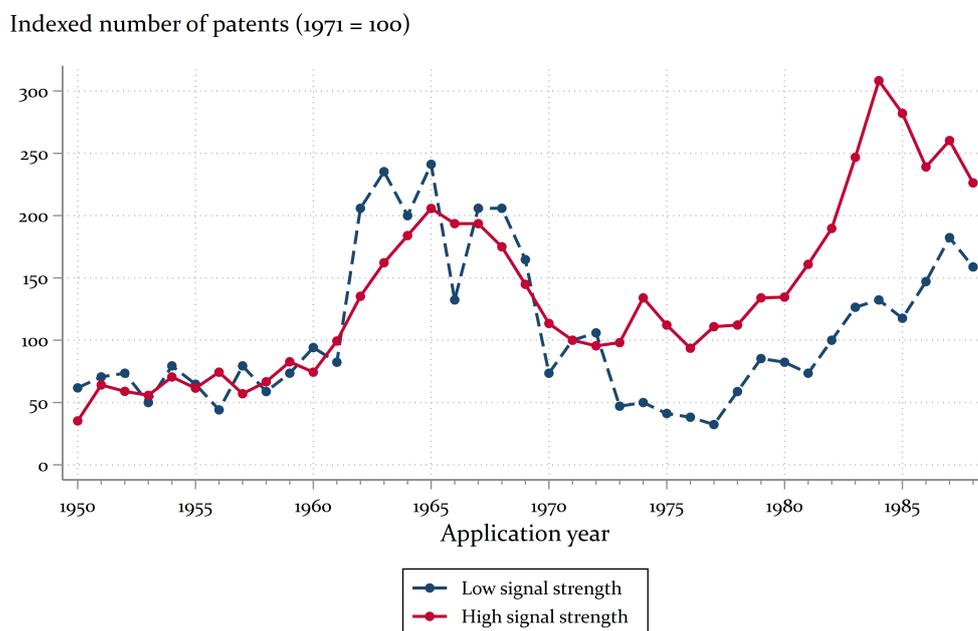
We expect to see the strongest effects in consumption goods, as these products are most advertised on television.⁸ Aggregate statistics confirm this notion: The share of patents filed in the consumer goods categories of IPC A from inventors located in municipalities with high signal strength shifts from 79% to 87% comparing pre- and post-1971 averages. This shift is disproportionate relative to the shift in patenting activities in all other classes, for which we observe an increase from about 81% to 84%.⁹ Moreover, Figure 2.7 graphically illustrates these trends. It displays the number of consumer goods patents filed in high and low signal strength regions over the years 1950–1988, indexed to 1971 values (=100). It shows that patenting activities in these regions followed a very similar pattern until the early 1970s, while diverging afterward. This observation is important as it mitigates concerns about a violation of parallel trends assumptions in our data. In combination, descriptive statistics in Figures 2.6 and 2.7 illustrate a compositional shift in patenting activities after 1971 in regions with good access to West German TV towards patenting in consumer goods fields.

⁸Table B.1 of Appendix B.1 shows how advertising on West German television between 1970 and 1973 was distributed across industry sectors. The largest shares were allocated to industry sectors associated with consumer goods.

⁹In Appendix B.3.2, we show patent counts by TV signal strength in IPC A and other IPC sections.

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Figure 2.7: Consumer Goods Patenting in the GDR by TV Signal Strength (1971=100)



Note: This figure shows the yearly number of patents indexed to 1971 (=100) for high signal strength municipalities (red solid line) and low signal strength municipalities (blue dashed line), equivalent to Figure 2.6. Only here, we display the subsample of consumer goods-related patents filed within the IPC A technology section.

2.5 Results

2.5.1 Main Results

To formally test our hypothesis, we start our analysis by estimating Equation 2.1 for the log-transformed number of patents in IPC A. Column (1) of Table 2.2 shows the estimated effect. The coefficient (0.25) implies an economically highly significant effect, resembling a 25% increase of IPC A patents in high signal strength municipalities compared to low signal strength municipalities. This effect is significant at the 1% level. The estimate for the remaining IPC sections, which is displayed in column (2), is small and insignificant. In columns (3) and (4), we differentiate between consumer goods patents in IPC A and patents covering other types of goods, as defined in Section 2.3.3. The observed increase in patenting in IPC A is primarily driven by consumer goods-related patents. For this type of patent, we observe an increase of 27%. We do not find a significant effect on other goods patents.

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Table 2.2: Main Results

Dep. Var.:	Log(1 + Number of patents)			
	IPC A	Other IPCs	Consumer Goods IPC A	Other Goods IPC A
	(1)	(2)	(3)	(4)
Treated x Post	0.25*** (0.08)	-0.03 (0.10)	0.27*** (0.07)	0.15 (0.12)
Mean Dep.	1.21	1.68	1.17	1.18
R2 (within)	0.73	0.80	0.68	0.72
Obs.	2743	9169	2195	1019

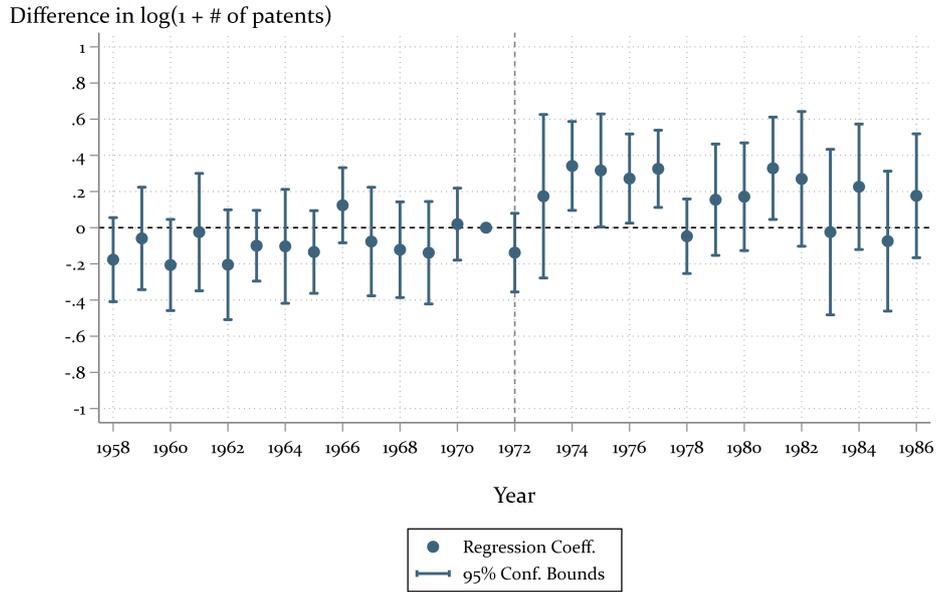
Note: This table shows difference-in-differences estimates of West German TV access. The treatment group consists of municipalities that have access to West German television. The control group consists of municipalities with very poor signal strength, inhibiting them from watching West German television. The dependent variable is the log-transformed number of patents. Column (1) shows the results for patents in IPC A, while column (2) displays the coefficient estimates for patents in all other IPC sections. Column (3) provides results for consumer goods patents in IPC A, while column (4) focuses on other goods patents in IPC A. Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). Robust standard errors, adjusted for clustering at the municipality level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To explore effect heterogeneity over time, we estimate a variant of Equation 2.1 with time-varying treatment effects. Panel (a) of Figure 2.8 displays the yearly treatment effects for the log-transformed number of patents in IPC A. We use 1971 as baseline period. The estimates are very small and statistically insignificant prior to Erich Honecker seizing power. This speaks in favor of the parallel trends assumption. After Erich Honecker succeeded Walter Ulbricht, the log-transformed number of patents in IPC A increases in high signal strength municipalities and shows significant coefficient estimates until 1977. After 1977, most coefficient estimates remain positive but the confidence intervals widen, thus rendering the estimates statistically insignificant at the 5% level. Nonetheless, the increase in patenting in IPC A is in line with our hypothesis that access to Western TV mostly impacts patents related to consumer goods. Also, in line with our hypothesis, in panel (b) we observe a zero effect on patenting in all other IPC sections.

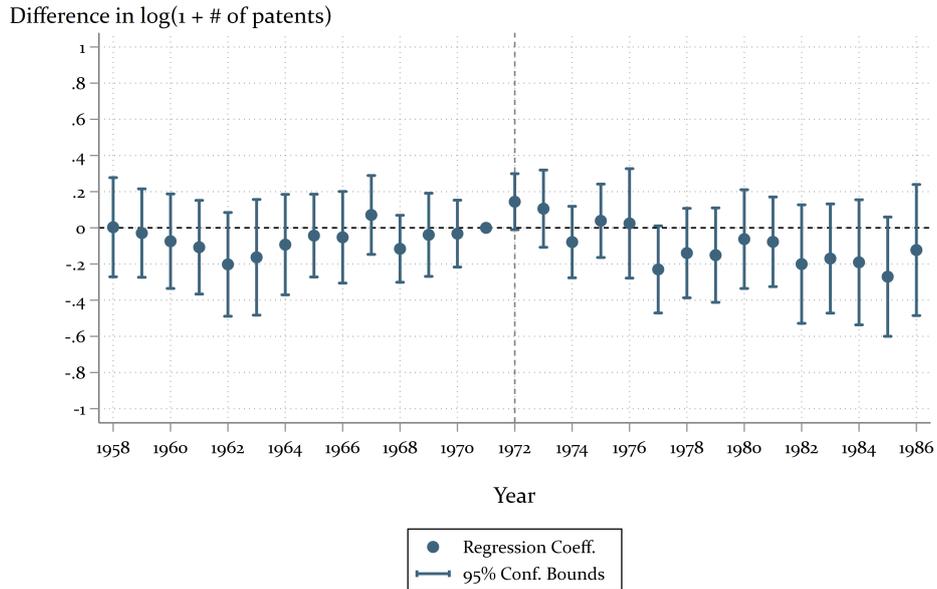
In Appendix Figure B.3, we provide yearly coefficient estimates for consumer goods patents in IPC A and other goods patents. These figures confirm our hypothesis of the increase in IPC A patenting being driven by consumer goods patents.

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Figure 2.8: Effects of West German TV Access on Patenting by IPC Section



(a) Difference in the Log-Transformed Number of Patents - IPC A



(b) Difference in the Log-Transformed Number of Patents - Other IPCs

Note: This figure shows the yearly average treatment effects on the treated of West German TV access on the log-transformed number of patents in high signal strength municipalities compared to municipalities that cannot access West German TV. The blue bars represent 95% confidence bounds that allow for clustering at the treated municipality level. Panel (a) shows results for patents in IPC A, whereas panel (b) shows results for patents in all remaining IPC sections.

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2.5.2 Robustness

One may be worried that our analysis compares economically different municipalities. For example, some municipalities may be economically strong and thus should have higher patenting activity, while other municipalities might struggle with their economic development and thus inventive activity is low. One approach to address this is to include control variables capturing the economic situation. However, we refrain from doing so because economic indicators of the GDR are often unreliable due to a tendency to sugarcoat production statistics, e.g., as reported by Schenk (2011). Instead, we use alternative compositions of the treatment and control group to address this concern. We focus on municipalities that are geographically close to each other and should therefore undergo a similar economic development.

We start by restricting our sample to only include municipalities in the treatment and control group that have a matching municipality at a similar distance to the inner German border. This is, however, not a one-to-one match. Instead, multiple municipalities in the treatment group are assigned one or more municipalities from the control group which are at most 10km closer to or further away from the inner German border. Table 2.3 shows that our results are robust to this adjustment. As in the main results in Table 2.2, patenting in IPC A increases in the treated municipalities after the change in government, while all other IPC sections remain unaffected. Again, the rise in patenting in IPC A is driven by consumer goods.

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Table 2.3: Municipalities with Similar Distance to Inner German Border

Dep. Var.:	Log(1 + Number of patents)			
	IPC A	Other IPCs	Consumer Goods IPC A	Other Goods IPC A
	(1)	(2)	(3)	(4)
Treated x Post	0.27*** (0.09)	-0.01 (0.12)	0.29*** (0.09)	0.12 (0.15)
Mean Dep.	1.27	1.77	1.22	1.24
R2 (within)	0.75	0.82	0.70	0.73
Obs.	1304	3821	1057	504

Note: This table shows difference-in-differences estimates of West German TV access. The treatment group consists of municipalities that have access to West German television. The control group consists of municipalities that cannot watch West German television. One or more treated municipalities are paired with one or more control municipalities which are at most 10km apart. The dependent variable is the log-transformed number of patents. Column (1) shows the results for patents in IPC A, while column (2) displays the coefficient estimates for patents in all other IPC sections. Column (3) provides results for consumer goods patents in IPC A, while column (4) focuses on other goods patents in IPC A. Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). Robust standard errors, adjusted for clustering at the municipality level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Next, we use a more restrictive estimation approach that includes only direct neighboring municipalities of treated municipalities in the control group. This amounts to 6% of the municipalities in our sample. Table 2.4 shows the results of this robustness check. While the coefficient estimates change in magnitude, the qualitative interpretation remains unchanged. Patenting in IPC A increases, while patenting in all other IPC sections remains unaffected. The increase in patenting activity in IPC A is driven by consumer goods patents.

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Table 2.4: Direct Neighboring Municipalities

Dep. Var.:	Log(1 + Number of patents)			
	IPC A	Other IPCs	Consumer Goods IPC A	Other Goods IPC A
	(1)	(2)	(3)	(4)
Treated x Post	0.30*** (0.10)	-0.22 (0.20)	0.36*** (0.10)	0.13 (0.10)
Mean Dep.	1.28	1.92	1.24	1.26
R2 (within)	0.81	0.83	0.77	0.81
Obs.	470	1101	392	171

Note: This table shows difference-in-differences estimates of West German TV access. The treatment group consists of municipalities that have access to West German television. The control group consists of municipalities that cannot watch West German television. We use direct neighboring municipalities of treated municipalities as the control group. The dependent variable is the log-transformed number of patents. Column (1) shows the results for patents in IPC A, while column (2) displays the coefficient estimates for patents in all other IPC sections. Column (3) provides results for consumer goods patents in IPC A, while column (4) focuses on other goods patents in IPC A. Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). Robust standard errors, adjusted for clustering at the municipality level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As an alternative robustness test, we explore whether our results are driven by a specific municipality. To do so, we rerun our analysis but exclude Berlin, which is the main patenting city of the treatment group. We then repeat the analysis, but this time we exclude the main patenting city of the control group, which is Dresden. The results displayed in Table 2.5 show that the estimated coefficients remain almost unchanged, and confirm the increase in IPC A patenting, which is driven by consumer goods patents. This applies to excluding either Berlin in columns (1) to (4) or Dresden in columns (5) to (8) from the sample.

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Table 2.5: Results Excluding Main Patenting Locations from Treatment and Control Group

Dep. Var.:	Excluding Berlin				Excluding Dresden			
	IPC A (1)	Other IPCs (2)	Consumer Goods IPC A (3)	Other Goods IPC A (4)	IPC A (5)	Other IPCs (6)	Consumer Goods IPC A (7)	Other Goods IPC A (8)
Treated x Post	0.24*** (0.07)	-0.03 (0.10)	0.25*** (0.07)	0.12 (0.12)	0.24*** (0.08)	-0.03 (0.11)	0.25*** (0.08)	0.09 (0.12)
Mean Dep.	1.18	1.67	1.14	1.13	1.19	1.67	1.15	1.13
R2 (within)	0.69	0.79	0.64	0.67	0.70	0.79	0.66	0.68
Obs.	2711	9120	2164	988	2714	9140	2166	990

Note: This table shows difference-in-differences estimates of West German TV access. The treatment group consists of municipalities that have access to West German television. The control group consists of municipalities that cannot watch West German television. Columns (1) to (4) exclude the city of Berlin from the treatment group. Columns (5) to (8) exclude the city of Dresden from the control group. Columns (1) and (5) show the results for patents in IPC A, while columns (2) and (6) display the coefficient estimates for patents in all other IPC sections. Columns (3) and (7) provide coefficient estimates for consumer goods patents in IPC A, while columns (4) and (8) focus on other goods patents in IPC A. Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). Robust standard errors, adjusted for clustering at the municipality level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

In Appendix B.4.2 we repeat our main results using the number of patents as well as the inverse hyperbolic sine transformation instead of a log transformation as dependent variable. Similar to our main results, we find a positive effect in IPC A, which is due to consumer goods in this IPC section. Other goods patents in IPC A show no significant difference between treatment

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and control group. This holds for both, the number of patents as the dependent variable and the inverse hyperbolic sine-transformed dependent variable. In Appendix B.4.3, we conduct a placebo test, using the distance to the inner German border as treatment. Reassuringly, all coefficient estimates are small and statistically insignificant.

2.5.3 Potential Mechanisms

The following section discusses potential mechanisms through which watching television, especially advertising, can influence inventive activity.

One way, in which watching television could lead to more consumer goods patents is by inspiring inventors and thus allowing them to develop new inventions. Dieter Mosemann, one of the most successful inventors in the history of the GDR, already acknowledged that “creativity comes from knowledge” (Rauner, 2010). Television serves as a catalyst for the dissemination of information and, as suggested by Mosemann, should thus spur creativity, once the newly obtained information enlarge recipients existing knowledge set. This consideration is consistent with theories on learning. For example, the active learning theory suggests that individuals process information more deeply and experience improved problem-solving abilities when verbal and visual information is combined (Dow, 2008). Similarly, the stimulation hypothesis states that information content that is displayed visually, such as on television shows, can actively stimulate creative processes (Calvert and Valkenburg, 2013). Finally, already Schumpeter (1942) described that there are different forms of innovation, one of which is innovation by imitation. Accessing new sources of information may thus foster imitation efforts of inventors.

An alternative mechanism could be that, by watching television ads, inventors implicitly learn about the underlying demand functions for specific product categories. This learning could be based on the frequency of showing advertisement spots for specific product categories or the total duration of advertisement for specific product categories. One inherent incentive of companies to exert costly effort to produce and disseminate advertisement is to raise consumer demand, which in turn increases product sales and revenues. The intuition is that public display of products increases the salience of the respective products and, thus, lifts the chances of potential consumers to buy the product. Indeed, the literature confirms that TV ads increase the demand for products and the consumer’s willingness to pay (e.g., Dave and Saffer, 2012; Kontos and Bomba, 2021). Anticipating this, inventors could be incentivized to conduct demand-driven development of new products. More specifically, East German inventors may perceive advertised products from the West to be particularly attractive both for East and West German citizens. In turn, they may shift their focus to developing new products similar to those displayed on West German television.

2. LEARNING BY WATCHING

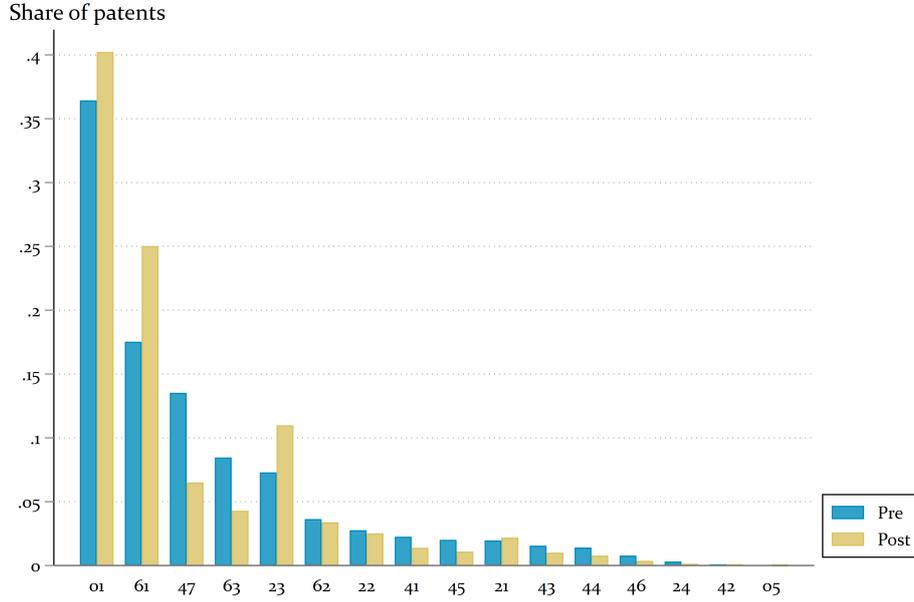
In general, exposure to TV likely triggers the aforementioned mechanisms. However, given the historical setting of the GDR, our specific empirical context allows us to largely mute the consumer demand-driven invention channel. Indeed, the GDR's economic system is particular since there was no free interplay of market forces. For this reason, the forces of supply and demand played a subordinate role in East Germany and should, therefore, leave inventors less responsive to such considerations. In contrast, having been largely shielded from Western consumer products before 1972, the learning- and imitation-induced shift in inventors' patenting activities is likely at play in our empirical setting.

We acknowledge that our data does not permit us to directly disentangle the two mechanisms. Still, we can use descriptive statistics to make inferences about how TV content might influence inventors via the learning channel. First, learning may influence what type of products inventors develop by providing them with ideas for *new* products. This should change the distribution of patents within the IPC A section. Second, learning may inspire new ways of technically implementing changes in *existing* products. Thus, inventors may not develop new products and thus patent in a new IPC class, but instead they may improve existing products. This would leave the distribution of patents within IPC sections unchanged.

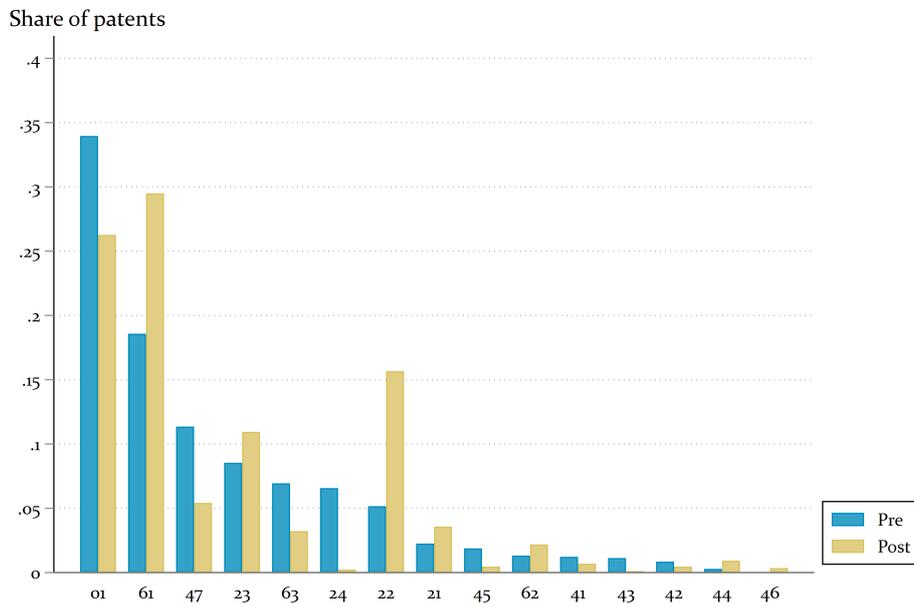
To test these considerations, we explore the distribution of patents within IPC section A in high and low signal strength regions before and after 1971. Figure 2.9 displays the respective distributions and shows that the composition of patents changes within IPC sections. In particular, the consumer goods classes in high signal strength regions experience a compositional shift, with the largest increases in agricultural products and food (IPC A01, A23) and decreases in the classes furniture and domestic articles or appliances (IPC A47), as well as sports, games, and amusement (IPC A63). In low signal strength regions, the share of patents in IPC A mostly changes in fields unrelated to consumer goods, such as medical and veterinary science (IPC A61) or butchering and meat treatment (IPC A22). These statistics show that inventors react to the knowledge absorbed via television by changing the type of products they develop. Especially in regions with good access to Western TV, the patent output of GDR inventors notably shifts within consumer goods categories. This insight suggests that learning via Western TV affects the direction of technological inventions by providing inventors with ideas for new products.

2. LEARNING BY WATCHING

Figure 2.9: Distribution of Technology Fields Within IPC Section A in High and Low Signal Strength Regions Before and After 1971



(a) High Signal Strength Regions



(b) Low Signal Strength Regions

Note: This figure shows the share of patents in IPC section A by IPC class. Panel (a) displays the share of patents in high signal strength regions before and after the policy shift in 1971. Panel (b) displays the corresponding shares in low signal strength regions.

2.6 Conclusion

This chapter explores whether television can impact the direction of inventive activity. To answer this question, we examine changes in patenting activities of GDR inventors in response to a major change in the GDR's policy regime in 1971, which decreased political and psychological hurdles for watching Western television. To identify the effect of the regime change on patenting activities, we explore geographical variation in access to West German television programs arising from exogenously determined, differential signal strength across municipalities in the GDR. Our results show a differential increase in patenting in affected municipalities by 25%. This surge in patenting is driven by patents related to consumer goods, i.e., product categories that are most advertised on West German television. Patents targeting other types of goods are not affected. We assess the robustness of our findings in several ways. For example, similar to a geographical regression discontinuity design, we restrict the sample to directly neighboring municipalities above and below the threshold that determines Western TV access. Here we find responses of 30% to 36% to the TV signal treatment. Further, we provide suggestive evidence that the mechanism behind our results is related to learning from media consumption, which ultimately affects the direction of technological inventions by providing inventors with ideas for new products.

With these findings, we make several contributions. First, we add to the historical record of studies investigating GDR policy by examining the shift from industrial products to household products after 1971. The role of inventive activity in this process has not been investigated in depth before. Furthermore, we advance the understanding of the effects of knowledge absorption on the direction of technological change by providing first evidence on the role of visual media (TV) as a source of knowledge spillovers. While the effects of media on political outcomes, women's status, social capital and fertility have been confirmed by numerous studies (see Bursztyn and Cantoni, 2016), its impact on inventive activity has been largely neglected so far. We employ a unique historical setting that allows us to analyze the effects of knowledge absorbed via television, and we show that information transmitted via media fosters inventive activity in specific areas of the economy.

With the steady increase in the use (and potential misuse) of a variety of media channels around the globe, these insights are particularly important as they document the direct link between information displayed via social media and real economic activities of market participants. Our analysis thus sheds light on the implications of media consumption which exerts a major influence on human behavior in modern societies.

3

(Un)Successful Integration into a New Science System?

The Case of East Germany

3.1 Introduction

Scientific achievements have long been perceived as the driving force of economic growth and of resulting advances in the living standard of a country. However, as the global knowledge stock expands, producing the necessary scientific achievements for sustained economic growth in isolation becomes increasingly challenging (Jones, 2009). This growing complexity intensifies the need for international collaboration of researchers and for deeper integration into the global science system to facilitate the exchange of ideas and leverage the whole pool of knowledge.

Yet, a researcher's integration into the global science system is not a random process. In particular, already integrated researchers may be crucial, taking on various roles. Formal coauthor relationships may, for example, enhance success by lowering the probability of failures while simultaneously increasing the probability of successful outcomes, and they may increase the global reach of a publication (Singh and Fleming, 2010; Wang et al., 2024). Further, coauthor relationships are associated with faster career progression, especially for women (Wal

In this chapter, the grammar and the wording of several paragraphs were refined using ChatGPT.

3. (UN)SUCCESSFUL INTEGRATION INTO A NEW SCIENCE SYSTEM?

et al., 2021). Taking on the role of a knowledge broker, researchers may facilitate connections by bridging peripheral researchers with well-connected members of the global scientific network (e.g., Fry, 2022). Beyond expanding network access, they may also share valuable knowledge, amongst others about the implicit “rules of the game”, such as publication strategies and effective approaches for securing grant funding. For example, the American Society for Cell Biology created the FRED Mentoring Program which is aimed at improving the grant funding success of early-career researchers by pairing them with an experienced mentor (The American Society for Cell Biology, 2022).

Well-connected scholars are especially relevant for the integration of researchers into the global science system, particularly when their existing scientific networks are disrupted by structural changes. A notable example of such a process is the transformation of the academic system in East Germany following the reunification. While this transition is widely perceived as successful, critics point out an insufficient social integration of East German researchers into the global science system, and a lower success rate in obtaining funding due to weaker professional networks (Pasternack, 2020; Balzer, 2019). However, comprehensive quantitative evidence on the transition process and its outcomes remains scarce.

This chapter intends to fill this gap by using a dual approach. The first part of this chapter provides an extensive descriptive analysis of the East German academic sector before 1990 and the changes following the reunification. In the second part of this chapter, I examine how the presence of West German researchers in East German university departments shaped the integration of East German researchers into the global science system following the reunification of Germany in 1990.

I investigate this question by analyzing East German university departments throughout the transition period triggered by the German reunification. Before 1990, East German researchers and university departments evolved largely in isolation from the Western science system. East German science was embedded in a heavily regulated and centrally-planned structure, characterized by limited international exchange with Western countries, lack of research resources and absence of competition (Buck-Bechler et al., 1994; Pasternack, 2010). Due to the reunification, East German researchers were required to quickly integrate into the Western system which adhered to global academic standards.

The transition process was accompanied by a wave of dismissals of scientific staff, requiring many East Germans to compete for their positions. At the same time, researchers from West Germany were appointed to professorship positions in East Germany. These researchers, having been trained in a fundamentally different academic environment, were not only unfamiliar with the East German system and culture, but were frequently perceived as threat by their East German colleagues. This sentiment of mistrust persists to some extent even today. For

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instance, when Prof. Marec von Lehe, an internationally renowned neurosurgeon, assumed a leading position at the University Hospital Ruppin-Brandenburg in 2018, a colleague advised him against explicitly mentioning his West German origin due to the lingering mistrust towards West Germans (Donschen et al., 2024).

The results of my descriptive analysis reveal fundamental differences between the East and the West German academic sectors. Before 1990, East German universities employed a larger share of female researchers compared to their West German counterparts. Additionally, the distribution of academic positions differed. East Germany employed a similar number of professors and qualified university lecturers, whereas in West German universities professors dominated. The distribution of researchers across disciplines also differed, with East German researchers outside of the social sciences being relatively evenly distributed across the life sciences, the natural sciences and engineering. In contrast, West Germany had a greater focus on the life sciences. In response to the transition process following the reunification, East Germany's research focus shifted towards the life sciences, thus becoming more aligned with that of West Germany. The transition process also led to a reduction of available research positions, which resulted in a loss of almost 50% of East German researchers. Those who retained their positions in East Germany demonstrated a higher average publication output than those who moved to a different position. West German researchers who relocated to East German universities had on average a higher publication output than those who stayed in West Germany or moved elsewhere.

To estimate the impact of incoming West German researchers on the scientific performance of researchers in East German university departments, I exploit a particular institutional feature of the transition process. To align the East German university system with international standards, personnel restructuring followed a strictly regulated procedure, in which hiring committees consisted primarily of external researchers. As a result, the influx of new faculty members, particularly those from West Germany, was exogenous to the East German university departments. I exploit this exogenous variation in a difference-in-differences approach, comparing the change in the quantity and quality of publications by East German researchers in a department receiving at least one West German researcher with the change in the quantity and quality of publications by East German researchers in departments receiving no West Germans. My analysis focuses on East German stayers, i.e., researchers who remain employed in the same department before and after the reunification. I focus on the years between 1980 and 2010, allowing me to examine both short- and long-run effects.

I find that the influx of West German researchers into East German university departments results in an average decrease of 0.07 publications per East German stayer relative to control departments, corresponding to a 21% decrease in publication output per stayer relative to the mean of the treatment group before 1990. This aggregate effect masks substantial heterogeneity

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across research fields. It is entirely driven by a significant drop in publication output per East German stayer within Medicine departments, whereas no significant changes are observed in the majority of other disciplines. I further explore the impact of West German researchers on publication quality. Medicine departments benefit from an increase of publications in higher-ranked journals, while overall departments in the other fields experience no significant changes in publication quality. In the assessment of the impact of West German researchers onto internationalization I focus on two key dimensions: a shift towards English-language publications and the success in obtaining third-party funding. In Medicine, I observe a larger share of English-language publications in response to the arrival of West German researchers, whereas no such effect occurs in the remaining disciplines. In contrast, the arrival of West German researchers is linked to a higher amount of funding from the German Research Foundation, both in Medicine and the remaining fields.

I provide evidence that differential collaboration patterns in Medicine and the remaining fields could be the mechanism behind the observed effects. In Medicine, overall collaboration increases, primarily driven by collaborations with West German universities. In all other fields, I observe no change in the amount of collaboration as such, but collaborative efforts become more concentrated within East Germany. These changes in collaboration patterns are accompanied by changes in average team size. In Medicine, average team size increases, while it decreases in the remaining fields. Taken together, these results are indicative of the West German researchers assuming distinct roles during the transition process. In Medicine, they acted as knowledge brokers, thereby facilitating connections between East German researchers and the scientific community, especially in West Germany. In the other fields, the network-expanding effect played a subordinate role. Instead, West Germans primarily influenced their East German colleagues by engaging either directly in joint research projects or sharing system-specific knowledge without a formal coauthor relationship.

My research makes several contributions. First, it adds to the literature studying the effects of the German reunification. The majority of studies in this area are purely descriptive, either providing qualitative analyses of the reunification process and its implications for researchers (e.g., Burkhardt, 1997; Archambault et al., 2017) or evidence from case studies (e.g., Pasternack, 2015). In this study, I construct a comprehensive and novel data set from historical sources, capturing a larger share of East German academics than previous research. I use this data to provide a quantitative assessment of changes in the East German scientific and university system during the reunification and attempt to causally estimate the effects. To the best of my knowledge, only one other recent study tries to identify a causal effect. Chan et al. (2021) examine the complementarities in collaboration, as measured by research similarity, and the effect on productivity. East German researchers with limited pre-reunification connections to West Germany and lower research field similarity are more likely to shift their research focus and to collaborate with Western researchers. My study, however, reveals that the arrival of

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West German researchers does not necessarily promote greater collaboration between East and West German institutions. Instead, the West German researchers aid along other dimensions, such as facilitating access to third-party funding and adjusting one's publication strategy by trading off research quantity and research quality.

This study also extends the literature on knowledge brokers (e.g., Obstfeld, 2005; Burt, 2007) by examining a context in which the incoming researcher is an outsider to the organizational and social culture and is initially met with skepticism. Prior research generally finds a positive impact of brokers on knowledge transfer, especially when they are insiders (e.g., Fry, 2022; Choudhury, 2016). However, the effectiveness of brokerage may be contingent on the receptiveness of the environment, as suggested by studies indicating that hostility or resistance can diminish the broker's impact (e.g., Wang, 2015). This study advances these insights by demonstrating that even in ex-ante hostile environments, knowledge brokerage can generate positive outcomes. Further, my findings suggest that incoming researchers may contribute along several margins, such as sharing their networks or sharing valuable system-specific knowledge. However, the benefits and underlying mechanisms are not uniform across all fields.

Finally, this study demonstrates that the arrival of colleagues with system-specific knowledge and established networks can mitigate the adverse consequences of large-scale disruptions of scientific systems. Much of the existing evidence focuses on disruptions caused by wars. This literature highlights the importance of human capital, especially for a swift and sustainable recovery (e.g., Ganguli and Waldinger, 2023; Waldinger, 2016). Prior research emphasizes that the return of refugees to their home country contributes to productivity gains through knowledge spillovers (e.g., Fry, 2022; Bahar et al., 2024; Fry and Ganguli, 2023). Further, studies show that financial support via grants can successfully incentivize scientists to stay in academia (e.g., Ganguli, 2017). My results suggest that large-scale disruptions in the science system can be mitigated by recruiting researchers who are already well integrated in the scientific community. These researchers facilitate the recovery and transition of the affected researchers and institutions along several dimensions, such as enhancing the access to third-party funding, shaping their colleagues' research agendas, and sharing system-specific tacit knowledge. Additionally, they may broaden the existing research networks of their colleagues, thereby creating new research opportunities.

The remainder of the chapter proceeds as follows. In Section 3.2, I provide details on the historical background. Section 3.3 explains the data construction. A descriptive analysis follows in Section 3.4, which differentiates between the time before the reunification (Subsection 3.4.1) and the years after the reunification (Subsection 3.4.2). Section 3.5 describes the empirical approach, and Sections 3.6 and 3.7 present the results. Section 3.8 discusses the potential mechanisms. Additional robustness tests are performed in Section 3.9. Finally, Section 3.10 concludes.

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3.2 Historical Background

After the Second World War, Germany's territory was divided among the victorious powers. Due to unbridgeable differences between the Western powers (Great Britain, France, and the United States) and the Soviet Union, this ultimately resulted in the division of Germany into two separate states (Grau et al., 2016). The Federal Republic of Germany (FRG, also called "West Germany" in the following) was initially jointly administered by Great Britain, France, and the United States. The German Democratic Republic (GDR, also called "East Germany" in the following) was initially administered by the Soviet Union. Besides differences in the economic development of the two German states, this separation also led to diverging developments in the scientific systems of East and West Germany.

West Germany followed the Humboldtian model of higher education, which dates back to Humboldt's ideas on education in 1809 (Bongaerts, 2022). This model of higher education propagates academic freedom along several dimensions. Universities were intended to be self-governing and researchers were supposed to have the freedom to choose their research agenda. Students were expected to participate actively in research discussions and were granted the freedom to seize different educational opportunities, e.g., via elective courses (Bongaerts, 2022). These fundamental principles of the unity of research and teaching, as well as academic freedom, were deeply embedded in West German universities already in pre-war Germany. The Western powers thus saw no need to fundamentally alter the structure of the education system (Kehm, 2015). Nevertheless, between 1949 and 1989, the scientific system of West Germany was shaped by several reforms and changes, such as a wave of expansions during the 1960s and a call for significant changes through student protests in the 1970s. The 1980s were characterized by rising student numbers, while the number of scientific staff in the universities stagnated, leading to overcrowded universities and an unfavorable student-staff ratio (Kehm, 2015).

The East German science system underwent an entirely different development. Instead of maintaining the traditional autonomy of the universities, the responsibility for the governance of higher education institutions was assigned to the State Secretary (Kehm, 2015). Education at these institutions was ideologically shaped, making Marxism-Leninism a mandatory part of all studies. In contrast to West Germany, East Germany's scientific system started to expand rather quickly by founding several new academic institutions between 1961 and 1971. The majority of them were specialized colleges of higher education with the task to train students in a single discipline. This led to a shift towards applied research in the East German science system. As of 1972, academic freedom was further reduced by heavily regulating cooperation between academia and industry, and by central planning of research and study curricula. Finally, during the years before the reunification, contract research for industry became increasingly important (Kehm, 2015).

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The stagnating economic development and the growing state intervention resulted in challenging working conditions for East German researchers. Due to a constant shortage of foreign currency in the GDR and centrally allocated funding, researchers often faced a lack of necessary material, such as laboratory equipment. Furthermore, the exchange with West German and international peers was heavily regulated and only permitted in exceptional cases (Günther and Schmerbach, 2010; Meyer, 1993). Competition for positions or research funding was largely absent in East Germany, because funding and staff were centrally planned and college places were centrally allocated. Further, ideology played an important role, even to the extent that promotions were not only based on academic achievements but also on ideological conformity (Friedrich and Hecker, 2023, p. 26).

During the course of the reunification, one major task was to unite the scientific systems of East and West Germany. In practice, this implied an imposition of the West German scientific system onto the East German institutions and researchers.

This transition presented several challenges for the individuals involved. Due to the considerably higher student-staff ratio in West Germany compared to East Germany, a substantial proportion of academic positions in East Germany was eliminated in an effort to align student-staff ratios with those at West German institutions. This development forced many East German researchers to resign from their roles. Disciplines with strong political influence, such as the social sciences, experienced a particularly pronounced impact of the restructuring process (Buck-Bechler et al., 1994). Almost all social science departments were dissolved and re-established from scratch. In contrast, East German researchers in less political sensitive fields, such as the natural sciences and engineering, had a comparatively higher likelihood of securing an academic position in the new system.

To integrate into the newly established system, all researchers at East German institutions were required to undergo a multi-stage, highly regulated process. In a first step, nearly all remaining positions were formally advertised, necessitating either the appointment of new professors or the reappointment of the former professor (Buck-Bechler et al., 1994). Reappointment was contingent on passing two distinct evaluations.

The first one consisted of a personal evaluation performed by the personnel committee. This assessment included a background check with respect to violations of human rights and rule of law, such as working for the Ministry of State Security (Buck-Bechler et al., 1994). A negative evaluation, indicating a violation, resulted not only in the dismissal of the researcher from her position, but also disqualified her for reappointment. A positive evaluation result, in contrast, was the prerequisite for reapplying for a position and being eligible for reappointment.

The second evaluation consisted of the professional evaluation conducted by the hiring committee. In alignment with policymakers' objective to establish internationally competitive

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departments (Wissenschaftsrat, 1990), all scientific staff was assessed based on their scientific performance. Criteria included, amongst others, the most important publications, the number of supervised dissertations and diploma theses, and the number and kind of past lectures held (Buck-Bechler et al., 1994, p. 150). Researchers who met the required qualification standards and had passed the personal evaluation, were considered for reappointment, either to their former positions or, in some cases, to a different position. However, passing these two evaluations did not guarantee reappointment.

This restructuring process extended over several years, with the most intensive phase occurring between 1990 and 1995 (Burkhardt, 1997).

The rapid transition to a different science system, coupled with the evaluation procedures imposed on researchers, often led to feelings of suspicion and mistrust of East German researchers towards their West German colleagues.¹ This sentiment was not limited to academia. Recent studies on the attitude of East German people in general indicate that East Germans, more broadly, have increasingly perceived themselves as disadvantaged compared to other demographic groups, especially West Germans (e.g., Pickel and Pickel, 2020). This perception of marginalization and devaluation developed during the reunification process and persists until today. The rapid transformation combined with experiences of condescending guidance from West Germans led to a feeling of being second-class citizens. This negative sentiment found expression in the term “Besserwessis”, a pejorative expression used to characterize West Germans as being presumptuous and overconfident. For such an attitude to develop, people did not need negative experiences on their own, but stories of negative experiences of friends or family were sufficient (Pickel and Pickel, 2020).

3.3 Data Construction

To analyze how the influx of West German researchers into East German university departments influenced the researchers therein, I construct a novel data set from various sources. Data construction proceeds in several steps.

My main data sources are so-called „Hochschullehrerverzeichnisse“, which are faculty directories covering all university lecturers in Germany. These books are published in different years up until today. I draw on multiple editions of these books. To capture the researchers prior to the German reunification, I digitize the printed versions published separately for East Germany and West Germany in April 1990. Figure C.1 in Appendix C.1 shows a sample page from the

¹My interviews with testimonies support this. Prof. Jutta Schnitzer-Ungefug, a German neurobiologist, confirmed that East German researchers frequently exhibited skepticism towards West Germans after the reunification. She emphasized that West German researchers had to proactively initiate contact with their East German colleagues and had to make a conscious effort to establish a positive and collaborative relationship. Similarly, Prof. Michael Hecker, a German microbiologist from the University of Greifswald, confirms this assessment in a conversation, pointing out that many of the East German researchers held a negative attitude towards the West German colleagues.

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faculty directory of East Germany in 1990. This data covers the exact name and degree of each researcher. It further includes information about the academic position a researcher holds, as well as her field of specialization and the department and institution she is employed at. Further, the exact address and phone number of her office are mentioned. The data covers the universe of professors and qualified university lecturers („Habilitierte“) in the separated German states. It does not include PhD students. As can be seen in Table 3.1, the digitized sample consists of 5,465 East German researchers and about four times as many West German researchers.² Data on the post-reunification period is derived from the directories published in 1993 and an addition published in 1995, which I digitize as well. Beyond the information mentioned before, the directories of these years also list the private address of a person as well as any additional affiliation the researcher may have. I match researchers from the 1990 directory to their counterpart in the 1993 and 1995 directories based on full name, title, position, and field of specialization using probabilistic record linkage following Wasi and Flaaen (2015). Wrong or ambiguous matches are discarded. It is evident from Table 3.1, that relying solely on the probabilistic match of the faculty directories provides a poor coverage of a researcher's whereabouts. Out of the 5,465 East German researchers in the 1990 directory, I am able to identify 478 of them in the faculty directories of 1993 and 1995, which amounts to 8.7%. For West German researchers, the rate is much higher, amounting to 84.6%. Given the poor coverage, I complement my data by manual search. All researchers from the 1990 data, who have not been matched in the post-reunification data, i.e., neither in 1993 nor in 1995, are searched on Google. I draw on information of university professorship catalogues (such as for University of Rostock), CV's, newspaper articles and Kürschner's Deutscher Gelehrtenkalender. This allows me to increase the number of East German researchers with known location after the reunification to 2,850, which covers 52.2% of my initial sample. For West Germans, the coverage increases to 92.9% of the initial sample.

I combine these data with publication data from Scopus. I begin by extracting from Scopus all individuals including their publication record for all institutions listed in the 1990 faculty directories using pybliometrics (Rose and Kitchin, 2019). In a second step, I match those researchers to the researchers listed in the faculty directories based on first name, last name and institution. In a second iteration, I match the remaining researchers based on first name initials, last name and institution. Finally, I manually check the matches for plausibility using research fields and areas of specialization. Matches that show different research areas in the faculty directories and Scopus are labeled as wrong and are subsequently discarded. My final sample consists of 1,867 East German researchers with both location information as well as publication data, and 12,309 West German researchers for whom this information is available.

²This does not include researchers in the social sciences. I focus my analysis on researchers active in the life sciences, the natural sciences, and engineering. The social sciences are excluded as these departments were almost entirely dissolved and reestablished after the reunification.

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My analysis focuses on East German researchers remaining in their pre-reunification institution. I refer to these people as „stayers“. To classify people into stayers or switchers, I compare their pre-reunification institution to their post-reunification institution. Anyone not changing institution is labeled as a stayer, whereas researchers moving to other universities, research institutes, or the private or public sector are classified as switchers. Despite this approach seeming to be straightforward, it faces some challenges. One problem during the classification process arises because some East German universities of applied sciences cease to exist during the restructuring process. Some institutions are merged with other existing institutions, while others are closed down altogether. In that case I classify people as stayers if their pre-reunification institution is merged with a different institution. For example, a researcher who held a position at „Hochschule für Verkehrswesen (HfV) Dresden“ is classified as a stayer because this institution was merged with TU Dresden after the reunification. Another issue arises because the post-reunification data on researchers has been published during the phase of transition and is thus incomplete. To address this problem, I complement the data by manual search.

Table 3.1: Availability of Location Information and Matching Rate with Scopus

<i>Availability of Location Information until 1995</i>			
	Sample 1990	1995 Location Based on	
		Faculty Directory	Faculty Directory + Manual Search
East Germany	5465	478	2850
West Germany	23398	19789	21748
Total	29317	21508	24598
<i>Match with Scopus</i>			
	Sample 1990	1995 Location Based on	
		Faculty Directory	Faculty Directory + Manual Search
East Germany	2813	355	1867
West Germany	13123	11331	12309
Total	15936	12487	14176

Note: This table displays the number of observations in the sample of 1990 as well as the number of observations with available location information in 1995. The lower part of the table shows the number of observations with publication information in Scopus.

The sample for my analysis covers the years between 1980, i.e., 10 years before the reunification, and 2010, i.e., 15 years after the restructuring process has been terminated.

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3.4 Descriptive Analysis

3.4.1 Descriptive Analysis of the Scientific Systems in the German States Before 1990

This section examines the scientific systems in the two separated German states before the reunification in 1990. While East and West Germany differed in size and population, the share of researchers in the overall population was very similar.³ When excluding the social sciences, East Germany had 5,465 researchers in 1990, which amounted to 0.033% of the East German population. West Germany, in contrast, had 23,398 researchers in absolute terms. This accounted for 0.038% of the West German population.

Absolute research output, as measured by the number of publications in the 10 years before the reunification, differed strongly. East Germany produced 12,419 publications, whereas West Germany had a publication output more than 8 times as high (104,631 publications).⁴ On average, West German researchers published twice as many publications as East German researchers. West Germans had an average publication output of 4.47 publications over the course of ten years, while East German researchers published on average about 2.27 publications between 1980 and 1989.

Table 3.2 displays the publication output distribution for East Germany and West Germany. It is evident that both distributions are right-skewed. 48.06% of West German researchers do not publish between 1980 and 1989. In East Germany, this share amounts to 56.85%. The second largest share of researchers in both countries publishes between 1 and 5 publications between 1980 and 1989. This group is larger in East Germany than in West Germany. In East Germany, the share of researchers publishing between 5 and 10 publications, or between 10 and 25 publications, drops below 10% each, while it remains above 10% in West Germany, implying that West Germany has a higher share of researchers with medium-range values of the publication output distribution. Researchers publishing more than 50 publications are rare in both countries, albeit the share of researchers falling into this category is about 7 times higher in West Germany than in East Germany. Figure C.2 in Appendix C.2 shows histograms displaying the frequency distribution of publication output for each country.

Given the distinct historical trajectories that have influenced the research system of each country and thus its output capacity, it is essential to recognize that each country has its own benchmark along which research output should be evaluated. Thus, to better evaluate the publication output distribution, Figure 3.1 depicts the output distribution of East German and West German researchers relative to their country's average researcher. The horizontal

³East Germany covered an area of about 108 square km, whereas West Germany had an area almost twice as large (249 square km). Also, in terms of population, East Germany with its 16.4 million inhabitants accounted for only about 26% of West Germany's population (61.8 million) (Statista Research Department, 1992).

⁴I avoid double counting of publications by assigning each researcher in a team a share of the publication.

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axis shows the percentile of the distribution. The vertical axis shows the publication output relative to the output of the average researcher in East Germany or West Germany, respectively. The red line shows East Germany, and the blue line represents West Germany. About 70% of West German researchers are less productive than the average West German researcher. For East Germany, this percentage is slightly higher, revealing about 72% of researchers being less productive than the average East German researcher. However, this difference is compensated by highly productive East German researchers. The graph reveals that as of the 90th percentile, the publication output of East German researchers relative to the output of their country's average researcher is larger than in West Germany. East German star researchers, defined as being in the 99th percentile of the output distribution, are about 9 times more productive than the average East German researcher, whereas West German star researchers are only about 8 times more productive than the West German average researcher. Thus, star researchers account for 9.25% of East Germany's total research output, compared to 8.08% for West German star researchers.

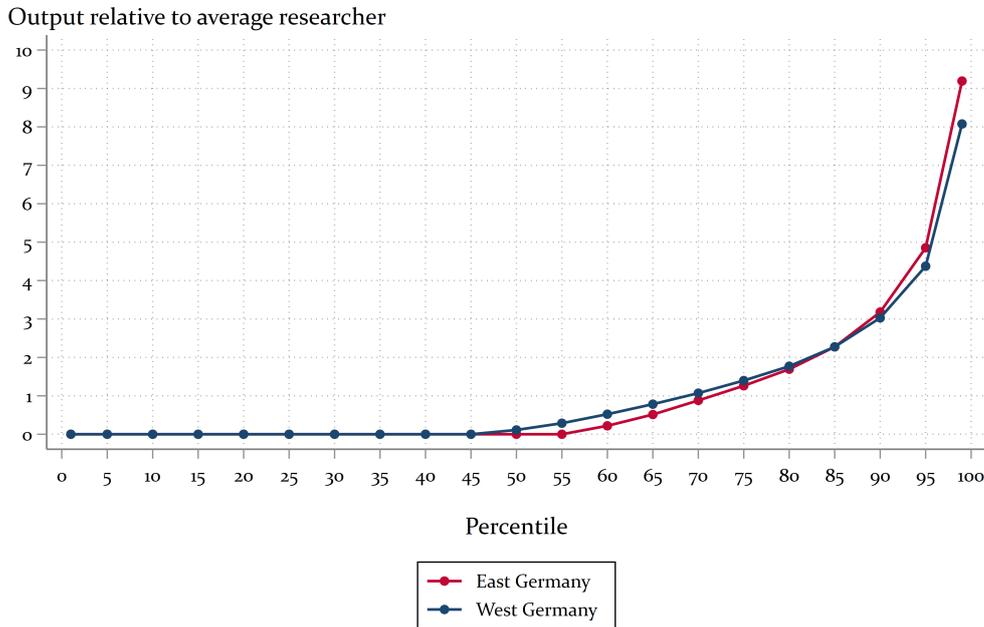
Table 3.2: Output Distribution

	East Germany	West Germany
	%	%
0 publications	56.85	48.06
1 publication	7.58	6.12
Between 1 and 5 publications	20.15	16.80
Between 5 and 10 publications	9.41	13.67
Between 10 and 25 publications	5.36	12.48
Between 25 and 50 publications	0.60	2.53
More than 50 publications	0.05	0.35

Note: This table shows the distribution of the publication output of researchers between 1980 and 1989 for East Germany and West Germany.

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Figure 3.1: Publication Output Distribution Relative to Country's Average Researcher



Note: This figure displays the publication output distribution of East and West German researchers relative to their country's average researcher between 1980 and 1989.

Next, I explore the distribution of researchers across positions. This allows me to draw conclusions about the organization of the university system in the two German states. My data differentiates between qualified university lecturers and professors. Table 3.3 reveals that East German researchers are relatively equally distributed between professors and other qualified university lecturers, while the number of qualified university lecturers accounts for only 17.69% of researchers in West Germany. The relative overrepresentation of qualified university lecturers in East Germany, compared to West Germany, can be attributed to the distinct role of this group within the East German tertiary education system. This group has been considered a distinct profession with permanent working contracts, which was mainly responsible for teaching at East German universities (Olbertz, 2001, p. 186). This may also be the reason for the relatively low average publication output of this group, compared to its West German counterpart and the group of East German professors. The researchers belonging to the group of East German professors publish on average 5.37 publications between 1980 and 1989, while the group of qualified university lecturers is less productive, publishing 3.44 publications in the same time period. In West Germany, the average output of both groups is considerably higher, amounting to 7.11 publications for the group of qualified university lecturers and 8.19 publications of professors.

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Table 3.3: Number and Publication Output of University Staff by Position

	East Germany		West Germany	
	Number	Average output	Number	Average output
Qualified University Lecturers	2111	3.44	4138	7.11
Professors	2604	5.37	19238	8.19
Unclassified	750	3.67	22	1.68
Total	5465	4.41	23398	7.97

Note: This table displays the number of researchers in 1989 split up by position as well as their average publication output by position between 1980 and 1989.

In the following paragraphs, I investigate the gender distribution of East and West German researchers prior to the reunification, as well as the distribution of researchers across research fields. Gender is assigned based on first names. In cases of unisex names or otherwise unclear gender, the variable is coded as missing. In general, East Germany was a world leader in terms of female employment. In 1989, more than 90% of East German women were employed (MDR, 2020). However, this does not translate into the science sector.

From Table 3.4 it is apparent that both German states employ fewer female researchers than male ones. East Germany has 342 female researchers, which account for about 6.26% of all researchers in my sample. In West Germany, that percentage is even lower. 697 female researchers account for about 3% of university researchers. Thus, while more females are active in East Germany than West Germany, the share of female researchers is still surprisingly low, indicating that science was a male-dominated employment area, which did not contribute substantially to the above-mentioned 90% of female employment in East Germany.

In both states, by far the most female researchers are active in the life sciences, especially in Medicine (404 females in West Germany and 168 females in East Germany). The lowest number of female researchers is found in engineering. Especially, Heat Technology and Process Engineering involves two females in East Germany and none in West Germany. Overall, the largest share of females is represented in the life sciences. The remaining female researchers of East Germany split between the natural sciences (19.59% of East German female researchers) and engineering (16.67% of East German female researchers). While these shares are roughly equal in East Germany, West Germany employs a larger share of females in the natural sciences (15.21% of female researchers in West Germany). Only 5.31% of females are active in engineering. With regard to male researchers, both German states employ the highest number of males in Medicine (1,197 in East Germany and 9,454 in West Germany). Males in Medicine account for 23.37% of male researchers in East Germany, and for 41.79% of male researchers

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in West Germany. The least frequented research area of male researchers, both in East and West Germany, is Material Science and Materials Technology.

To draw conclusions on the focal research fields in each country, I turn to investigating the distribution of all researchers, irrespective of gender, across research areas. It is apparent that Medicine is by far the most prominent research area in both German states. About 24.98% of East German researchers and 42.29% of West German researchers are active in this field. The remainder of researchers is distributed across the other research areas, with the majority of research fields involving less than 10% of researchers each. The least prominent research field falls into the area of engineering in both states. Material Science and Materials Technology involves only 0.83% of West German researchers. In East Germany, 2.27% of East German researchers are active in this field.

Looking at research areas at a more aggregated level, it becomes evident that the life sciences are the focal area in West Germany. The distribution of researchers across research areas is strongly shifted towards the life sciences, with 54.92% of researchers being active in this area. In contrast to this, the natural sciences involve 28.14% of researchers, while engineering is the least prominent area, with only 16.12% of West German researchers working in it. In East Germany, the differences between the three aggregated research areas are less prominent. 27.23% of East German researchers, and thus a similar share compared to West Germany, are active in the natural sciences. The life sciences and engineering engage a similar share of East German researchers, with 36.38% of researchers in the life sciences and 36.07% in engineering. The relatively strong focus on engineering in East Germany compared to West Germany is due to the GDR government's focus on investments into computer science and automation technology (Eichberg, 2017).

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Table 3.4: Gender Distribution Before Reunification by Field

	East Germany			West Germany		
	Female	Male	Unclassified	Female	Male	Unclassified
<i>Life Sciences</i>	218	1769	1	546	12259	46
Biology	20	209	0	112	1899	4
Medicine	168	1197	0	404	9454	38
Agricultural Science, Forestry and Veterinary Medicine	30	363	1	30	906	4
<i>Natural Sciences</i>	67	1421	0	106	6460	19
Chemistry	28	465	0	26	1503	7
Physics	13	299	0	15	1659	1
Mathematics	16	482	0	35	1836	4
Geoscience	10	175	0	30	1462	7
<i>Engineering</i>	57	1913	1	37	3719	15
Mechanical Engineering and Production Engineering	23	571	1	15	966	4
Heat Technology/ Process Engineering	2	217	0	0	375	4
Material Science and Materials Technology	9	115	0	3	192	0
Computer Science, System and Electrical Engineering	14	612	0	5	1028	3
Construction Engineering and Architecture	9	398	0	14	1158	4
<i>Unclassified</i>	0	18	0	8	183	0
Total	342	5121	2	697	22621	80

Note: This table displays the distribution of female and male researchers across the two German states by research field. Research field classification follows the Classification of Subjects and Review Boards of the German Research Foundation (DFG), where each research field corresponds to the level of Review Board of the DFG. Entries marked in italics correspond to aggregate research areas.

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Finally, looking at the career age distribution of researchers in Table 3.5, one can observe West German researchers being on average slightly older than East German ones. Career age is measured as the difference between the year of observation and the year of first publication of a researcher. West German researchers have an average career age of 20.48 years. In contrast, East German researchers have an average career age of 17.13 years. At the upper end of the distribution, it is evident that West Germans are much older than East Germans. At the 99th percentile, East German researchers have a career age of 38 years, whereas West Germans have a career age of 53 years. This is likely due to the fact that West German researchers sometimes continued to research and lecture at university after retirement, whereas this was less common in East Germany (e.g., Leake et al., 1963; Detmer, 2017).

Table 3.5: Career Age Distribution Before Reunification

	East Germany	West Germany
Mean	17.13	20.48
Percentile		
p1	1	1
p5	3	6
p10	5	9
p25	11	14
p50	17	19
p75	23	26
p95	32	39
p99	38	53
N	2524	13827

Note: This table displays the distribution of career ages of East and West German researchers in 1989. Career age is measured as the difference between the year of observation and the year of first publication of a researcher.

3.4.2 Descriptive Analysis of the Changes in the Scientific System After German Reunification

The German reunification process essentially started with the fall of the Berlin Wall in 1989 and entailed a period of massive transformation for the East German science system. It took several years and the majority of changes were implemented until 1995 (Burkhardt, 1997). The following section investigates the changes for the East German science system descriptively.

The adjustment of the East German science system to the West German system necessitated employment changes for many East German researchers. Some researchers retired or were dismissed, others left Germany for academic positions abroad or moved to academic jobs in

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another East or West German institution. Finally, some researchers left academia to find jobs in the public or private sector.

The changes in employment are summarized in Table 3.6. Out of the 2,850 East German researchers with known employment status after the reunification, 2,052 were able to retain their initial position at their home university (stayer). The remainder either transferred to a different university or a research institute (switcher), or exited academia. 408 of the East German switchers (14.32% of East German researchers with known employment status) remained employed in East Germany. 145 of them (35.54% of switchers within East Germany) changed to a different East German university, while 194 of them (47.55% of switchers within East Germany) moved to a private or public sector employer. 270 East German researchers (9.47% of the East German researchers with known employment status) transitioned to a West German university and about 4.21% of them moved to either a research institute or a university abroad. It is important to note that I lack employment information post-reunification for 47.85% of the 5,465 East German researchers. It is likely that those people who are neither listed in the faculty directories nor can be found via online search, have exited the science system.⁵

For West German researchers, I am able to obtain employment information for 21,748 (92.95%) of researchers in my data. Of those, 19,336 (88.91% of West German researchers with known employment status) did not change employer between 1990 and 1995 (stayer). 149 West German researchers moved to an East German university, while 2,253 researchers relocated to another West German university. A negligible percentage relocated abroad. Overall, only 11.09% of West German researchers changed their employer between 1990 and 1995. This is a much lower share than in East Germany. The high mobility in East Germany is likely driven by a reduction of available positions due to an alignment of student-staff-ratios with Western standards. These reductions affected mainly the group of academic mid-level staff that experienced a reduction of over 50% of available positions (Meyer, 1993; Buck-Bechler et al., 1994).

⁵For example, according to Prof. Michael Hecker, 70 to 80% of academic staff of the University of Greifswald left the university. About one third of them left voluntarily or due to age, while others had to leave due to involvement with the Ministry of State Security or due to other types of misconduct.

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Table 3.6: Employment Changes After Reunification

<i>East Germany</i>					
	Stayer	Post-reunification status			Total
		Switcher		Abroad	
		within East	to West		
Private/Public Sector	0	194	0	0	194
Research Institute	0	65	0	10	75
University	2052	145	270	110	2577
Unknown	0	4	0	0	4
Total	2052	408	270	120	2850

<i>West Germany</i>					
	Stayer	Post-reunification status			Total
		Switcher		Abroad	
		to East	within West		
Private/Public Sector	0	0	2	0	2
Research Institute	0	0	5	0	5
University	19336	149	2253	3	21741
Unknown	0	0	0	0	0
Total	19336	149	2260	3	21748

Note: This table displays the distribution of East German and West German researchers with known employment status across employer types. Stayers are defined as those researchers that remain employed at their pre-1990 university. Switchers are defined as those researchers that change employer between 1990 and 1995.

During the transition phase, researchers were reappointed to their former position, but also new researchers were hired. Table 3.7 displays the distribution of stayers and new hires by gender.

Given that I do not have information about the employment status of 47.85% of East German researchers and 7.05% of West German researchers, I do not incorporate those into the assessment of the gender distribution after the reunification. Nevertheless, even when only focusing on those researchers who were able to retain their position, it becomes evident that the distribution of males and females does not change. 6.84% of East German stayers are female researchers. Compared to the pre-reunification share of 6.26%, this indicates that females were not disproportionately disadvantaged compared to men during the transition process. Similarly, the share of female employment in the West German science sector remains comparable to the pre-reunification share (2.93% post-reunification compared to 2.98% prior to 1990).

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Table 3.7: Gender Distribution of Stayers and Newly Hired Researchers After Reunification

	East Germany		West Germany	
	Stayers	New Hires	Stayers	New Hires
Female	140	29	566	276
Male	1907	529	18711	4720
Unclassified	0	308	60	555
Total	2047	866	19337	5551

Note: This table displays the distribution of female and male researchers in the two German states after the reunification in 1995. It differentiates between researchers who remained employed at their pre-reunification institution (stayers) and researchers who have been either employed at a different institution before the reunification or who entered the sample as new hires after the reunification.

The gender distribution of the new hires during the reunification process does not mirror the pre-reunification gender distribution. In fact, East German universities hire a lower share of females compared to the distribution of stayers. Only 29 (3.35%) of newly hired researchers in East Germany are females, 61.09% are males and for the remaining 35.57% of new hires the gender cannot be determined. In West Germany, 276 (4.97%) of the newly hired researchers are female, while 85.03% are male and for 10.0% the gender information is missing. Thus, even after the reunification, science remained a male-dominated occupation. This underlines the claim made in Burkhardt (1993) that the opportunity offered by the reunification process to reform the scientific system and to promote a higher share of females in science was not seized.

Although the absolute number of females has decreased in all research areas, these reductions are larger in engineering and the life sciences than in the natural sciences. These changes alter the distribution of females across research fields in East Germany. 8.88% of female researchers are active in engineering (compared to 16.67% before the reunification), 59.17% are active in the life sciences (compared to 63.74% before the reunification) and 24.85% of female researchers are active in the natural sciences (compared to 19.59% before the reunification). Taking a more detailed look at the research fields, it becomes apparent that all fields except Heat Technology/ Process Engineering lose some female researchers. The smallest of the reductions occurs in Mathematics, where the decrease amounts to only two female researchers in absolute terms. The largest reductions in the absolute number of female researchers can be observed in Medicine, and in Mechanical Engineering and Production Engineering. Male researchers are severely hit by the restructuring process as well. The absolute number of male researchers is reduced to 511 in engineering, to 951 in the life sciences, and to 800 in the natural sciences. Thus, the distribution of male researchers across fields shifts to 39.04% of males being active

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in the life sciences (compared to 34.54% before the reunification), 32.84% being active in the natural sciences (compared to 27.75% prior to the reunification), and 20.98% being employed in engineering (compared to 37.36% before the reunification).

When investigating West Germany, it is striking to see that the absolute number of females in almost all research fields increases. For male researchers, the pattern is more nuanced. While decreases in the life sciences can be observed, these are balanced by higher numbers of male researchers in engineering and the natural sciences after the reunification. Overall, West German universities expanded during the reunification process, employing more researchers than before 1990, whereas a large shrinkage in positions for researchers occurred in East Germany during the transition phase.

The reunification process altered the focal research areas in East Germany. In particular, the relatively strong focus on engineering was decreased and shifted towards the natural sciences and the life sciences. In West Germany, the distribution of researchers remained largely unchanged. Thus, the adjustment process in East Germany has redistributed manpower across research areas, leading to a similar research focus (as measured by the distribution of researchers across research areas) as in West Germany.

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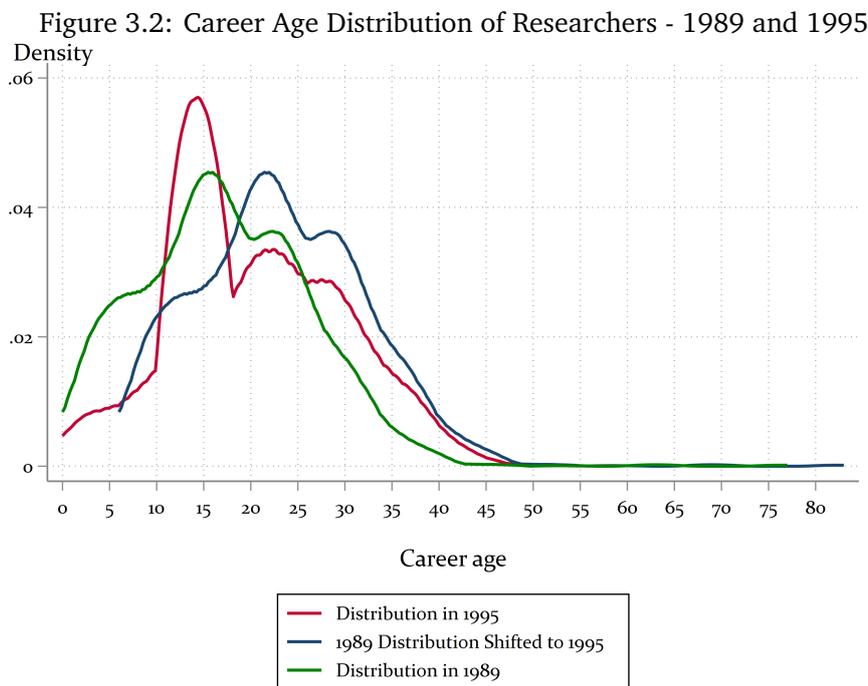
Table 3.8: Gender Distribution After Reunification by Field

	East Germany			West Germany				
	Female	Male	Unclassified Total	Female	Male	Unclassified Total		
<i>Life Sciences</i>	100	951	136	1187	569	11881	260	12710
Biology	11	125	2	138	125	1825	27	1977
Medicine	77	678	96	851	415	9157	192	9764
Agricultural Science, Forestry and Veterinary Medicine	12	148	38	198	29	899	41	969
<i>Natural Sciences</i>	42	800	122	964	119	6718	192	7029
Chemistry	14	268	0	282	26	1538	47	1611
Physics	8	176	5	189	16	1705	28	1749
Mathematics	14	296	111	421	45	2009	96	2150
Geoscience	6	60	6	72	32	1466	21	1519
<i>Engineering</i>	15	511	31	557	42	3816	119	3977
Mechanical Engineering and Production Engineering	3	128	9	140	15	978	17	1010
Heat Technology/ Process Engineering	2	56	8	66	0	357	25	382
Material Science and Materials Technology	5	38	1	44	3	208	8	219
Computer Science, System and Electrical Engineering	4	196	9	209	7	1088	32	1127
Construction Engineering and Architecture	1	93	4	98	17	1185	37	1239
<i>Unclassified</i>	12	174	19	205	112	1016	44	1172
Total	169	2436	308	2913	842	23431	615	24888

Note: This table displays the distribution of female and male researchers across the two German states by research field. Research field classification follows the Classification of Subjects and Review Boards of the German Research Foundation (DFG), where each research field corresponds to the level of Review Board of the DFG. Entries marked in italics correspond to aggregate research areas.

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Next, I investigate the career age distribution of researchers after the reunification. Several different changes influence the career age distribution. First, given that often older East German researchers made use of special arrangements for early retirement (e.g., Buck-Bechler et al., 1994; Alt, 2019), I would expect the post-reunification distribution of East German researchers to be shifted towards younger researchers. However, one also has to consider that younger researchers, being at the early stages of their career, typically had fewer publications compared to their more senior colleagues. This might have placed them at a disadvantage during the evaluation process, potentially resulting in them leaving East Germany or academia entirely. This would shift the age distribution towards higher career ages. Finally, new hires, including those from West Germany, influenced the age distribution as well.



Note: This figure shows the career age distribution of researchers. The green line displays the distribution in 1989. The blue line projects this distribution to 1995, illustrating the case if all researchers had remained active and continued their careers until 1995. The red line displays the distribution in 1995, including any losses and new hires.

Figure 3.2 reveals that there is indeed a mixture of effects in the career age distribution of East German researchers. The green line shows the career age distribution in 1989. The blue line displays the career age distribution of researchers in 1995 if all researchers from 1989 had remained active and no new researchers had entered the system. Thus, one could refer to this line as placebo distribution. The red line shows the actual career age distribution in 1995. Comparing the blue and the red distribution curves, it is evident that the lower part of the 1995 distribution (approximately until career age 10) has a lower mass than in 1989. Between career age 10 and 17, a spike in the red curve is visible, highlighting an excess mass of younger researchers. For higher career ages, the red curve lacks mass compared to the blue

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one, suggesting a lower number of senior researchers. These patterns suggest that indeed researchers of higher career age have exited academia. The spike observed between career age 10 and 17 arises from the newly hired researchers.

Table 3.9 displays the career age distribution for East and West German researchers in 1995. The average career age in East Germany is 20.37, while the average career age in West Germany is 23.91. Across the distribution, West German researchers are about 3 years older than East German researchers.

Table 3.9: Career Age Distribution After Reunification

	East Germany	West Germany
Mean	20.37	23.91
Percentile		
p1	1	3
p5	5	10
p10	10	14
p25	14	14
p50	20	23
p75	27	30
p95	37	44
p99	42	57
N	1990	15924

Note: This table displays the distribution of career ages of East and West German researchers in 1995. Career age is measured as the difference between the year of observation and the year of first publication of a researcher.

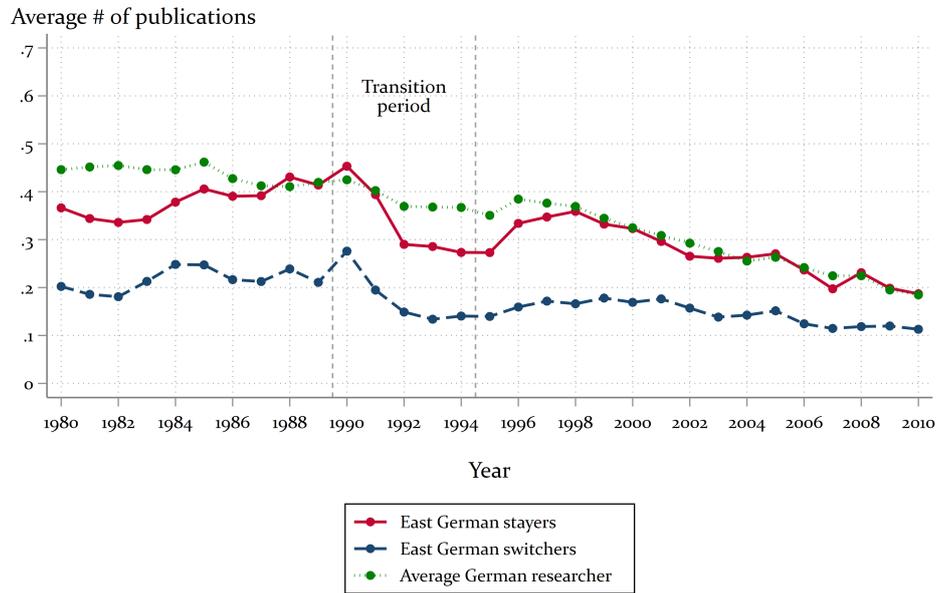
After exploring several characteristics of the East German science system after the reunification, I turn to investigating the publication output across different groups of researchers. Figure 3.3 plots the yearly average number of publications for both switchers and stayers in East and West Germany. Panel (a) displays East German stayers in red and East German switchers in blue. The green line shows the publication output for the average German researcher, which is the average publication output of all East and West German researchers. It is evident that East German stayers are almost twice as productive as switchers, producing on average 0.32 publications per year between 1980 and 2010, compared to 0.18 publications per year during the same time span. While there is a clear difference in levels, the publication trends of East German stayers and switchers are similar. The average German researcher has an output of 0.35 publications per year between 1980 and 2010.

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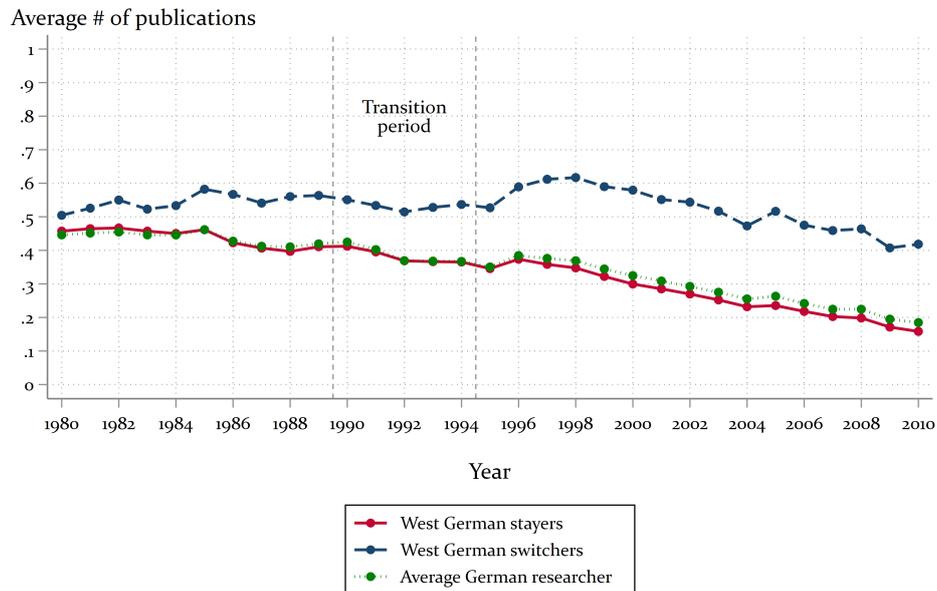
Panel (b) compares West German stayers and switchers. Stayers are about as productive as the average German researcher, whereas switchers are much more productive than the average German researcher. West German switchers are about 1.5 times as productive as stayers (0.53 publications per year between 1980 and 2010, compared to 0.34 publications per year). This difference in levels goes along with a difference in trends. Up until 1998, switchers experience an increasing trend in publication output, as compared to a rather flat trend for the stayers. Both groups, however, experience a declining publication output trend after 1998.

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Figure 3.3: Average Publication Numbers for Stayers and Switchers in East Germany and West Germany



(a) East German Stayers and Switchers



(b) West German Stayers and Switchers

Note: These figures show the average number of yearly publications of researchers between 1980 and 2010. Panel (a) compares East German stayers and East German switchers. Panel (b) compares West German stayers and West German switchers. Stayers are defined as remaining employed at the same institution between 1989 and 1995. Switchers are defined as changing their institution between 1989 and 1995. The green line depicts the average German researcher, which pools the publication output of both East and West German researchers.

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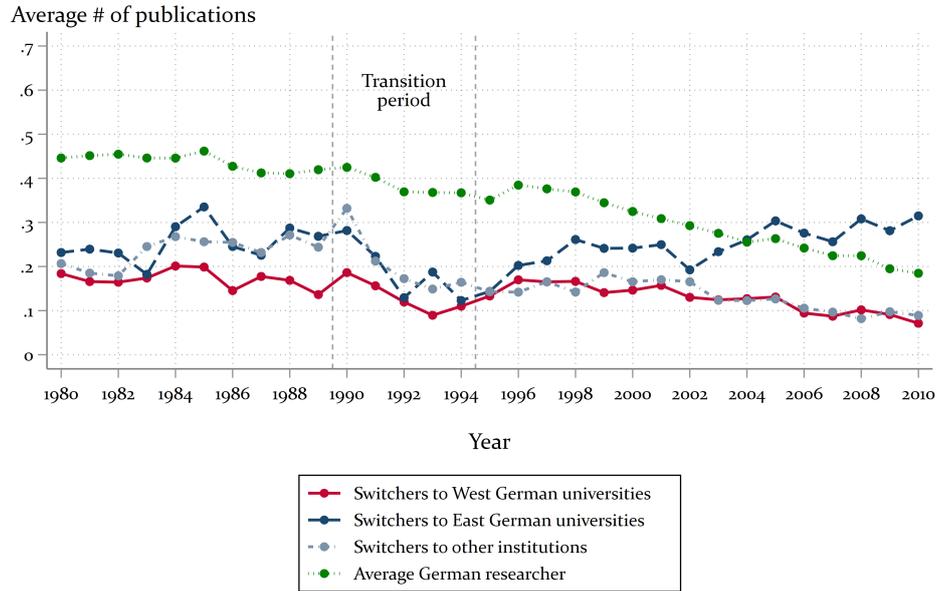
In a next set of analyses, I investigate the publication output of switchers depending on their destination of move in more detail. In panel (a) of Figure 3.4, I compare East German switchers to West German universities (red line), to East German universities (blue line), and to other institutions (grey line). All three groups have an annual publication output below the average German researcher. Switchers to East German universities and to other institutions follow a similar trend before the reunification, while switchers to West Germany produce fewer publications. After the transition period, switchers to East German universities experience a surge in publication output. The declining trend of the switchers to West Germany resembles the trend of switchers to other institutions. Switchers to West Germany publish on average 0.14 publications per year between 1980 and 2010, while switchers within East Germany are almost twice as productive during the same time span, producing on average 0.24 publications per year.

Panel (b) of Figure 3.4 compares West German switchers to East German universities (red line), to West German universities (blue line), and to other institutions (grey line). Switchers to East German universities publish on average the highest number of papers per year and follow an increasing trend that continues until 2005. Switchers to another West German university follow an increasing trend until 1998. They publish less than switchers to East Germany. Both groups perform better than the average German researcher, suggesting that West German switchers are highly productive researchers. This evidence refutes the frequently asserted claim that the West German academics who secured positions in East Germany after the reunification were less capable and unable to establish successful careers in West Germany.⁶ Switchers to other institutions are the lowest performing group with an average output of 0.24 publications between 1980 and 2010. Switchers to East Germany publish on average 0.68 publications and switchers to a West German university publish on average 0.52 publications during the same time period.

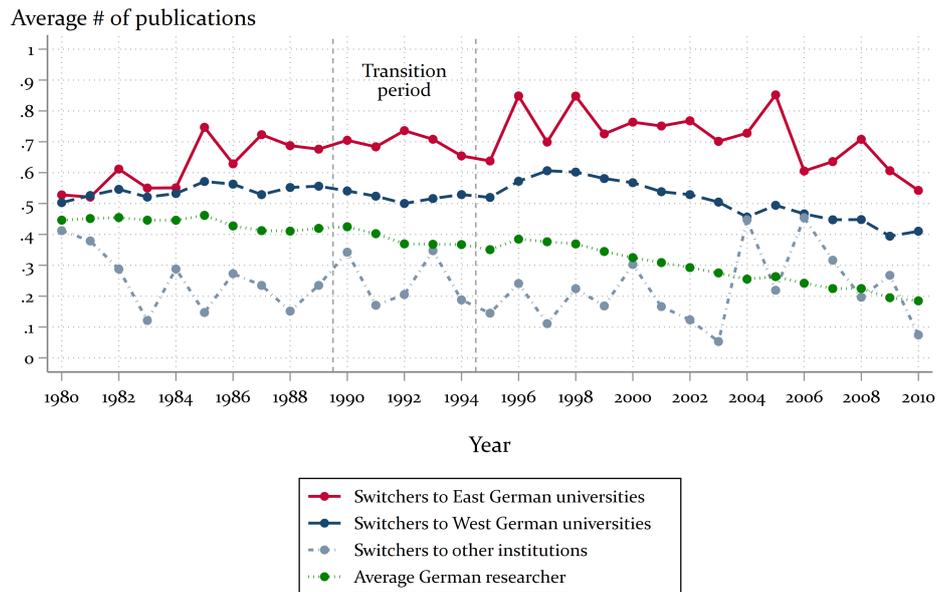
⁶Appendix Table C.1 supports this claim by showing that the average pre-reunification publication quality of West German switchers to East Germany is comparable to that of West Germans not falling into this category.

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Figure 3.4: Average Publication Numbers for East and West German Switchers



(a) East German Switchers



(b) West German Switchers

Note: These figures show the average number of yearly publications of researchers between 1980 and 2010. Panel (a) compares East Germans switching to West German universities (red line), other East German universities (blue line), or institutions other than East or West German universities (grey line). Panel (b) compares West Germans switching to East German universities (red line), other West German universities (blue line), or institutions other than East or West German universities (grey line). Other institutions include private and public sector employment, research institutes, and employment abroad. Switchers are defined as changing their institution between 1989 and 1995. The green line depicts the average German researcher, which pools the publication output of both East and West German researchers.

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3.5 Empirical Approach

In the following analysis I estimate how the influx of West German researchers into East German university departments affected the publication behavior of the remaining East German researchers (in the following referred to as “stayers”). To identify the effect, I exploit a unique feature of the restructuring process. The goal of this process was to build a university system that allows for high quality research and is internationally competitive (Wissenschaftsrat, 1990). This was achieved by a multi-stage procedure that involved the personal and professional evaluation of all East German researchers. Hiring committees were appointed by the ministers of the federal states in a strictly regulated procedure to avoid any impression of nepotism (Buck-Bechler et al., 1994). These committees consisted mostly of prominent West German researchers, with the chair of the committee always being from West Germany. If any East Germans were involved in the committee, they had very little say in the hiring decisions as their own career depended on a positive evaluation of their professional suitability by the West German committee members. This made the East German committee members very hesitant to oppose any of the opinions of the West German committee members (Buck-Bechler et al., 1994, p. 47). This procedure ultimately implies that East German university departments and the researchers therein could not select who was hired. In particular, the influx of colleagues from West Germany was a quasi-random process for the East German department members.

This allows me to identify the effect of the influx of West German researchers onto the publication behavior and the international orientation of the remaining East German researchers. To investigate this, I need an estimate of how publication activity of East German researchers in departments with West German influence would have evolved had the West German researchers not entered the department. To construct an estimate of this counterfactual, I exploit that not all departments across all East German universities appointed West German researchers during the restructuring process. My control group thus consists of stayers at East German departments that did not hire any West German researchers. Appendix C.3 provides details on the number of departments in each research field in the treatment and control group, and provides summary statistics for the data.

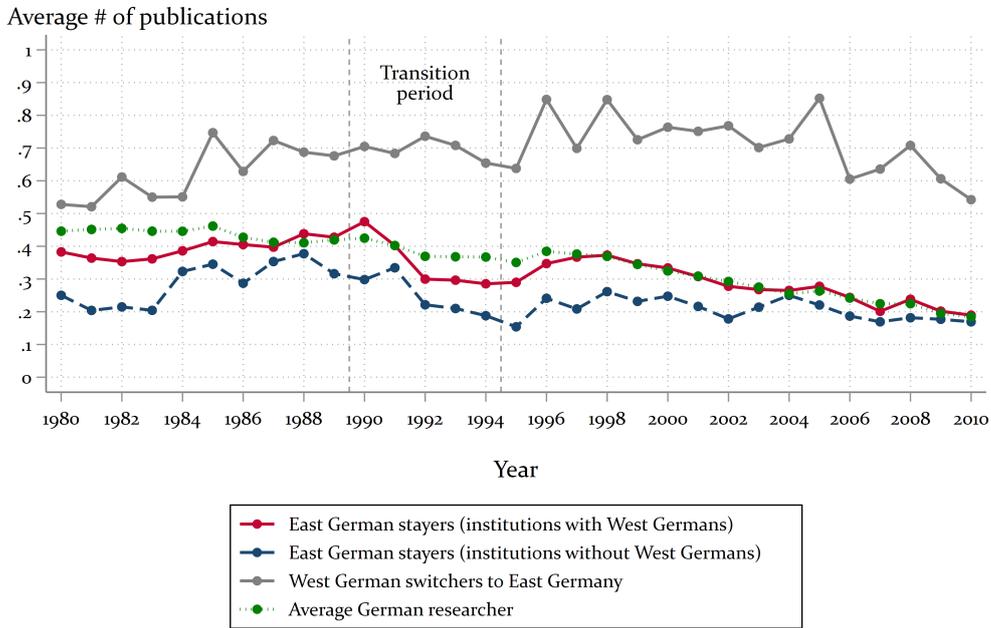
East German researchers in departments without West German colleagues are a useful control group if their publication output follows the same trend as the publication output of East German researchers in departments appointing West German researchers would have, had the department not hired any West Germans. Although I cannot verify this assumption directly, the hiring procedure outlined above suggests that the influx of West Germans into a university department was unlikely to be influenced by the researchers already present in the department.

Figure 3.5 explores the publication trends of the incoming West Germans (grey line), the treatment group (red line) and the control group (blue line) over time. Both East German

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researchers in the treatment group and in the control group follow an increasing trend before 1990. During the transition phase, both groups experience a decline in average publication output, followed by a small increase between 1995 and 1998. The treatment group's publication output trend resembles the output trend of the average German researcher (green line), except for a slightly larger drop in publications during the transition phase. West German researchers moving to East Germany display the largest average publication output and follow an increasing trend until 2005. They produce on average 0.65 publications per year during the sample period. The treatment group has an average publication output of 0.31 publications per year, while the control group only publishes on average 0.22 publications per year.

Figure 3.5: Average Publication Numbers for East German Stayers at Institutions with and without West Germans, as well as West German Switchers



Note: This figure shows the average number of yearly publications of researchers between 1980 and 2010. It differentiates East German stayers by whether or not their institution hired any West Germans during the restructuring phase. It further shows the average publication output for West Germans switching to East Germany. Stayers are defined as remaining employed at the same institution between 1989 and 1995. Switchers are defined as changing their institution between 1989 and 1995. The green line depicts the average German researcher, which pools the publication output of both East and West German researchers.

To quantify the effect of the influx of West German researchers on the East German stayers, I estimate a difference-in-differences specification. I begin by estimating the following equation at the department level⁷:

$$y_{dt} = \beta_1 \cdot Post_t + \beta_2 \cdot WestGermans_d \cdot Post_t + \mu_t + \gamma_d + \varepsilon_{dt} \quad (3.1)$$

where subscript d denotes the department of a university and t indexes the time in calendar

⁷I provide results at the individual level in Appendix C.4.1.

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years. y_{dt} corresponds to the outcome of interest, $Post_t$ is an indicator which equals one in the years after the reunification process started (i.e., it equals one in the years after 1989), and $WestGermans_d$ is an indicator equal to one for the treated university department and zero otherwise. In all specifications, I include calendar year fixed effects (μ_t) and fixed effect for each department at a university. The standard errors allow for clustering at the department d level. β_2 measures the average increase in the outcome variable following the influx of West German researchers for treated university departments relative to control university departments.

My main analysis investigates the impact of the West German researchers onto publication quantity and quality of the East German stayers. The outcomes of interest are the number of publications produced by East German stayers divided by the number of stayers in a department, and the average SCImago Journal Rank. I exclude the publication counts of the incoming West German researchers to avoid confounding the productivity effects of the West German researchers with their own productivity.

3.6 Results

3.6.1 Publication Quantity

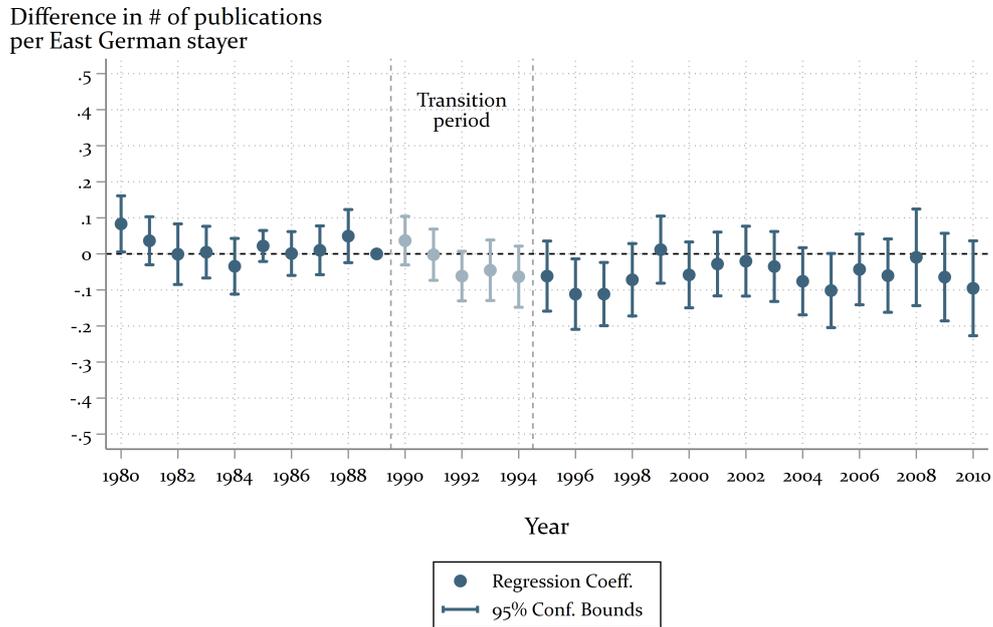
My analysis aims at measuring the impact of West German switchers to East German departments on the staying East German researchers. To study this question, I begin by estimating the resulting change in the department's publication output divided by the number of East German stayers.

Figure 3.6 displays the yearly treatment effects from a regression comparing publications per stayer of departments hiring at least one West German researcher to publications per stayer of departments without any West German researcher. I use the year 1989, which is the year prior to the beginning of the reunification process, as baseline. The coefficient estimates prior to the beginning of the reunification, i.e., between 1980 and 1989, are small and statistically not significantly different from zero. This supports the parallel trends assumption. During the transition period, which took place between 1990 and 1995, a drop in the publication output per stayer of treated departments relative to control departments can be observed, albeit none of the coefficients is statistically significant. Most of the coefficients after the transition phase are smaller than zero, but not statistically significant either.

Column (1) of Table 3.10 presents the difference-in-differences estimation results for Equation 3.1. The coefficient estimate of the influx of West German researchers relative to departments hiring no West Germans is negative and significant at the 5% level. The effect is around 20.79% of the average number of publications per stayer of treated universities before the reunification. For an average-sized department of 15 East German stayers, this would imply a reduction of 1.02 publications per year.

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Figure 3.6: Effects of Incoming West Germans on East German Departments' Publications per Stayer



Note: This figure shows the estimated difference in the yearly number of publications per East German stayer in East German university departments hiring at least one West German researcher compared to East German university departments hiring no West German researchers. The blue bars represent 95% confidence bounds that allow for clustering at the department level.

The literature indicates that Medicine departments encountered distinct challenges during the reunification process, which were unique to this discipline. These include Medicine facing the dual challenge of functioning as an academic discipline while simultaneously ensuring the healthcare provision for all of East Germany (Pasternack, 2015). This “dual role” of Medicine required a significant amount of effort and reallocation of time and resources. According to Pasternack (2015), especially the transition of patient care to the new health insurance system necessitated a reorganization of the relationship between research, teaching, and health care provision. Further, Medicine departments were hit by large scandalization campaigns immediately after the reunification (Pasternack, 2015). East German Medicine departments were accused of unethical behavior. The settlement of these cases involved large research projects, which required significant amounts of energy and resources (Pasternack, 2015). These particular challenges may have shaped how the East German researchers reacted to the influx of their West German colleagues. Thus, I analyze the response of Medicine departments to the influx of West German researchers separately from the remaining departments in all upcoming analyses.⁸

⁸Table C.5 in Appendix C.4 provides summary statistics for all fields, excluding Medicine departments, and for Medicine departments separately.

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Columns (2) and (3) of Table 3.10 display the effect of West German researchers on the publication output per stayer, when excluding Medicine (column 2), and for Medicine (column 3). The coefficient estimate for the remaining departments is small and positive, but insignificant at conventional levels. Medicine departments, in contrast, experience a decline in publication output per stayer by 0.339. This amounts to a reduction of 58.85% relative to the pre-reunification mean of the treatment group.

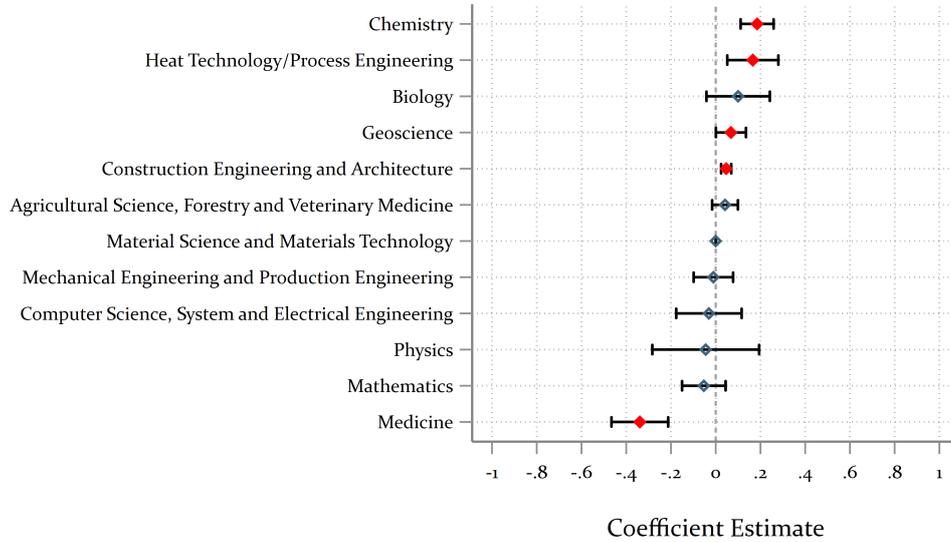
Table 3.10: Impact of West German Researchers on Publication Quantity

Dep. Var.:	# of Publications per East German Stayer		
	Baseline	Excluding Medicine	Medicine
	(1)	(2)	(3)
Treated x Post	-0.068** (0.032)	0.018 (0.025)	-0.339*** (0.065)
Mean Dep.	0.223	0.212	0.322
R2 (within)	0.044	0.032	0.583
Obs.	4123	3720	403

Note: This table displays the difference-in-differences estimates of the influx of West German researchers into East German university departments on the publication output per East German stayer. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Figure 3.7: Effect on Publication Quantity by Research Field



Note: This figure shows the results from a difference-in-differences estimation with East German university department publication output per stayer in the denoted field as the dependent variable. The treatment group are East German departments that hire at least one West German researcher. The control group consists of East German departments that do not hire any West German researchers. All specifications include year fixed effects and department fixed effects. The bars indicate 95% confidence intervals using standard errors that allow for clustering at the department level. Coefficients plotted as a hollow diamond indicate coefficients not significantly different from zero at this level. Full (red) diamonds indicate coefficients that are significantly different from zero.

Figure 3.7 explores the heterogeneity across fields in more detail. It displays the results from separate regressions for each field following Equation 3.1. The effects differ across disciplines, with the majority of fields showing positive coefficient estimates or estimates close to zero. Chemistry, Heat Technology/Process Engineering, Geoscience, as well as Construction Engineering and Architecture seem to benefit from the influx of the West German researchers, with the largest effect occurring in Chemistry. In contrast, Medicine stands out with a large and significant negative effect. It is the largest effect in absolute magnitude.⁹

3.6.2 Journal Quality

In this section, I explore changes in journal quality in response to the influx of West German researchers. West Germans were raised and trained in the science system that East Germans first have to adapt to. Therefore, West German researchers should be better informed about trending research questions, state-of-the-art methods, and the journals to be targeted for a successful career, as well as the publication process itself. If they share this knowledge with their East German colleagues, these researchers should be ultimately more successful in publishing their research in high-quality journals as compared to researchers at university departments without a West German researcher.

⁹I explore additional heterogeneity in Appendix C.4.4.

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To assess whether East German stayers are able to publish their work in more prestigious journals in response to the influx of West German researchers, I draw on the SCImago Journal Rank (SJR).¹⁰ This quality measure takes into account the number of citations a paper receives, as well as the prestige of the citing journals, by giving more weight to citations from higher-ranked journals than from lower-ranked ones (Daemen Library, 2025). Unfortunately, this data is only available as of 1999. To circumvent the problem of missing data in the pre-treatment period, i.e., the years between 1980 and 1989, I assign each journal its average SCImago Journal Rank between 1999 and 2010.¹¹

The results of the estimation are shown in Table 3.11. Columns (1) to (3) use the SJR as the measure of quality. Column (4) adds an additional quality measure for Medicine only, which is the number of publications in top 5 medical journals. Across all disciplines, I observe a small and insignificant coefficient estimate for publication quality. Columns (2) and (3) display results for all fields excluding Medicine, and for Medicine, respectively. While the other disciplines experience a decline in journal quality relative to the control group, Medicine in fact experiences an increase in journal quality due to the influx of West German researchers. The increase in journal quality amounts to 71.94% of the average journal quality in Medicine. Finally, the result in column (4) seconds this finding by showing an increase in the number of publications in top 5 medical journals.

Table 3.11: Impact of West German Researchers on Publication Quality

Dep. Var.:	SJR			# Publications in Top 5
	Baseline	Excluding Medicine	Medicine	Medical Journals
	(1)	(2)	(3)	(4)
Treated x Post	-0.049 (0.084)	-0.140 (0.096)	0.546*** (0.147)	0.005* (0.003)
Mean Dep.	0.931	0.957	0.759	0.003
R2 (within)	0.044	0.036	0.434	0.083
Obs.	1613	1397	216	403

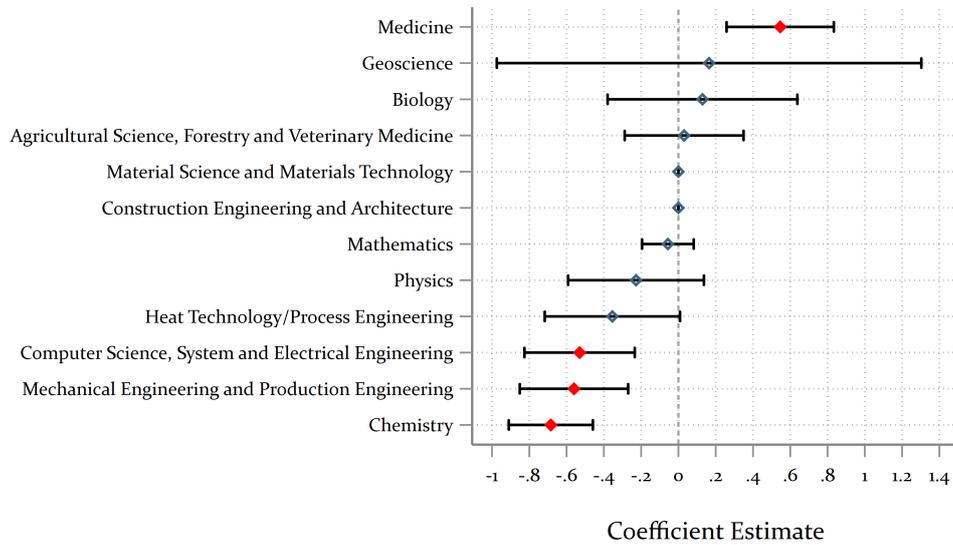
Note: This table displays the difference-in-differences estimates of the influx of West German researchers into East German university departments on publication output quality. Columns (1) to (3) use the average SCImago Journal Rank as dependent variable. Column (4) uses the number of publications in top 5 medical journals as dependent variable. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

¹⁰I thank Michael Rose for providing me with this data.

¹¹I recognize that this approach may yield problems if, e.g., journal ranks greatly vary over time. To assess if this is the case, I examined the journal ranks over time for a randomly selected sample of journals and found that the journal ranks show little changes over time.

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Figure 3.8: Effect on Publication Quality by Research Field



Note: This figure shows the results from a difference-in-differences estimation with average SCImago Journal Rank in the denoted field as the dependent variable. The treatment group are East German departments that hire at least one West German researcher. The control group consists of East German departments that do not hire any West German researchers. All specifications include year fixed effects and department fixed effects. The bars indicate 95% confidence intervals using standard errors that allow for clustering at the department level. Coefficients plotted as a hollow diamond indicate coefficients not significantly different from zero at this level. Full (red) diamonds indicate coefficients that are significantly different from zero.

Next, I explore effect heterogeneity across disciplines by estimating separate regressions for each research field. The results are displayed in Figure 3.8. It is striking to observe that the most pronounced negative effects on publication quality largely occur in those fields that show a positive coefficient estimate of West German researchers on department publication output per stayer. In particular, journal quality in Chemistry, Mechanical Engineering and Production Engineering, and Computer Science decreases. In contrast to this, journal quality in Medicine increases.¹²

My results from this section and the previous one suggest that East German researchers are trading off research quantity and quality to some extent. In Medicine, researchers respond to the influx of West Germans by publishing less, but in more prestigious journals. In other fields, such as Chemistry, they publish on average more papers, but in journals of lower average quality. Whether this should be interpreted as a desirable result or not is not straightforward.

On the one hand, this may be regarded as positive development if East German researchers follow the advice of their West German colleagues and focus on those aspects that are most conducive to building a successful career. In particular, this may mean publishing at a higher

¹²I explore additional heterogeneity in Appendix C.4.4.

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frequency even at the expense of quality in some fields.¹³ On the other hand, this could be interpreted as East Germans either rejecting the advice of their West German colleagues, or the West Germans not sharing information, which might ultimately result in lower quality publications. The first interpretation could point towards better integration into the global science system, while the second one could be viewed as reluctance or difficulty to adapt to the new system. Table C.6 in Appendix C.4.3 explores in detail if the observed tradeoff could be the result of an adjustment process towards a more Western publication style. The evidence presented in Appendix C.4.3 is in line with this explanation.

3.7 Further Results: Internationalization

3.7.1 Publication Language

Have East German researchers' publications become more international? This section sheds light on this question by analyzing changes in the publication language. In particular, if the influx of West German researchers has helped East German stayers integrate more successfully into the international science system, I would expect to find a shift towards English-language publications and away from other publication languages, such as German. If, in contrast, the staying researchers merely increased their publication output in local journals instead of successfully establishing a paper trail in internationally recognized outlets, I would expect to observe a shift towards German-language publications.

¹³A comparison of publication strategies in the various disciplines can be found in Schütte et al. (2009).

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Table 3.12: Impact of West German Researchers on Publication Language

Dep. Var.:	Share of Publications			
	Excluding Medicine		Medicine	
	Share	Share	Share	Share
	German	English	German	English
	(1)	(2)	(3)	(4)
Treated x Post	0.045 (0.037)	-0.046 (0.037)	-0.302*** (0.007)	0.302*** (0.007)
Mean Dep.	0.099	0.901	0.045	0.955
R2 (within)	0.105	0.106	0.334	0.335
Obs.	2331	2331	308	308

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the share of German- or English-language publications by East German stayers. Publications are classified as German if the title, as listed in Scopus, is German. Publications are classified as English if the title, as listed in Scopus, is English. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.12 displays the results of this analysis. Columns (1) and (2) show the effect when excluding Medicine departments from the analysis, while columns (3) and (4) display the coefficient estimates for Medicine departments. Surprisingly, I find a positive coefficient estimate on the share of German-language publications, when excluding Medicine in column (1). However, it is small and statistically insignificant. The effect on English-language publications, which is shown in column (2), is negative but insignificant. This suggests that internationalization in terms of publication language was only of limited success in non-Medicine departments.

When estimating the effect of the West German researchers on the share of German-language publications in Medicine, I find a negative and significant effect. The share of German-language publications decreases by 0.302 (column 3), while the share of English-language publications increases (column 4). This shift is in line with a successful internationalization of East German researchers in Medicine departments. However, internationalization in terms of publication language seems to be largely absent in the remaining departments.

3.7.2 Funding

International science is increasingly characterized by competitive funding mechanisms that require research institutions to navigate complex application procedures to secure resources.

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Following the German reunification, East German university departments, which had previously been insulated from resource competition, faced the challenge of adapting to this competitive environment. However, many East German departments were unfamiliar with the procedures and requirements for successful grant applications, thus making this adjustment difficult. In contrast, West German researchers, who have been active in the competitive science system prior to the reunification, possessed the necessary expertise for securing third-party funding effectively. This knowledge could be leveraged by departments hiring West German researchers, which provides them with a distinct advantage over departments without West German researchers.

To explore whether West German researchers aid East German departments in obtaining third-party funding, I analyze funding data from the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) covering the years 1996 to 2010. Table 3.13 summarizes the results.¹⁴

Table 3.13: Impact of West German Researchers on DFG Funding

Dep. Var.:	DFG grants (in million euro)	
	Excluding Medicine	Medicine
	(1)	(2)
Treated x Post	0.640** (0.288)	2.414** (1.099)
Mean Dep.	0.417	1.267
R2 (within)	0.337	0.303
Obs.	2945	403

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the amount of DFG funding received between 1996 and 2010. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Column (1) presents the results from the analysis when Medicine departments are excluded. The remaining departments obtain on average 0.640 million euro of additional DFG funding. Medicine departments hiring West German researchers obtain on average 2.414 million euro of additional DFG funding (column 2).

¹⁴Appendix C.5 provides details on the average amount of DFG funding received over time by East German Medicine departments and other East German departments (Figure C.3), as well as the average amount of DFG funding received by treated and control departments (Figure C.4).

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It is important to note that I can only draw on funding data for the years after 1995.¹⁵ Also, I am not able to include all of the departments of my main analysis in the funding analysis because the field classification scheme of the DFG has changed several times over the years, leading to disaggregation and aggregation of some fields in engineering. Since I cannot unambiguously assign these fields to the departments in my data, I drop these from the estimation. This reduces my sample by 18.8%. Nevertheless, my results point towards an increased success rate in the application for third-party funding in departments with West German researchers, suggesting a tacit knowledge flow from these researchers to the East Germans in the department. Historical evidence points in that direction as well (see Friedrich and Hecker, 2023).¹⁶

3.8 Mechanism: Collaboration Changes Due to Inflow of West German Researchers

West German researchers may take on various roles within an East German department. On the one hand, they may contribute to the scientific output of their colleagues both with their field-specific expertise as well as with their institutional knowledge. This could mean sharing knowledge about the implicit “rules of the game”, such as which journals to target, what projects to pursue, and how to navigate the academic system. On the other hand, West German researchers may share their networks and may connect East German researchers to other colleagues, in particular in West Germany.

In this section, I investigate changes in collaboration patterns to draw conclusions about the mechanism at play. If West Germans primarily aid their colleagues by sharing field-specific knowledge or institutional knowledge about the science system through direct coauthorship relations, I would expect to see a shift towards department-internal collaborations. If, instead, the network-expanding role is the dominant mechanism, I would expect to find an increase in collaborations with external researchers, especially from West Germany. To investigate these potential roles, I examine changes in collaboration patterns. I explore whether the share of department-internal collaborative publications reacts to the influx of the West German colleagues, where a collaboration is department-internal if all authors on the publication are employed in the same department. I further explore the geographic dissemination of coauthors. In particular, I differentiate between collaborative publications involving at least one West German coauthor (not including any West German researcher who transferred to an East German institution), collaborative publications involving only researchers at East German

¹⁵Given that third-party funding schemes did not exist in East Germany before the reunification, I assume a funding level of zero for the years 1980 to 1989 in my estimation.

¹⁶Prof. Michael Hecker, an East German microbiologist, for example states: “My microbiologist friends from West Germany quickly introduced me to the procurement of third-party funding, without which financing experimental research was unthinkable. The first projects from the German Research Foundation and the then Federal Ministry of Research and Technology (BMFT) were not long in coming.” (translated from Friedrich and Hecker (2023, p. 134)).

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institutions and, finally, collaborative publications involving at least one coauthor from abroad. It is important to note that I was not able to identify all institution locations of the coauthors.

Table 3.14 displays the results from the analysis of the influx of West German researchers on the share of collaborative publications. Columns (1) to (5) explore the effect for departments excluding Medicine. Columns (6) to (10) investigate the effect in Medicine.

While the share of collaborative publications in the fields except Medicine does not increase as a response to the influx of the West German researchers, I find a small increase in the share of department-internal collaborative publications (column 2). This finding points towards East German researchers centering their collaborations within the department, potentially drawing on the knowledge of the West German colleague. In line with this, I do not find a significant effect on the share of collaborative publications with a West German university (column 3) or an institution abroad (column 5). Instead, the share of collaborative publications with East German universities increases (column 4). This coefficient estimate incorporates the rise in department-internal collaborations, but also suggests increased collaborations with East German university departments other than the home department.

In Medicine, column (6) reveals an increase in the share of collaborative publications in response to the recruitment of West German researchers. In contrast to the effect across the other disciplines, the share of department-internal collaborative publications does not respond (column 7). Instead, East German researchers in Medicine departments engage in more collaboration with West German universities, as is shown by the rise in the share of collaborative publications with West German university departments in column (8). This suggests that West German researchers take on a brokerage role in Medicine departments and connect their East German colleagues to researchers at West German institutions. These newly formed collaborations seem to substitute for collaborations within East Germany, since the share of collaborative publications with East German universities declines (column 9). Finally, there is no effect on collaborations with institutions abroad (column 10).

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Table 3.14: Impact of West German Researchers on Collaboration

Dep. Var.:	Share of Collaborative Publications									
	Excluding Medicine					Medicine				
	Baseline	Internal	with West Germany	within East Germany	with abroad	Baseline	Internal	with West Germany	within East Germany	with abroad
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Treated x Post	0.004 (0.052)	0.008* (0.004)	0.005 (0.007)	0.058** (0.028)	0.004 (0.019)	0.075** (0.025)	0.003 (0.008)	0.027** (0.010)	-0.077* (0.040)	-0.004 (0.009)
Mean Dep.	0.811	0.007	0.008	0.105	0.059	0.817	0.008	0.017	0.241	0.037
R2 (within)	0.104	0.016	0.014	0.045	0.028	0.122	0.093	0.145	0.117	0.108
Obs.	2331	2211	2211	2211	2207	308	304	304	304	304

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the share of collaborative publications by East German stayers. Publications are classified as collaborative if the publication involves at least two authors. Publications are defined as department-internal if all authors belong to the same department. Publications are classified as collaborative with West Germany if at least one author on the publication is employed at a West German university. Publications are classified as collaborative within East Germany if all authors on the publication are employed at East German universities. Publications are classified as collaborative with abroad if at least one author on the publication is employed at an institution outside of (East and West) Germany. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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A second dimension of collaboration I explore is the effect on average team size, measured by the number of authors listed on a publication. Changes in the average team size could point towards a changing nature of projects. For example, the global science system might reward very demanding, large, time-consuming projects more than small and quick ones. These tendencies could be reflected in the average team size on the publications. West German researchers might know about this inclination and might advise their East German colleagues on the choice of research projects.¹⁷ Table 3.15 presents the results of this analysis. Column (1) presents the effect across all disciplines except Medicine, while column (2) examines the effect in Medicine. In column (1), I observe a decline in average team size by 0.258, which corresponds to a 9.79% decline relative to the average team size of publications from treated departments before the reunification. Researchers in Medicine departments respond to the influx of West German colleagues by increasing the average team size by 2.143 researchers. This increase is sizeable, amounting to a 61.58% increase relative to the average team size of publications of treated departments before the reunification.

Table 3.15: Impact of West German Researchers on Team Size

Dep. Var.:	Average Team Size	
	Excluding Medicine (1)	Medicine (2)
Treated x Post	-0.258* (0.134)	2.143*** (0.192)
Mean Dep.	3.280	4.832
R2 (within)	0.214	0.614
Obs.	2331	308

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on average team size, measured by the number of authors listed on a publication. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

¹⁷An interview with Prof. Michael Hecker, who was a microbiologist at the University of Greifswald, confirms this. He pointed out that, after the reunification, especially fields like Medicine and the life sciences in general, were under pressure to secure third-party funding to finance experimental research. To be successful in this process, he highlighted that the proposed projects had to be ambitious and usually involved larger teams.

3.9 Discussion of Concerns and Robustness

A potential concern for the identification of the impact of West German researchers onto East German stayers relates to a non-random assignment of West Germans to East German university departments. As outlined in the previous sections, historical evidence indicates that East German university departments had only limited influence over hiring decisions. This was due to the composition of the hiring committees, which were appointed by the ministers of the federal states and consisted mainly of members external to the university (Buck-Bechler et al., 1994). Thus, the researchers of the East German university departments were unable to select their future colleagues.

Nevertheless, one could still be worried about selection on the side of the West Germans. West German researchers were not centrally assigned to a specific university, but applied for a position at a university of their own choice. In my sample, I can only observe the West German researchers who were ultimately hired by the department. Of course, the initial applicant pool is usually much larger than the number of hired researchers. One could be worried that the best and brightest West German researchers apply to the most prolific East German institutions. This implies that larger and more prestigious universities attract a greater number of applications from more accomplished researchers, while the less renowned institutions receive fewer or no applications, which may be of lower overall quality. With respect to the hired researchers, it can be assumed that all institutions hire the best and most productive ones from their applicant pool since all universities had the main goal to build competitive departments (Wissenschaftsrat, 1990). To assess this conjecture, I investigate the correlation between the 10-year publication output of the departments before the reunification (i.e., the cumulated sum of publications between 1980 and 1989) and the pre-reunification publication output of the West German switchers. I find a small negative correlation of -0.0453 , which is insignificant at conventional levels.

Alternatively, West Germans might select the institutions they apply to based on the attractiveness of the surrounding city. I can partly control for this through the department fixed effects, provided that the city characteristics, such as local infrastructure or cultural life, are constant over time and affect all departments equally within the city. If city attractiveness varied over time, this would not be absorbed by the department fixed effects. Unfortunately, my data does not allow me to control for city attractiveness directly.

To further address the concern of potential selection effects, I conduct an additional analysis by constructing a more restrictive control group based on coarsened exact matching. I match on the average department age in the year before the reunification, which is defined as the average of the individual researchers' ages in the year before the reunification. I also match on the share of professors in the department in the year before the reunification. I use 8 equally

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spaced cutpoints for both average department age and share of professors. Table 3.16 shows the results of this analysis. Columns (1) to (4) use the number of publications per East German stayer as the dependent variable. Although the coefficient estimates increase slightly when using the matched control group, the qualitative interpretation of my results is not altered. Columns (5) to (8) explore the robustness of the effect on journal quality by using the SCImago Journal Rank as the dependent variable. When using the matched control group, the coefficient estimate when excluding Medicine is slightly larger, but the sign remains unchanged (column 6). The coefficient estimate for Medicine departments increases slightly as well (column 8). Overall, the qualitative interpretation of my results remains unchanged.

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Table 3.16: Matched Results

Dep. Var.:	# of Publications per East German Stayer				SJR			
	Excluding Medicine		Medicine		Excluding Medicine		Medicine	
	Baseline	Matched	Baseline	Matched	Baseline	Matched	Baseline	Matched
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated x Post	0.018 (0.025)	0.040 (0.033)	-0.339*** (0.065)	-0.363*** (0.082)	-0.140 (0.096)	-0.168 (0.119)	0.546*** (0.147)	0.554*** (0.146)
Mean Dep.	0.212	0.295	0.322	0.379	0.957	1.021	0.759	0.761
R2 (within)	0.032	0.127	0.583	0.673	0.036	0.051	0.434	0.437
Obs.	3720	2263	403	372	1397	1079	216	216

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the number of publications per East German stayer in columns (1) to (4) and on the average SCImago Journal Rank in columns (5) to (8). The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. Control departments are matched to treated departments based on average department age and share of professors. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Another concern arises from the inevitable loss of colleagues. One may be worried that this is correlated with the number of incoming West German researchers. If this is the case, my analysis might confound the two effects. Historical evidence suggests that this is unlikely to be the case, because the massive downsizing affected mainly the group of academic mid-level staff (Meyer, 1993; Buck-Bechler et al., 1994). Professors were less affected by the loss of positions. My data underlines this conjecture. Out of the 2,052 East Germans that were able to retain their positions after the reunification 67.3% of them belonged to the group of professors.

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Additionally, I check the correlation between the number of colleagues lost (calculated via the change in department size between 1989 and 1995) and the number of incoming West Germans. The correlation is 0.0152 and insignificant at conventional levels, suggesting that the influx of West Germans is unrelated to the number of colleagues lost in a department.

Furthermore, I examine whether the effect can be specifically attributed to the recruitment of West German researchers or if a similar effect would arise from hiring any new researcher. To test this, I use the influx of new East German colleagues as a placebo treatment. If the observed effects are the result from the system-specific knowledge embodied in researchers from West Germany, I should not find an effect of the placebo treatment. Table 3.17 displays the results. I neither find a significant effect of East German switchers to East German university departments on the number of publications per East German stayer nor on the publication quality.

Table 3.17: Placebo: Impact of East German Switchers

Dep. Var.:	# of Publications per East German Stayer		SJR	
	Excluding Medicine	Medicine	Excluding Medicine	Medicine
	(1)	(2)	(3)	(4)
Placebo x Post	0.009 (0.024)	0.043 (0.106)	0.077 (0.140)	0.085 (0.090)
Mean Dep.	0.212	0.322	0.957	0.759
R2 (within)	0.032	0.442	0.032	0.438
Obs.	3720	403	1397	216

Note: This table shows difference-in-differences estimates of the influx of East German switchers into East German university departments on the number of publications per East German stayer in columns (1) and (2) and on the average SCImago Journal Rank in columns (3) and (4). The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To determine whether my results are driven by a small subset of highly productive individuals, I re-estimate my results while excluding the top 1% and the top 5% of researchers based on their pre-reunification publication output. Columns (1) to (3) of Table 3.18 show the effect when Medicine departments are excluded from the analysis. The estimated coefficients decrease in magnitude when excluding the top 1% and the top 5% of researchers. In fact, when excluding the top 5% of researchers, the sign of the coefficient turns negative. Nevertheless, all coefficient estimates remain small and insignificant. In Medicine, excluding the top 1% and top 5% of researchers decreases the estimated coefficients in absolute magnitude (see columns 5 and 6), but the effect remains negative and significant at the 1% level.

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Table 3.18: Leaving Out Top X Researchers

Dep. Var.:	# of Publications per East German Stayer					
	Excluding Medicine			Medicine		
	Baseline	Without	Without	Baseline	Without	Without
		Top 1%	Top 5%		Top 1%	Top 5%
	(1)	(2)	(3)	(4)	(5)	(6)
Treated x Post	0.018 (0.025)	0.003 (0.022)	-0.005 (0.022)	-0.339*** (0.065)	-0.329*** (0.062)	-0.286*** (0.059)
Mean Dep.	0.212	0.202	0.183	0.322	0.300	0.264
R2 (within)	0.032	0.032	0.033	0.583	0.590	0.553
Obs.	3720	3720	3720	403	403	403

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the number of publications per East German stayer when dropping the top 1% and the top 5% of researchers. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Further robustness tests are displayed in Appendix C.6. I address the skewed nature of the publication distribution in Table C.9 by re-estimating my main specification using a log-transformed dependent variable and an inverse hyperbolic sine transformation of my dependent variable. My results remain qualitatively unaffected. Figure C.5 shows that my results are not driven by a particular university.

3.10 Conclusion

This chapter revisits the German reunification to study the effects of this large-scale disruption to the East German science system on the researchers and university departments therein. The reunification process triggered a fundamental restructuring of the East German science system, which led to the adoption of the competitive, funding-based Western model. This transformation encompassed a major reorganization of East German institutions, widespread layoffs of scientific staff, and profound disruptions in the career trajectories of many researchers. Albeit the transition process has taken place more than three decades ago, it is still debated in German society. The common narrative states that the East German science system was lagging behind the West German science system and that the overall goal of establishing internationally competitive universities could only be achieved by rapidly integrating processes and approaches from the West into the East German system. This transition was expected to improve research output and to broaden the existing scientific networks of the East German researchers.

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My study confirms this view only partially and highlights that a more nuanced discussion is necessary. In the first part of this study, I provide an extensive descriptive comparison of university science in East and West Germany before and after the reunification. Before the reunification, East Germany's science system employed a larger share of female researchers than West Germany, albeit employment of female researchers was low in both countries. This finding contrasts with East Germany's overall female employment rate of 90%, indicating that the scientific sector played a limited role in shaping this high level of female workforce participation. Additionally, East Germany exhibited a comparatively higher share of qualified university lecturers than West Germany. The two countries also differed in research focus: while East German researchers were approximately equally distributed between the life sciences, the natural sciences and engineering, the majority of West German researchers were concentrated in the life sciences. In response to the reunification, the research focus of East Germany became more aligned with West Germany by shifting towards the life sciences. The reunification came along with severe reductions in available positions for university researchers. My data allows me to quantify this loss of East German researchers, which amounts to almost 50% of pre-reunification levels. This implies a substantial reduction of available collaboration partners and knowledge transmitters. The transition process involved maintaining previously employed East German researchers, as well as hiring new researchers, especially from West Germany. The new hires were predominantly male. This can be viewed as a missed opportunity of the transition to achieve a more equal gender distribution in academia (Burkhardt, 1993). East German researchers, who were able to retain their position after the reunification, were on average more productive than those who left academia. The new hires from West Germany were, on average, highly productive researchers. This refutes the often made claim that the group of incoming West Germans consisted only of those unable to establish a successful career in West Germany.

In the second part of the study, I examine the causal effect of the group of West German researchers moving to East German universities onto the remaining East German researchers. The new West German colleagues impacted the East German researchers, but not unambiguously positive. Most strikingly, my results reveal a tradeoff between publication quantity and publication quality. This tradeoff is field-specific, with Medicine shifting towards fewer, but higher quality publications, whereas other fields, such as Chemistry, reduced the quality of publications while simultaneously increasing the number of papers published. My analyses suggest that this tradeoff reflects an adjustment process towards a more Western publication style. Further results show that the internationalization of East German researchers was only partially successful. While East Germans in Medicine increased their share of publications in English-language journals, the remaining fields did not experience such a shift. Finally, I investigate how West Germans impact their departments' success in obtaining third-party funding, which is positive across all fields.

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My study points towards learning effects through adjustments in collaboration patterns as the underlying reason for the observed changes. These are tied to different, field-specific roles that West German switchers take on during the transition process. In Medicine, West Germans predominantly served as a knowledge broker, connecting their East German colleagues to researchers at West German institutions. This results in a larger share of publications with coauthors in West Germany at the expense of collaborative publications with East German colleagues. In the remaining fields, the network-expanding effect played a subordinate role. Instead, East Germans responded to the influx of West German researchers by increasing their collaborations within East Germany, also within the own department. This could be interpreted as West German switchers acting as coauthor or as knowledge source by sharing system-specific tacit knowledge. This interpretation is confirmed by an increasing shift of East German researchers towards publishing in outlets favored by West Germans.

This study makes several important contributions. It provides a fundamental analysis of the transformation process in the East German science system, which allows to re-evaluate the historical record. In particular, my study is among the first to provide comprehensive quantitative analyses that allow policy makers to assess in which dimensions the transition process was successful. Further, it can speak to the long-lasting debate about the productivity of the incoming West German researchers. As I point out, the transition effects were not unambiguously positive. In particular, the observed quantity-quality tradeoff in publication output as a result of the adjustment towards a more Western publication behavior raises the question, if existing potential was discarded. Possibly, a more customized approach, allowing for adjustments within the West German science system as well, would have been preferable.

I further contribute by compiling a novel data set from historical sources that provides ample possibilities for future research. Fruitful avenues for further research could be, e.g., a more detailed investigation of the coauthor networks that formed due to the influx of West German researchers. Investigating the impact of the hiring committee composition on the research focus of the departments would be interesting to understand to what extent individuals, who are not actively engaged in research at the department, can shape the department's research environment. Moreover, an examination of additional long-run measures of department success could provide valuable insights into how the transition process has shaped departments' performance today. Outcomes of interest could be the number of special research fields (SFB's) from the German Research Foundation or the number of ERC grants received.

Beyond the specific context of the German reunification, this study contributes to the broader discussion on the role of knowledge brokers, particularly in times of disruptions in scientific systems. The study's findings underscore that knowledge brokers can provide considerable benefits to their colleagues through the knowledge they embody, even if the environment is ex-ante hostile. The observed effects are field-specific and reflect the different roles knowledge brokers

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can assume, such as expanding networks or sharing system-specific knowledge. The results further highlight the crucial role of these individuals in mitigating the adverse consequences of disruptions in scientific systems by helping their colleagues adjust their research agendas, sharing their networks, and facilitating access to third-party funding. Overall, while the influx of well-connected researchers can facilitate the integration of individuals from disrupted scientific systems and improve access to funding, the effects are field-specific and may be influenced by the receptiveness of the existing academic environment.

These findings have important policy implications. In circumstances of large-scale disruptions to academic and research systems – whether due to political transitions, economic crises, or conflicts – targeted recruitment of researchers with established international networks can be a valuable strategy to accelerate the recovery of the disrupted system, in particular of the affected individuals and institutions. However, to ensure positive outcomes of these efforts across all fields, policymakers should consider disciplinary differences and the potential resistance of existing academic communities. By deepening our understanding of how scientific communities adapt to disruptions and which role well-connected researchers can play, we can design more effective policies to support knowledge transfer, academic collaboration, and resilience in times of change.

A

Appendix to Chapter 1

ICT, Collaboration, and Innovation: Evidence from BITNET

A.1 Appendix to Sections 1.3 and 1.4

A.1.1 Descriptive Statistics

Table A.1: Summary Statistics in the Year before BITNET Adoption

<i>Main sample</i>				
	Mean	Standard deviation	Minimum	Maximum
# univ. patents/100k	0.39	1.56	0.00	53.20
# cit.-wght. univ. patents/100k	1.35	5.73	0.00	117.42
Average cit. per univ. patent	3.98	3.51	0.00	34.00
<i>Backward citations</i>				
	Mean	Standard deviation	Minimum	Maximum
# backward citations/100k	2.28	8.75	0.00	194.01
# backward citations to BITNET unis/100k	0.93	3.85	0.00	105.22
# backward citations to other unis/100k	1.35	5.96	0.00	173.15
# backward citations to own uni/100k	0.11	0.86	0.00	33.82
<i>Collaboration</i>				
	Mean	Standard deviation	Minimum	Maximum
# single-authored univ. patents/100k	0.17	0.87	0.00	26.30
# collaborative univ. patents/100k	0.22	0.97	0.00	37.55
# collab. univ. patents/100k with new inventors	0.18	0.72	0.00	21.90
# collab. univ. patents/100k with existing teams	0.04	0.34	0.00	15.65
# collab. univ. patents/100k with BITNET inventors	0.01	0.09	0.00	2.35
# collab. univ. patents/100k with other inventors	0.21	0.95	0.00	37.55
Average team size	2.22	0.76	1.00	6.00
<i>Patent content</i>				
	Mean	Standard deviation	Minimum	Maximum
# directly science-related univ. patents/100k	0.09	0.31	0.00	4.39
# indirectly science-related univ. patents/100k	0.14	0.49	0.00	7.44
# not directly science-related univ. patents/100k	0.25	1.35	0.00	52.15
# univ. patents with words new to world/100k	0.11	0.47	0.00	15.65
# univ. patents with words new to region/100k	0.27	1.24	0.00	37.55
# univ. patents with old words/100k	0.01	0.10	0.00	2.83

Note: This table displays the averages of the outcomes of interest for treated universities and associated control universities in the year before the introduction of BITNET. Patents are collaborative if they were filed by more than one inventor. Inventor teams have new inventors if the team had not previously patented in this constellation. Patents are (in)directly related to science if they directly cite a scientific article (or cite a patent that does so).

A.1.2 Alternative Control Group Specification

In our current specification, we use later-adopting universities as the control group for earlier adopting universities. This implies that some control universities drop from the control group when they connect to BITNET in the post period of the focal university. We think this is a sensible approach because a university that adopts BITNET shortly after the treated university might be a better control than a control university that adopts BITNET many years later.

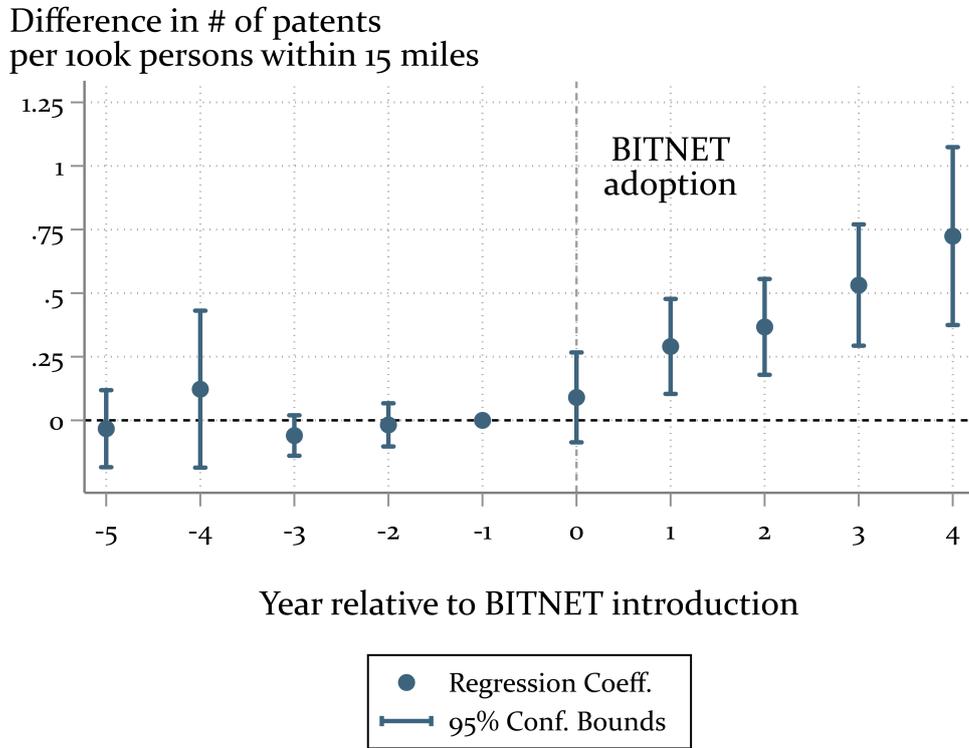
Yet, our results stay qualitatively and quantitatively very similar if we use “clean controls”, that is, if we use only those universities as control observations for any focal university that adopt BITNET after the end of the treatment period for the focal university. This is the approach used in Deshpande and Li (2019), and related to the one used in Cengiz et al. (2019). Table A.2 replicates the main table and Figure A.1 replicates the main figure of our paper. In line with our identification assumption that the timing of BITNET adoption is not related to trends in university patenting, the results are similar if we do or do not use clean controls. If anything, the results in this analysis are larger.

Table A.2: Main Results Using “Clean Controls”

Dep. Var.:	Univ. patents	Cit.-wght.	univ.	Average	University patents p.c.		Backward citations		Company		
	p.c.	patents p.c.	citations		Non-urban	Urban	All	univ. patents p.c.	patents		
	(1)	(2)	(3)	(4)	Area		(6)	(7)	(8)	(9)	(10)
BITNET x Post	0.30*** (0.08)	1.59*** (0.35)	-0.30** (0.14)	0.57*** (0.14)	0.05*** (0.01)	0.05*** (0.01)	2.56*** (0.49)	2.04*** (0.38)	0.51** (0.23)	0.04 (0.04)	0.33 (0.27)
Mean Dep.	0.19	0.69	4.15	0.26	0.10	0.26	1.17	0.48	0.68	0.06	7.19
R2 (within)	0.02	0.03	0.09	0.02	0.26	0.02	0.02	0.04	0.01	0.01	0.05
Obs.	91690	91690	49896	21800	25200	21800	91690	91690	91690	91690	91690

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET after the treatment period of the treated university. All specifications include year fixed effects and institution group fixed effects. Column (1) as well as columns (4) and (5) use patents by university-connected inventors adjusted by the population in the 15 miles region around the university as the dependent variable. Column (2) uses forward citations to these patents per population as the dependent variable and column (3) uses average 5-year forward citations per patent among university-connected inventors as the dependent variable. Columns (4) and (5) split the sample by median local population density. Columns (6) to (9) use backward citations per capita as the dependent variable. Columns (7) and (8) distinguish between citations to patents where at least one inventor is around a BITNET-connected university vs. not. Column (9) uses patents with self-citations as the dependent variable, a subset of BITNET-connected patents. Column (10) uses patents per 100,000 population by company inventors (not connected to universities) as the dependent variable. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Figure A.1: Effects of BITNET on Local Patenting Relative to the Connection Date Using Clean Controls



Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the number of university patents per 100,000 population within 15 miles of universities adopting BITNET relative to universities that only adopt BITNET after the treatment period of the focal university. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

A.1.3 Alternative Difference-in-Differences Methods

Table A.3 reports estimates from alternative specifications using novel methods for difference-in-differences estimation with variations in treatment timing (Callaway and Sant’Anna, 2021). The first column shows the average treatment effect on the treated (ATT) when using a simple weighted aggregation of the treatment effect. The second column shows the ATT when using the group-specific aggregation. The third column shows the ATT when averaging over the dynamic effects. In all columns, the effects are sizable and significantly different from zero. They are qualitatively similar to the results from our event-study design.

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Table A.3: Main Results Using Difference-in-Differences Specifications

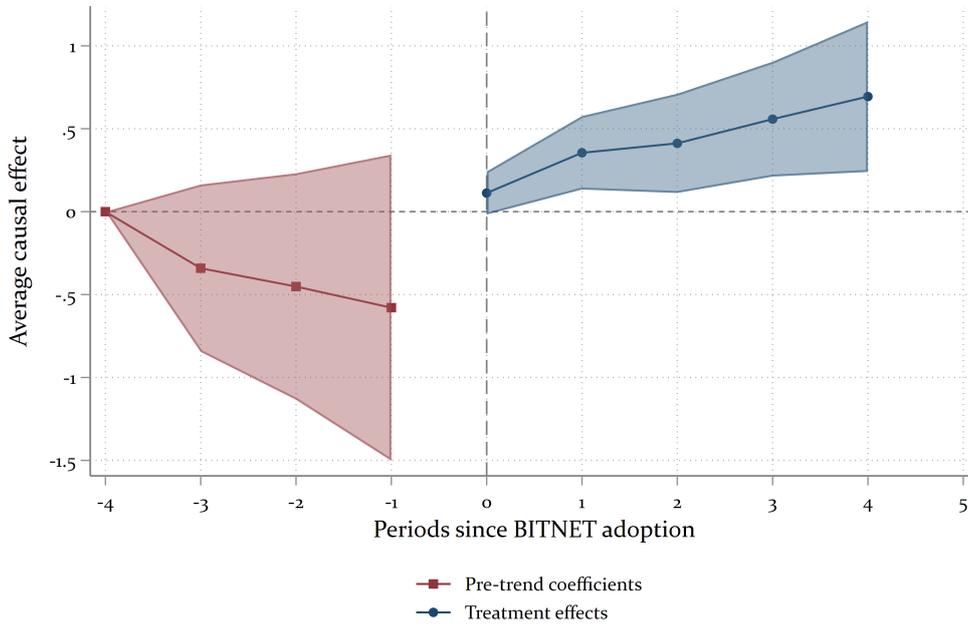
Dep. Var.:	Numer of patents p.c.		
Spec.:	Callaway and Sant'Anna		
Aggregation:	Simple weighted	Group-specific	Dynamic
	(1)	(2)	(3)
ATT	0.41** (0.11)	0.34** (0.08)	0.38** (0.11)

Note: This table shows difference-in-differences specifications of the impact of BITNET on local patenting with the number of patents per capita in the 15 miles around the university as the dependent variable. We use the methods suggested by Callaway and Sant'Anna (2021). All specifications include year fixed effects and institution fixed effects. Columns (1), (2), and (3) use the simple weighted, the group-specific, and the dynamic aggregation methods suggested by Callaway and Sant'Anna (2021) using their doubly-robust estimation procedure, respectively. Bootstrapped standard errors in parentheses, ** $p < 0.05$

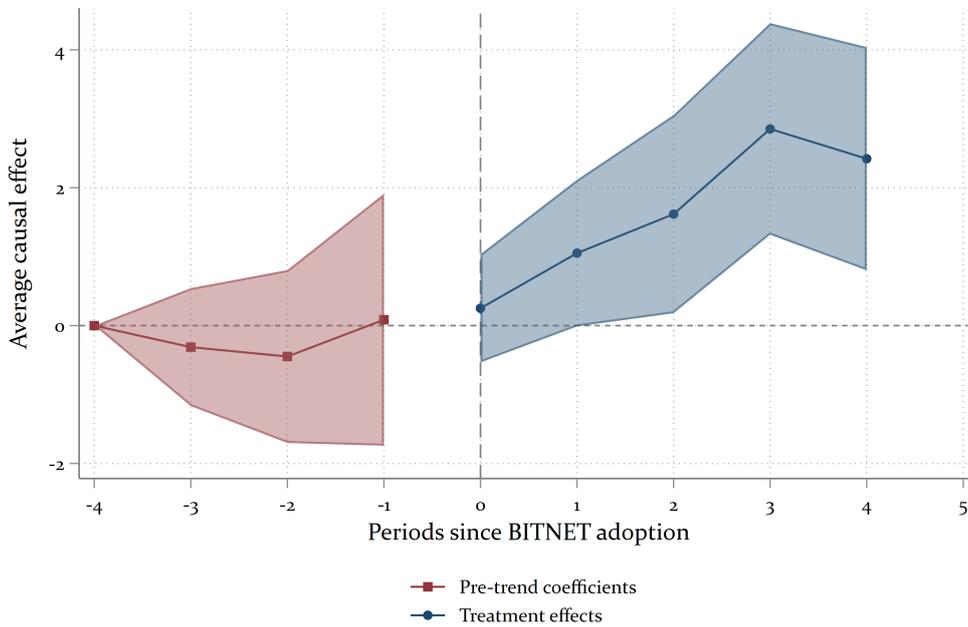
We also report the results from the estimator suggested by Borusyak et al. (2021). Figure A.2 shows that in line with our main estimates, the estimated treatment effects in the period before BITNET adoption are insignificantly different from zero and do not show a clear or strong pre-trend. After BITNET adoption, both the number of patents and citation-weighted patents per capita increase in the treated relative to the control universities.

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Figure A.2: Treatment Effects Analysis Following Borusyak et al. (2021)



(a) Patents per 100,000 Population



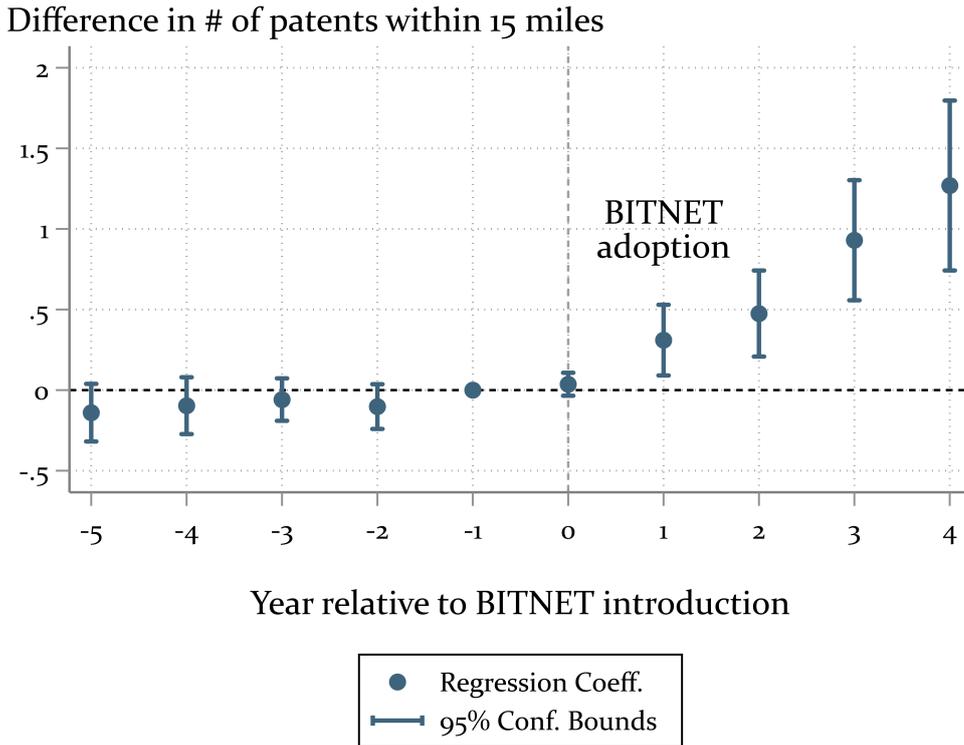
(b) Citation-Weighted Patents per 100,000 Population

Note: These figures show the yearly average treatment effects on the treated of BITNET adoption on universities adopting BITNET relative to universities that only adopt BITNET after the treatment period of the focal university. We use the methodology proposed by Borusyak et al. (2021) to estimate these graphs. Panel (a) uses the number of university patents per 100,000 population within 15 miles as dependent variable. Panel (b) uses citation-weighted patents per 100,000 population within 15 miles as dependent variable. The shaded areas represent 95% confidence bounds that allow for clustering at the treated institution level.

A.1.4 Estimates with a Different or without Scaling of the Outcome Variable

In Figure A.3 below, we show the treatment effects around BITNET adoption using the number of patents as the dependent variable. The results are qualitatively similar to our time-varying results in the main specification.

Figure A.3: The Impact of BITNET on the Local Number of Patents

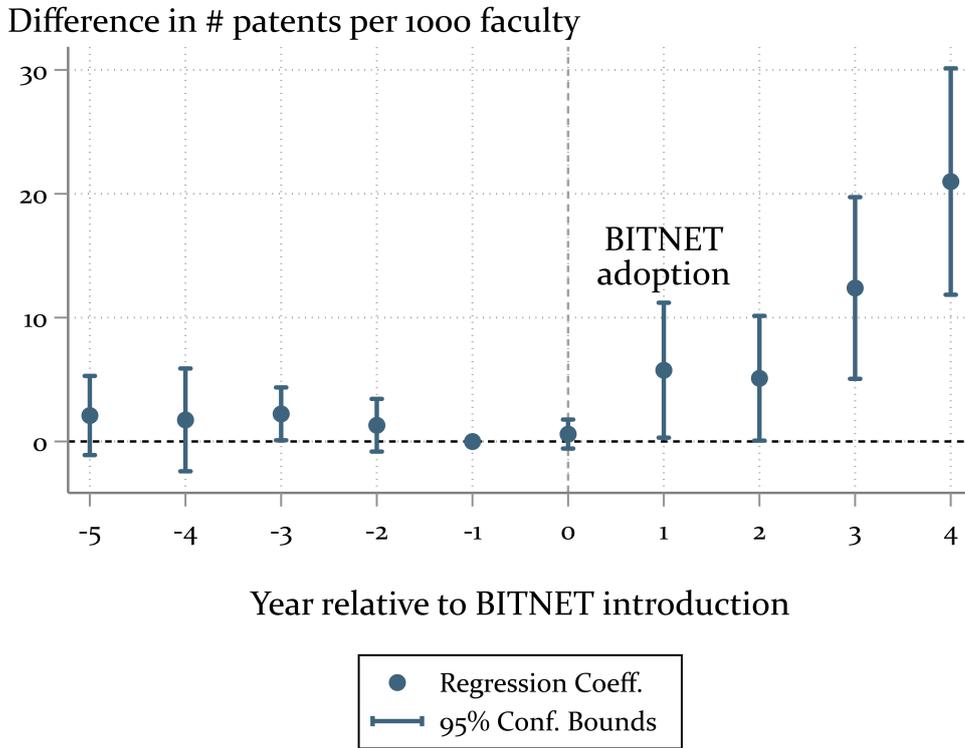


Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the number of university patents within 15 miles of universities adopting BITNET relative to universities that only adopt BITNET later. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

We additionally show a specification where we use the number of patents assigned to the respective universities scaled by a measure of university size as outcome. To construct a measure of university size, we count the number of active faculty at patenting universities using data from Microsoft Academic. We define an author as faculty if she published for an institution at least twice in the top 10,000 highest impact journals with a gap of five or more years. To count the number of patents directly assigned to a university we use the direct match between patents and universities provided by Microsoft Academic to identify the right assignee name for the university. Then, we count all patents of the identified assignee. Figure A.4 shows the results from this analysis. We find qualitatively similar results to our main analysis, suggesting that using population as scaling of the dependent variable does not drive our results.

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Figure A.4: Treatment Effects Analysis Normalized by University Faculty



Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the number of directly assigned university patents per faculty of universities adopting BITNET relative to universities that only adopt BITNET later. We take the number of faculty and the patent assignments from Microsoft Academic. We define an author as faculty if she published for an institution at least twice in the top 10,000 highest impact journals with a gap of five or more years. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

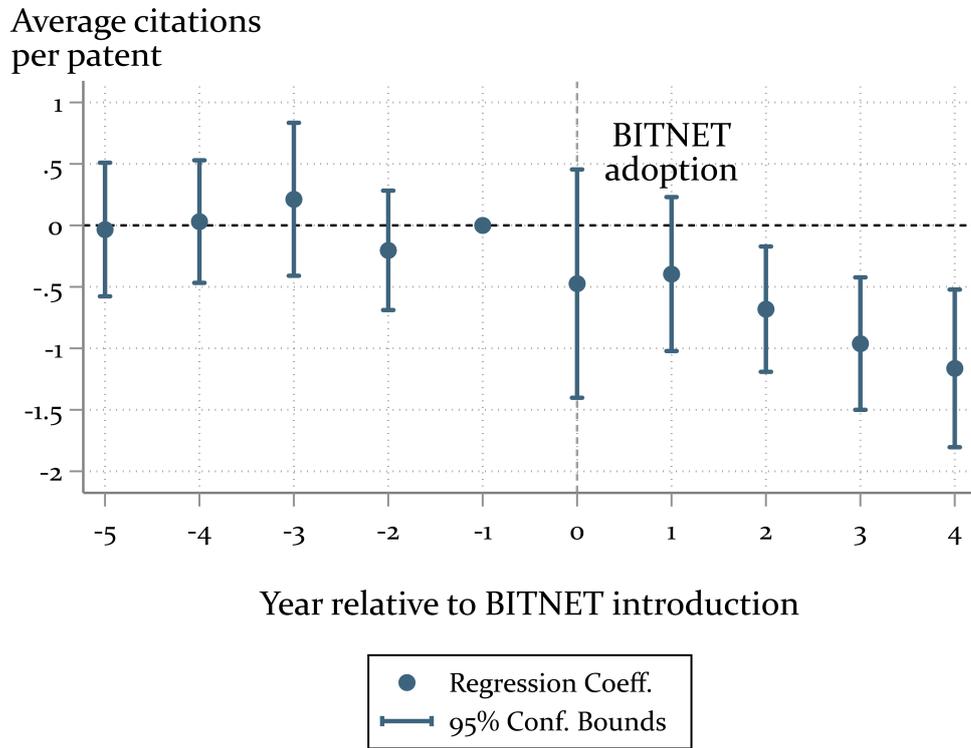
A.1.5 Additional Results on Patent Quality

Figure A.5 shows how the introduction of BITNET relates to the average number of citations per patent. As in our main graphs, there is no difference in the average citations per patent between treatment and control groups in the time period before the introduction of BITNET. After the introduction, the negative effect on average citations appears soon, becoming statistically significantly different from zero around two years after the introduction of BITNET.

Figure A.6 shows the results from difference-in-differences regressions around BITNET introduction using different quality measures as dependent variables. We translate the point estimates to percent changes for better interpretability. The upper part of the figure shows results for all university patents, while the lower part shows results for university patents closely related to science only, the main driver of our effects. Row (1) shows that average forward citations decrease around treated universities relative to control universities, as just shown above. Row (2) shows that also the share in the top 1% of the citation distribution decreases. Row (3) uses patent renewals as alternative measure of patent quality (e.g., Pakes, 1986; Schankerman and Pakes, 1986). The effect is negative but not statistically different from zero. Row (4) uses the size of the patent family as a quality measure (Putnam, 1996; Harhoff et al., 2003) and finds a negative effect. Finally, Row (5) uses the patent quality measure by Kelly et al. (2021) as dependent variable and finds no effects. Thus, average patent quality seems to have at least not increased, no matter which measure we look at. This is broadly in line with our finding of a negative impact on average citations.

Is this finding also true for patents closely related to science, the main driver of our effects on patenting? Rows (6) through (10) repeat the analysis using the same quality measures, but focusing on patents closely related to science instead of all university patents. The effects are more pronounced and negative, suggesting that the patents induced through BITNET were indeed of lower quality than the average patent filed in the control group.

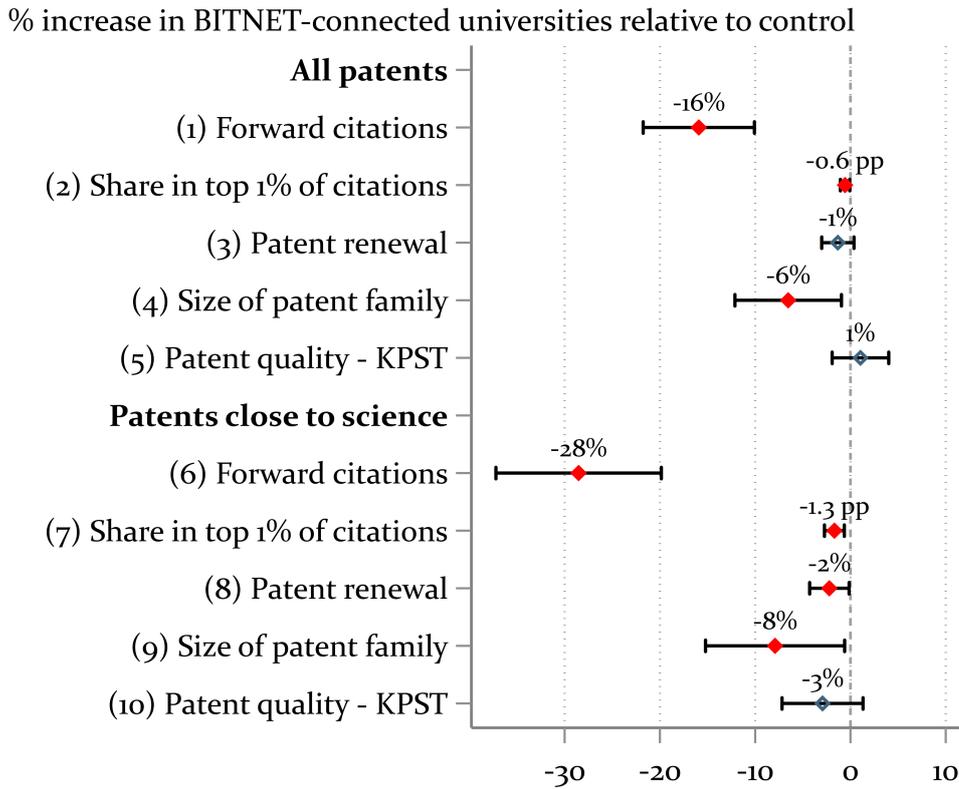
Figure A.5: The Impact of BITNET on the Average Citations to Local Patents



Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the average forward citations to university patents within 15 miles of universities adopting BITNET relative to universities that only adopt BITNET later. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

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Figure A.6: The Impact of BITNET on Different Measures of Patent Quality



Note: This figure shows the results from a difference-in-differences estimation with measures of quality of university patents in the 15 miles region around a university as the dependent variable. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that connect to BITNET later. All specifications include year fixed effects and institution group fixed effects. The bars indicate 90% confidence intervals using standard errors that allow for clustering at the treated institution level. Coefficients plotted as a hollow diamond indicate coefficients not significantly different from zero at this level. Full (red) diamonds indicate coefficients that are significantly different from zero.

A.1.6 Additional (Time-Varying) Heterogeneity of Effects

In Table A.4 below, we show more heterogeneity results. In column (1), we repeat our baseline estimate for comparison. In columns (2) and (3), we split the sample by the treated university's patenting levels before BITNET existed, i.e., in 1980. We find that the effect is largely driven by universities that already showed above-median patenting levels in 1980. This could point to a complementary between ICT and local inventive capacity. In columns (4) and (5), we show a split by adoption year and find that the effect is larger for early adopters (until the end of 1984), but is also substantial for late adopters.

Table A.4: Impact on Number of University Patents p.c. Across Different Types of Universities

Dependent Variable:	University patents p.c.				
	Baseline	Above Median Patenting	Below Median Patenting	Early Adopters	Late Adopters
Split:	(1)	(2)	(3)	(4)	(5)
BITNET x Post	0.30*** (0.08)	0.56*** (0.17)	0.20** (0.08)	0.48*** (0.18)	0.24*** (0.08)
Mean Dep.	0.30	0.70	0.23	0.42	0.27
R2 (within)	0.00	0.01	0.00	0.00	0.00
Obs.	531063	102175	264225	200777	330286

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. The dependent variable is the number of patents per 100,000 population in the 15 miles region around a university. All specifications include year fixed effects and institution group fixed effects. Column (1) uses our baseline sample and repeats column (1) of Table 1.1. Columns (2) and (3) split the sample by median patenting rates per 100,000 population in the 15 miles region around universities in 1980, the year before the first BITNET adoption. Columns (4) and (5) split the sample into early and late BITNET adopters. Early adopters are those universities that are connected by the end of 1984. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

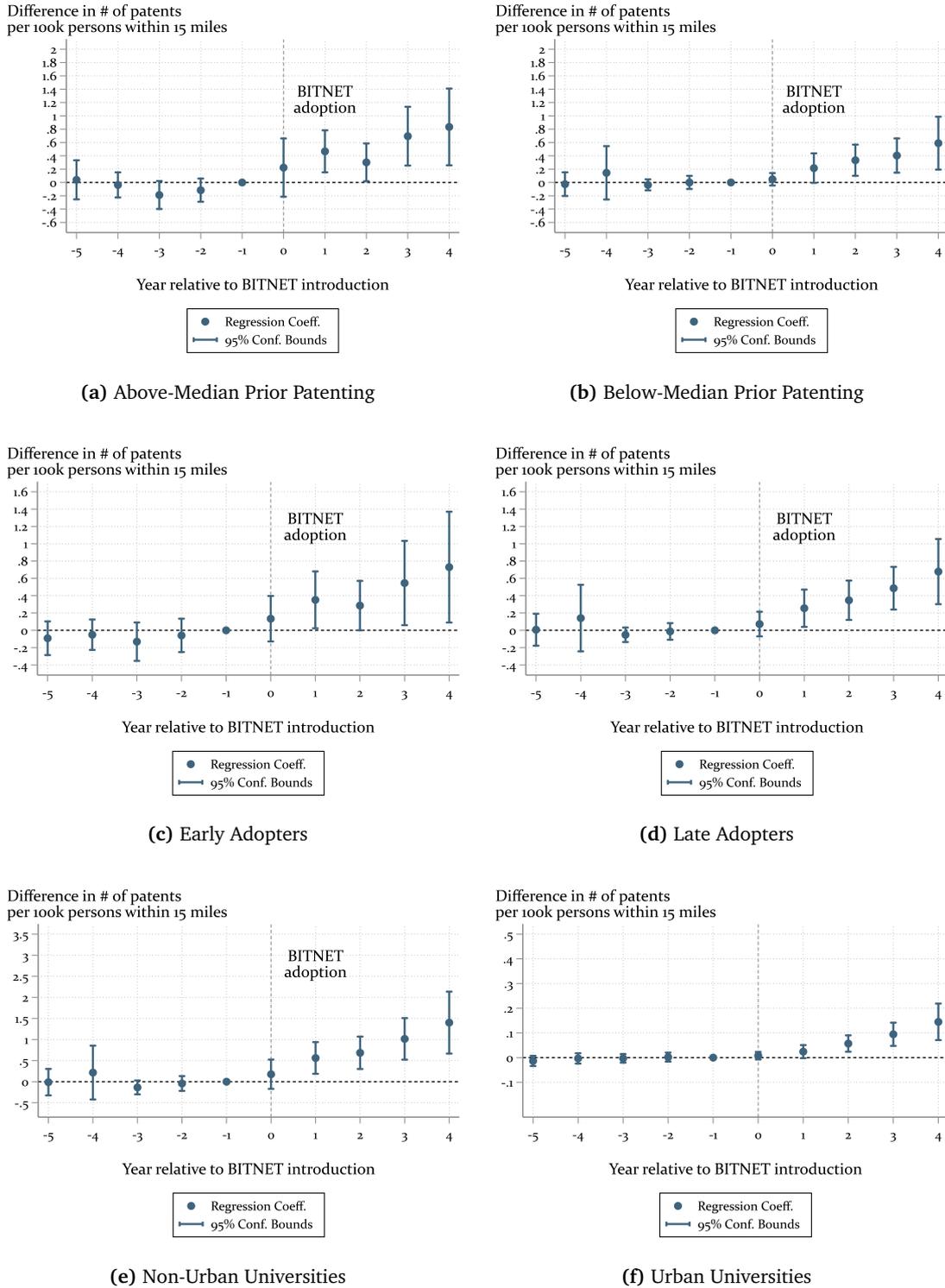
In panels (a) and (b) of Figure A.7, we show the effects by above- and below-median patenting before BITNET adoption. In both figures, the difference between treatment and control universities is insignificant in the time period before BITNET adoption. After BITNET adoption, patenting increases around universities that had above-median patenting in 1980, while we only see smaller effects arising around universities with historically low patenting rates. In panels (c) and (d) of the figure, we split our sample into early and late adopters. We again find that before BITNET adoption, there is no differential trend between treatment and control group both for early and for late adopters. After BITNET adoption, both sets of universities see increases in patenting. This increase is larger for early adopters than for late adopters.

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In panels (e) and (f), we split the sample into non-urban and urban universities (by median population density). Again, in line with our identification assumption, there is no difference in patenting between treatment and control group both for non-urban and for urban universities before BITNET adoption. After BITNET adoption, patenting substantially increases around non-urban universities. Around urban universities, there is only a small increase in patenting around treated universities that also sets in later. Note the difference in scales that is necessary such that any impact is visible for urban universities. This reinforces our finding that non-urban universities benefit from BITNET while urban universities do not.

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Figure A.7: Treatment Effects Analysis by Sub-Groups



Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the number of university patents per 100,000 population within 15 miles of universities adopting BITNET relative to universities that only adopt BITNET later across sub-groups. Panels (a) and (b) split the sample by median per capita patenting in 1980. Panels (c) and (d) split the sample by whether the focal university adopted BITNET before or after 1984. Panels (e) and (f) split the sample by median population around universities. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

A.1.7 Funding Shocks as Potential Explanation

If there is a funding increase concurrent to the BITNET introduction, this might bias our results. We use two complementary approaches to provide evidence that this is likely not an issue in our setting.

First, we directly control for the funding that universities have at their disposal by using federal funding per university and an estimate of the number of faculty as controls. The federal funding data per university is from Hausman (2021), which Naomi Hausman thankfully shared with us. Unfortunately, this data is available only for a subset of our universities. To estimate the number of faculty, we use data from Microsoft Academic. We define an author as faculty if she published for an institution at least twice in the top 10,000 highest impact journals with a gap of five or more years.

We show the results of this analysis using the number of patents as outcome in Table A.5. The results are qualitatively similar when estimating this in per capita terms. Column (1) shows our baseline estimate for comparison. Column (2) controls for the number of faculty in the respective year. Column (3) adds the funding measure from Hausman (2021). Column (4) includes both measures. The table shows that our results are qualitatively unaffected by these additional controls.

Figure A.8 shows the time-varying treatment effects on patents within 15m of the respective university around BITNET adoption when controlling for both measures of university funding. Again, the estimates are very similar to the estimates without controlling for these variables. This analysis suggests that concurrent funding shocks are unlikely to explain our results. Note, however, that data limitations make this analysis not entirely conclusive. Thus, we cannot entirely rule out funding shocks as a partial confounder.

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Table A.5: Impact on Number of University Patents p.c. Controlling for Funding Shocks

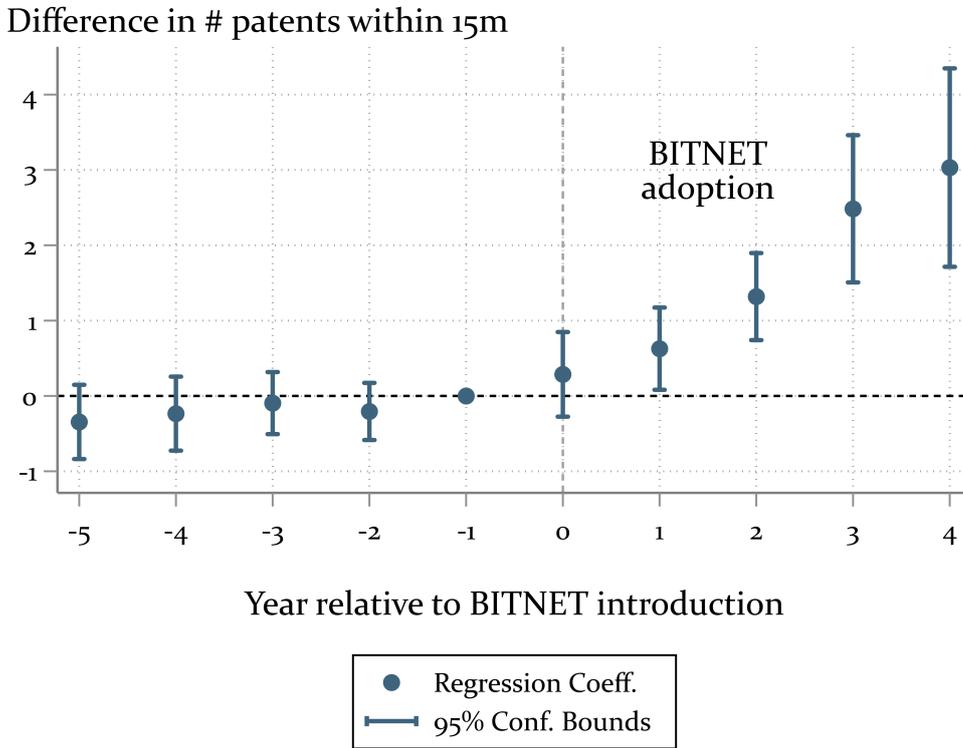
Dep. Var.:	University patents			
	(1)	(2)	(3)	(4)
BITNET x Post	0.50*** (0.12)	0.35*** (0.13)	1.34*** (0.33)	1.51*** (0.32)
Faculty (in 100)		0.30*** (0.02)		-0.28*** (0.05)
Total funding (in 10,000 USD)			0.09*** (0.02)	0.12*** (0.02)
Mean Dep.	1.24	1.35	2.33	2.33
R2 (within)	0.10	0.12	0.04	0.05
Obs.	531063	365537	19791	19791

Note: This table shows difference-in-differences estimates of BITNET adoption on local university patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. All columns use university patenting in 15 miles around the universities as dependent variable. Column (2) controls for the number of faculty that we take from Microsoft Academic. We define an author as faculty if she published for an institution at least twice in the top 10,000 highest impact journals with a gap of five or more years. In column (3) we control for total funding from all government agencies, using the data from Hausman (2021). To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In a second, complementary, approach, we also directly investigate the possibility that concurrent funding shocks by the government induce both BITNET adoption and higher patenting, without a direct effect of BITNET. We leverage that patents that rely on U.S. government funding must acknowledge that they do. Using the data by Fleming et al. (2019), we can thus split the dependent variable into whether patents rely on U.S. government funding, either directly or indirectly. If government funding increased at the same time as BITNET was introduced, we would expect that patents acknowledging government funding grow faster than patents that do not acknowledge funding. In particular - if there is no BITNET effect and we only see a funding shock - we would expect little reaction from patents that do not acknowledge funding.

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Figure A.8: Innovation Impact Controlling for Funding



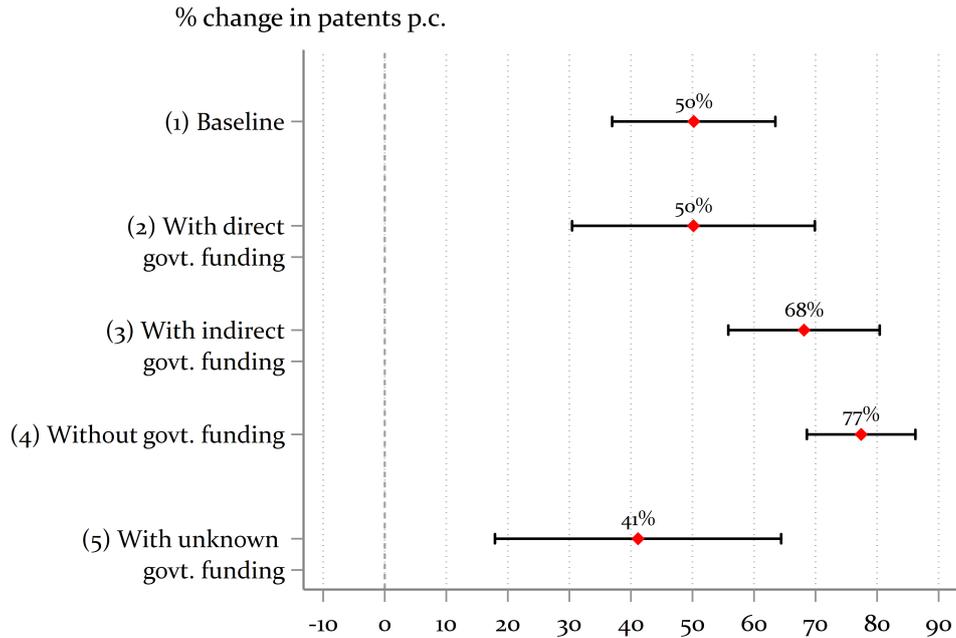
Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on the number of patents within 15 miles of universities adopting BITNET relative to universities that only adopt BITNET later. In the graph, we control for faculty members and total funding support available at the universities. We count faculty members by identifying authors in Microsoft Academic. We define an author as faculty if she published for an institution at least twice in the top 10,000 highest impact journals with a gap of five or more years. For the funding data, we rely on a name matching to the data from Hausman (2021). The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

We show the results from the analysis in changes relative to post-period means using the margins command in Stata in Figure A.9. The first line shows our baseline effect for comparison. It amounts to an around 50% increase in local per capita patenting. In the second line, we show the impact of BITNET on patenting per capita for patents that directly acknowledge U.S. government funding. Relative to the mean of the control group in the year before BITNET adoption, this is an effect of around 50%, proportional to the main result. In the third line, we repeat the analysis using those patents as dependent variable that do not directly rely on government funding but cite either a patent or an article that acknowledges government funding (“indirect government funding”). We find a somewhat larger effect (68%). We show the impact on patents without direct or indirect funding from the U.S. government in line (4). In relative terms, the effect is by far the largest, with an increase of 77%. Many patents in the data by Fleming et al. (2019) do not contain positive or negative information on their reliance on U.S. government funding. In this group, the relative effect is around 41% (line 5). All in all,

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it does not seem as if our effects are exclusively driven by increases in funding that occur at the same time as the introduction of BITNET. All categories see increases in patenting that are roughly proportional to the categories' baseline patenting levels. If anything, the largest relative effect occurs among patents for which we know that they do not rely on U.S. government funding.

Figure A.9: Treatment Effect by Acknowledgment of U.S. Government Funding



Note: This figure shows the results from a difference-in-differences estimation with university patents per 100,000 population in the 15 miles region around a university in the first line and university patents with the respective characteristic per 100,000 population in the 15 miles region around a university as the dependent variable in all subsequent lines. We show the results from the analysis in changes relative to post-period means using the margins command in Stata. All specifications include year fixed effects and institution group fixed effects. The bars indicate 95% confidence intervals using standard errors that allow for clustering at the treated institution level. Coefficients plotted as a hollow diamond indicate coefficients not significantly different from zero at this level. Full (red) diamonds indicate coefficients that are significantly different from zero. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

A.1.8 Relation to Bayh-Dole Act

The Bayh-Dole Act was an important step in inducing more innovation closely connected to science and local economic activity around universities (Hausman, 2021). But while the Bayh-Dole Act greatly changed the nature of university patenting, we think it did so for all universities, i.e., treatment and control universities alike. For example, looking at a treated university that joined BITNET in 1984, it is difficult to understand how Bayh-Dole (enacted in 1980) led to an increase in patents in 1985 only at the treated university but not at the control universities, and how it did not increase patents at either the treated or control universities in 1983.

This seems possible only if Bayh-Dole had an impact on patenting that is synchronized both in location (at treated but not at control universities) and time (after BITNET but not before) with the introduction of BITNET. There are, therefore, two key concerns related to the Bayh-Dole Act. Universities adopting BITNET earlier might also have been more keen to increase technology transfer by (i) introducing TTOs and by (ii) incentivizing their faculty with royalty payments.

In this subsection, we show that we arguably do not confound the impact of BITNET with the impact of the 1980 Bayh-Dole Act and the subsequent establishment of technology transfer offices or the introduction of royalties by universities (e.g., Henderson et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002).

To this end, we first leverage data on the number of full-time equivalent staff at universities devoted to technology transfer, e.g., in a technology transfer office. We thank Arvids Ziedonis for providing us with this data. Column (1) repeats our baseline estimate. Column (2) controls for an indicator whether the university employs staff devoted to technology transfer (i.e., a technology transfer office, TTO) in a given year. Our main result is unaffected, while we do see positive impacts of TTOs on university patenting. In columns (3) and (4), we split our sample into whether the treated university ever had staff devoted to technology transfer or not. The impacts of BITNET are somewhat larger for universities that had a TTO, suggesting a complementarity between BITNET and TTOs. However, even in universities without a TTO, we see positive and significant effects of BITNET adoption on university patenting. Our analyses thus suggest that the establishment of TTOs and the introduction of BITNET had independent effects on local university innovation.

Second, we extend this analysis to universities' licensing regimes. A key part of the Bayh-Dole Act was that universities could now incentivize their research staff to translate research findings to inventions by allowing researchers to benefit from subsequent royalty payments (Lach and Schankerman, 2008; Ouellette and Tutt, 2020). We therefore use the data provided by Ouellette and Tutt (2020) to investigate whether we confound these potential royalty payments with our estimates of BITNET.

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We show the results of our main specification controlling for royalty payments in Table A.7. The first column repeats our baseline estimate. In column (2) we additionally control for whether the university grants its researchers shares of the royalties resulting from their patents. Note that the royalty variable is time-varying since the data contain information on when the universities introduced royalties. Our estimate is unaffected. Columns (3) and (4) then divide the sample according to whether the university has ever granted its researchers royalty shares from its patents. The table shows that royalties do not materially affect our estimate for the impact of BITNET on local university patenting. While royalty-granting universities benefit somewhat more, the effect on universities that do not is also sizable.

Overall, we believe that these results show that the Bayh-Dole Act does not confound our estimates on the patenting impact of BITNET adoption.

Table A.6: Impact on Number of University Patents p.c.: Relation to University Technology Transfer Offices

Dep. Var.:	University patents p.c.			
Sample	Baseline	Baseline	TTO Univ.	Non-TTO Univ.
	(1)	(2)	(3)	(4)
BITNET x Post	0.30*** (0.08)	0.29*** (0.08)	0.60*** (0.18)	0.18*** (0.06)
TTO		0.08*** (0.02)		
Mean Dep.	0.30	0.30	0.82	0.22
R2 (within)	0.00	0.00	0.02	0.01
Obs.	531063	518154	43907	265600

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. The dependent variable is the number of patents per 100,000 population in the 15 miles region around a university. All specifications include year fixed effects and institution group fixed effects. Column (1) uses our baseline sample and repeats column (1) of Table 1.1. Column (2) controls for an indicator whether the university employs staff devoted to technology transfer in a given year. Columns (3) and (4) split our sample into whether the treated university ever had staff devoted to technology transfer (i.e., a technology transfer office) or not. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Table A.7: Impact of BITNET Accounting for Royalty Payments

Dep. Var.:	University patents p.c.			
	Baseline		Royalties	
Sample:			Yes	No
	(1)	(2)	(3)	(4)
BITNET x Post	0.30*** (0.08)	0.31*** (0.08)	0.59*** (0.18)	0.15*** (0.06)
Royalty Fee	-1.64*** (0.03)			
Mean Dep.	0.30	0.30	0.37	0.27
R2 (within)	0.00	0.01	0.00	0.00
Obs.	531063	531063	219265	311798

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. All columns use patents by university-connected inventors adjusted by the population in the 15 miles region around the university as the dependent variable. The royalty data stems from Ouellette and Tutt (2020). We label those universities without information on royalties as not granting them. Column (2) controls for whether the treated university ever pays royalties to university inventors. Columns (3) and (4) split the sample by this variable. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

A.1.9 Results without Top X Universities

To provide evidence that our results are not driven by few selected universities, we show in this section that our results are robust to dropping the top 5, top 10, top 20, and top 25 universities in terms of pre-BITNET patenting.

Table A.8: Impact on Number of University Patents p.c. without Top X Universities

Dep. Var.:	University patents p.c.				
Sample	Baseline	w/o Top 5	w/o Top 10	w/o Top 20	w/o Top 25
	(1)	(2)	(3)	(4)	(5)
BITNET x Post	0.30*** (0.08)	0.31*** (0.08)	0.30*** (0.08)	0.26*** (0.06)	0.25*** (0.06)
Mean Dep.	0.30	0.30	0.30	0.30	0.29
R2 (within)	0.00	0.00	0.00	0.00	0.00
Obs.	531063	518512	505660	478728	464855

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. The dependent variable is the number of patents per 100,000 population in the 15 miles region around a university. All specifications include year fixed effects and institution group fixed effects. Column (1) uses our baseline sample and repeats column (1) of Table 1.1. Columns (2) to (5) drop the top 5, 10, 20, and 25 universities in terms of patenting per population before the introduction of BITNET. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.1.10 Matching

In Table A.9, we show that our results are robust when we use a more detailed matching strategy. In particular, we show that additionally matching on the number of patents in the year before BITNET adoption as well as matching on number of patents and on population before BITNET adoption does not affect our results.

Table A.9: Results Using Additional Matching Strategies

Dep. Var.:	University patents p.c.			Cit.-wght. univ. patents p.c.		
	Baseline	+ Patenting	+ Patenting & Population	Baseline	+ Patenting	+ Patenting & Population
Matching:	(1)	(2)	(3)	(4)	(5)	(6)
BITNET x Post	0.30*** (0.08)	0.29*** (0.08)	0.29*** (0.08)	1.43*** (0.35)	1.40*** (0.35)	1.40*** (0.35)
Mean Dep.	0.30	0.29	0.29	1.01	0.98	0.97
R2 (within)	0.00	0.00	0.00	0.01	0.01	0.01
Obs.	531063	530326	439080	531063	530326	439080

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. The dependent variable is the number of patents per 100,000 population in the 15 miles region around a university in columns (1) through (3). All specifications include year fixed effects and institution group fixed effects. Column (1) uses our baseline sample and repeats column (1) of Table 1.1. Columns (2) and (3) additionally match on patenting in the year before BITNET adoption and patenting before BITNET and population, respectively. To match control universities to treatment universities, we use Coarsened Exact Matching (Iacus et al., 2012) with 5 bins on patenting and on population. We repeat this analysis in columns (4) through (6) using citation-weighted patents as the dependent variable. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

A.1.11 Specification

Below, we show that our results are robust to accounting for the skewed nature of patenting outcomes. We first repeat our baseline specifications for the number of patents per population and the number of citation-weighted patents per population. We then use inverse hyperbolic sine transformations of these outcomes. Our results are qualitatively unaffected.

Table A.10: Main Results Using Different Specifications

Spec.:	Levels		IHS	
	Univ. patents p.c.	Cit.-wght. patents p.c.	Univ. patents p.c.	Cit.-wght. patents p.c.
Dep. Var.:	(1)	(2)	(3)	(4)
BITNET x Post	0.30*** (0.08)	1.43*** (0.35)	0.09*** (0.02)	0.13*** (0.03)
Mean Dep.	0.30	1.01	0.19	0.44
R2 (within)	0.00	0.01	0.03	0.07
Obs.	531063	531063	531063	531063

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. Columns (1) and (2) repeat our baseline specification using patents and citation-weighted patents in levels as dependent variable. Columns (3) and (4) repeat our baseline specification using an inverse hyperbolic sine transformation as dependent variable. All variables are weighted with the population in the 15 miles region around the university. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

A.1.12 Results across Regions

To provide evidence that our results are not driven by regional shocks affecting overall patenting in the area around adopting universities, we show that the effects are similar across different regions in the United States. To this end, we repeat our baseline specification splitting the U.S. into four broad regions.

Table A.11: Results across Regions: Impact on Number of University Patents p.c.

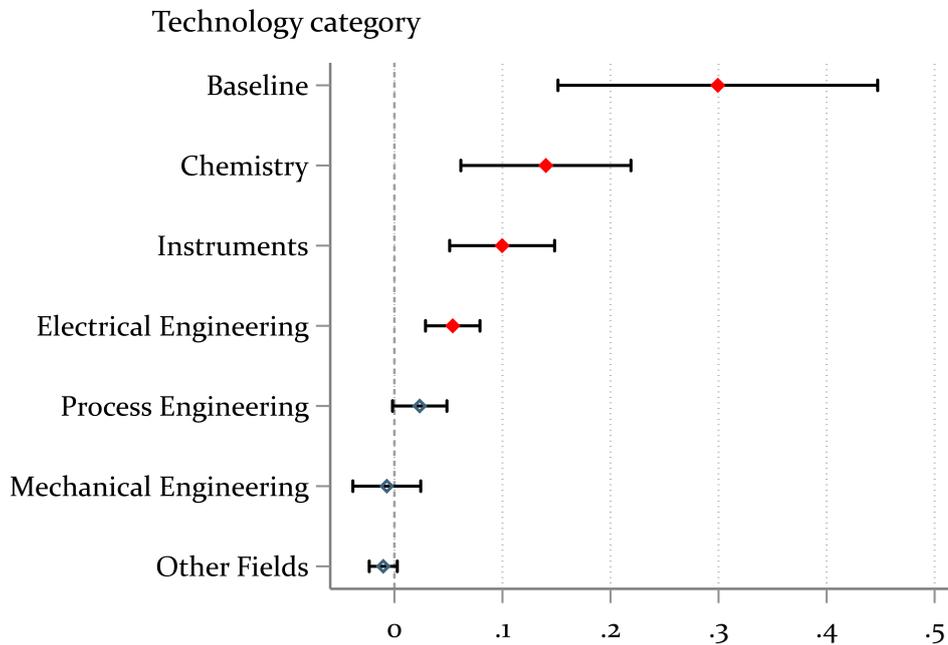
Dep. Var.:	University patents p.c.				
Sample:	Baseline	Northwest	Northeast	Southwest	Southeast
	(1)	(2)	(3)	(4)	(5)
BITNET x Post	0.30*** (0.08)	0.50*** (0.15)	0.21** (0.09)	0.13* (0.08)	0.68** (0.31)
Mean Dep.	0.30	0.31	0.31	0.31	0.28
R2 (within)	0.00	0.00	0.00	0.00	0.00
Obs.	531063	56545	322260	79085	73173

Note: This table shows difference-in-differences estimates of BITNET adoption on local patenting. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. The dependent variable is the number of patents per 100,000 population in the 15 miles region around a university. All specifications include year fixed effects and institution group fixed effects. Column (1) uses our baseline sample and repeats column (1) of Table 1.1. Columns (2) to (4) split the sample according to the region in which the university is located. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012). Robust standard errors, adjusted for clustering at the treated institution level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.1.13 Effects by Technology Category

We show the effects by technology category in Figure A.10. Each line is the difference-in-differences coefficient on the interaction between time and BITNET in a different regression that uses patents in the respective field as the dependent variable. The absolute effects on the number of patents per capita are most pronounced in Chemistry and Instruments, but these effects are proportional to baseline patenting levels. We find the largest relative effects in Electrical Engineering, but effects are hardly distinguishable (not shown). This suggests that the adoption of BITNET might have had a productivity-enhancing effect on inventors in several technology areas.

Figure A.10: Innovation Effects of BITNET by Technology Category



Note: This figure shows the results from a difference-in-differences estimation with university patents per 100,000 population in the 15 miles region around a university in the first line and university patents in the denoted field per 100,000 population in the 15 miles region around a university as the dependent variable in all subsequent lines. Thus, the coefficients in the next lines add up to the first line. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that are connected to BITNET later. All specifications include year fixed effects and institution group fixed effects. The bars indicate 95% confidence intervals using standard errors that allow for clustering at the treated institution level. Coefficients plotted as a hollow diamond indicate coefficients not significantly different from zero at this level. Full (red) diamonds indicate coefficients that are significantly different from zero.

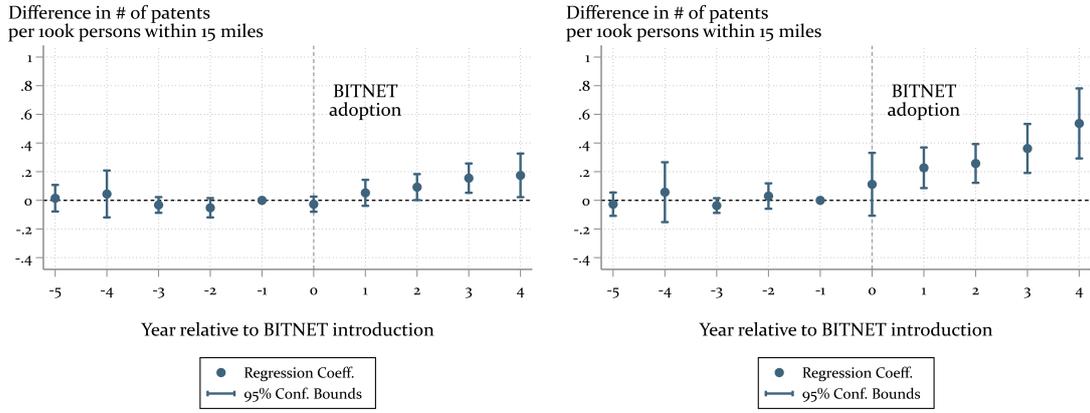
A.2 Appendix to Section 1.5

A.2.1 Time-Varying Effects on Team Formation

Figure A.11 shows the time-varying impacts of BITNET on team formation. Panels (a) and (b) show estimates using single-authored and team patenting as dependent variables, respectively. In line with our identification assumption, outcomes do not differ between treatment and control universities before BITNET adoption. After BITNET adoption, all types of inventors become somewhat more productive, but inventor teams increase their patenting substantially more than single inventors. Panels (c) and (d) show patenting by new and by old teams, respectively. We define new teams as teams that had at least one new team member (including entirely new teams that had not patented together before), whereas teams that had patented in the same composition before count as old teams. Again, in line with our identification assumption, outcomes do not differ between treatment and control universities before BITNET adoption. After BITNET introduction, we find that both types of teams increase their patenting but new teams increase their patenting substantially more than old teams. Finally, panel (e) shows the impact of BITNET adoption on average team size. The positive impact observed in Table 1.2 is visible, but it is much more noisily estimated than the other results.

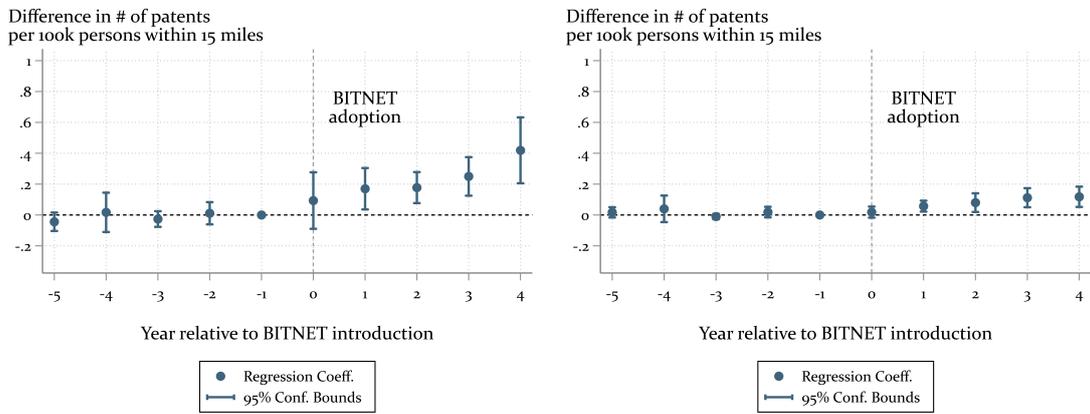
A. APPENDIX TO CHAPTER 1

Figure A.11: Time-Varying Effects on Team Formation



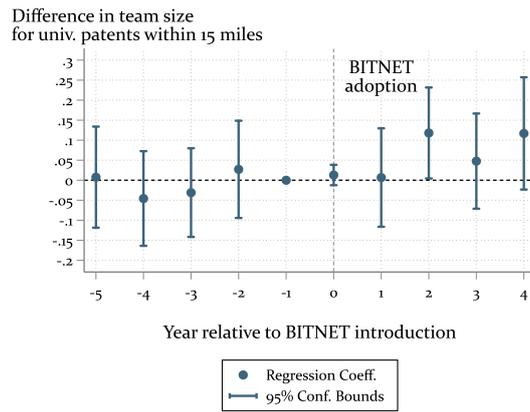
(a) Single-Authored Patents

(b) Patenting by Teams



(c) Patenting by new Teams

(d) Patenting by old Teams



(e) Average Team Size

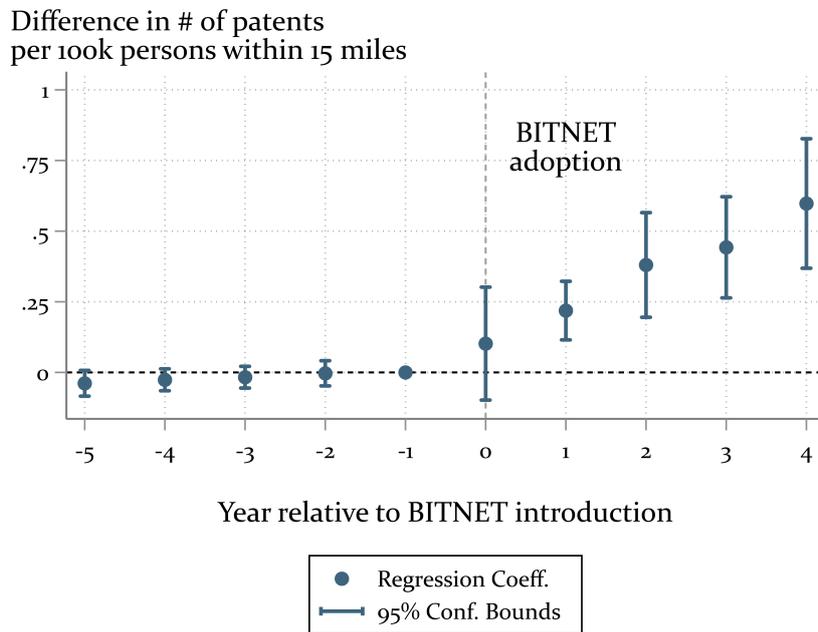
Note: This figure shows the yearly average treatment effects on the treated of BITNET adoption on different outcomes of universities adopting BITNET relative to universities that only adopt BITNET later. Panels (a) to (d) use the number of university patents filed by different types of inventors per 100,000 population within 15 miles around the university. Panels (a) and (b) use single-authored and team patents as dependent variables, respectively. Panels (c) and (d) use patenting by new teams and by existing teams, respectively. Panel (e) uses average team size on university patents filed within 15 miles around the university as dependent variable. The blue bars represent 95% confidence bounds that allow for clustering at the treated institution level. To adjust for the different number of control universities, we use the weights suggested by Iacus et al. (2012).

A.2.2 Time-Varying Effects on Patents Closely Related to Science

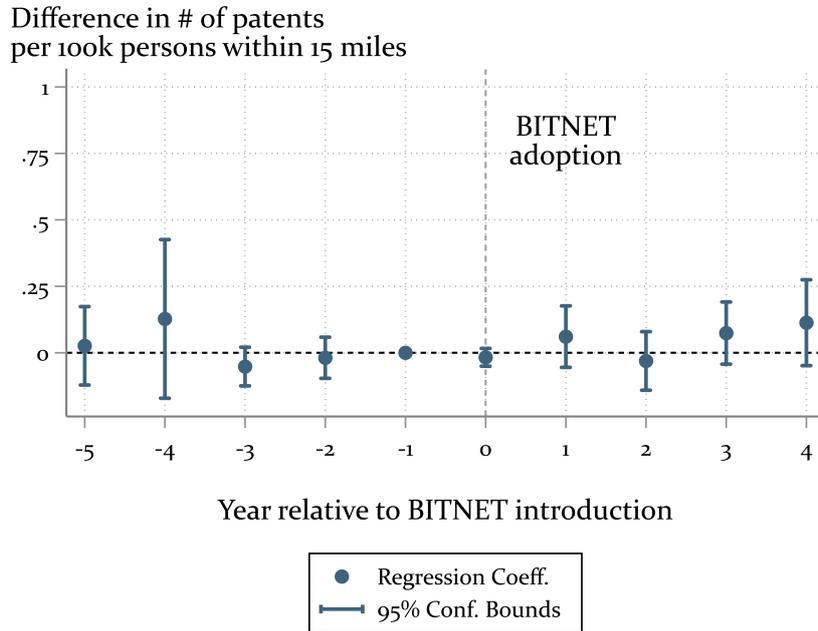
In Figure A.12, we show the time-varying version of our results on patents closely connected to science. Closely connected patents are those which either directly cite academic articles or cite patents that directly cite academic articles. Patents not closely connected to science are all other patents. The data is from Ahmadpoor and Jones (2017). In line with our identification assumption, both types of patents do not differ between treatment and control group before BITNET adoption. After BITNET adoption, patents closely connected to science increase around treated universities. In contrast, other patents are unaffected.

A. APPENDIX TO CHAPTER 1

Figure A.12: Patent Types



(a) Patents Closely Related to Science per 100,000 Population



(b) Other Patents per 100,000 Population

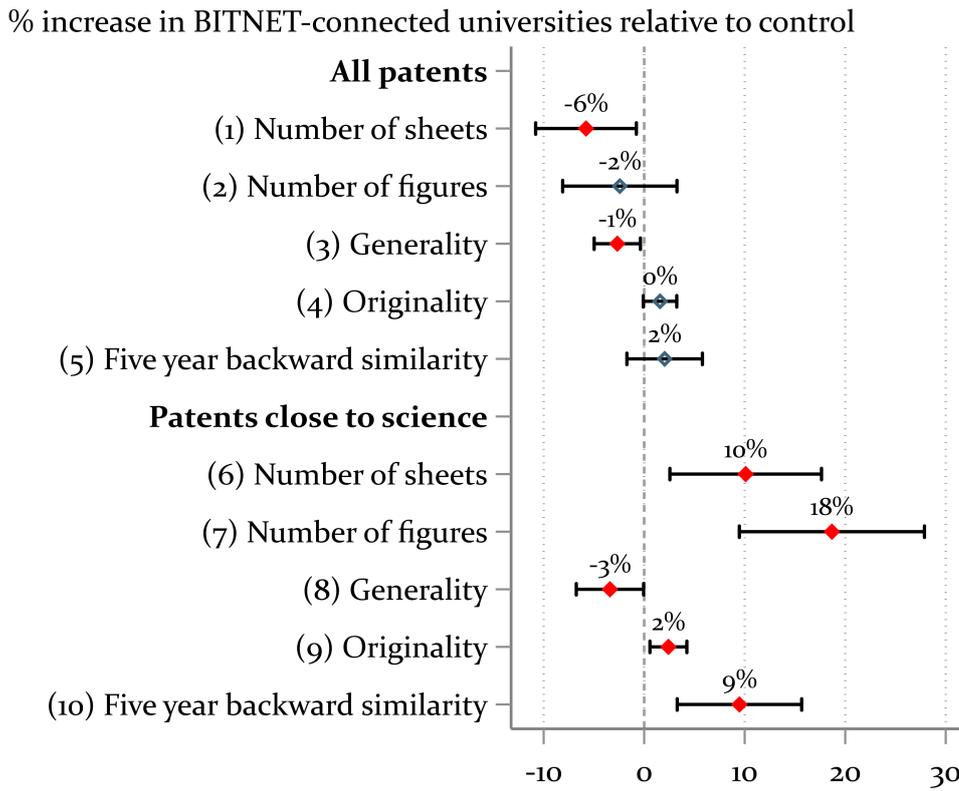
Note: These figures show the yearly average treatment effects on the treated of adopting BITNET relative to institutions adopting BITNET at a later point in time. Panel (a) uses the number of patents p.c. that either cite a scientific article directly or that cite another patent which directly cites a scientific article. Panel (b) uses the number of patents p.c. that neither directly cite a scientific article nor cite a patent which directly cites a scientific article. We use the weights of Iacus et al. (2012) to arrive at the average treatment effect on the treated.

A.2.3 Other Margins of Patent Content

In Figure A.13 we analyze various measures of patent content. We show our results for all university patents as well as for patents closely related to science only. We find that patents seem to have more information, draw on a wider range of prior art (originality), but are less widely used (generality) and more similar to prior work.

In rows (1) to (5) we look at all patents and do not find a strong pattern. If at all, the number of sheets, the length of the patents, appears to go down. We find much stronger effects when we restrict our analysis to patents closely connected to science, the drivers of our effect. These patents become longer (row 6) and use more figures (row 7) after BITNET adoption. Following the adoption of ICT, they show lower generality (row 8, measuring the range in technologies that cite the patent - Hall et al. 2001) and higher originality (row 9, measuring the range in technologies that are cited by a patent - Hall et al. 2001), but are also substantially more similar to prior U.S. patents (row 10 - Kelly et al. 2021). Overall, after the adoption of BITNET, patents closely related to science around adopting universities seem to have more, but less impactful content.

Figure A.13: The Impact of BITNET on the Content of Patents



Note: This figure shows the results from a difference-in-differences estimation with measures of content of university patents in the 15 miles region around a university as the dependent variable. The treatment group are universities that are already connected to BITNET. The control group consists of universities that are not yet connected to BITNET but that connect to BITNET later. All specifications include year fixed effects and institution group fixed effects. We show the results from the analysis in changes relative to post-period means using the margins command in Stata. The bars indicate 90% confidence intervals using standard errors that allow for clustering at the treated institution level. Coefficients plotted as a hollow diamond indicate coefficients not significantly different from zero at this level. Full (red) diamonds indicate coefficients that are significantly different from zero.

B

Appendix to Chapter 2

*Learning by Watching: Western TV Access and Innovation Activity in the
German Democratic Republic*

B.1 Appendix to Section 2.2

In Table B.1, we explore the share of advertising on West German television (ZDF) between 1970 and 1973, split by industrial sector. The shares within industrial sector remain very similar over time. Further, it is evident that a substantial share of advertising is directed to sectors related to consumer goods. The highest shares are allocated to Food (between 12.5% and 14.4%), Cosmetics and Personal Care (between 13.6% and 14.8%), and Detergents and Cleaning Products (between 10.8% and 11.8%).

Table B.1: Percentage of TV Advertising on West German Television (ZDF) by Industrial Sector

#	Category	1970 (%)	1971 (%)	1972 (%)	1973 (%)
1	Detergents and Cleaning Products	11.8	11.4	10.8	11.1
2	Cosmetics and Personal Care	14.8	13.6	14.2	14.8
3	Alcoholic Beverages	8.9	11.0	11.8	10.7
4	Coffee, Tea	3.3	3.2	3.5	4.1
5	Tobacco Products, Lighters	5.7	4.0	3.0	0.5
6	Food	12.5	14.4	13.1	13.7
7	Sweets	5.0	4.4	4.9	5.1
8	Pharmaceuticals	3.4	3.5	3.2	4.1
9	Chain Stores	0.9	1.0	0.8	1.0
10	Department Stores	0.3	0.3	0.4	0.4
11	Mail-Order Companies	0.6	0.8	0.6	0.9
12	Electrical Appliances	5.6	5.4	4.8	6.2
13	Motor Vehicles and Accessories	2.9	3.3	3.8	3.1
14	Optics, Photography, Watches	1.3	1.2	1.6	1.7
15	Textiles and Shoes	4.6	4.2	3.6	2.7
16	Furniture and Accessories	2.5	2.1	1.8	2.4
17	Insurance, Financial Institutions	4.0	4.4	5.2	5.1
18	Magazines, Newspapers	1.2	1.2	1.5	1.2
19	Office and Writing Supplies	0.5	0.5	0.7	0.5
20	Household Goods	3.8	2.6	3.2	4.3
21	Miscellaneous	6.4	7.5	7.5	6.3
	Total	100.0	100.0	100.0	100.0

Note: This table displays the percentage of TV advertising on the West German television program ZDF between 1970 and 1973 by industrial sector. Source: Zentralverband der deutschen Werbewirtschaft e.V, personal communication, Sept. 16th, 2024.

B.2 Appendix to Section 2.3

B.2.1 IPC Classification

The International Patent Classification (IPC) was established by the Strasbourg Agreement in 1971 and provides a language-independent classification of patents and utility models based on technology areas (World Intellectual Property Organization, 2019). The classification scheme includes the following sections and classes:

IPC Sections and Classes:

A - Human Necessities

- A01 - Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing
- A21 - Baking; Equipment for Making or Processing Doughs; Doughs for Baking
- A22 - Butchering; Meat Treatment; Processing Poultry or Fish
- A23 - Foods; Foodstuffs or Non-Alcoholic Beverages; Preparation, Treatment or Preservation Thereof
- A24 - Tobacco; Cigars; Cigarettes; Simulated Smoking Devices; Smokers' Requisites
- A41 - Wearing Apparel
- A42 - Headwear
- A43 - Footwear
- A44 - Haberdashery; Jewellery
- A45 - Hand or Travelling Articles
- A46 - Brushware
- A47 - Furniture; Domestic Articles or Appliances; Coffee Mills; Spice Mills; Suction Cleaners in General
- A61 - Medical or Veterinary Science; Hygiene
- A62 - Life-Saving; Fire-Fighting
- A63 - Sports; Games; Amusements
- A99 - Subject Matter Not Otherwise Provided For in This Section

B - Performing Operations; Transporting

- B01 - Physical or Chemical Processes or Apparatus in General
- B02 - Crushing, Pulverising, or Disintegrating; Preparatory Treatment of Grain For Milling

B. APPENDIX TO CHAPTER 2

- B03 - Separation of Solid Materials Using Liquids or Using Pneumatic Tables or Jigs; Magnetic or Electrostatic Separation of Solid Materials From Solid Materials or Fluids; Separation by High-Voltage Electric Fields
- B04 - Centrifugal Apparatus or Machines for Carrying-Out Physical or Chemical Processes
- B05 - Spraying or Atomising in General; Applying Fluent Materials to Surfaces, in General
- B06 - Generating or Transmitting Mechanical Vibrations in General
- B07 - Separating Solids from Solids; Sorting
- B08 - Cleaning
- B09 - Disposal of Solid Waste; Reclamation of Contaminated Soil
- B21 - Mechanical Metal-Working Without Essentially Removing Material; Punching Metal
- B22 - Casting; Powder Metallurgy
- B23 - Machine Tools; Metal-Working Not Otherwise Provided For
- B24 - Grinding; Polishing
- B25 - Hand Tools; Portable Power-Driven Tools; Handles For Hand Implements; Workshop Equipment; Manipulators
- B26 - Hand Cutting Tools; Cutting; Severing
- B27 - Working or Preserving Wood or Similar Material; Nailing or Stapling Machines in General
- B28 - Working Cement, Clay, or Stone
- B29 - Working of Plastics; Working of Substances in a Plastic State in General
- B30 - Presses
- B31 - Making Articles of Paper, Cardboard or Material Worked in a Manner Analogous to Paper; Working Paper, Cardboard or Material Worked in a Manner Analogous to Paper
- B32 - Layered Products
- B33 - Additive Manufacturing Technology
- B41 - Printing; Lining Machines; Typewriters, Stamps
- B42 - Bookbinding; Albums; Files; Special Printed Matter
- B43 - Writing or Drawing Implements; Bureau Accessories
- B44 - Decorative Arts
- B60 - Vehicles in General

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- B61 - Railways
- B62 - Land Vehicles For Travelling Otherwise Than on Rails
- B63 - Ships or Other Waterborne Vessels; Related Equipment
- B64 - Aircraft; Aviation; Cosmonautics
- B65 - Conveying; Packing; Storing; Handling Thin or Filamentary Material
- B66 - Hoisting; Lifting; Hauling
- B67 - Opening or Closing Bottles, Jars or Similar Containers; Liquid Handling
- B68 - Saddlery; Upholstery

C - Chemistry; Metallurgy

- C01 - Inorganic Chemistry
- C02 - Treatment of Water, Waste Water, Sewage, or Sludge
- C03 - Glass; Mineral or Slag Wool
- C04 - Cements; Concrete; Artificial Stone; Ceramics; Refractories
- C05 - Fertilisers; Manufacture Thereof
- C06 - Explosives; Matches
- C07 - Organic Chemistry
- C08 - Organic Macromolecular Compounds; Their Preparation or Chemical Working-Up; Compositions Based Thereon
- C09 - Dyes; Paints; Polishes; Natural Resins; Adhesives; Compositions Not Otherwise Provided For; Applications of Materials Not Otherwise Provided For
- C10 - Petroleum, Gas or Coke Industries; Technical Gases Containing Carbon Monoxide; Fuels; Lubricants; Peat
- C11 - Animal or Vegetable Oils, Fats, Fatty Substances or Waxes; Fatty Acids Therefrom; Detergents; Candles
- C12 - Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation of Genetic Engineering
- C13 - Sugar Industry
- C14 - Skins; Hides; Pelts or Leather
- C21 - Metallurgy of Iron
- C22 - Metallurgy; Ferrous or Non-Ferrous Alloys; Treatment of Alloys or Non-Ferrous Metals

B. APPENDIX TO CHAPTER 2

C23 - Coating Metallic Material; Coating Material With Metallic Material; Chemical Surface Treatment; Diffusion Treatment of Metallic Material; Coating by Vacuum Evaporation, by Sputtering, by Ion Implantation or by Chemical Vapour Deposition, in General; Inhibiting Corrosion of Metallic Material or Incrustation in General

C25 - Electrolytic or Electrophoretic Processes; Apparatus Therefor

C30 - Crystal Growth

C40 - Combinatorial Technology

C99 - Subject Matter Not Otherwise Provided For in This Section

D - Textiles; Paper

D01 - Natural or Man-Made Threads or Fibres; Spinning

D02 - Yarns; Mechanical Finishing of Yarns or Ropes; Warping or Beaming

D03 - Weaving

D04 - Braiding; Lace-Making; Knitting; Trimmings; Non-Woven Fabrics

D05 - Sewing; Embroidering; Tufting

D06 - Treatment of Textiles or the Like; Laundering; Flexible Materials Not Otherwise Provided For

D07 - Ropes; Cables Other Than Electric

D21 - Paper-Making; Production of Cellulose

D99 - Subject Matter Not Otherwise Provided For in This Section

E - Fixed Constructions

E01 - Construction of Roads, Railways, or Bridges

E02 - Hydraulic Engineering; Foundations; Soil-Shifting

E03 - Water Supply; Sewerage

E04 - Building

E05 - Locks; Keys; Window or Door Fittings; Safes

E06 - Doors, Windows, Shutters, or Roller Blinds, in General; Ladders

E21 - Earth or Rock Drilling; Mining

E99 - Subject Matter Not Otherwise Provided For in This Section

F - Mechanical Engineering; Lighting; Heating, etc.

F01 - Machines or Engines in General; Engine Plants in General; Steam Engines

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- F02 - Combustion Engines; Hot-Gas or Combustion-Product Engine Plants
- F03 - Machines or Engines for Liquids; Wind, Spring, or Weight Motors; Producing Mechanical Power or a Reactive Propulsive Thrust, Not Otherwise Provided For
- F04 - Positive-Displacement Machines For Liquids; Pumps For Liquids or Elastic Fluids
- F15 - Fluid-Pressure Actuators; Hydraulics or Pneumatics in General
- F16 - Engineering Elements or Units; General Measures For Producing And Maintaining Effective Functioning of Machines or Installations; Thermal Insulation in General
- F17 - Storing or Distributing Gases or Liquids
- F21 - Lighting
- F22 - Steam Generation
- F23 - Combustion Apparatus; Combustion Processes
- F24 - Heating; Ranges; Ventilating
- F25 - Refrigeration or Cooling; Combined Heating And Refrigeration Systems; Heat Pump Systems; Manufacture or Storage of Ice; Liquefaction or Solidification of Gases
- F26 - Drying
- F27 - Furnaces; Kilns, Ovens or Retorts
- F28 - Heat Exchange in General
- F41 - Weapons
- F42 - Ammunition; Blasting
- F99 - Subject Matter Not Otherwise Provided For in This Section

G - Physics

- G01 - Measuring; Testing
- G02 - Optics
- G03 - Photography; Cinematography; Analogous Techniques Using Waves Other Than Optical Waves; Electrography; Holography
- G04 - Horology
- G05 - Controlling; Regulating
- G06 - Computing; Calculating or Counting
- G07 - Checking-Devices

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G08 - Signalling

G09 - Educating; Cryptography; Display; Advertising; Seals

G10 - Musical Instruments; Acoustics

G11 - Information Storage

G12 - Instrument Details

G16 - Information And Communication Technology [ICT] Specially Adapted
For Specific Application Fields

G21 - Nuclear Physics; Nuclear Engineering

G99 - Subject Matter Not Otherwise Provided For in This Section

H - Electricity

H01 - Electric Elements

H02 - Generation, Conversion, or Distribution of Electric Power

H03 - Electronic Circuitry

H04 - Electric Communication Technique

H05 - Electric Techniques Not Otherwise Provided For

H10 - Semiconductor Devices; Electric Solid-State Devices Not Otherwise
Provided For

H99 - Subject Matter Not Otherwise Provided For in This Section

B.2.2 Inventor Mobility

To construct our estimation sample, we need to infer location information for inventors for which we cannot observe a location directly. To do this, we impute the location using patents from previous or later years. This approach assumes that inventors do not systematically change location over time. Historical evidence corroborates this assumption (e.g., Kern and Hainmueller, 2009; Grünert, 1996). In the following, we provide descriptive evidence on the lack of systematic mobility changes using our sample data. Table B.2 shows the changes in the geographic distribution of patenting activity by comparing patenting activity between 1957–1965 and patenting activity between 1984–1989. The table lists the six most patenting-intensive municipalities and provides information about changes in each municipality's share in overall patenting activity, as well as changes in each municipality's rank. These largest municipalities account for about half of the patenting activity in East Germany. Most patents are filed by inventors located in Berlin or Dresden. The share of each municipality in overall patent production changes relatively little between the two time periods. The largest change of 5.89% occurs for Berlin. Likewise, the overall ranking remains relatively stable: Here, the largest change occurred in Jena, where the main manufacturer of optical and precision mechanical devices in the GDR, the VEB Carl-Zeiss, was headquartered.

B. APPENDIX TO CHAPTER 2

Table B.2: Changes in Geographic Distribution of Patenting Activity

Municipality	Patent share (1957–1965)	Patent share (1984–1989)	Change in share	Rank (1957–1965)	Rank (1984–1989)	Change in rank
Berlin	14.17	20.06	5.89	1	1	0
Dresden	13.63	9.54	−4.09	2	2	0
Leipzig	8.00	6.91	−1.09	3	3	0
Karl-Marx-Stadt	5.62	6.52	0.9	4	4	0
Jena	2.24	5.12	2.88	7	5	2
Magdeburg	3.09	4.07	0.98	5	6	−1
Total	49.63	52.22	5.47			

Note: This table compares the top six patenting locations of 1984–1989 to their patenting output in 1957–1965. The latter time frame refers to the latest period in which we observe consistent location information in the original patent documents. The change in the patent share is the difference between the patent share (in %) in 1957–1965 and 1984–1989. The rank lists the main patenting municipalities in decreasing order. The change in rank is the difference between the rank in 1957–1965 and 1984–1989.

B.2.3 Summary Statistics by IPC Section

Table B.3: Summary Statistics by IPC Section

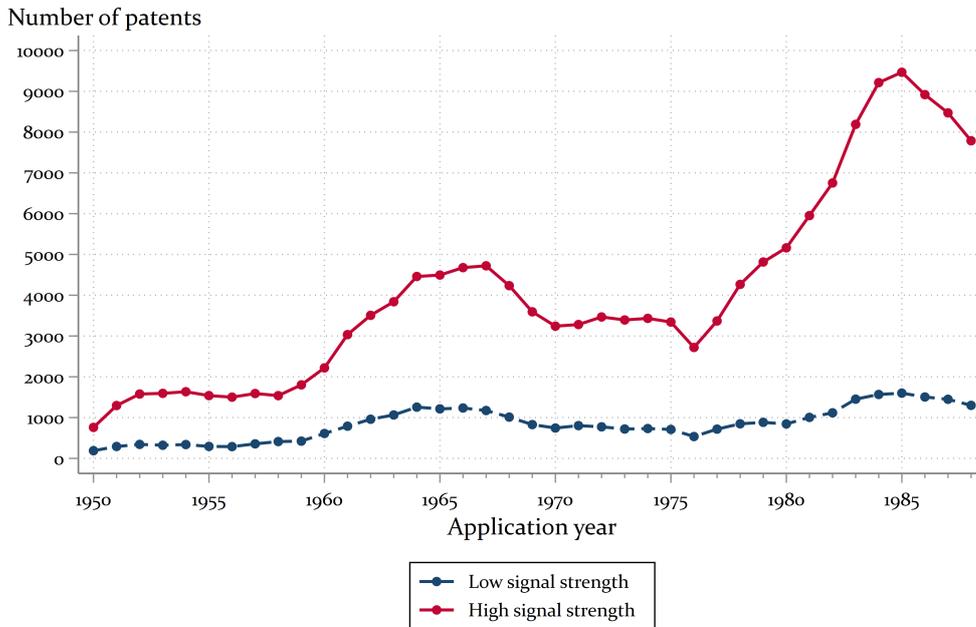
Variable	Mean	Std. dev.	Min	Max	Median	P25	P75
# patents in IPC A	3.96	9.45	1.00	177.00	1.00	1.00	3.00
# patents in IPC B	7.27	23.13	1.00	438.00	2.00	1.00	5.00
# patents in IPC C	7.91	22.35	1.00	436.00	2.00	1.00	5.00
# patents in IPC D	3.75	8.20	1.00	112.00	2.00	1.00	3.00
# patents in IPC E	3.62	6.84	1.00	92.00	1.00	1.00	3.00
# patents in IPC F	5.05	11.97	1.00	156.00	2.00	1.00	4.00
# patents in IPC G	7.49	26.37	1.00	501.00	2.00	1.00	4.00
# patents in IPC H	7.33	28.48	1.00	446.00	2.00	1.00	4.00

Note: This table displays summary statistics by patent technology sections. It shows the average number of patents filed on the municipality level for the sample period of 1958–1986.

B.3 Appendix to Section 2.4

B.3.1 Yearly Patent Counts by TV Signal Strength

Figure B.1: Patenting by TV Signal Strength



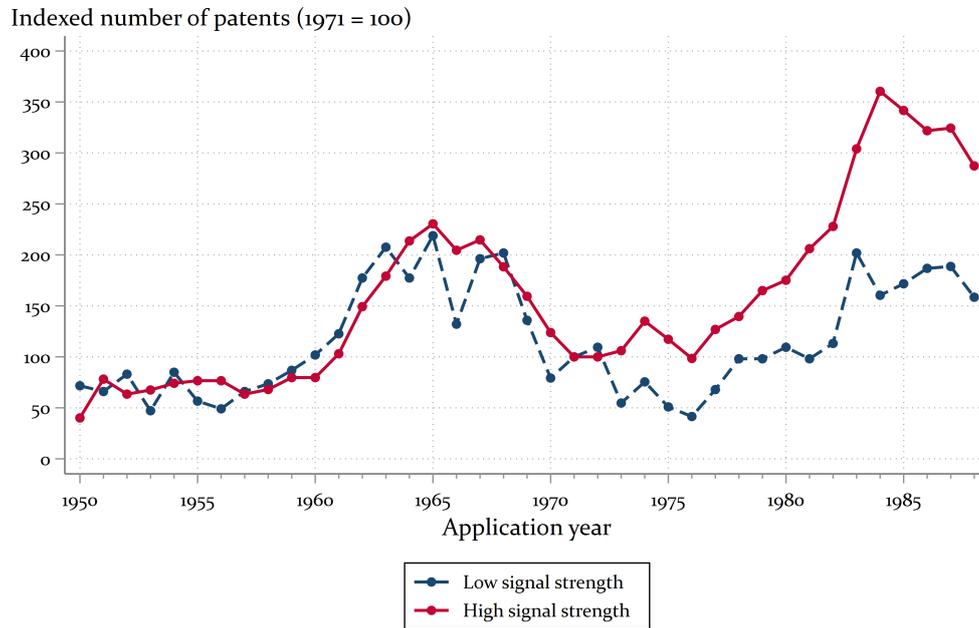
Note: This figure shows the yearly number of patents for high signal strength municipalities (red solid line) and low signal strength municipalities (blue dashed line).

B.3.2 Yearly Patent Counts by TV Signal Strength - IPC A vs. Other IPCs

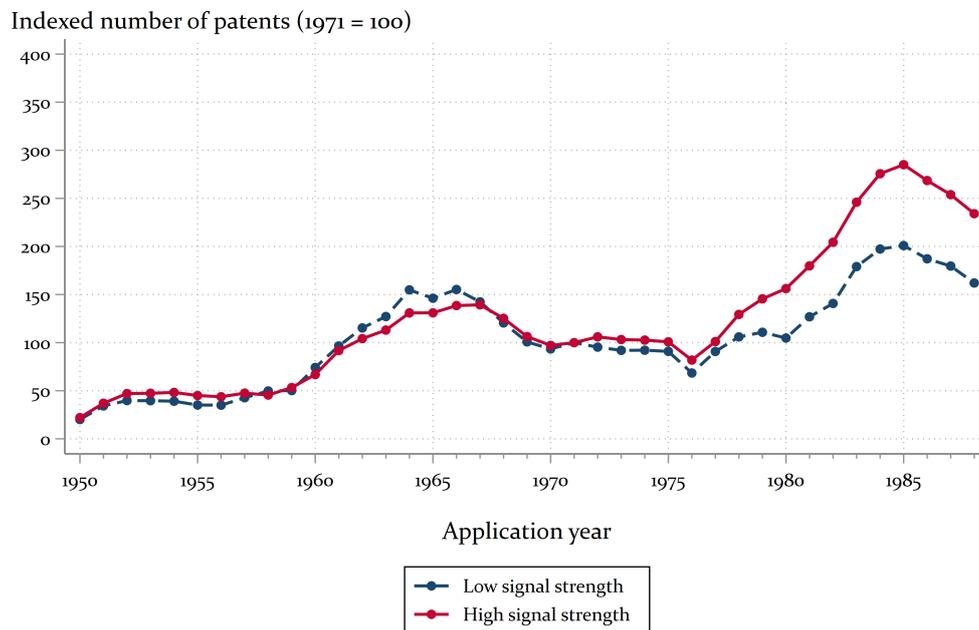
This figure shows the yearly number of patents in high and low signal strength regions differentiated between IPC A (panel a) and all other IPC sections (panel b). In panel (a), we see that patenting trends before 1971 are similar between high and low signal strength municipalities. Patenting in IPC A picks up more strongly in high signal strength municipalities compared to low signal strength municipalities after 1971. Patenting trends before 1971 are similar in all other IPC sections as well, with high signal strength regions increasing their yearly patent output more than low signal strength regions after 1971 (panel b).

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Figure B.2: Number of Patents in High Signal Strength Municipalities in IPC A vs. Other IPCs



(a) Patent Count in IPC A Indexed to 1971



(b) Patent Count in Other IPCs Indexed to 1971

Note: This figure shows the yearly patent counts in high and low signal strength municipalities in IPC A in panel (a), and the yearly patent counts in high and low signal strength municipalities in the other IPC sections in panel (b). Patent counts in both subfigures are indexed to 1971.

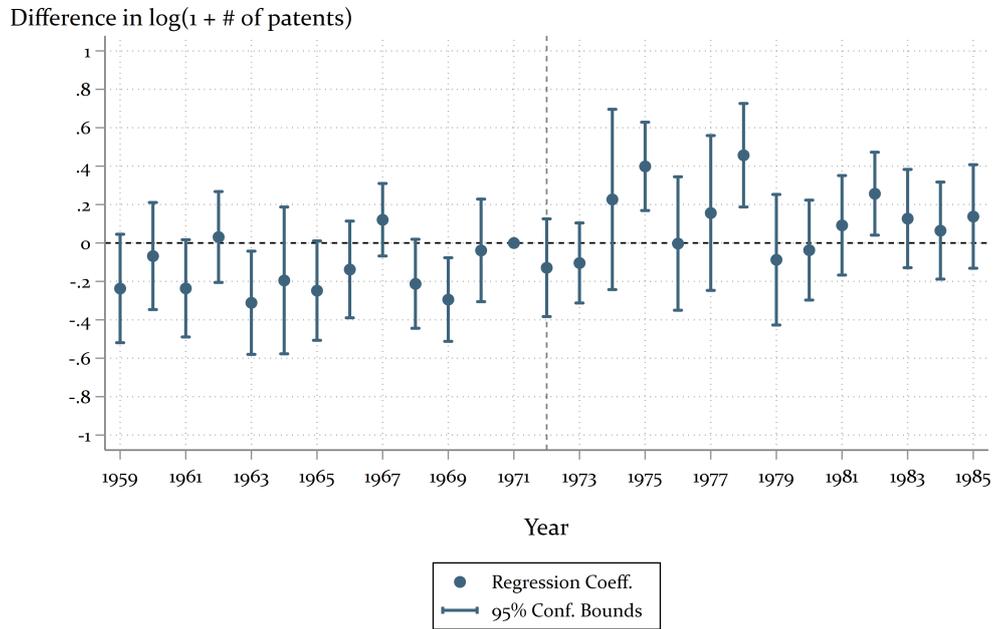
B.4 Appendix to Section 2.5

B.4.1 Yearly Coefficient Estimates for Consumer Goods Patents and Other Goods Patents

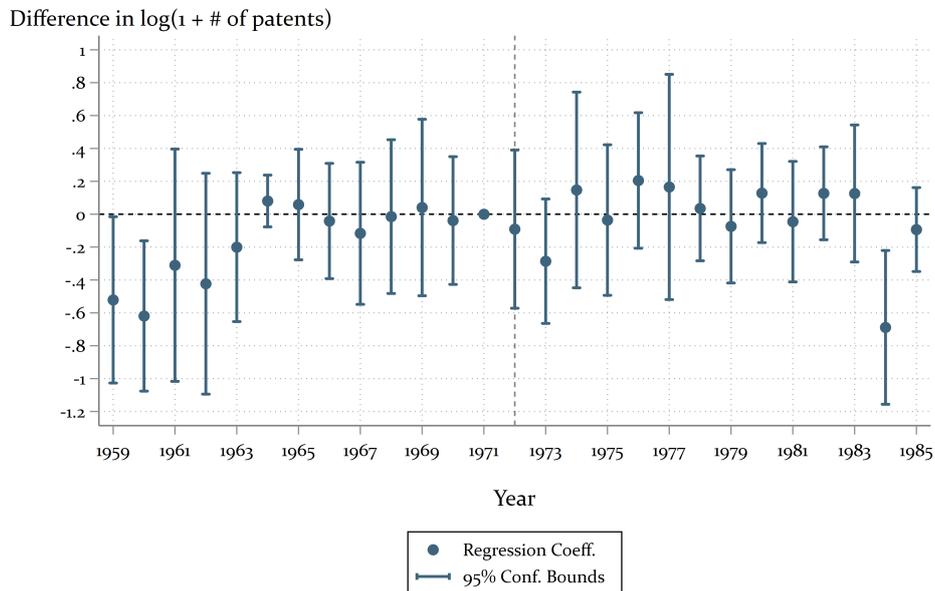
Figure B.3 provides yearly coefficient estimates for consumer goods patents in IPC A and other patents in IPC A, where we define consumer goods patents as those belonging to one of the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47) and sports, games, amusements (A63). Although noisier, panel (a) reveals a post-1971 increase in consumer goods patents in high signal strength municipalities relative to low signal strength municipalities. Panel (b) shows insignificant coefficient estimates before and after 1971 for other patents in IPC A.

B. APPENDIX TO CHAPTER 2

Figure B.3: Effect of West German TV Access on Patenting in IPC A - Consumer Goods vs. Other Goods



(a) Difference in the Log-Transformed Number of Consumer Goods Patents in IPC A



(b) Difference in the Log-Transformed Number of Other Patents in IPC A

Note: This figure shows the yearly average treatment effects on the treated of West German TV access on the log number of patents in high signal strength municipalities compared to municipalities that cannot access West German TV. The blue bars represent 95% confidence bounds that allow for clustering at the treated municipality level. Panel (a) shows results for consumer goods patents in IPC A, whereas panel (b) shows results for all other patents in IPC A. Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63).

B.4.2 Alternative Specifications

In this section, we show that our results do not depend on the log transformation of the dependent variable. To do so, we repeat the analysis using both the number of patents as well as the inverse-hyperbolic-sine-transformed number of patents as the dependent variable. Columns (1) to (4) of Table B.4 use the number of patents as the dependent variable. The results show that the qualitative interpretation of our main results holds. We observe an increase in patenting activity in IPC A in treated municipalities after the change in government (column 2). The coefficient estimate for all other IPC sections, shown in column (3), is positive but insignificant. Column (4) reveals that consumer goods drive the observed effect in IPC A. Other goods patents remain unaffected.

In columns (5) to (8) of Table B.4, we move on to employing the inverse hyperbolic sine transformation of the number of patents. The effects mirror our main results. The baseline coefficient is small and statistically insignificant. As columns (7) and (8) show, patenting in IPC A increases, while patenting in all other IPC sections remains unchanged. The surge in patenting in IPC A is driven by consumer goods.

Table B.4: Alternative Specifications

Spec.:	Number of patents				IHS (Number of patents)			
	IPC A	Other IPCs	Consumer	Other	IPC A	Other IPCs	Consumer	Other
Dep. Var.:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	IPC A	Other IPCs	Consumer	Other	IPC A	Other IPCs	Consumer	Other
			Goods IPC A	Goods IPC A			Goods IPC A	Goods IPC A
Treated x Post	2.51** (1.06)	3.97 (3.88)	2.44*** (0.93)	1.48 (1.02)	0.31*** (0.09)	-0.04 (0.12)	0.33*** (0.09)	0.17 (0.14)
Mean Dep.	4.21	15.98	3.52	3.66	1.54	2.10	1.50	1.50
R2 (within)	0.64	0.78	0.60	0.62	0.71	0.79	0.67	0.70
Obs.	2743	9169	2195	1019	2743	9169	2195	1019

Note: This table shows difference-in-differences estimates of West German TV access. The treatment group are municipalities that have access to West German television. The control group consists of municipalities that cannot watch West German television. Columns (1) to (4) use the number of patents as the dependent variable. Columns (5) to (8) use the inverse hyperbolic sine transformation of the number of patents as the dependent variable. The results using patents in IPC A as the dependent variable are shown in columns (1) and (5). Columns (2) and (6) display results using patents in all other IPC sections. Results for consumer goods patents in IPC A are displayed in columns (3) and (7), and other goods patents in IPC A are explored in columns (4) and (8). Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). Robust standard errors, adjusted for clustering at the municipality level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

B.4.3 Placebo Test Using Distance to Border

We further test the robustness of our results by using the distance to the inner German border (in hours) as a placebo treatment. We believe this test to be sensible because personal exchange of East and West Germans was facilitated during the 1970s. In particular, the Basic Treaty of 1972 and the Transit Treaty of 1971, which regulated transit traffic between East and West Germany, eased travel of West German citizens to the GDR, and vice versa. Amongst others, people were allowed to visit all of the GDR and to visit not only relatives, but also acquaintances (MDR, 2021; wikipedia, 2024).

Our hypothesis states that inventors learn from or are inspired by watching West German television, and that this process ultimately leads to more patents, in particular in consumer goods, which is the technology category most shown on TV. Our results should not be driven by any direct contacts to West Germans or spillover effects through interactions with West Germans. If any of these effects were at play, the distance to the inner German border should affect patenting outcomes. Especially, the closer an inventor is located to the inner German border, the more likely and the easier it might be to exchange ideas with West Germans, which would affect patenting activity in these locations positively. We test this in Table B.5. Across all columns, we find very small and insignificant coefficients. This strengthens the assumption that our results are not driven by any other form of knowledge flow, but by being exposed to West German television.

Table B.5: Placebo Test Using Distance to Border

Dep. Var.:	Log(1 + Number of patents)			
	IPC A	Other IPCs	Consumer Goods IPC A	Other Goods IPC A
	(1)	(2)	(3)	(4)
Dist. to border (hrs) x Post	-0.06 (0.05)	0.00 (0.05)	-0.08 (0.06)	-0.07 (0.09)
Mean Dep.	1.21	1.69	1.17	1.18
R2 (within)	0.72	0.80	0.68	0.71
Obs.	2738	9146	2191	1017

Note: This table shows difference-in-differences estimates of using the distance to the inner-German border (in hours) as a placebo treatment. The dependent variable is the log-transformed number of patents. Column (1) shows the results for patents in IPC A, while column (2) displays the coefficient estimates for patents in all other IPC sections. Column (3) provides coefficient estimates for consumer goods patents in IPC A, while column (4) focuses on other goods patents in IPC A. Consumer goods patents are defined as patents in the following IPC A classes: agricultural products and food (A01, A23), wearing apparel (A41-A45), furniture (A47), and sports, games, amusements (A63). Robust standard errors, adjusted for clustering at the municipality level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

C

Appendix to Chapter 3

(Un)Successful Integration into a New Science System?: The Case of East

Germany

C.1 Appendix to Section 3.3

Figure C.1: Sample Page from the Faculty Directory of East Germany in 1990

Hecker

- Hecker, Michael;** Dr.sc.nat.; ord.Prof.
Physiologie der Mikroorganismen; Sektion Biologie
Univ. Greifswald; Domstraße 11; 2300 Greifswald
☎ 630
- Heckner, Karl-Heinz;** Dr.rer.nat.; HSD
Physikalische Chemie; Sektion Chemie
Humboldt-Universität zu Berlin; Bunsenstr.1; 1080 Berlin
☎ 2202411353
- Hedrich, Peter;** Dr.sc.oec.; ord.Prof.
Betriebswirtschaft; Sektion Betriebswirtschaft
TH Zittau; Theodor-Körner-Allee 16; 8800 Zittau
☎ 610
- Hegemann, Manfred;** Dr.habil.; HSD
Tierphysiologie; Sektion Biologie
Univ. Greifswald; Domstraße 11; 2200 Greifswald
☎ 630
- Hegenbarth, Ernst;** Dr.rer.nat.habil.; ord.Prof.
Experimentalphysik; Sektion Physik
TU Dresden; Mommsenstraße 13; 8027 Dresden
☎ 4630
- Hegewald, Gerhard;** Dr.sc.med.; HSD
Katastrophenmedizin/Pathologie; Abteilung Katastrophen-
medizin
Univ. Greifswald; Domstraße 11; 2200 Greifswald
☎ 630
- Hegewald, Helmar;** Dr.sc.phil.; ord.Prof.
Ethik; Sektion Gesellschaftswissenschaften
TU Dresden; Mommsenstraße 13; 8027 Dresden
☎ 4630
- Hehl, Karl;** Dr.sc.nat.; ao.Prof.
Theoretische Physik; Sektion Physik
Univ. Jena; Goetheallee 1; 6900 Jena
☎ 820
- Heichel, Günter;** Dr.sc.paed.; ao.Prof.
Biologiedidaktik/Biologiemethodik/Gesundheitserziehung;
Sektion Biowissenschaften
Univ. Halle-Wittenberg; Universitätsplatz 10; 4020 Halle
☎ 8320
- Heicking, Lieselotte;** ao.Do.
Tonsatz/Gehörbildung; Abteilung Komposition/Tonsatz
Hochschule für Musik Berlin; Charlottenstr. 55; 1086 Berlin
☎ 2272411
- Heide, Klaus;** Dr.rer.nat.habil.; HSD
Glaschemie; Sektion Chemie
Univ. Jena; Goetheallee 1; 6900 Jena
☎ 820
- Heidel, Günter;** Dr.sc.med.; ord.Prof.
Geschichte der Medizin; Abteilung für Geschichte der Medizin
MEDAK Dresden; Fetscherstraße 74; 8019 Dresden
☎ 4580
- Heidelbach, Johann-Georg;** Dr.sc.med.; HSD
HNO-Krankheiten; Klinik für Hals-Nasen-Ohrenkrankheiten
MEDAK Dresden; Fetscherstraße 74; 8019 Dresden
☎ 4580
- Heidenreich, Eberhard;** Dr.sc.techn.; ord.Prof.
Mechanische Verfahrenstechnik und Verarbeitungstechnologie;
Sektion Verarbeitungs- und Verfahrenstechnik
TU Dresden; Mommsenstraße 13; 8027 Dresden
☎ 4630
- Heidenreich, Erich;** Dr.sc.nat.; ord.Prof.
Anorganisch-Technische Chemie; Sektion Chemie
Univ. Jena; Goetheallee 1; 6900 Jena
☎ 820
- Heidenreich, Gotthard;** Dr.-Ing.; HSD
Regionalplanung; Sektion Gebietsplanung und Städtebau
HAB Weimar; Geschwister-Scholl-Str. 8; 5300 Weimar
☎ 730
- Heider, Gunther;** Dr.med.vet.; ord.Prof.
Geflügelkrankheiten; Sektion Tierproduktion und
Veterinärmedizin
Humboldt-Universität zu Berlin; Philippstraße 13; 1040 Berlin
☎ 2895302
- Heider, Kurt-Matthias;** Dr.sc.med.; HSD
Strahlentherapie; Klinik und Poliklinik für Radiologie
Univ. Halle-Wittenberg; Universitätsplatz 10; 4020 Halle
☎ 8320
- Heidrich, Dietmar;** Dr.sc.nat.; ao.Do.
Quantenchemie; Sektion Chemie
Univ. Leipzig; Karl-Marx-Platz 10; 7010 Leipzig
☎ 7190
- Heidrich, Marianne;** Dr.sc.paed.; ord.Prof.
Methodik des Muttersprachunterrichts; Sektion Germanistik/
Slawistik
PH Leipzig; Karl-Heine-Straße 22 b; 7031 Leipzig
☎ 49770
- Heidrich, Peter;** Dr.theol.habil.; ao.Do.
Religionsgeschichte; Sektion Theologie
Univ. Rostock; Universitätsplatz 1; 2500 Rostock
☎ 3690
- Heidrich, Theodor;** Dr.sc.paed.; ord.Prof.
Methodik des Deutschunterrichts; Sektion Germanistik/Slawistik
PH Leipzig; Karl-Heine-Straße 22 b; 7031 Leipzig
☎ 49770
- Heidrich, Wolfgang;** Dr.sc.oec.;
Mathematik und Kybernetik in der Ökonomie; Sektion Wirt-
schaftswissenschaften
Humboldt-Universität zu Berlin; Spandauer Str. 1; 1020 Berlin
☎ 2168350
- Heiking, Wolfram;** Dr.paed.; Prof.m.künstl.Lt.
Komposition/Tonsatz; Abteilung Komposition/Tonsatz
Hochschule für Musik Berlin; Charlottenstr. 55; 1086 Berlin
☎ 2272411
- Heilmann, Bernd;** Dr.sc.paed.; ao.Do.
Rehabilitationspädagogik; Sektion Pädagogik und Psychologie
Univ. Rostock; Universitätsplatz 1; 2500 Rostock
☎ 3690
- Heilscher, Karl;** Dr.sc.techn.; ord.Prof.
Technologie der Obst- und Gemüseverarbeitung; Sektion Nah-
rungsgüterwirtschaft und Lebensmitteltechnologie
Humboldt-Universität zu Berlin; Neue Schönhauser Str. 20;
1020 Berlin
☎ 2806602
- Heimbuch, Reiner;** ao.Do.;
Horn; Abteilung Blasinstrumente
Hochschule für Musik Weimar; Platz der Demokratie 2-8;
5300 Weimar
☎ 5241
- Hein, Christian;** Dr.sc.nat.; HSD
Polytechnik/Elektrotechnik; Sektion Polytechnik
Univ. Halle-Wittenberg; Universitätsplatz 10; 4020 Halle
☎ 8320
- Hein, Dieter;** Dr.sc.techn.; HSD
Automatisierungstechnik; Sektion Schiffsbetriebstechnik
TH für Seefahrt Warnemünde/Wustrow; Richard-Wagner-Str. 31;
2530 Warnemünde
☎ 570
- Hein, Eva;** Dr.sc.jur.; HSD
Arbeitsrecht; Sektion Rechtswissenschaften
Hochschule für Recht und Verwaltung; August-Bebel-Str. 89;
1590 Potsdam
☎ 76701

Note: This figure shows a sample page from the faculty directory of East Germany in 1990.

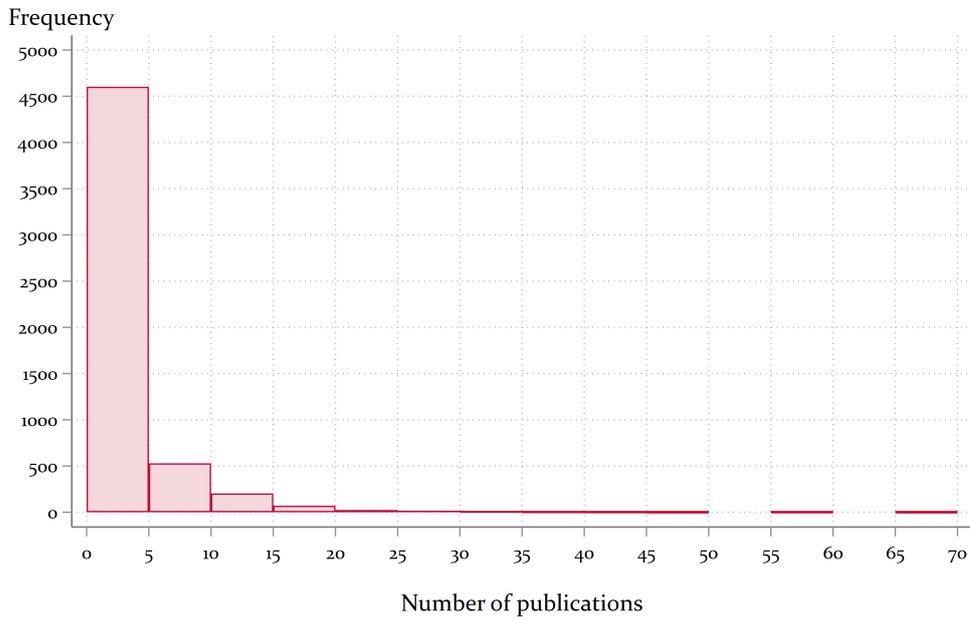
C.2 Appendix to Section 3.4

C.2.1 Publication Output Distribution Between 1980 and 1989

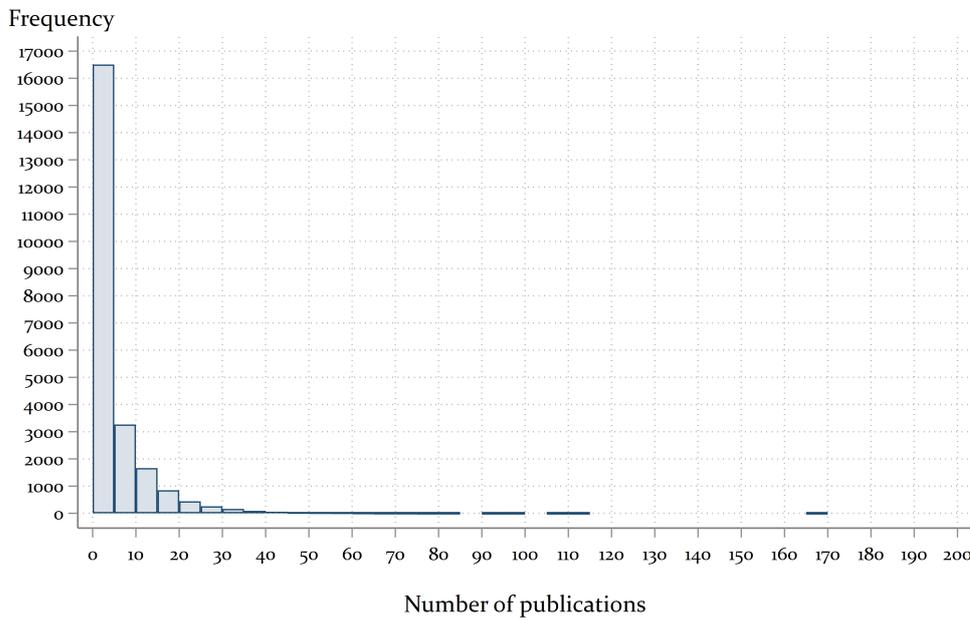
Figure C.2 provides additional details about the publication output distribution of East and West German researchers in panel (a) and panel (b), respectively. Both distributions are right-skewed. About 4,600 East German researchers publish between zero and five publications. In West Germany, about 16,500 researchers publish between zero and five publications. The output distribution of West German researchers shows a longer tail than the output distribution of East German researchers.

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Figure C.2: Publication Output Distribution



(a) Publication Output Distribution of East German Researchers (1980–1989)



(b) Publication Output Distribution of West German Researchers (1980–1989)

Note: These figures show the distribution of the aggregated number of yearly publications of researchers between 1980 and 1989 for East Germans (panel a) and West Germans (panel b).

C.2.2 Pre-reunification Publication Quality of West German Researchers

This section provides details on the pre-reunification publication quality of West German switchers to East Germany and West German researchers not in this category. I measure publication quality using the SCImago Journal Rank. Unfortunately, this data is only available as of 1999. To address the issue of missing data in the period 1980 to 1989, I assign each journal its average SCImago Journal Rank between 1999 and 2010. I acknowledge that this approach may be problematic if, e.g., journal ranks greatly vary over time. However, I investigated a randomly selected sample of journals and concluded that journal ranks show little variation over time.

Table C.1: Pre-Reunification Journal Quality of West German Switchers to East Germany and Other West German Researchers

Field	West German Switchers to East	Other West Germans
Biology	1.944	2.662
Medicine	0.776	0.333
Agric. Science, Forestry and Vet. Medicine	0.911	0.566
Chemistry	1.884	1.225
Physics	1.404	1.320
Mathematics	1.267	1.549
Geoscience	1.043	2.340
Mechanical Engin. and Production Engin.		0.657
Heat Technology/Process Engineering	1.148	0.961
Material Science and Materials Technology		0.746
Computer Science, System and Electrical Engin.	0.973	1.034
Construction Engineering and Architecture		1.752
Total	1.261	1.262

Note: This table displays the average pre-reunification journal rank for West German switchers to East Germany and for West German researchers not moving to East Germany between 1980 and 1989 by field. For fields with empty cells average journal quality could not be calculated.

Pre-reunification publication quality of West German switchers to East Germany exceeds the average publication quality of the remaining West German researchers in several fields, such as Medicine, Agricultural Science, Chemistry, Physics, and Heat Technology. In the remaining fields, West German switchers to East Germany perform worse than the remaining West Germans. Pre-reunification publication quality of West German switchers to East Germany could not be calculated in Mechanical Engineering, Material Science, and Construction Engineering. Across all fields, the average pre-reunification quality for West German switchers to East Germany and the remaining West German researchers is very similar. Thus, based on this analysis, it can

be concluded that West German switchers to East Germany are of similar capability as West German researchers not moving to East Germany.

C.3 Appendix to Section 3.5

C.3.1 Number of Treatment and Control Departments

This section presents additional information about the sample. Table C.2 displays the number and share of departments in the treatment and control group.

Table C.2: Treated and Control Departments

	Control		Treated	
	N	%	N	%
Agricultural Science, Forestry and Veterinary Medicine	5	3.76	2	1.50
Biology	6	4.51	2	1.50
Chemistry	14	10.53	1	0.75
Computer Science, System and Electrical Engineering	14	10.53	3	2.26
Construction Engineering and Architecture	7	5.26	1	0.75
Geoscience	5	3.76	1	0.75
Heat Technology/Process Engineering	5	3.76	1	0.75
Material Science and Materials Technology	4	3.01	0	0.00
Mathematics	16	12.03	6	4.51
Mechanical Engineering and Production Engineering	12	9.02	3	2.26
Medicine	3	2.26	10	7.52
Physics	9	6.77	3	2.26
Total	100	75.19	33	24.81

Note: This table displays the number and share of treated and control departments.

C.3.2 Summary Statistics

Table C.3 displays summary statistics for the constructed dataset. Departments in my sample publish on average 0.223 publications per East German stayer and have an average SCImago Journal Rank of 0.370. The share of English-language publications is almost ten times larger than the share of German-language publications. Departments in the sample receive an average amount of DFG funding of 0.422 million euro. Collaborative publications account for 81.2% of total publication output. Few publications are generated department-internally only. Collaborations within East Germany are more common than collaborations with West Germany or with institutions abroad.

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Table C.3: Summary Statistics

<i>Main Outcomes</i>				
	Mean	Std. dev.	Min.	Max.
# publications/ # stayers	0.223	0.275	0.000	2.372
Average SCImago Journal Rank	0.370	0.579	0.000	5.771
# of publications in Top 5 Medicine journals/ # stayers	0.000	0.010	0.000	0.500
<i>Internationalization</i>				
	Mean	Std. dev.	Min.	Max.
# German publ./ # stayers	0.020	0.062	0.000	1.500
# English publ./ # stayers	0.203	0.260	0.000	2.372
Share of German publ.	0.093	0.198	0.000	1.000
Share of English publ.	0.907	0.198	0.000	1.000
<i>Funding</i>				
	Mean	Std. dev.	Min.	Max.
Amount of DFG funding (in mio. euro)	0.422	1.391	0.000	21.733
<i>Collaboration</i>				
	Mean	Std. dev.	Min.	Max.
# collaborative publications/ # stayers	0.177	0.237	0.000	2.156
# collab. publ. with West Germany/ # stayers	0.002	0.015	0.000	0.427
# collab. publ. within East Germany/ # stayers	0.026	0.084	0.000	2.083
# collab. publ. with institutions abroad/ # stayers	0.012	0.051	0.000	1.010
# department-internal collab. publ./ # stayers	0.001	0.014	0.000	0.346
Share of collab. publ.	0.812	0.291	0.000	1.000
Share of department-internal collab. publ.	0.007	0.057	0.000	1.000
Share of collab. publ. with West Germany	0.009	0.058	0.000	1.000
Share of collab. publ. within East Germany	0.122	0.231	0.000	1.000
Share of collab. publ. with abroad	0.056	0.161	0.000	1.000
Average team size	3.461	1.598	1.000	18.250

Note: This table displays the averages of the outcomes of interest for treated and control departments. Publications are classified as German if the title, as listed in Scopus, is German. Publications are classified as English if the title, as listed in Scopus, is English. Publications are classified as collaborative if the publication involves at least two authors. Publications are defined as department-internal if all authors belong to the same department. Publications are classified as collaborative with West Germany if at least one author on the publication is employed at a West German university. Publications are classified as collaborative within East Germany if all authors on the publication are employed at East German universities. Publications are classified as collaborative with abroad if at least one author on the publication is employed at an institution outside of (East and West) Germany.

C.4 Appendix to Section 3.6

C.4.1 Main Results at Individual Level

In this section, I provide evidence on individual level effects. The results are displayed in Table C.4. Columns (1) to (3) focus on publication quantity. Researchers in departments other than Medicine experience a small, positive coefficient estimate which is just significant at the 10% level (column 2). Relative to the pre-reunification average publication output of the treatment group, the effect amounts to 22.4%. From column (3), it is evident that researchers in Medicine departments decrease their publication output in response to the inflow of West German researchers. The effect is much larger in absolute magnitude than the effect on researchers in other departments.

Columns (4) to (6) show the coefficient estimates when using publication quality as the outcome of interest. The coefficient estimate in departments other than Medicine is negative and insignificant, suggesting that researchers in these departments do not respond to the inflow of West German researchers with changes in publication quality (column 5). Researchers in Medicine benefit from their West German colleagues by increasing their average SCImago Journal Rank. Overall, these effects are in line with the results presented in Section 3.6.

Table C.4: Main Results at Individual Level

Dep. Var.:	# of Publications per East German Stayer			SJR		
	Baseline	Excluding Medicine	Medicine	Baseline	Excluding Medicine	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)
Treated x Post	-0.135*** (0.042)	0.049* (0.027)	-0.446*** (0.043)	-0.013 (0.094)	-0.199 (0.123)	0.568*** (0.163)
Mean Dep.	0.319	0.277	0.422	0.910	0.989	0.766
R2 (within)	0.207	0.081	0.781	0.087	0.047	0.497
Obs.	4123	3720	403	1613	1397	216

Note: This table displays the difference-in-differences estimates of the influx of West German researchers into East German university departments on the publication quantity and the publication quality of the East German stayers. Results are derived from a regression following Equation 3.1, but weighted by the number of East German stayers. Columns (1) to (3) use the number of publications per East German stayer as dependent variable. Columns (4) to (6) use the average SCImago Journal Rank as dependent variable. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.4.2 Summary Statistics for Medicine and Other Fields Excluding Medicine Between 1980 and 1989

This section provides summary statistics distinguishing between Medicine departments and departments in other fields during the pre-reunification period. It is evident that Medicine departments publish on average twice as many publications per stayer as the remaining departments. Average journal quality of Medicine departments, however, amounts to only two-thirds of the average journal quality in the remaining departments. While the overall share of collaborative publications is similar across fields, Medicine departments tend to publish a higher share of their publications in English. Research teams in Medicine are larger on average than in the remaining fields.

Table C.5: Summary Statistics for Medicine and Other Fields Excluding Medicine Between 1980 and 1989

	Excluding Medicine			Medicine				
	Mean	Std. dev.	Max.	Mean	Std. dev.	Max.		
# publications/ # stayers	0.216	0.273	0.000	2.083	0.453	0.328	0.000	1.284
Average SCImago Journal Rank	0.934	0.475	0.102	7.304	0.626	0.254	0.165	2.098
<i>Internationalization</i>								
	Excluding Medicine			Medicine				
	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.
# German publ./ # stayers	0.037	0.087	0.000	0.778	0.009	0.018	0.000	0.109
# English publ./ # stayers	0.178	0.241	0.000	2.083	0.444	0.321	0.000	1.284
Share of German publ.	0.171	0.261	0.000	1.000	0.018	0.026	0.000	0.130
Share of English publ.	0.829	0.261	0.000	1.000	0.982	0.026	0.870	1.000
<i>Funding</i>								
	Excluding Medicine			Medicine				
	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.
Amount of DFG funding (in mio. euro)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.5: Summary Statistics for Medicine and Other Fields Excluding Medicine Between 1980 and 1989 (continued)

	Excluding Medicine			Medicine				
	Mean	Std. dev.	Max.	Mean	Std. dev.	Max.		
# collaborative publications/ # stayers	0.149	0.222	0.000	2.083	0.360	0.271	0.000	1.008
# collab. publ. with West Germany/ # stayers	0.000	0.013	0.000	0.427	0.001	0.003	0.000	0.029
# collab. publ. within East Germany/ # stayers	0.029	0.104	0.000	2.083	0.106	0.125	0.000	0.521
# collab. publ. with institutions abroad/ # stayers	0.007	0.037	0.000	0.642	0.014	0.025	0.000	0.140
# department-internal collab. publ./ # stayers	0.001	0.015	0.000	0.283	0.002	0.010	0.000	0.083
Share of collab. publ.	0.703	0.365	0.000	1.000	0.795	0.139	0.000	1.000
Share of department-internal collab. publ.	0.007	0.051	0.000	0.619	0.005	0.020	0.000	0.135
Share of collab. publ. with West Germany	0.003	0.052	0.000	1.000	0.002	0.008	0.000	0.064
Share of collab. publ. within East Germany	0.152	0.277	0.000	1.000	0.257	0.180	0.000	0.763
Share of collab. publ. with abroad	0.041	0.142	0.000	1.000	0.038	0.048	0.000	0.224
Average team size	2.680	1.081	1.000	10.000	3.451	0.497	2.000	4.962

Note: This table displays the averages of the outcomes of interest for treated and control departments between 1980 and 1989, distinguishing between all fields excluding Medicine and Medicine departments. Publications are classified as German if the title, as listed in Scopus, is German. Publications are classified as English if the title, as listed in Scopus, is English. Publications are classified as collaborative if the publication involves at least two authors. Publications are defined as department-internal if all authors belong to the same department. Publications are classified as collaborative with West Germany if at least one author on the publication is employed at a West German university. Publications are classified as collaborative within East Germany if all authors on the publication are employed at East German universities. Publications are classified as collaborative with abroad if at least one author on the publication is employed at an institution outside of (East and West) Germany. Note that the average DFG funding amount is equal to zero for all fields between 1980 and 1989 because DFG funding became available to East German university departments only after the reunification.

C.4.3 Publication Outlet Overlap

To investigate if East German researchers profit from the knowledge of their new West German colleagues, I explore changes in the choice of publication outlet. From my data, I extract the 30 journals that the researchers at the West German switchers' departments mostly published in before and after the transition process. I then compare this with the 30 most-frequented journals of researchers in East German treated and control departments before and after the end of the transition process. I calculate the share of each group's journals that overlaps with the top 30 West German publication outlets. Table C.6 displays the results. I show that treated departments have a greater overlap in journal choice with West German departments after they have recruited a West German colleague than before the reunification. In contrast, control group departments do not show such a systematic relationship. Some departments display a greater overlap with West German departments' publication outlets after the reunification as well, while others actually decrease their overlap.

Table C.6: Overlap with 30 Most-Frequented West German Departments' Publication Outlets

Department	Pre-Transition		Post-Transition	
	Control	Treated	Control	Treated
Biology	0.000	0.167	0.000	0.433
Medicine	0.000	0.000	0.000	0.267
Agric. Science, Forestry and Vet. Medicine	0.000	0.100	0.000	0.533
Chemistry	0.267	0.300	0.400	0.567
Physics	0.233	0.433	0.267	0.633
Mathematics	0.133	0.333	0.100	0.333
Geoscience	0.000	0.067	0.000	0.233
Mechanical Engin. and Production Engin.	0.067	0.133	0.167	0.400
Heat Technology/Process Engineering	0.100	0.033	0.167	0.167
Material Science and Materials Technology	0.000	0.167	0.067	0.433
Computer Science, System and Electrical Engin.	0.100	0.033	0.233	0.233
Construction Engineering and Architecture	0.233	0.067	0.100	0.100

Note: This table displays the share of the 30 most-frequented journals of the treatment and control group before and after the transition process in the 30 most-frequented publication outlets of West German departments.

C.4.4 Heterogeneity of Effects

This section examines the heterogeneity of the impact of West German researchers on the number of publications per East German stayer and on the SCImago Journal Rank along several dimensions. The results of this analysis are displayed in Table C.7 and Table C.8, respectively.

Column (1) of Table C.7 repeats the baseline effect of the West German inflow on publication

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quantity when Medicine is excluded. In columns (2) and (3), I differentiate between large and small departments based on the number of researchers in the year before the reunification. Departments with a number of researchers above the median are defined as large, while departments with fewer researchers than the median are defined as small. Estimating this specification, I find little difference between large and small departments. Both coefficient estimates are positive, but small and statistically insignificant. Columns (4) and (5) differentiate between ex-ante highly productive departments and less productive ones. Departments producing more than the median number of publications per East German stayer in the year before the reunification are classified as highly productive, while departments producing fewer than the median number of publications are defined as less productive. The estimated coefficients are positive and insignificant. Again, I find little difference between the two groups. Overall, my results suggest that there is very little heterogeneity with respect to pre-reunification size and publication output in the departments excluding Medicine.

In columns (6) to (10) of Table C.7, I move on to exploring heterogeneity in Medicine departments. Column (6) repeats the baseline effect, while columns (7) and (8) differentiate between large and small departments, where large departments are defined as employing more than the median number of researchers in the year before the reunification and are labeled as small otherwise. The negative and significant effect on publication output persists in both groups, albeit it is larger in absolute magnitude in large departments. In columns (9) and (10) I distinguish between ex-ante highly productive and less productive Medicine departments, with a department being classified as highly productive if its publication output in the year before the reunification is larger than the median, and classified as less productive otherwise. Highly productive departments experience a larger effect in absolute magnitude than less productive departments. Nevertheless, the negative and significant effect persists also within less productive departments.

Table C.7: Effect Heterogeneity - Publication Quantity

Dep. Var.:	# of Publications per East German Stayer														
	Excluding Medicine						Medicine								
	Baseline	Large	Small	Highly Prod.	Less Prod.	Baseline	Large	Small	Highly Prod.	Less Prod.	Baseline	Large	Small	Highly Prod.	Less Prod.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
Treated x Post	0.018 (0.025)	0.012 (0.033)	0.030 (0.045)	0.016 (0.053)	0.020 (0.026)	-0.339*** (0.065)	-0.497*** (0.101)	-0.245* (0.104)	-0.567*** (0.123)	-0.276*** (0.077)					
Mean Dep.	0.212	0.255	0.168	0.408	0.110	0.322	0.451	0.172	0.532	0.191					
R2 (within)	0.032	0.050	0.030	0.096	0.024	0.583	0.795	0.333	0.823	0.460					
Obs.	3720	1860	1860	1271	2449	403	217	186	155	248					

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the number of publications per East German stayer. Departments are classified as large if they have a number of researchers above the median in the year before the reunification, otherwise they are labeled as small. Departments are classified as highly productive if they have a number of publications per East German stayer above the median in the year before the reunification, otherwise they are labeled as less productive. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

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Table C.8 investigates effect heterogeneity in publication quality. Column (1) repeats the baseline effect when Medicine is excluded. As in the previous analysis, I distinguish between large and small departments based on the number of researchers in the year before the reunification. While large departments show a small, negative and insignificant coefficient estimate (column 2), small departments experience a negative and significant effect on the average SCImago Journal Rank.¹ In columns (4) and (5), I differentiate between ex-ante highly productive departments and less productive ones. As in the previous analysis, the distinction is based on a median split. Highly productive departments show a small and insignificant coefficient estimate. The estimated effect for less productive departments is similar in size and insignificant as well.

The second part of Table C.8 examines effect heterogeneity in Medicine departments. Column (6) repeats the baseline effect and columns (7) and (8) differentiate between large and small departments. The coefficient estimate for large departments is significant and about twice as large as the estimated effect for small departments. When distinguishing between ex-ante highly productive and less productive departments, heterogeneity is again sizable. Highly productive departments increase their average SCImago Journal Rank about 2.4 times more than less productive departments. Nevertheless, the positive coefficient estimates persist in small departments and less productive ones, albeit these are imprecisely estimated and thus cannot be distinguished from zero.

¹These findings should be interpreted with caution, as they are driven by few extremely small departments. In unreported regressions I exclude these and the heterogeneity along this dimension vanishes.

Table C.8: Effect Heterogeneity - Publication Quality

Dep. Var.:	SJR											
	Excluding Medicine						Medicine					
	Baseline	Large	Small	Highly Prod.	Less Prod.	Baseline	Large	Small	Highly Prod.	Less Prod.		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)		
Treated x Post	-0.140 (0.096)	-0.070 (0.120)	-0.283* (0.147)	-0.050 (0.112)	-0.059 (0.128)	0.546*** (0.147)	0.650** (0.182)	0.330 (0.155)	0.826*** (0.109)	0.341 (0.218)		
Mean Dep.	0.957	0.950	0.974	1.083	0.808	0.759	0.780	0.696	0.806	0.724		
R2 (within)	0.036	0.032	0.098	0.139	0.047	0.434	0.573	0.516	0.765	0.391		
Obs.	1397	968	429	760	637	216	161	55	92	124		

Note: This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the average SImago Journal Rank. Departments are classified as large if they have a number of researchers above the median in the year before the reunification, otherwise they are labeled as small. Departments are classified as highly productive if they have a number of publications per East German stayer above the median in the year before the reunification, otherwise they are labeled as less productive. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Overall, heterogeneity within Medicine seems to be somewhat larger than in other departments. Highly productive Medicine departments respond especially strong to the inflow of West German researchers. In the remaining departments, researchers do not respond with changes in publication quantity. Small departments and ex-ante less productive ones react with a more pronounced drop in publication quality.

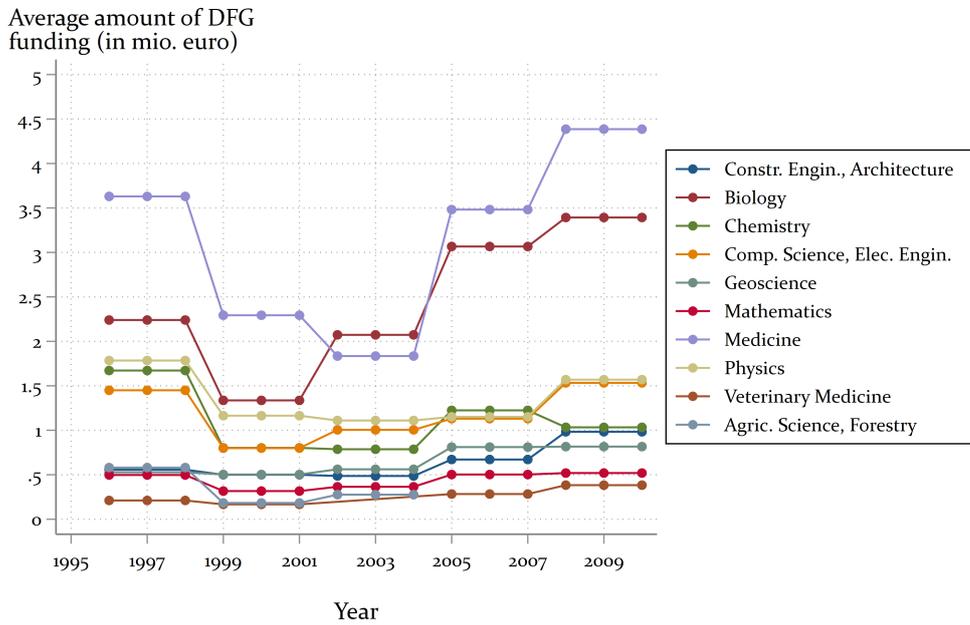
C.5 Appendix to Section 3.7

C.5.1 Development of Average DFG Funding Over Time

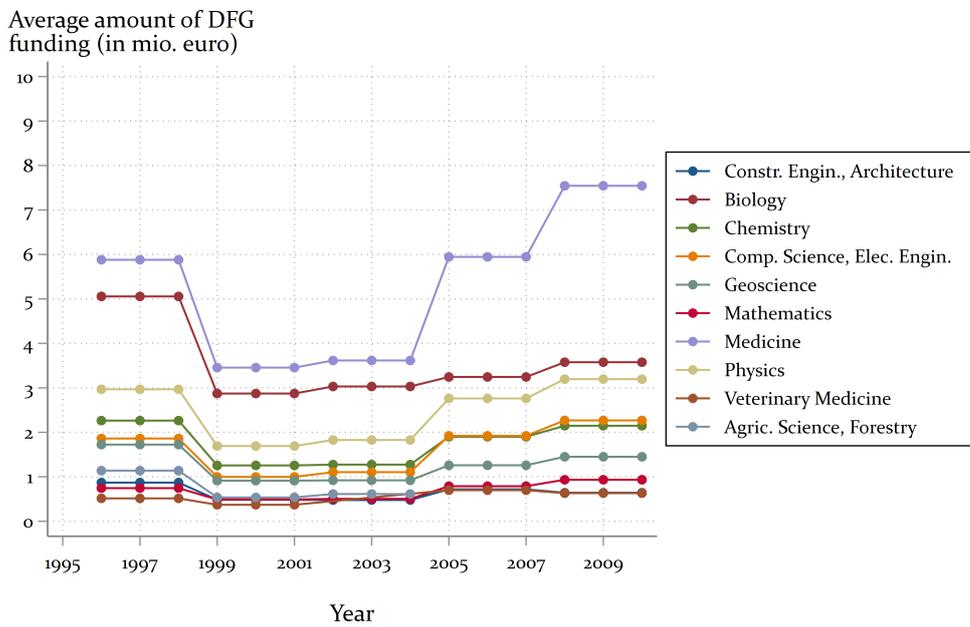
Appendix C.5.1 provides details on the development of average DFG funding over time. Figure C.3 displays the average amount of DFG funding by research field in East Germany and West Germany. For better visibility, the y-axis differs between panel (a) and panel (b). It is apparent that the distribution across fields is similar between East and West Germany. Medicine receives the highest average funding amount in both countries (on average 3.15 million euro per year in East Germany between 1996 and 2010 and on average 5.27 million euro per year in West Germany between 1996 and 2010). This is followed by Biology, which exhibits an increasing trend in East Germany compared to a rather stable average funding amount of around 3.54 million euro in West Germany. Both countries receive the fewest amounts of funding in Mathematics and Veterinary Medicine. On average, between 1996 and 2010 all other fields excluding Medicine receive 5.61 million euro of funding per year in East Germany and 8.62 million euro of funding per year in West Germany.

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Figure C.3: Average Amount of DFG Funding by Research Field for East Germany and West Germany



(a) East Germany



(b) West Germany

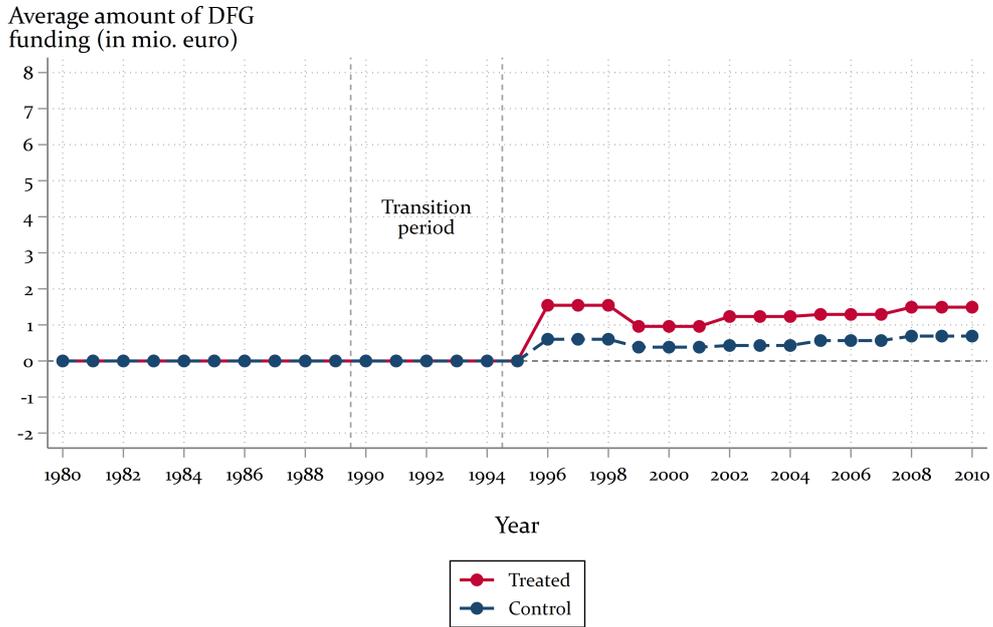
Note: These figures show the average amount of DFG funding of East and West German university departments between 1996 and 2010 over time. Panel (a) shows average DFG funding amounts by research field for East German universities. Panel (b) shows average DFG funding amounts by research field for West German universities.

C.5.2 Average DFG Funding Over Time in Treatment and Control Group

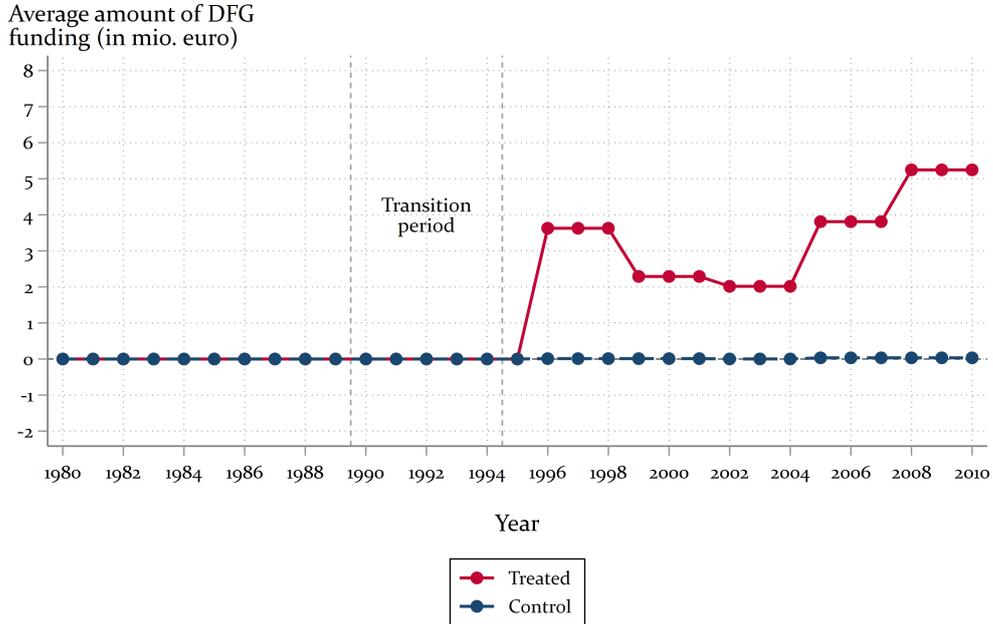
Figure C.4 shows the yearly average amount of DFG funding for treated and control departments. Panel (a) shows the development over time for all fields except Medicine, while panel (b) shows the development over time for Medicine departments. Due to a lack of data, I can only show averages as of 1996. It is evident that both for Medicine and all other disciplines, East German university departments that recruit West German researchers receive larger amounts of DFG funding than departments without West German colleagues. This observation is especially pronounced in Medicine.

C. APPENDIX TO CHAPTER 3

Figure C.4: Average Amount of DFG Funding by Treated and Control Departments at East German Universities



(a) Excluding Medicine



(b) Medicine

Note: These figures show the average amount of DFG funding of East German university departments between 1980 and 2010 over time. Panel (a) compares departments with West German researchers (treated) to departments without West German researchers (control) for all fields except Medicine. Panel (b) compares departments with West German researchers (treated) to departments without West German researchers (control) for Medicine.

C.6 Appendix to Section 3.9

In this section I present additional robustness tests.

C.6.1 Alternative Specifications

I begin by addressing the skewed nature of the publication distribution by re-estimating my main specification using a log transformed dependent variable and an inverse hyperbolic sine transformation of my dependent variable. Columns (1) and (2) of Table C.9 repeat the coefficient estimates using a dependent variable in levels. Columns (3) and (4) display results using a log transformation of the dependent variable. Columns (5) and (6) show coefficient estimates from regressions using an inverse hyperbolic sine transformation. My results remain qualitatively unaffected.

Table C.9: Results Using Alternative Specifications

Dep. Var.:	# of Publications per East German Stayer					
	Levels		Logs		IHS	
Spec.:	Excluding Medicine	Medicine	Excluding Medicine	Medicine	Excluding Medicine	Medicine
	(1)	(2)	(3)	(4)	(5)	(6)
Treated x Post	0.018 (0.025)	-0.339*** (0.065)	0.013 (0.018)	-0.243*** (0.050)	0.016 (0.022)	-0.309*** (0.060)
Mean Dep.	0.212	0.322	0.171	0.259	0.201	0.306
R2 (within)	0.032	0.583	0.039	0.587	0.037	0.591
Obs.	3720	403	3720	403	3720	403

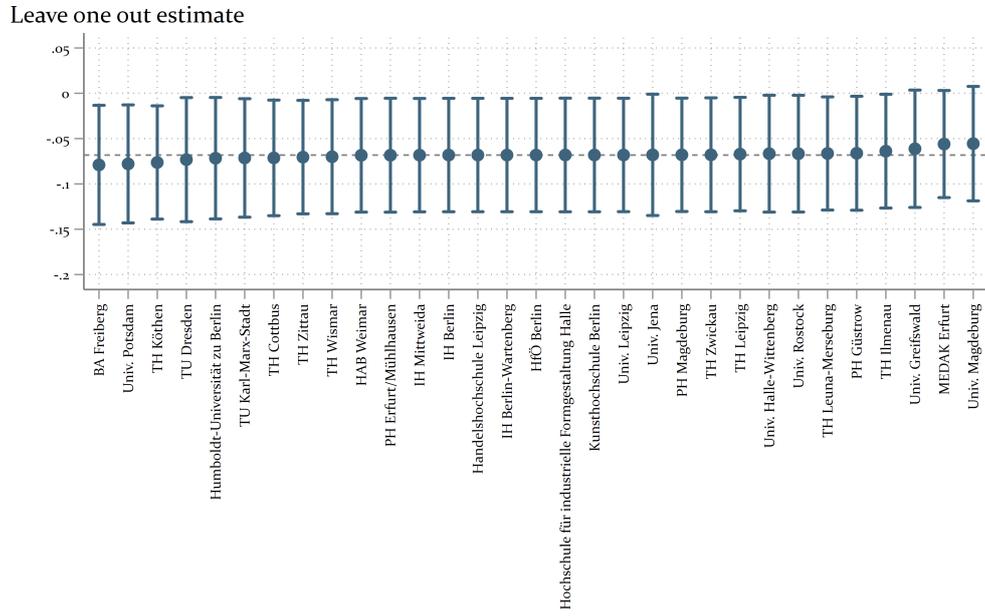
This table shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the number of publications per East German stayer. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. All specifications include year fixed effects and department fixed effects. Robust standard errors, adjusted for clustering at the department level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.6.2 Effect of Leaving Out One University

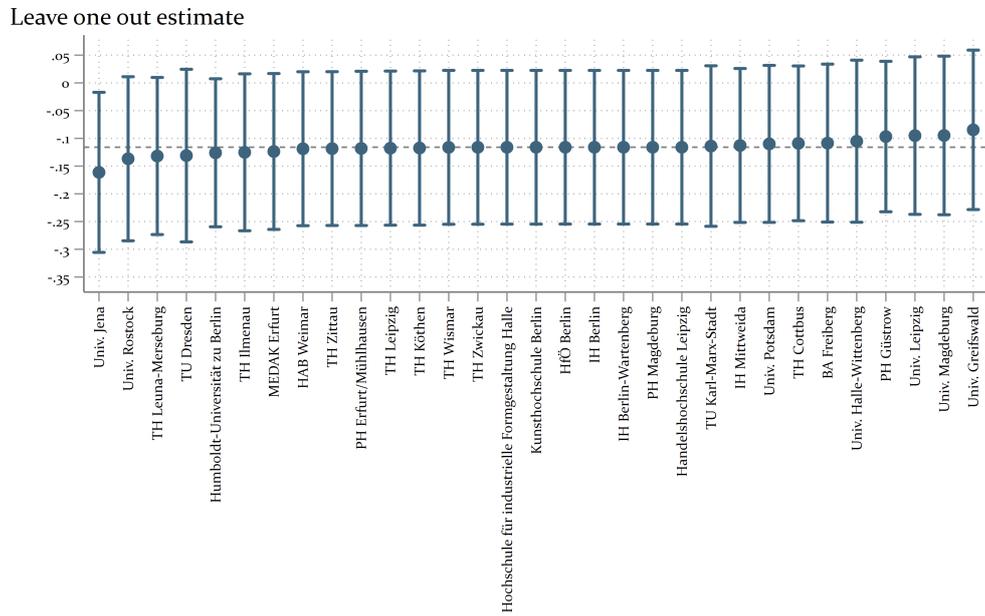
Next, I explore if a specific university drives the observed effects. I estimate Equation 3.1 with the number of publications per East German stayer and the average SCImago Journal Rank as the dependent variable, leaving out one university at a time. The result is displayed in Figure C.5. The grey line marks the coefficient estimate if all universities are included. I can rule out that my results are driven by a particular university.

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Figure C.5: Effect of Leaving Out One University



(a) Effect of Leaving Out One University on Publication Quantity



(b) Effect of Leaving Out One University on Publication Quality

Note: This figure shows difference-in-differences estimates of the influx of West German researchers into East German university departments on the number of publications per East German stayer (panel a) and on the average SClmag Journal Rank (panel b) when leaving out one university in turn. The treatment group consists of East German departments hiring at least one West German researcher. The control group consists of East German departments hiring no West German researcher. The blue bars represent 95% confidence bounds that allow for clustering at the department level.

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