Industrial Espionage and Productivity*

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Abstract

In this paper, we investigate the economic returns to industrial espionage by linking information from East Germany's foreign intelligence service to sector-specific gaps in total factor productivity (TFP) between West and East Germany. Based on a data set that comprises the entire flow of information provided by East German informants over the period 1968-1989, we document a significant narrowing of sectoral West-to-East TFP gaps as a result of East Germany's industrial espionage. This central finding holds across a wide range of specifications and is robust to the inclusion of several alternative proxies for technology transfer. We further demonstrate that the economic returns to industrial espionage are primarily driven by relatively few high quality pieces of information and particularly strong in sectors that were closer to the West German technological frontier. Our findings also show that, over the time period considered, industrial espionage crowded out standard overt R&D in East Germany.

JEL Classification: D24, F52, N34, N44, O30, O47, P26
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"The Ministry for State Security has the goal of acquiring, in steadily increasing volume, scientific-technical information and documents from West Germany and other capitalist countries." – Erich Mielke, Minister of State Security (1957-1989), *BStU, Policy Documents. DA, 3/55/DSt 100938*

1 Introduction

Throughout history, from the Byzantine Empire's clandestine acquisition of silk worms from China in the 6th century AD to contemporary breaches of cyber networks, industrial espionage has remained a pervasive channel for technology transfers. In particular during the period following the end of the Second World War, industrial espionage became key to state development as the communist bloc attempted to catch up with the capitalist world's technological advantage. Through secret agents in the West, technologies relating to the atomic bomb, supersonic airplanes and computers were – trade embargoes notwithstanding – transferred into production in countries like the Soviet Union and East Germany.[1]

Despite the rich history of illicit technology transfer and its continuing contemporary importance, industrial espionage and its associated costs and benefits have received little attention in economics. Undoubtedly, the secret nature of the practice obscures its economic significance which, in terms of costs, may amount to "billions of dollars per year, constituting a serious national security concern" according to one US government report.[2] Even more opaque are the economic benefits accruing to those countries actively engaging in industrial espionage. Its persistent and widespread use, however, suggests that these benefits are substantial.

In this paper, we study the relationship between state-sponsored industrial espionage and technological progress, focusing on the effect of industrial espionage on productivity. The centerpiece of our empirical analysis is a dataset that comprises the entire recorded stock of information East German foreign intelligence sources gathered abroad during the period 1968 to 1989. This unique database, which survived the political turmoils after the fall of the Berlin Wall in November 1989 only through a stroke of luck, includes detailed information on 189,725 individual pieces of information, including their precise date of receipt at the East German Ministry for State Security (MfS, commonly referred to as *the Stasi*), the code names of their sources and a list of keywords describing each item's content. To operationalize this wealth of data, we use the keywords provided to attribute each piece of information to the industry sector it pertains to. We then merge the obtained information flows to industry-specific total factor productivity (TFP) measures which we compute from time series data on sectoral gross value added, employment and capital investment in both West and East Germany between 1970 and 1989. In our main estimation equation, we regress sectoral differences in TFP growth rates between West and East Germany on the flow of sector-specific information generated by industrial espionage, controlling for direct measures of R&D activity in both parts of Germany. Our estimates thus speak directly to the question in how far industrial espionage allowed the East German economy to keep up with technological progress

[1] "Top 3 Successes of Soviet Economic Espionage,", Moscow Times, Jan 29 2015. http://www.themoscowtimes.com/business/article/russian-spy-ring-treads-in-soviet-s-footsteps-in-economic-espionage-case/515095.html; "'Ace' spy revealed Concorde secrets", BBC News, September 14 1999, http://news.bbc.co.uk/2/hi/uk_news/politics/447464.stm

[2] "Annual Report to Congress on Foreign Economic Collection and Industrial Espionage", National Counterintelligence Center, July 1995. https://www.fas.org/sgp/othergov/indust.html

in the West.

Our results show evidence of significant economic returns to industrial espionage. A one standard deviation increase in the covert inflow of information results in a 6.6 percentage point decrease of the log TFP gap and a 5.5 percentage point decrease in the log output per worker gap between West and East Germany. These results are robust across a large number of specifications and little affected if we allow for alternative channels of technology transfer. To address potential endogeneity concerns, we employ an instrumental variable strategy in which we either only utilize information accruing from informants who were already active at the beginning of the sample period or exploit the sudden discontinuation of certain informants as providers of information as an exogenous source of variation. Analysing different dimensions of heterogeneity, we document that the positive effect on East German productivity growth is driven primarily by relatively few high quality pieces of information. We further show that industrial espionage in East Germany tended to crowd out investments in regular overt R&D and that it was particularly effective in those sectors that were closest to the West German technological frontier. To conclude, we run a counterfactual simulation of how East German TFP would have evolved in the absence of industrial espionage, showing that it had overall a noticeable but quantitatively modest mitigating effect on the productivity gap to West Germany. For some sectors such as the electronics sector, however, we find that industrial espionage was vital to avoid a significant further opening of the technological gap.

To the best of our knowledge, we are the first to empirically assess the role of industrial espionage for technological progress. In doing so, our paper touches upon several relevant strands of the economics literature. In economic history, the role of espionage has been investigated with a focus on its adverse consequences. One example is the research coming out of the archival study of the former Soviet Union's intelligence agency, the KGB (Harrison, 2008, Harrison, 2013, and Harrison and Zaksauskiene, 2016). Lichter, Löffler and Siegloch (2015) exploit discontinuities at state borders within East Germany to show that higher levels of Stasi surveillance lead to lower levels of social capital. In this field of research, our paper provides evidence of some of the benefits of secrecy in the form of industrial espionage activities. Related to our work is also the economic history literature on innovation and economic development (Schmookler, 1962, Schmookler, 1966, Sokoloff, 1988, Moser and Voena, 2012, and Moser, 2013).

Moreover, our study relates to the literature on the role of innovation in explaining productivity growth (Griliches, 1980, Griliches and Lichtenberg, 1984, Romer, 1990, Grossman and Helpman, 1991, Aghion and Howitt, 1992, and Howitt, 2000). This literature finds predominantly large economic returns to R&D but has remained silent on the effects of industrial espionage. Instead, it has focused on relevant overt channels of technology diffusion such as international trade (Coe and Helpman, 1995, Eaton and Kortum, 1999, Keller, 2004, and Cameron, Proudman and Redding, 2005) and foreign direct investment (Fons-Rosen, Kalemli-Ozcan, Sørensen, Villegas-Sanchez and Volosovych, 2013). Factors such as the distance to the world technology frontier, human capital, and institutions (Griffith, Redding and Van Reenen, 2004; Acemoglu, Aghion and Zilibotti, 2006) have also been shown to bear directly on the choice of technology adoption versus innovation. A starting point of our research is the conjecture that intelligence capabilities could serve as an important additional channel of technology diffusion, especially in the presence of trade sanctions and limits on foreign investment. Moreover, whereas standard forms of technology diffusion like trade and foreign investment rely on the free flow of capital and goods, we demonstrate that industrial espionage appears to be particularly effective in their absence.

Furthermore, a lingering identification challenge in past studies has been separating the positive effects of knowledge spillovers from the negative business stealing effects through product market rivalry (Bloom, Schankermann and Van Reenen, 2013). In our case, the limited product market rivalry between East and West German industries allows us to effectively estimate effects of knowledge spillovers separate from any business stealing effects.[3]

The rest of the paper is organized as follows. Section 2 provides the historical context to the use of industrial espionage in East Germany. Section 3 describes the data sources used in the paper. Section 4 presents the empirical framework and estimation strategy. Section 5 presents the main results, and Section 6 concludes.

2 Historical Background

Possibly the earliest recorded incidence of state-sponsored industrial espionage occurred in the 6th century AD, when two Nestorian monks successfully smuggled silkworm eggs, likely hidden in bamboo canes, from China into the Byzantine Empire. This daring feat, an important juncture in the economic history of the Early Middle Ages, led to the breaking of two monopolies: that of Chinese silk production and that of the Persian silk trade with the West. As a result, Byzantine silk became one of the Empire's most profitable commodities while also providing a valuable medium of exchange, and several cities developed into major textile centers as a result (Norwich, 1990; Laiou, 2002).[4]

In a somewhat similar vein, East German industrial espionage was to a large extent a response to the West's implementation of economic containment policies at the onset of the Cold War (Jackson, 2001). Instrumental in this process was the East-West trade embargo established after the Second World War and facilitated through The Coordinating Committee for Multilateral Export Controls (CoCom).[5] This entity served as a tool for Western countries to implement export controls on an extensive list of goods bound for the communist bloc countries. These included not just goods from the military and nuclear sectors, but also industrial "dual-use" products which could be used for military purposes, especially those characterized by advanced technologies.

Meanwhile, early East-to-West migration allowed the Stasi to expand its intelligence network in the West, allowing the infiltration of key centers of power in the Federal Republic of Germany. The broader extent of Stasi's infiltration of West Germany is today widely known, as is its internal repressive nature (Koehler, 2000), but its industrial espionage has been much less covered, an exception being Macrakis (2008), who through archival research provides a historical overview and several case studies with a specific focus on the IT sector. Research on the economic impact of East German industrial espionage is (to our knowledge) nonexistent.

Most of the Stasi's industrial espionage was conducted under its foreign intelligence unit

[3]In this context, we demonstrate the absence of any effects of East German industrial espionage on TFP growth in West German industries.

[4]Much later, throughout the late eighteenth and early nineteenth centuries, "[t]he United States emerged as the world's industrial leader by illicitly appropriating mechanical and scientific innovations from Europe" as "American industrial spies roamed the British Isles, seeking not just new machines but skilled workers who could run and maintain those machines" (Ben-Atar, 2004).

[5]Some countries, such as the US, further prevented any country that was deemed to be "dominated or controlled by communism" (Section 231 of the Trade Expansion Act of 1962) from obtaining a Most Favored Nation status, which would have significantly lowered trade barriers with East Germany.

(*Hauptverwaltung Aufklärung*, HVA), led by the spy chief Markus Wolf. During Wolf's tenure, the HVA would create perhaps one of the world's best intelligence networks ever seen (Macrakis, 2008):

> *"During the thirty-five years of its existence, the HVA managed to penetrate West Germany's most sensitive institutions, institutions ranging from the chancellor's office and foreign office to intelligence and security agencies to their most prestigious scientific and technical establishments. In 1989 the SWT had agents planted at internationally competitive companies like IBM, Siemens, AEG/Telefunken, SEL, Texas Instruments, and DEC."*

The department in charge of stealing scientific-technical secrets from the West started off as a small unit with only around 35 staff members. By 1989, it had grown into the well-organized Sector for Science and Technology (*Sektor Wissenschaft und Technik*, SWT), which then counted up to four hundred staff members, representing roughly 40 percent of all HVA employees (Macrakis, 2008), and thousands of informants. Over time, the East German espionage network in West Germany facilitated significant technology transfers, despite the trade embargo of strategic goods set up by the Western powers.

In the 1970s, East German political leadership decided to become a world leader in computers, and significant resources were directed to producing microchips as well as infiltrating the Western electronics industry. Companies like IBM and Siemens became highly valued targets of espionage. By 1970, East German electronics experts had already acquired and reverse engineered more than a dozen computers, such as the IBM 360, and by 1973 the Dresden-based VEB Robotron was producing computers "at a rate of eighty to one hundred per year" (Macrakis, 2008).[6]

Illicit technology transfer from West to East was a contentious issue at the time and concerns over technology leaks to the Soviet bloc increased, especially in the US. The election of Ronald Reagan as President of the United States in 1981 accelerated this process: a state of economic emergency was declared and severe regulation of exports implemented. The overwhelming majority of US actions to stem transfer of technology, however, relates directly to the Soviet Union, and in most documentation there is barely any mention of East Germany (Weyhrauch, 1986). As the trade embargo against the Communist bloc intensified, East Germany came to rely increasingly on its industrial espionage. Toward this end, staff members mapped out all major West German companies, collecting information in the form of so-called object files, while its officers engaged in systematic recruitment of leading personnel. Most of the sources were male salaried employees, predominantly engineers or employees with science degrees, although a number of sources also worked in personnel departments, were businessmen, and a few were even officers at the U.S. Army base in Augsburg (Macrakis, 2008). These informers were not necessarily leaders in their field or heads of departments or even scientists. Several of the most important sources were employees like engineer Dieter Feuerstein (codename "Petermann") at MBB, who passed on top-secret military plans, Peter Alwardt (codename "Alfred") at AEG/ Telefunken, who worked as an engineer, and Peter Köhler (codename "Schulze"), who worked for Texas Instruments.[7]

[6]As a sign of the computer industry's importance in the SIRA database of collected information discussed in the next section, "IBM" is the 30th most common keyword appearing in the data. Meanwhile, the keywords "Microelectronics," "Software," "Computer Science," and "Electronic Data Processing" are in seventh, eight, ninth, and eighteenth place respectively.

[7]For a comprehensive analysis of the recruitment, motivation and social background of the Stasi's West German

Meanwhile, Western intelligence activities in East Germany remained by most accounts behind those of its East German counterpart in recruiting reliable informants, especially so in the economic sectors. Partly, this may have been the result of priorities, topically as well as methodologically, as Western espionage focused disproportionately on political and military – rather than economic – espionage, using signals intelligence more effectively than human intelligence. In addition, the West German foreign intelligence agency (*Bundesnachrichtendienst*, BND) was heavily compromised by moles in the early years of the Cold War (Schmidt-Eenboom, 2009). Periodical purges and outright witch hunts of suspected traitors cast a wide net of suspicion over the guilty and innocent alike. Furthermore, Stasi officials have often boasted of the degree to which the Western intelligence sources in East Germany were, in fact, double agents, with one general putting that number at around 90 percent (Schmidt-Eenboom, 2009). It is therefore unlikely that in those instances where Western espionage activities were successful in East Germany, they were related to the economic sector or any substantive technology transfers from the East to the West. As such, the transfer of technologies was overwhelmingly a one-way street. As for Western intelligence agencies other than the West German BND, these tended to focus most of their efforts on the Soviet Union rather than East Germany. The CIA's own former historian, for example, has described the agency's activities in the country as "deaf, dumb, and blind" (Fischer, 2009).

Despite the documented extent to which the Stasi engaged in industrial espionage, some historians have argued that its scientific-technical intelligence activities were ultimately a failure, as the secretive nature of high-tech espionage clashed with the openness required for successful scientific development (Macrakis, 2008). Additionally, as more and more resources were poured into stealing rather than generating technologies, East Germany's own innovation ultimately suffered. The politically motivated charge to achieve world status leadership in computers failed, despite the resources devoted. Yet as late as 1989, East Germany was also seen by some as "Communism that works" – "the Communist world's high-technology leader...its capital goods known for quality workmanship".[8] According to Macrakis (2008), internal estimates by the Stasi suggested that its industrial espionage had saved the East German industry about 75 million East German *Marks* in R&D expenditures.

The argument that East German industrial espionage was a failure because it stifled overt R&D is not necessarily sufficient to conclude that *overall* economic returns to the former were negative. In later sections, we systematically investigate this question and also provide evidence on the extent to which secret and open R&D are substitutes.

3 Data

The empirical analysis in this paper relies on a number of different data sources, with two being of particular importance. First and foremost, we exploit unique data on industrial espionage, taken directly from the HVA's main electronic database SIRA (*System der Informationsrecherche der Hauptverwaltung Aufklärung*).[9] In addition, we use data recently published by Heske (2013) on output, employment and investments in different economic sectors in both West and East

informants, see Knabe (1999), Müller-Enbergs (1998, 2007, 2011) and Herbstritt (2011).

[8]"East Germany Losing Its Edge", The New York Times, May 15, 1989, http://www.nytimes.com/1989/05/15/business/east-germany-losing-its-edge.html?pagewanted=all

[9]The SIRA database is currently managed and maintained by the The Agency of the Federal Commissioner for the Stasi Records (BStU).

Germany. In the following section, we describe these two main data sources in more detail and provide information on additional complementary data sets.

3.1 SIRA Data

Our main data on the MfS's industrial espionage activities are taken directly from SIRA's Sub-Database 11 (*Teildatenbank 11*), which essentially comprises records about all scientific-technical information that the Stasi's informants in the West passed on to the HVA between 1968 and 1989. In total, some 189,725 pieces of information were recorded over this time period, corresponding to an annual average inflow of 8,624 items.[10] Figure 1 displays the distribution of this flow of information over time. Ignoring the early years 1968 and 1969 as well as the final year 1989 since they are only incompletely covered by the SIRA data, the figure shows that the annual inflow of information was initially on a declining trend but that this trend reversed in 1979, after which the annual inflows increased steadily, eventually peaking in 1988, the last year prior to the fall of the Berlin wall, with a record of 15,658 pieces of information.

Upon arrival at the Stasi, specialist internal evaluators created for each incoming piece of information an electronic entry in the SIRA database in which they recorded, among other things, the date of arrival of the information, the source of the information and one or several, often highly specific, keywords to describe the information's content. After this initial documentation, the received material was then passed on to potentially interested parties, typically state-run enterprises and/or East German research facilities, for further assessment and economic exploitation. In total, the Sub-Database 11 comprises 143,005 distinct keywords, 68.5 percent of which are only used once throughout the entire period.[11] On average, each piece of information is described by 5.6 distinct keywords but the distribution is skewed to the right, with a median of 5, a 95th percentile of 10 and a maximum of 145 keywords.

To operationalize these keywords and connect them to our sectoral time series data, we selected in a first step the 2,000 most frequently occurring keywords, which together account for 63.8 percent of all keyword entries in the database, and assigned them to their corresponding sectors. Table A-1 in the appendix lists the 30 most frequently and 10 least frequently used keywords from this subsample, together with their English translations, their frequency in the data, and the sectors to which we allocated them. Examples of frequently used keywords are *Military Technology*, *Electronics*, *Chemistry*, *Microcomputer*, *Metallurgy*, *Optics*, *IBM*, and *Nuclear Power Plant*. Overall, we were able to assign 55 percent of the 2,000 most common keywords to at least one of the 16 sectors for which we have information on output, employment, and investments.[12] After this allocation procedure, the vast majority of the distinct pieces of information in our sample are described by between 1 and 5 sector-specific keywords, and only 18.6 percent are not described by any sector-specific keyword.

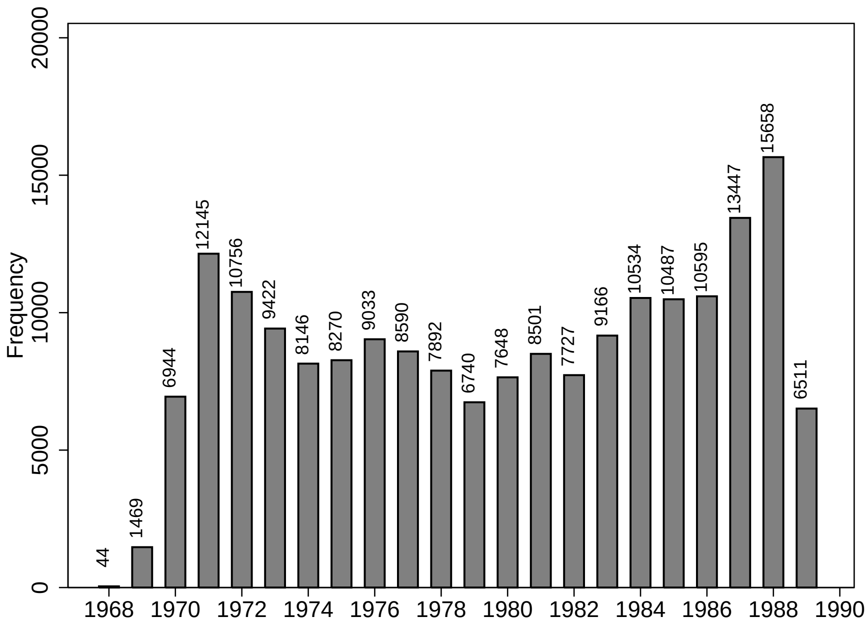
Figure 2 shows the sectoral distribution of the 151,614 pieces of information that could be allocated to at least one of the 16 available sectors over the period 1968 to 1989. We count a piece of

[10] Not all of these pieces of information included keywords to describe their content; see below.

[11] Some of the keywords cannot be unambiguously interpreted, as they occasionally include abbreviations or unknown numerical codes.

[12] The remaining 45 percent are either not classifiable (80.9 percent) or refer to other sectors of the economy such as agriculture, construction, automobile repairs and consumer goods, transportation and communication, finance, leasing and public and private services, health, military, or the aerospace industry (19.1 percent). Note that a given keyword can relate to more than one sector.

Figure 1: Information Inflow, 1968-1989

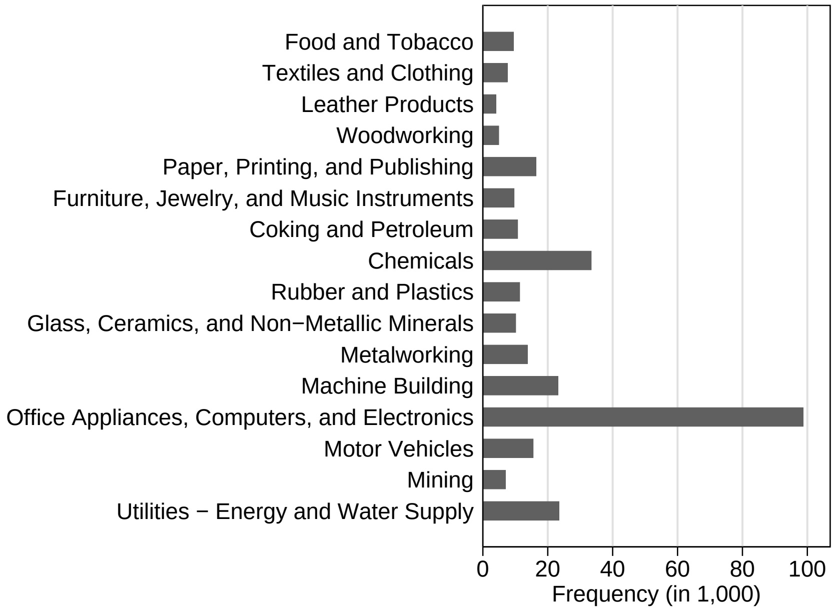


Note: Figure shows the annual inflow of information received by the HVA between 1968 and 1989. Data for 1968 and 1989 incomplete.

information as pertaining to a specific sector if it is described by at least one keyword corresponding to that sector. A given information may therefore pertain to more than one sector. In line with historical accounts, the sector *Office Appliances, Computers and Electronics* constituted by far the most important sector for industrial espionage, with 98,713 pieces of related information in total, followed by the sectors *Chemicals* (33,409), *Utilities* (23,485) and *Machine Building* (23,152).

Looking at the providers of these pieces of information, the SIRA database identifies 2,453 distinct informants based on their assigned code names. Table A-2 in the appendix lists the 20 most productive of them over the period 1968 to 1989. Informant "FROEBEL" with registration number XV/6603/80, who worked at the GDR's embassy in Washington, was the top source in terms of quantity, delivering 5,344 distinct pieces of information over this time period, with the first piece received in 1982 and the last in 1989. His overall reliability was rated as "A", which meant "reliable" and was awarded in 61.7 percent of all cases (33.6 percent of informants were assessed as "trustworthy", and 4.7 percent as "not checked"). However, the listed informants were certainly an exceptional group in terms of the amount of information they generated. Across the entire distribution of informants, the median and mean inflow of information amounts to only 6 and 63 items respectively, reflecting the highly right skewed distribution illustrated in Figure B-1 in the appendix. The information provided by most informants throughout their time in the service of the HVA was thus limited, reflecting the cautious approach by the HVA in handling its sources as well as the difficulties for most informants to tap into relevant information. Figure B-2 in the appendix depicts the distribution of the first and last active year in which each informant is observed in the data. The left panel suggests that recruitment of new informants was an ongoing process, with increased efforts from the mid-1980s onwards. The right panel shows that informants also continuously ceased to provide further information, the reason of which we cannot ascertain. We will exploit this fact later on in the construction of one of our instrumental variables.

Figure 2: Sectoral Distribution of Information



Note: Figure shows the sector-specific inflows of information received by the HVA between 1968 and 1989.

3.2 Industry Level Data

The second key database for our empirical analysis are the sector-specific time series for gross value added, total employment, and gross fixed capital investment constructed by Heske (2013). The purpose of this publication was to provide a comparable, retroactive accounting of the development of key economic indicators for different industry sectors in West and East Germany over the time period 1950 to 2000. Due to the fundamental differences in economic systems before German unification in 1990, with a market-based economy in West Germany pitted against a centrally-planned economy in East Germany, such computations constitute a challenging task, not least because West and East Germany followed different national accounting standards throughout the pre-unification period.[13]

The historical starting point of Heske's work are the insights gained from the so-called "Retroactive Accounting Project" (*Rückrechnungsprojekt*) which the Federal Statistical Office of unified Germany initiated in 1991 and whose mission included, besides the collection, protection and documentation of the existing statistical data in the former GDR, the retroactive computation of key economic indicators based on current methodological concepts and taxonomies (Lachnit, 1993). In 2000, this work led to a first publication providing detailed information about the production and expenditure side of GDP in the former GDR between 1970 and 1989, expressed in current East German *Mark*.[14]

[13]While West Germany's national accounting was based on the nowadays standard "System of National Accounts" (SNA), East Germany applied, together with the Soviet Union and other Eastern Bloc countries, the so-called "Material Product System" (MPS). Only after unification in 1990, the two systems were harmonized by introducing the SNA system on the territories of the former GDR. One of the key difference between the two systems is that the MPS, in contrast to the SNA, does not consider public and private services as contributors to an economy's value added.

[14]Statistisches Bundesamt: Sonderreihe mit Beiträgen für das Gebiet der ehemaligen DDR, Heft 33, Wiesbaden 2000.

In a series of publications, Heske (2005, 2009, 2013) builds on these initial findings but makes four important contributions. First, he translates all values of output and investment in the GDR into constant East German *Mark* with respect to the base year 1985, taking account of the complex issues arising from the qualitative upgrading of existing and introduction of new products.[15] Second, he converts all values into constant 1995 euros, thus allowing a direct comparison between the economic performance of West and East Germany over time. A key advantage in this process is the fact that many of the goods produced in the former GDR were observed both priced in East German *Mark* and, after the monetary union on 1 July 1990, in West German *Deutsche Mark*, allowing the computation of differentiated sector-specific conversion coefficients. Third, Heske extends the time horizon to the earlier period 1950 to 1970, for which the existing data basis, however, is significantly more limited. Finally, and crucially for our analysis, he constructs separate time series for individual economic sectors. The depth of the sectoral differentiation is thereby governed by data availability, allowing in the end a distinction of three broad industry sectors – mining, energy and water, and manufacturing – and, within manufacturing, a further differentiation of 14 sub-sectors.

Figure B-4 in the appendix shows time series for log gross value added per worker in West and East Germany by sector between 1969 and 1989. Apart from the energy and water sector, the productivity of workers in West Germany exceeds that of workers in East Germany, in many sectors, including some of the biggest ones such as Metalworking and Office Appliances, Computers, and Electronics, by a substantial amount (1.89 and 1.96 log points, respectively, on average over the time period considered). For comparison, we also add the corresponding figures for West Germany calculated on the basis of the UNIDO Industrial Statistics Database.

As a subordinate institution, the East German Statistical Office lacked independence from the government and the ruling SED party, which viewed statistical information as a potential tool of agitation and propaganda. Consequently, the reliability of statistical information in the former GDR has been subject of extensive and controversial discussions (see, e.g., Statistisches Bundesamt, 1999). In the context of our study, it is therefore important to emphasize, that the sector-specific time series data we use are constructed from original primary data sources as well as unpublished internal documents of the East German Statistical Office. Most of these sources and documents were, at the time, labeled as "confidential" and, as internal material, not subject to politically-motivated manipulation, which tended to occur at the final publication stage. Overall, we are therefore confident that these data provide an overall good reflection of the key economic developments in West and East Germany over the time period considered.[16]

3.3 Patent and Trade Data

To isolate the impact of industrial espionage on productivity, it is important to control for other key drivers of productivity, especially R&D investments which have been shown to be particularly relevant. Unfortunately, there are no consistent data series available of sector-specific R&D invest-

[15] A key characteristic of the price formation mechanism in the centrally-planned economy of the former GDR was the existence of significant differences between the prices set at the production stage, and the prices set at the final consumption stage. While producer prices (*Industrieabgabepreise*) were periodically adjusted to reflect changes in the costs of production, consumer prices were predominantly set with a view to political and social conditions.

[16] Two important studies by the Deutsches Institut für Wirtschaftsforschung (DIW, 1987) and the Federal Statistical Office (Hölder, 1992) reach a similar conclusion regarding the reliability of the statistical information in the former GDR.

ments in West and East Germany over our observation window 1969 to 1989. To proxy for both countries' own R&D activities, we therefore use the annual number of sector-specific patent applications, scaled by industry output.[17] For West Germany, we obtain these from the DEPATISnet database of the German Patent Office and the EPAB database of the European Patent Office. From these online databases, we extracted the annual number of West German patent applications for each IPC category between 1970 and 1989 and then summed up the number of applications across all IPC's belonging to one of our 16 industry sectors.[18] In cases, in which a given IPC pertained to more than one industry sector, we assigned fractions of the corresponding numbers of patents to each industry using weights taken from the MERIT concordance table IPC - ISIC (rev. 2).

The source of our East German patent data are formerly confidential publications summarizing the annual innovation activities in the GDR (*Ergebnisse der Erfindertätigkeit und Schutzrechtsarbeit*) for the period 1970 to 1989, published by the East German Statistical Office (SZS). For each year and state combine, these publications report a number of innovation-related outcomes, including the number of patent applications.[19] To construct sector-specific outcomes, we assign each state combine to one of our 16 industry sectors and sum the number of patent applications across combines operating in the same sector. Figure B-5 in the appendix shows the number of patent applications by sector in West and East Germany for the period 1970 to 1989.

Finally, we use trade data from the "World Trade Flows 1962-2000" collected by Feenstra et al. (2005) to source imports data for West and East Germany.[20] We convert the SITC revision 2 format of the trade data to the ISIC2 system of our industry data using the concordance constructed by Muendler (2009). Following Cameron et al. (2005), we construct a sector-specific measure of the relative import intensity between West and East Germany, defined as the difference in the West and East German ratios of sector-specific imports from the whole world divided by output.

4 Empirical Framework

4.1 Main Specification

In this section, we present our empirical framework. In each industry j of country i, either West Germany (W) or East Germany (E), output Y^i_{jt} in period t is produced using physical capital K^i_{jt} and labor L^i_{jt} according to a standard neoclassical production function.

$$Y^i_{jt} = A^i_{jt} F(K^i_{jt}, L^i_{jt}) \tag{1}$$

[17]See Lach (1995) for related study estimating the productivity returns to patents as a proxy for R&D, and Hall et al. (2005) for estimates of the market value returns to patents.

[18]The European Patent Office has accepted patent applications for its member states since 1978. The overall number of applications is the sum of all A, B1- and C1-Schriften recorded by the German Patent Office and all A1 and A2 documents recorded by the European Patent Office.

[19]The other innovation outcomes provided are the number of patent applications from R&D activities (1970-1982), the number of innovators applying for patents (1980-1982), the number of patent engineers working in the patent office (*Büro für Schutzrechte*) (1980-1989), and the number of university cadres working in R&D (1986-1989). While we cannot use these alternative measures due to their restricted time coverage, their correlation with the number of patent applications is very high, 0.998 with respect to the number of patent applications from R&D activities, 0.978 with respect to the number of innovators applying for patents, 0.971 with respect to the number of patent engineers, and 0.976 with respect to the number of university cadres working in R&D. For an overview of the patent law in the former GDR and its development in the post-war period, see Wiessner (2013).

[20]The dataset is available at the UC Davis Center for International Data `http://cid.econ.ucdavis.edu/wix.html`.

where A^i_{jt} denotes total factor productivity (TFP) and F is assumed to be homogeneous of degree one. We assume that TFP is not just a function of the R&D knowledge stock, G^i_{jt}, but also of the stock of knowledge accruing from espionage activities, E^i_{jt}. In the spirit of the empirical literature on R&D and productivity growth (Griliches, 1980; Griliches and Lichtenberg, 1984; and Griffith et al., 2004), after taking logarithms and differencing with respect to time, the rate of sector-specific TFP growth is given by

$$\Delta \ln A^i_{j,t+1} = \alpha + \beta^i \Delta \ln E^i_{jt} + \gamma^i \Delta \ln G^i_{jt} + \theta^i \ln\left(A^F_{jt}/A^i_{jt}\right) + \mathbf{X'}^i_{jt}\mathbf{\Phi}^{\mathrm{i}} + \lambda^i_j + \pi^i_t + \mu_{jt} + \varepsilon^i_{jt} \qquad (2)$$

where $\ln(A^F_{jt}/A^i_{jt})$ measures a country's distance to the world technological frontier A^F_{jt}, X^i_{jt} is a vector of country-specific control variables, λ^i_j are country-sector fixed effects, π^i_t are country-year fixed effects, and μ_{jt} are world-sector-year fixed effects.[21] The parameters γ^i and β^i are the elasticities of output with respect to the R&D knowledge stock and the knowledge stock acquired through industrial espionage, respectively. Assuming negligible rates of depreciation of both types of knowledge, the speed of technological progress in West and East Germany can be expressed as

$$\Delta \ln A^i_{j,t+1} = \alpha + \rho^i \left(\frac{S^i_{jt}}{Y^i_{jt}}\right) + \eta^i \left(\frac{R^i_{jt}}{Y^i_{jt}}\right) + \theta^i \ln\left(\frac{A^F_{jt}}{A^i_{jt}}\right) + \mathbf{X'}^i_{jt}\mathbf{\Phi}^{\mathrm{i}} + \lambda^i_j + \pi^i_t + \mu_{jt} + \varepsilon^i_{jt},$$

where $S^i_{jt} = \Delta E^i_{jt}$ is the inflow of sector-specific information acquired through industrial espionage and $R^i_{jt} = \Delta G^i_{jt}$ is a measure of sector-specific R&D investments, implying that $\rho^i = dY^i_{j,t+1}/dE^i_{jt}$ is the rate of return to industrial espionage and $\eta^i = dY^i_{j,t+1}/dG^i_{jt}$ the rate of return to R&D.

Our main outcome of interest is the gap in the TFP growth rate between the two parts of Germany which, from the perspective of East Germany, can we viewed as the change in the distance to the technological frontier in West Germany. Taking differences between West and East Germany's TFP growth rates, $\Delta \ln\left(A^W_{j,t+1}\right) - \Delta \ln\left(A^E_{j,t+1}\right)$, and defining $\lambda_j \equiv \lambda^W_j - \lambda^E_j$, $\pi_t \equiv \pi^W_t - \pi^E_t$, $\mathbf{X}_{jt} \equiv \mathbf{X}^W_{jt} - \mathbf{X}^E_{jt}$ and $\varepsilon_{jt} \equiv \varepsilon^W_{jt} - \varepsilon^E_{jt}$, leads to our main estimation equation

$$\Delta \ln\left(\frac{A^W_{jt+s}}{A^E_{jt+s}}\right) = \rho \left(\frac{S^E_{jt}}{Y^E_{jt}}\right) + \eta r_{jt} - \theta \ln\left(\frac{A^W_{jt}}{A^E_{jt}}\right) + \mathbf{X}'_{jt}\mathbf{\Phi} + \lambda_j + \pi_t + \varepsilon_{jt}, \qquad (3)$$

where $r_{jt} \equiv \left(R^W_{jt}/Y^W_{jt} - R^E_{jt}/Y^E_{jt}\right)$ and $\rho = -\rho^E$, and where we initially assume that the marginal effects of R&D investments, the distance to the world technology frontier and the control variables on TFP in West and East Germany are the same ($\eta^W = \eta^E = \eta, \theta^W = \theta^E = \theta$, and $\Phi^{\mathrm{W}} = \Phi^{\mathrm{E}} = \Phi$). The vector of sector-specific fixed effects λ_j in equation (3) allows for country-industry-specific fixed effects in TFP growth in West and East Germany, for example due to differential reliance on international know-how and different initial conditions across sectors in terms of research facilities and human capital after World War II. The vector of year fixed effects π_t allows for differential technological advances on the country level that affect all industry sectors in the same way. Note that by taking differences between West and East German TFP growth, we also implicitly control for all time-varying sector-specific TFP shocks μ_{jt} that affect West and East Germany in the same way.

Note that equation (3) does not include a term for West German industrial espionage S^W_{jt} which is unobserved and would thus be part of the error term. Although West Germany, like most

[21] A similar regression specification can also be found in Buccirossi et al. (2013)

Western countries at the time, engaged in military and political espionage, we have been unable to uncover evidence of any meaningful scale of West German industrial espionage. Since East Germany's industrial espionage was to such a large extent driven by trade embargoes which West Germany did not suffer from, the relative return to industrial espionage compared to standard R&D ought to have been rather low in West Germany. Moreover, assuming that the returns to industrial espionage in both countries are positive, and that industry-level espionage is positively correlated in the two countries, the omission of West German espionage activities, by way of the standard omitted variable bias formula (Angrist and Pischke, 2009) would lead to an understatement of the effect of East German industrial espionage on the productivity gap in equation (3).[22]

The identifying assumption in estimating equation (3) is that, conditional on the included control variables, the quantity of sector-specific information provided by East German informants is exogenous and therefore uncorrelated with the error term $\varepsilon_{jt}(= \varepsilon_{jt}^{W} - \varepsilon_{jt}^{E})$. There are a number of potential threats to this assumption. First, assuming a constant espionage intensity, there may be a mechanical relationship between more productivity-enhancing innovations in circulation in West Germany and the amount of information East German informants are able to get their hands on. This would introduce a positive correlation between our inflow measure and ε_{jt}^{W}, which in turn would lead to an upward bias of our parameter of interest ρ. In this case, our findings would constitute a lower bound of the true effect of industrial espionage on relative TFP growth. The second threat arises if the East German government decided to intensify its efforts to acquire new technologies in those sectors that either threatened to fall behind or caught up particularly fast with the West. While the included relative sector-specific time trends in TFP growth $\lambda_j(= \lambda_j^W - \lambda_j^E)$ pick up much of the long-run strategic direction of particular sectors, there may still be time periods in which the demand for new technologies was unusually high or low relative to the long-run trend, introducing a correlation between the error term and the inflow of information from espionage. To deal with this problem, we introduce a proxy for sector-specific R&D investments - patent applications - which are likely to capture much of the variation over time in the demand for sector-specific information that may be related to the relative productivity growth between West and East Germany. We also propose two instrumental variable strategies in which we exploit the initial placement of informants on the one hand and their discontinuation as providers of information on the other hand as exogenous sources of variation.

4.2 Obtaining Estimates of TFP

As there are no direct measures of TFP available for the time period considered, we use our industry-level data to back out measures of sector-specific TFP by means of a standard growth accounting exercise (Mankiw et al., 1992; Caselli, 2005; Caselli and Coleman, 2006). As a starting point, we assume that the production functions in equation (1) are Cobb-Douglas, so that

$$Y_{jt}^{i} = A_{jt}^{i}(K_{jt}^{i})^{\alpha}(L_{jt}^{i})^{1-\alpha}$$

[22] Of course, West German counterintelligence measures were an important tool to prevent unwanted technology transfers from the West to the East, but these measures are likely to have reduced S_{jt}^{E} directly.

Transforming outputs and inputs into per capita terms, taking logs, differencing over time and rearranging leads to

$$\Delta \ln A^i_{jt} = \Delta \ln y^i_{jt} - \alpha \Delta \ln k^i_{jt} \tag{4}$$

where y^i_{jt} and k^i_{jt} denote output per worker and the capital-labor ratio, respectively.[23] Unfortunately, as in many industry level datasets, there is no information on the capital stock employed in different sectors of the economy. Before we can use equation (4) to back out estimates of technological progress, we therefore have to construct measures of the sector-specific capital-labor ratios for both West and East Germany. Following much of the literature (e.g. Caselli 2005), we generate estimates of the capital stock in each industry sector using the perpetual inventory equation

$$K_{jt} = I_{jt} + (1 - \delta)K_{jt-1},$$

where I_{jt} is investment, measured as gross fixed capital investment in constant 1995 euros, and δ the depreciation rate. In line with standard practice, we compute the initial sector-specific capital stock K_{j0} using the steady state formular $I_{j0}/(g_j + \delta)$, where I_{j0} is the value of investment in the first year available in the data (1950), and g_j the sector-specific average geometric growth rate for the investment series between 1950 and 1970, the first year for which we have data on industrial espionage. As in Caselli (2005), we set the depreciation rate δ to 0.06 for all sectors in our baseline calibration and compute the capital-labor ratio by dividing the resulting K_{jt} by the number of workers in the sector L_{jt}.

In a competitive market like West Germany, the parameter α corresponds to the capital share. Following the literature, we set this share equal to 0.33 in equation (4) and then use the relative changes in output per capita and in the capital-labor ratios to back out estimates of technological progress $\widehat{\Delta \ln A^W_{jt}}$ and $\widehat{\Delta \ln A^E_{jt}}$, which we then plug into our main estimation equation (3). Figure 3 displays the estimated TFP profiles for each of our 16 sectors between 1969 and 1989. Apart from the Food and Tobacco, Coking and Petroleum, and the Utilities sectors, West Germany's total factor productivity always outstrips East Germany's, often by a significant amount, in particular in major sectors such as Textiles and Clothing, Metalworking, and Office Appliances, Computers, and Electronics.

Before we present the results from our estimation of equation (3), we need to determine the time intervals over which we construct the sector-specific changes in log TFP and corresponding inflows of information and investments in R&D. Even though annual data are available, it is reasonable to consider longer first differences in the context of this study, since it is unlikely that the arrival of new information about West German technology would be translated into measurable changes in East German productivity within a single year. Our main specification will therefore relate changes in log TFP gaps over a three-year period (between t and t+3) to the cumulative inflow of information from industrial espionage and the number of patent applications over the previous three years (between t-3 and t) as the main regressors of interest, both scaled by the sector-specific output in period t.[24] To exploit the available data as efficiently as possible, and

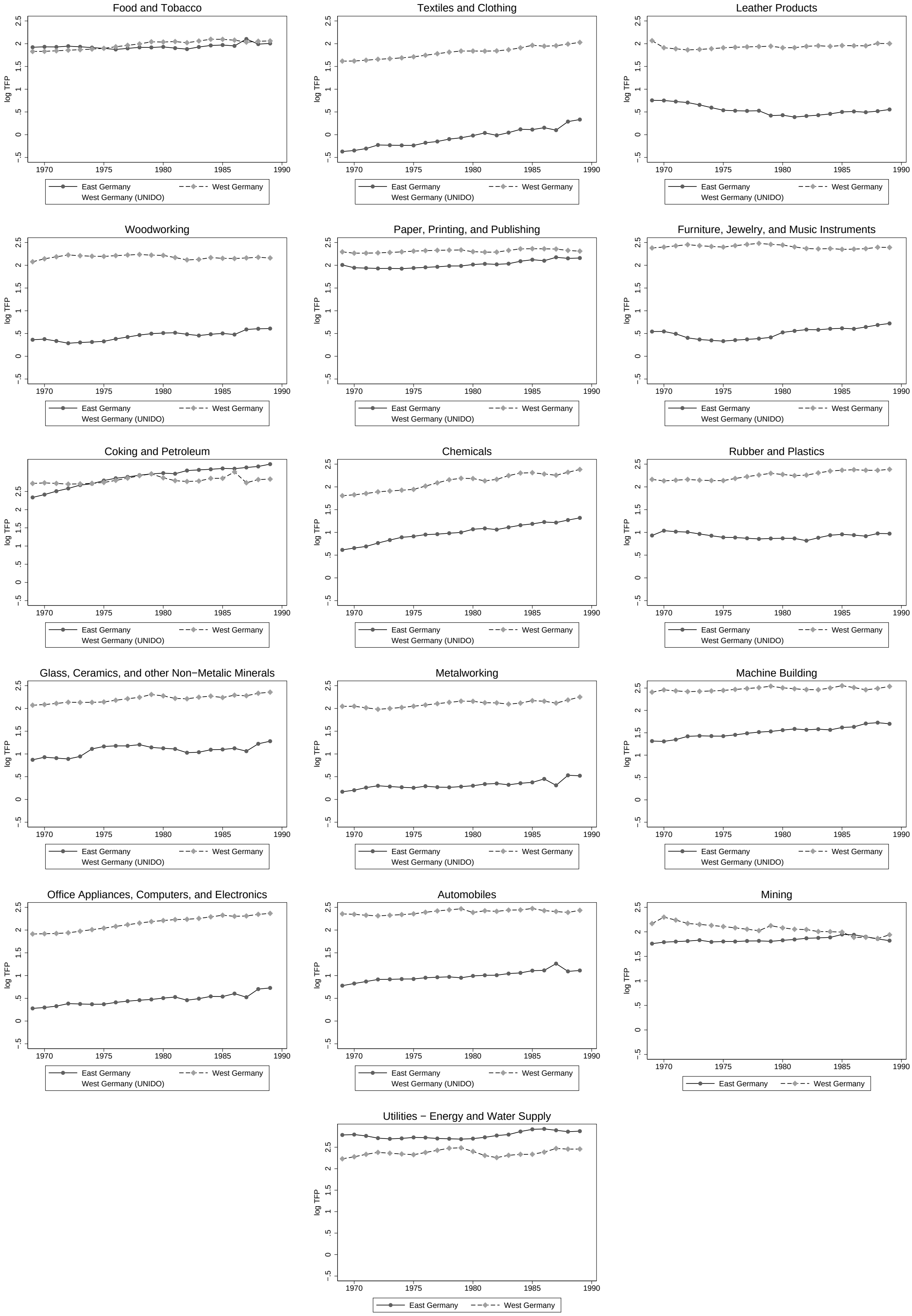
[23] Note that one could extend the production function by allowing for differences in human capital between East and West Germany and over time. Fuchs-Schündeln and Izem (2011) show that skills between East and West were actually highly transferable, mitigating concerns about substantial differences in human capital in the two regions.

[24] Results based on annual observations are consistent with our main findings and highly significant, but smaller

to avoid arbitrariness in choosing specific start and end dates, we use overlapping observations in our main specification and cluster the standard errors to account for the mechanically introduced serial correlation across overlapping observations (compare Harri and Brorsen, 2009). We present both conventional standard errors clustered at the sectoral level and p-values calculated using the wild cluster bootstrap method proposed by Cameron, Gelbach and Miller (2008), which represents an important inference improvement when the number of clusters, as in our case, is relatively low. Similar to Griffith et al. (2004), we weight the regressions by the average number of workers in each sector over the sample period. For robustness, we also present results using non-overlapping observations, as well as unweighted estimations and specifications in which we weight observations by the average output in each sectors.

in magnitude.

Figure 3: Log Total Factor Productivity by Sector



Note: The individual panels depict the estimated log TFP by sector for West and East Germany over the period 1969 to 1989. TFP measures are constructed using the perpetual inventory method as described in the text, assuming an annual depreciation rate of the capital stock of 6% and a capital share of output of 33%.

Table 1 provides an overview of all variables used in our empirical specification. The main regressor of interest is the inflow of information scaled by sector-specific output. Between 1972

Table 1: Summary Statistics

	West Germany		East Germany		Difference	
	Mean	SD	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)	(5)	(6)
Inflow/Y			1.530	(1.400)		
TFP Growth	0.025	(0.072)	0.046	(0.070)	-0.020	(0.096)
Output per Worker Growth	0.050	(0.079)	0.090	(0.070)	-0.040	(0.098)
Patents/Y	0.392	(0.372)	0.313	(0.433)	0.079	(0.225)
Log TFP	2.227	(0.250)	1.194	(0.866)	1.033	(0.752)
Log Output per Worker	3.679	(0.414)	2.385	(1.091)	1.294	(0.782)
Imports/Y	3.072	(6.115)	0.356	(0.386)	2.716	(6.129)
Capital/Y	2.267	(1.146)	4.086	(2.464)	-1.819	(2.780)
Labor/Y	0.027	(0.010)	0.144	(0.120)	-0.117	(0.113)

Note: Summary stats computed for 3-year overlapping observations for the period 1970 to 1989. Number of observations 240 (234 for Import/Y ratio).

and 1986, the average number of pieces of information per million euros of output was 1.53 with a standard deviation of 1.40, reflecting substantial variation over time and industry sectors in the information generated by industrial espionage. The average 3-year growth rate of TFP amounted to 2.5 percent in West Germany and 4.6 percent in East Germany. Output per worker grew somewhat faster, 5 percent on average in West and 9 percent in East Germany. The number of patent applications per 1 million euros of output was broadly comparable in West and East Germany, 0.392 in the West and 0.313 in the East. The levels of log TFP, the log output per worker and the import intensity were substantially higher in West Germany than in East Germany over the time period considered. In contrast, both the capital intensity and worker intensity were higher in East Germany.

5 Results

5.1 Main Results

In Table 2, we present the main results of the effect of industrial espionage on the productivity gap between West and East Germany based on equation (3). Focusing on the left panel first, the most parsimonious specification that includes only our measure of sector-specific inflows of information and a full set of time- and industry-specific fixed effects reveals a significant effect of industrial espionage on the log TFP gap with a point estimate of -0.039. In column (2), we add the gap in the number of patent applications per 1 million euros of output between West and East Germany, r_{jt}, as a proxy for sector-specific R&D investments as an additional control variable. The inclusion of this control variable may help address two potential sources of omitted variable bias. On the one hand, increased overt R&D activities in specific sectors in East Germany are likely to go hand in hand with greater efforts in acquiring corresponding information by means of covert operations in West Germany, introducing a downward bias in our parameter of interest. On the other hand, more West German R&D activities could mean more available information that can be siphoned off by East German informants, giving rise to an upward bias. As column (2) reveals, the latter effect dominates: controlling for the patent gap between West and East

Table 2: Industrial Espionage and Productivity

	Log TFP			Log Output per Worker		
	Baseline spec	Patents gap	Lagged gap	Baseline spec	Patents gap	Lagged gap
	(1)	(2)	(3)	(4)	(5)	(6)
Inflow/Y	-0.039**	-0.045**	-0.047***	-0.030*	-0.039**	-0.039**
	(0.018)	(0.018)	(0.012)	(0.015)	(0.016)	(0.015)
Patents/Y Gap		0.069**	-0.025		0.102***	0.011
		(0.028)	(0.022)		(0.026)	(0.028)
Log TFP Gap			-0.589***			
			(0.097)			
Log Output/Worker Gap						-0.515***
						(0.100)
P-value WB	0.032	0.020	0.004	0.068	0.058	0.104
Beta	-0.791	-0.905	-0.952	-0.579	-0.738	-0.738
Adj R2 (within)	0.31	0.33	0.55	0.31	0.35	0.52
Obs	240	240	240	240	240	240

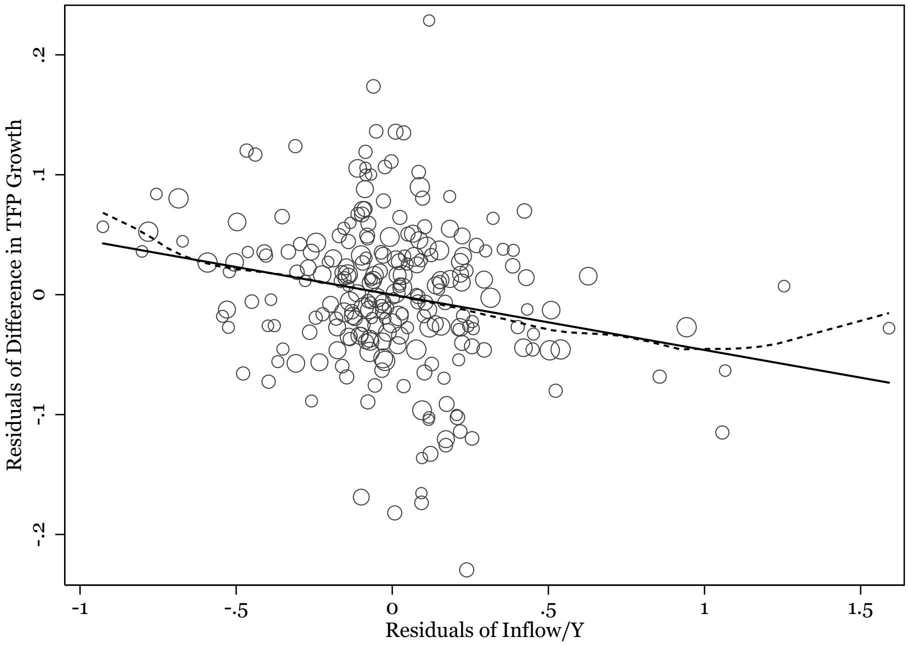
Note: Sample based on 3-year intervals and overlapping observations for the period 1970 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log TFP gap between West and East Germany over the period t to t+3 in columns (1) to (3) and the change in the log output per worker gap over the period t to t+3 in columns (4) to (6). Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values, relating to the Inflow/Y estimate, from (Cameron et al., 2008) clustered wild bootstraps using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

Germany reduces our main parameter of interest to -0.045. The coefficient of the patent gap control variable itself is positive, indicating, as expected, a positive role for own R&D activities on future TFP growth. Column (3) represents our preferred specification, where we add the initial log TFP gap as a further control variable. This leads to a small additional decrease of our main parameter of interest to -0.047, which is highly significant based on both the conventional cluster-robust standard errors reported in parentheses and p-values from Cameron et al. (2008)'s wild bootstrap-clustering. The estimated coefficient suggests an economically meaningful effect of industrial espionage on productivity growth, with a one standard deviation increase of 1.4 in the information flow per 1 million euros of output reducing the gap in log TFP between West and East Germany by 6.6 percentage points. Note that the coefficient of the initial log TFP gap, multiplied by minus one, measures the marginal effect θ of the distance to the world technological frontier on TFP growth (compare equation (2)). In line with the results of Griffith et al. (2004), we thus find evidence for technology transfer as a source of productivity growth for countries behind the technological frontier.

Figure 4 visualizes the negative relationship between industrial espionage and changes in the log TFP gap between West and East Germany by plotting their residualized values corresponding to our preferred specification in column (3) of Table 2. Importantly, this relationship is not driven by any particular outliers in the data and, over a large range of the inflow variable's support, well approximated by a linear functional form.

The right panel of Table 2 shows the corresponding results for the change in the log output per worker gap between West and East Germany. The results closely mirror those for the log TFP gap, which is consistent with a narrowing productivity gap driving a narrowing output per worker

Figure 4: Industrial Espionage and Productivity



Note: The figure plots residualized changes in the log TFP gap between West and East Germany against residualized sector-specific inflows of information on the basis of the specification reported in column (3) of Table 2. Circles are proportionate to the square root of the average number of workers in an industry. The solid black line represents a simple OLS regression line whereas the dashed line represents the fit from a linear local polynomial estimator.

gap between West and East Germany.[25]

Table A-3 in Appendix A reports results for the same set of specifications but based on non-overlapping observations for the years 1973, 1976, 1979, 1982 and 1985. While less precisely estimated due to the smaller sample size, all estimates remain significant and comparable in magnitude to their counterparts in Table 2. Table A-4 in Appendix A reports results using yearly rather than 3-yearly intervals. As expected, due to the shorter time horizon to translate new information into technological progress, the effect of industrial espionage on the change in the log TFP and output per worker gap between West and East Germany is somewhat muted relative to our main findings, with points estimates of -0.029 and -0.030, respectively.

5.2 Robustness Checks

In Table 3, we perform a number of robustness checks of our main results, which are restated for comparison in column (1). We focus on the impact of industrial espionage on the log TFP gap but report the corresponding results for output per worker in Table A-5 of Appendix A. In column (2), we weight each observation with the average value of output in each sector over the sample period rather than the average number of workers. This increases the parameter on the inflow variable by more than half to -0.074. In contrast, not weighting at all leaves the estimated effect almost unaffected as shown in column (3). In column (4), we exclude all observations pertaining

[25]Note from equation (4) that the coefficient from this regression, ρ_y, is equal to the sum of the corresponding coefficient from the log TFP specification and the scaled coefficient from a specification where the dependent variable is the relative change in the sector-specific capital-labor ratio, $\rho_A + \alpha\rho_k$. Since $\rho_y = -0.039$ and $\rho_A = -0.047$ in our preferred specifications, the effect of industrial espionage on the relative growth in capital intensity is thus $\rho_k = 0.024$.

Table 3: Robustness - Log TFP

	Main spec	Weighted by output	No weights	No IT	Sector trends	Trade gap	Trade & High-tech	Capital/Labor gaps
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inflow/Y	-0.047***	-0.074**	-0.046***	-0.043**	-0.041***	-0.047***	-0.050*	-0.050***
	(0.012)	(0.031)	(0.013)	(0.017)	(0.012)	(0.012)	(0.027)	(0.010)
Patents/Y Gap	-0.025	-0.024	0.001	0.022	0.007	-0.020	0.025	-0.025
	(0.022)	(0.045)	(0.032)	(0.045)	(0.078)	(0.023)	(0.091)	(0.019)
Log TFP Gap	-0.589***	-0.783***	-0.565***	-0.595***	-1.201***	-0.590***	-0.552***	-0.535***
	(0.097)	(0.172)	(0.091)	(0.095)	(0.095)	(0.103)	(0.163)	(0.101)
Imports/Y Gap						-0.001	-0.001	
						(0.002)	(0.002)	
Capital/Y Gap								0.016
								(0.009)
Labor/Y Gap								-0.060
								(0.100)
P-value WB	0.004	0.048	0.028	0.048	0.012	0.004	0.082	0.002
Beta	-0.952	-0.785	-0.669	-0.417	-0.829	-0.942	-1.013	-1.006
Obs	240	240	240	225	240	234	234	240

Note: Sample based on 3-year intervals and overlapping observations for the period 1970 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log TFP gap between West and East Germany over the period t to t+3. Column (1) restates our main results from column (3) of Table 2. In column (2), observations are weighted by the average sector-specific gross value added. In column (3), observations are unweighted. In column (4), we exclude the IT sector from the estimation sample. In column (5), we include sector-specific linear time trends in the specification. In column (6), we include the gap in the sector-specific import/output ratio between West and East Germany as an additional control variable. In column (7), we additionally include interactions of sector dummies with the difference between West and East Germany in a) the share of high tech imports in total imports and b) the share of high tech imports imported from CoCom countries. In column (8), we include the gap in the capital/output and employment/output ratios between West and East Germany as additional control variables. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values, relating to the Inflow/Y estimate, from (Cameron et al., 2008) clustered wild bootstraps using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

to the sector Office Appliances, Computers and Electronics, which was of particular interest to the East German government and which comprises by far the biggest share of the overall information received (compare figure 2). As in the previous column, our parameter of interest remains almost unchanged. In column (5), we add industry-specific linear time trends to our specification, which effectively allows for accelerating or decelerating relative productivity growth in different sectors. This leads to a small decrease in the estimated impact of industrial espionage on log TFP gaps, from -0.047 to -0.041.

To account for the impact of international trade on productivity growth, we first add the gap in sector-specific import intensities between West and East Germany as a control variable in column (6).[26] In column (7), we additionally include interactions of industry dummies with the West-East difference in a) the share of high-technology imports in total imports and b) the fraction of high-technology imports imported from CoCom countries.[27] These interactions serve as additional controls for potential technology transfers through trade by allowing East (relative to

[26] Note that while the point estimate of the import gap variable is close to zero and not significant in the reported specification, if one excludes the initial log TFP gap, it increases to a highly significant 0.005 (0.001), suggesting a productivity-enhancing role from international trade.

[27] The CoCom signatory countries are Australia, Belgium, Canada, Denmark, France, Germany, Greece, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Turkey, the United Kingdom and the United States. See also Section 2.

West) Germany's ability to import advanced technologies to have a differential effect on different industries over time.[28] The inclusion of these trade-related controls has overall little impact on the effect of information inflows from industrial espionage on changes in the log TFP gaps. Finally, in column (8), we include the West-to-East gaps in capital and labor intensities to the estimation equation with once more negligible effects on our parameter of interest. Overall, Table 3 and Table A-5 reveal our main findings to be highly robust to alternative sets of control variables and specifications.

5.3 Instrumental Variables

One potential concern with our analysis thus far is that the results could be confounded by time-varying unobservable factors that jointly affect the extent of industrial espionage and the speed at which the productivity gaps between West and East Germany change in particular industries. One such source of endogeneity could be a mechanical one in which the presence of more productivity-enhancing innovations in West Germany widens the productivity gap to the East while at the same time increasing the inflow of espionage information even in the absence of any strategic behaviour on behalf of the Stasi and its informants. This is because, at constant espionage intensity, if there is more information on new innovations around, it is easier for informants to siphon some of it off. In this case, our inflow measure would be positively correlated with the error term ε_{jt}^{W} in equation 3, upward biasing our estimate of the impact of industrial espionage on the productivity gap between West and East Germany. Apart from this mechanical source of endogeneity, it is conceivable that East Germany strategically intensified its espionage activities in precisely those sectors in which it correctly expected to either catch up with the West, in which case our parameter of interest would be downward biased, or technologically fall behind in the future, in which case our estimate would be upward biased.

By exploiting variation around sector-specific linear time trends in relative productivity growth, which are absorbed by the vector of λ_j's, and additionally controlling directly for the initial gap in TFP as well as the gap in the number of patent applications as a proxy for R&D investments, we already expect to capture much of the East German government's changing preferences for certain sectors over time. To address any remaining concerns, we implement two instrumental variable approaches, both exploiting the fact that the Stasi's main way of strategically changing the volume and sectoral distribution of espionage information was through a differential allocation of new informants across sectors.[29]

In the first approach, we assume that the presence of "old" informants, defined as informants who were already active at the beginning of the sample period in 1970, and their differential access to information across different sectors at the time are exogenous to any subsequent changes in preferences of the Stasi. More specifically, we instrument the inflow of information received between the end of period t-3 and period t with the inflow of information received from informants who already provided information at the beginning of the sample period in 1970, holding their sectoral distribution constant. Let $\theta_{i,70}$ be the share of the total information received in 1970

[28] A key concern underlying the CoCom-imposed embargo was the use of dual-purpose technologies, i.e. technologies that could be used in multiple industries. The products that are counted as "high-technology" are given by the SITC codes provided in Gibbons (1979).

[29] Reshuffling existing informants across sectors was difficult since most informants had specific technical training and were gathering information under the cover of a long-term career in specifically targeted West German companies.

Table 4: Instrumental Variables

	Log TFP				Log Output per Worker			
	Old Informants		Exit of Informants		Old Informants		Exit of Informants	
	First stage	IV results	First stage	IV results	First stage	IV results	First stage	IV results
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inflow/Y		-0.060***		-0.094***		-0.054**		-0.089**
		(0.022)		(0.030)		(0.025)		(0.035)
Patents/Y Gap	-0.672	-0.023	0.031	-0.047	-0.658	0.015	0.070	-0.002
	(0.432)	(0.021)	(0.228)	(0.044)	(0.431)	(0.025)	(0.200)	(0.045)
Log TFP Gap	0.222	-0.590***	0.594	-0.704***				
	(0.414)	(0.093)	(0.583)	(0.134)				
Log Output/Worker Gap					0.301	-0.515***	0.815*	-0.622***
					(0.301)	(0.095)	(0.394)	(0.125)
Instrument Old Informants	0.681***				0.683***			
	(0.089)				(0.091)			
Instrument Weighted Exits			-5.072***				-5.252***	
			(0.732)				(0.660)	
F-stat		58.6		48.1		56.8		63.3
Obs	240	240	192	192	240	240	192	192

Note: Sample based on 3-year intervals and overlapping observations for the period 1970 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log TFP gap between West and East Germany over the period t to t+3 in columns (1) to (4) and the change in the log output per worker gap over the period t to t+3 in columns (5) to (8). In columns (1), (2), (5) and (6), the instrument is constructed as $\left(\sum_{i\in 1970}\theta_{i,70}\lambda_{ij,70}\sum_{s=t-2}^{t} I_s\right)/Y_{jt}^E$, where $\theta_{i,70}$ is the share of the total information received in 1970 that was sent by informant i, $\lambda_{ij,70}$ is the fraction of that information pertaining to sector j, and I_s is the total inflow in period s received from sources already active in 1970. In columns (3), (4), (7) and (8), the instrument is constructed as $\left(\sum_{s=t-5}^{t-3}\sum_{i^*(s)|\bar{I}_{i^*j}\geq 20}\bar{I}_{i^*j}\right)/Y_{jt}^E$, where $\bar{I}_{i^*j}$ is the average annual inflow of information generated by informant i^* pertaining to sector j over the entire sample period, and $i^*(s)$ denotes all informants who are last observed in period s. Standard errors clustered at the sectoral level in parentheses.

that was sent by informant i, and let $\lambda_{ij,70}$ be the fraction of that information pertaining to sector j. In the spirit of a classical shift-share analysis, the instrument is then constructed as $\sum_{i\in 1970}\theta_{i,70}\lambda_{ij,70}\sum_{s=t-2}^{t} I_s$, where I_s is the total inflow in year s received from sources who were already active in 1970. In the absence of any sector-specific demand shocks for information, one would expect this inflow to be, in terms of content, related to different industries according to the initial placement of the original sources across these industries (as captured by $\lambda_{ij,70}$) and their relative effectiveness in generating information (as captured by $\theta_{i,70}$).

Columns (1) and (5) of Table 4 show the first stage results from the instrumental variable estimation for the change in the log TFP gap and the log output per worker gap, respectively. The predicted inflow of information, constructed under the assumption of constant relative productivities and sectoral distributions of the old informants, is a strong predictor of the actual information inflows, with F-statistics of 58.6 and 56.8, respectively. As reported in columns (2) and (6), the IV estimates are somewhat more negative than our baseline OLS estimates, which could indicate some degree of endogeneity, either because of the mechanical relationship described above or because espionage activities tended to be intensified in those industries in which West Germany was correctly anticipated to pull away. A Hausman test, however, shows that the differences between the OLS and IV estimates are not statistically significant.

In our second IV approach, we exploit the fact that a number of informants who used to provide a steady stream of information at some point cease to deliver any further information. This could be because these informants lost or retired from their jobs or because they were uncovered or at danger of being uncovered, in which case the Stasi would either deactivate or try to repatriate them before they could be apprehended. While we cannot ascertain the specific reasons for why individual sources discontinued their work for the Stasi, it is likely that in many cases these reasons were orthogonal to the Stasi's strategic objectives. We operationalize this intuition by instrumenting the inflow of information received between the end of period t-3 and period t with the hypothetical inflow that would have been expected to arrive at the Stasi from informants who exited in the previous (3-year) period had they continued to provide information at the same rate as before. More specifically, the instrument is constructed as $\sum_{s=t-5}^{t-3} \sum_{i^*(s)|\bar{I}_{i^*j} \geq 20} \bar{I}_{i^*j}$, where $\bar{I}_{i^*j}$ is the average annual inflow of information generated by informant i^* pertaining to sector j over the entire sample period, and $i^*(s)$ denotes all informants who are last observed in period s. Note that, when constructing the instrument, we only include relatively productive informants who previously generated more than 20 pieces of information per year since the discontinuation of their work is particularly likely to be exogenous to the Stasi's strategic objectives.[30]

As expected, columns (3) and (7) of Table 4 show that the exit of informants has a negative effect on the future inflow of information. The second-stage estimates in columns (4) and (8) are once again more negative than our baseline OLS estimates, in line with an intensification of industrial espionage in sectors in which the productivity gap to West Germany was expected to widen, but, as before, these differences are not statistically significant.[31] In the remaining sections, we therefore continue to focus on our more conservative OLS specification.

5.4 Quality of Information

In 1980, the Stasi started to systematically evaluate the quality of information received on a scale from one (very valuable) to five (no value). Over the entire time period considered, 40.1% of all pieces of information in our sample were qualitatively assessed in that way, with the vast majority receiving a value of three (66.1%), a fair amount receiving a value of two (23.8%) and only a relatively small fraction standing out with an assessment of one (2.8%).[32]

Given the large volume of information received, with more than 8,600 items per year, it is likely that relatively few pieces contained sufficiently novel and utilizable information to be able to generate noticeable productivity gains in East Germany's economy. To investigate this possibility, we estimate an extended specification in which we break down the overall measure of sector-specific espionage inflows into its quality components. Apart from the numerical quality assessments 1 to 5, we distinguish a residual category labeled "no assessment" which was explicitly entered at the time of assessment through the Stasi, and a category "missing" which denotes pieces of information that were genuinely not quality-assessed. To avoid having to discard most of the information collected before 1980, we implement an imputation algorithm in which we replace any missing quality

[30] As a robustness check, we also use alternative thresholds of 0, 10 and 50 pieces of information which leads to similar, in the case of the 50 threshold in magnitude somewhat larger, estimates. We also use a simple count of the number of exits as an alternative instrument, conditional on satisfying the imposed productivity thresholds, with again similar results.

[31] The correlation between the two instruments in our sample is 0.583, reflecting the fact that they capture different sources of variation in the inflow of information. Estimating the model using both instruments jointly yields an estimate of -0.106 (0.032), with a p-value for the overidentification test based on the Hansen J statistic of 0.458.

[32] Since 1988, SIRA distinguishes between the date of arrival of a piece of information and the date of assessment of the quality of this information. Conditional on occuring at a later date, the quality assessment took place 124 days after arrival (10^{th} percentile 68 days, 90^{th} percentile 228 days). For consistency, throughout the analysis, we use the date of arrival as the relevant date based on which we assign a piece of information to a given year.

Table 5: Quality of Information

	Δ Log TFP Gap			Δ Log Output per Worker Gap		
	Main spec	Observed quality	Imputed quality	Main spec	Observed quality	Imputed quality
	(1)	(2)	(3)	(4)	(5)	(6)
Inflow/Y	-0.047***			-0.039**		
	(0.012)			(0.015)		
Quality - No Value		-0.938	-0.189		-0.020	-0.175
		(1.649)	(0.257)		(1.862)	(0.173)
Quality - Low Value		-1.250*	-0.292***		-1.319*	-0.311***
		(0.681)	(0.069)		(0.670)	(0.077)
Quality - Average Value		0.131	-0.016		0.119	-0.006
		(0.126)	(0.033)		(0.134)	(0.041)
Quality - Valuable		-0.097	0.166		-0.036	0.169
		(0.326)	(0.117)		(0.399)	(0.166)
Quality - Very Valuable		-4.005***	-2.778**		-3.725***	-2.633**
		(0.872)	(1.072)		(1.117)	(1.132)
Quality - No Assessment		1.326***	0.702*		1.145***	0.774*
		(0.292)	(0.362)		(0.269)	(0.392)
Quality - Missing		-0.071***	-0.034		-0.056**	-0.010
		(0.022)	(0.050)		(0.026)	(0.054)
Patents/Y Gap	-0.025	0.025	0.033	0.011	0.062	0.065
	(0.022)	(0.037)	(0.046)	(0.028)	(0.050)	(0.060)
Log TFP Gap	-0.589***	-0.588***	-0.624***			
	(0.097)	(0.090)	(0.092)			
Log Output/Worker Gap				-0.515***	-0.521***	-0.570***
				(0.100)	(0.100)	(0.106)
Adj R2 (within)	0.55	0.57	0.57	0.52	0.53	0.54
Obs	240	240	240	240	240	240

Note: Sample based on 3-year intervals and overlapping observations for the period 1970 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log TFP gap between West and East Germany over the period t to t+3 in columns (1) to (3) and the change in the log output per worker gap over the period t to t+3 in columns (4) to (6). Standard errors clustered at the sectoral level in parentheses.

assessment with the rounded average quality of the informant generating the information, which we calculate from all available quality assessments for this informant over the sample period.[33] Figure B-3 in the appendix shows the distribution of quality assessments both before and after our imputation procedure, where we aggregate for better readability the "no assessment" and "missing" categories into a "missing" category, quality values 1 and 2 into a "high" category, quality value 3 into a "medium" category, and quality values 4 and 5 into a "low" category. Overall, the coverage of quality information improves substantially, from 40.1% of all pieces of information in our sample to 81.4%, distributed relatively evenly over the period considered.

Table 5 shows the impact of the different quality types of information on the log TFP gap

[33] In an alternative specification, we regress the observed quality assessments on a full set of informant fixed effects and a cubic function of experience, calculated as the accumulated years since an informant first appeared in the SIRA database, and predict an informant-specific experience-adjusted quality measure for each piece of information with missing quality assessment. This imputed measure allows for the fact that informants may get better at providing high quality information, either through learning or improved access to relevant material over time, for example due to career progression. Interestingly, the estimated experience quality profile is almost flat so that the results based on these adjusted quality measures are very similar to the ones presented in Table 5.

(left panel) and the log output per worker gap (right panel) between West and East Germany, where columns (1) and (3) once more restate our baseline results for comparison. The regressions underlying columns (2) and (4) are based on the observed information in the data, with little quality input prior to the 1980s and consequently a large fraction of observations with missing quality information. In spite of this lack of information, there is already some indication that the effect of the highest quality information (-4.005 and -3.725) far exceeds that of all other groups, even though the relationship between quality and impact on productivity growth is not monotonic as expected, with the low value group also showing relatively large effects. Columns (3) and (6), which are based on the sample with imputed quality information, confirm these results, showing that the largest impact of industrial espionage on the productivity gap between West and East Germany is due to the inflow of high quality information, with point estimates of -2.778 (1.072) for the log TFP gap and -2.633 (1.132) for the log output per worker gap. In contrast, the parameters for the inflows of low and average quality information are much smaller in magnitude and, in the case of the large group with average quality value, statistically not significant. These findings suggest that a large fraction of the information received by the Stasi was dispensable and that the positive effects on East German productivity growth were primarily driven by relatively few select pieces of information.

5.5 Channels

In Table 6, we allow for West and East German lagged TFP and patents per output to appear separately in the regression, essentially relaxing the restrictions on the equality of some of the coefficients underlying equation 3. We also use the two countries' respective TFP growth rates as separate outcomes instead of solely looking at the growth in their log TFP gap. We would expect industrial espionage to have an impact on East German productivity growth but no impact on West German productivity growth. Note that this prediction is rather specific to the historical context considered and a consequence of the relatively strict separation of the markets in which West and East German firms operated during the Cold War. In an internationally competitive market, industrial espionage may lower productivity growth in the targeted country by increasing product market competition.

Comparing columns (1) and (2), the inclusion of separate East and West German TFP levels and patent intensities has qualitatively little bearing on our main parameter of interest, suggesting that the assumption of equal coefficients η_{it}^E and η_{it}^W and θ_{it}^E and θ_{it}^W, respectively, in equation (3) is rather innocuous.[34] Quantitatively, the higher flexibility of the specification in column (2) leads to a around 1/3 smaller estimated effect of the impact of industrial espionage on changes in the log TFP gap (from -0.047 to -0.032). Importantly, as shown in column (4), what drives the relationship between changes in the log TFP gap and East German industrial espionage is the latter's positive and significant effect on East German TFP growth. The effect on West German TFP growth, in contrast, is close to zero and statistically not significant as shown in column (3).

The last two columns of Table 6 report results from a specification in which the dependent variable is the future patent intensity in West and East Germany. While industrial espionage has

[34]Note that the sign of the coefficient on West German patent applications is the opposite of what one would expect if patent applications were a good proxy for productivity-enhancing R&D investments. However, as before, if one excludes the initial log TFP measures from the specification, the coefficients of West and East German patent intensities both have the expected sign, 0.055 (0.075) and -0.087 (0.114), respectively.

Table 6: Channels

	Log TFP				Patenting	
	FRG/GDR		FRG	GDR	FRG	GDR
	(1)	(2)	(3)	(4)	(5)	(6)
Inflow/Y	-0.047***	-0.032***	-0.007	0.025**	-0.001	-0.101**
	(0.012)	(0.009)	(0.009)	(0.009)	(0.007)	(0.041)
Patents/Y Gap	-0.025					
	(0.022)					
Log TFP Gap	-0.589***					
	(0.097)					
GDR Patents/Y		-0.089	-0.033	0.056	0.034	0.103
		(0.057)	(0.063)	(0.044)	(0.027)	(0.062)
FRG Patents/Y		-0.138**	-0.081	0.056	0.847***	-0.217***
		(0.063)	(0.074)	(0.077)	(0.037)	(0.069)
GDR Log TFP		0.593***	0.094	-0.498***	-0.075	0.018
		(0.098)	(0.099)	(0.089)	(0.046)	(0.139)
FRG Log TFP		-0.651***	-0.406***	0.245	0.056	0.099
		(0.101)	(0.136)	(0.153)	(0.062)	(0.232)
P-value WB	0.002	0.012	0.508	0.052	0.878	0.048
Beta	-0.952	-0.640	-0.182	0.685	-0.006	-0.297
Adj R2 (within)	0.55	0.56	0.67	0.46	0.99	0.97
Obs	240	240	240	240	240	239

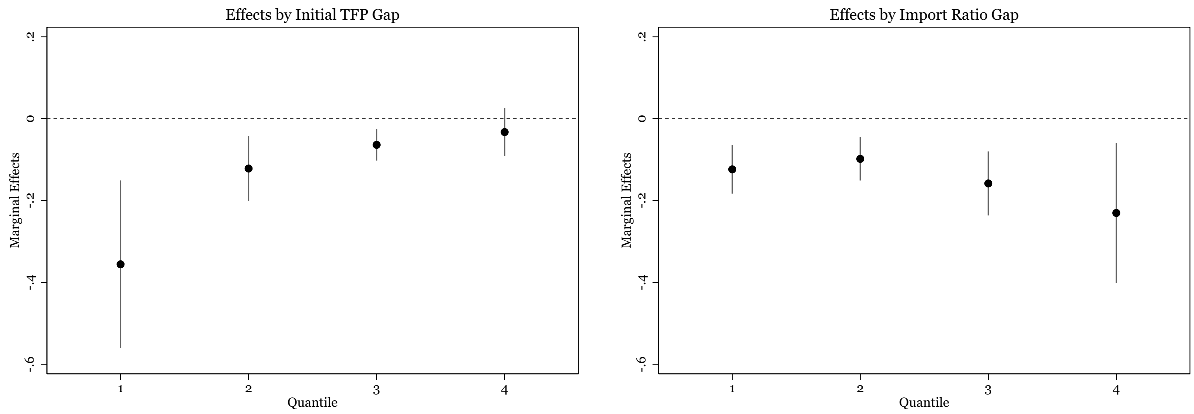
Note: Sample based on 3-year intervals and overlapping observations for the period 1970 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log TFP gap between West and East Germany over the period t and t+3 in columns (1) and (2), the change in log TFP between t and t+3 in West and East Germany, respectively, in columns (3) and (4), and the number of patent applications between t and t+3 per million euros of output in West and East Germany, respectively, in columns (5) and (6). Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values, relating to the Inflow/Y estimate, from (Cameron et al., 2008) clustered wild bootstraps using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

no effect on future patenting in West Germany (column (5)), it significantly reduces patenting in East Germany (column (6)). This finding is consistent with reports in Macrakis (2008) of industrial espionage essentially crowding out overt R&D in East Germany.

5.6 Heterogeneity

In this section, we illustrate heterogeneous effects along two important dimensions, the initial TFP gap and the imports gap. First, we relate to the literature that studies how R&D affects productivity growth depending on a country's distance to the technological frontier (Griffith et al., 2004; Cameron et al., 2005; Acemoglu et al., 2006) by allowing the effects of industrial espionage to vary by the initial West-to-East log TFP gap. Our starting point here is the specification from column (6) in Table 3 which also includes the imports gap between West and East Germany. Here, we add interactions for all continuous variables (the inflow, patents, and imports variables) with dummy variables for the quartiles in the initial TFP gap and allow the four dummy variables to substitute for the linear TFP gap term. The left panel of figure 5 depicts the results. The estimates for the first and second quartiles are negative and statistically different from zero (-0.368 and -0.125, respectively). These two are also jointly statistically different from those for the

Figure 5: Heterogenous Effects of Industrial Espionage



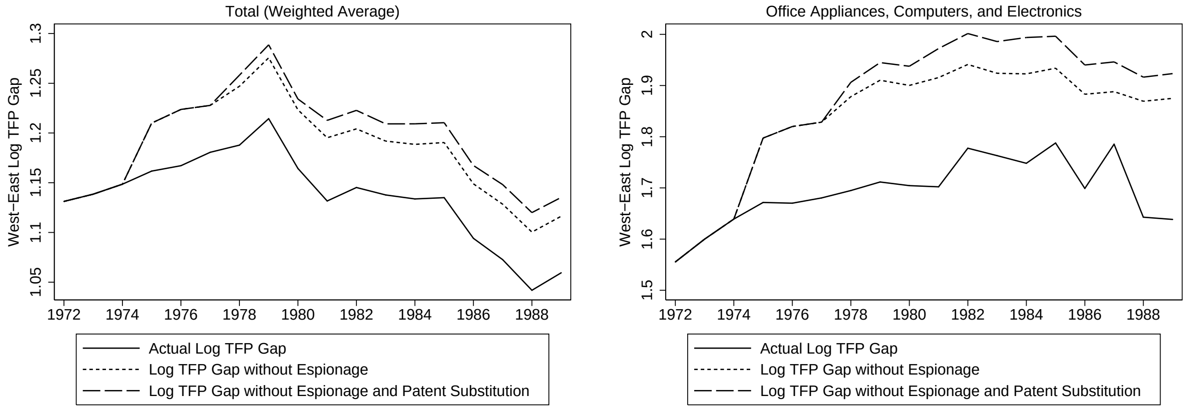
Note: The graphs plot the marginal interaction effects from equation (3) with the modification that the inflow of information variable is interacted with the quartiles of the initial log TFP gap (left panel) and the import intensity gap (right panel) in period t. Confidence intervals are constructed from standard errors clustered at the sectoral level.

third and fourth quartiles (with a p-value of 0.004), which exhibit estimates of -0.061 and -0.030, and where only the former estimate is statistically different from zero. These findings show that industrial espionage was more effective in narrowing the productivity gap in industries where East Germany was technologically relatively close to West Germany. This could be because these were the circumstances where East German researchers and engineers were most likely to succeed in implementing the new technological knowledge acquired from the West in their own production process. This result contrasts with the past findings of the returns to *standard* forms of R&D which suggests a larger return in industries further away from the frontier (Griffith et al., 2004).

As a second relevant dimension of heterogeneity, we examine the effect of industrial espionage along the measure of relative import barriers by, in addition to the previous model, further interacting our inflow measure (as well as the continuous variables and TFP gap dummies) with different quartiles of the West-to-East import intensity gap (where we again substitute the linear imports gap variable and its interactions with the initial TFP gap with the four quartiles of the imports gap). If industrial espionage served as a form of technology transfer when regular channels such as trade were unavailable, we would expect larger-in-magnitude estimates in cases where, all else equal, the gap between West and East German import intensities were larger. The right panel of figure 5 illustrates that while the average marginal effects for the first and second quartiles of -0.125 and -0.101 respectively are similar in terms of magnitude, the effects for the third and fourth quartiles are more pronounced with point estimates of -0.161 and -0.231, respectively. In terms of adjacent pairwise tests of differences, only that between the second and the third quartile reveals a significant difference, and then only at the ten percent level.[35] Nonetheless, the average estimate above the median is nearly twice that of the average estimate below the median and a test of the difference between the first and second on the one hand, and the third and fourth on the other, has a p-value of 0.114. This suggests that industrial espionage was particularly useful in those sectors where East Germany's ability to import products from abroad was most restricted. It is thus tempting to interpret this last result as East Germany's industrial espionage in some industrial sectors being a natural response to Western countries' attempts at stifling technology transfer in these very sectors.

[35]The p-values are 0.230 (quartiles 1 and 2), 0.052 (quartiles 2 and 3), and 0.322 (quartiles 3 and 4) respectively.

Figure 6: Counterfactual Simulations



Note: The graphs plot the counterfactual gap in log TFP between West and East Germany for manufacturing as a whole (left panel) and for the *Office Appliances, Computers and Electronics* sector (right panel). To aggregate across all sectors, we take the employment-weighted average of each sector's actual and counterfactual log TFP time series. The counterfactual simulations are based on the empirical results reported in columns (4) and (6) of Table 6 for the full model without espionage and on column (4) only for the model without espionage and patenting substitution, holding patenting constant.

5.7 Counterfactual Simulation

Our empirical results thus far show that the Stasi's industrial espionage fostered East Germany's productivity growth while at the same time crowding out its overt R&D activities. Based on our estimates, we are able to simulate how TFP in East Germany would have evolved in the absence of industrial espionage. For this purpose, we set S^E_{jt}/Y^E_{jt} to zero for all industries and time periods and, starting with the first three-year period 1970-1972, forward predict counterfactual productivity profiles for East Germany under two scenarios. In the first scenario, we assume that East Germany does not respond to the lack of knowledge transfer through industrial espionage by increasing its own patenting efforts, thus maintaining the actual patenting levels observed in the data. As suggested by our main findings, in the absence of industrial espionage, TFP growth in East Germany would be lower although part of this effect is counteracted by the fact that lower future levels of TFP give rise to a positive effect on subsequent TFP growth by increasing the distance to the productivity frontier (as indicated by the negative coefficient of -0.498 on the GDR Log TFP regressor in column (4) of Table 6). In the second scenario, we internalize the crowding out effect of industrial espionage on future patenting as suggested by the negative coefficient of -0.101 on the information inflow regressor in column (6) of Table 6. Without industrial espionage, East German patenting would thus increase which partly compensates the direct negative effect of industrial espionage on productivity growth (according to the positive coefficient of 0.056 on the GDR Patents/Y regressor in column (4) of Table 6). Finally, the increase in patenting would also have a secondary positive effect on TFP growth by fostering future patenting as suggested by the positive coefficient of 0.103 on the GDR Patents/Y regressor in column (6) of Table 6.[36]

The solid line in the left panel of figure 6 displays the actual log TFP gap between West and East Germany between 1972 and 1989, which we construct as the difference in the employment-weighted average of the 16 sector-specific log TFP time series in both countries. The productivity gap initially increased from 1.13 log points (210%) in 1972 to 1.21 log points (235%) in 1979

[36]While the effect of changes in the level of East German TFP on future patenting is small with a coefficient of 0.018 (column (6), Table 6), we still use the new simulated TFP levels in our predictions of future patenting to be consistent with our treatment in the TFP growth specification.

before then decreasing to 1.06 log points (189%) in 1989. Allowing East Germany to react to the absence of industrial espionage by increasing its own patenting (scenario 2), the counterfactual productivity gap depicted by the short-dashed line reveals that the log TFP gap between West and East Germany would have been about 0.056 log points (5.8%) bigger over the time period, with relatively little variation over time. Assuming that East Germany's patenting does not respond to the absence of industrial espionage (scenario 1) would lead to a further widening of the log TFP gap by another 0.019 log points on average.[37] Overall, industrial espionage thus played a noticeable but quantitatively modest role in bringing East Germany's productivity in manufacturing closer to its West German counterpart.

The right panel of figure 6 shows the corresponding actual and counterfactual log TFP gaps for the *Office Appliances, Computers and Electronics* sector, by far the most targeted sector by East Germany's industrial espionage (see figure 2). Contrary to the overall development in manufacturing, the actual log TFP gap between West and East Germany in this sector widened over time, from 1.56 log points (376%) in 1972 to 1.64 log points (416%) in 1989. In the absence of industrial espionage, this divergence would have been a lot more pronounced, reaching 1.87 log points (549%) with full patent substitution and 1.92 log points (582%) without any East German patent response in 1989. Evidently, in this fast-changing sector, while not sufficient to reduce the technological gap with West Germany, industrial espionage at least helped East Germany avoid falling significantly further behind.

The counterfactual simulations show that industrial espionage benefited the East German economy by accelerating productivity growth. However, they do not speak to the question of whether the resources committed were efficiently used. While a full cost-benefit analysis is beyond the scope of this paper, we can use existing estimates to get an idea about this important question. As it happens, the HVA itself produced annual estimates of the economic benefits attributable to the utilization of espionage information. According to the long-term head of the HVA's Sector for Science and Technology (SWT), Horst Vogel, these benefits amounted to around 300 million East German *Mark* in the 1970s and increased substantially to more than 1.5 billion East German *Mark* at the end of the 1980s (Vogel, 2008). In contrast, the last head of the HVA, Werner Großmann, stated in front of a parliamentary committee that the yearly budget for operational purposes of the HVA at the end of the 1980s amounted to around 17.5 million East German *Mark* and 13.5 million *Deutsche Mark* (Deutscher Bundestag, 1998), which would suggest a very high return on the investment in espionage activities.

6 Concluding Remarks

This paper represents the first ever systematic evaluation of the economic returns to industrial espionage. The Stasi archives, and their rich information on industrial espionage, combined with the comprehensive industrial data available provide a unique setting for studying this question. Key to understanding the results, however, is the historical and political context considered. This relates both to the external setting faced by East Germany during the Cold War and the appropriateness of East German institutions for secrecy.

[37] Note that due to the 3-year intervals employed in our main specification and the lag structure between dependent and independent variables, the first time period in which actual and counterfactual TFP in East Germany can diverge is 1975, and the first time period in which the predicted increase in patenting can generate an additional effect is 1978.

For the East German economy, the immediate returns to industrial espionage were substantial. But perhaps just as noteworthy is the crowding out of standard forms of R&D. The Western embargoes on the East, coupled with an abundance of intelligence sources in strategically important locations, likely lowered the cost of industrial espionage relative to R&D. And while this may have proved productive in catching up with its capitalist neighbors under a communist regime where investments in secrecy processes likely exhibited economies of scale, these processes may have lost much of their value once Germany unified. At that point, when Western firms would have had decades of experience in developing the skills for conducting productive R&D, Eastern firms would most likely have lost their primary sources of technological know-how. An interesting question for future research is therefore to what degree the espionage-related capabilities of the East German economy bore some responsibility for its post-unification performance.

Arguably, few contemporary intelligence agencies have been able to make industrial espionage as effective a tool – against externally-imposed technology embargoes – as the Stasi did during the Cold War. Still, the topic of industrial espionage is as relevant today as it was at the height of the Cold War. Methods may have changed to accommodate new technologies for spying, but governments remain interested in technology transfer outside of the regular channels. Moreover, several countries face restrictions on technology transfer, either through outright sanctions, like Iran and North Korea, or as a result of intellectual property rights protection as in China or India. As such, even though the success with which East Germany penetrated West German commercial and scientific institutions may be unique, the value of industrial espionage as a form of illicit technology transfer is much more ubiquitous.

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Appendix A Tables

Table A-1: Keyword Allocation

Rank	Original Keyword	English Translation	Freq.	Sector 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	Other Sector	Unclassified
1.	Objekt	Object	19,786																		✓
2.	Militaertechnik	Military Technology	12,471																	✓	
3.	Elektronik	Electronics	11,807													✓					
4.	Elektrotechnik	Electrical Engineering	11,307													✓					
5.	S	-	10,968																		✓
6.	Austausch_Ausgeschlossen	Exchange Precluded	10,419																		✓
7.	Mikroelektronik	Microelectronics	9,666													✓					
8.	Software	Software	9,645													✓					
9.	Rechentechnik	Computer Science	9,046													✓					
10.	Nachrichtentechnik	Communications Engineering	7,868					✓								✓					
11.	Chemie	Chemistry	7,519								✓										
12.	R	-	5,734																		✓
13.	Anwendung	Application	5,331																		✓
14.	NA	-	5,312																		✓
15.	Hardware	Hardware	4,326													✓					
16.	Technologie	Technology	3,734																		✓
17.	MT	-	3,582																		✓
18.	EDV	Electronic Data Processing	3,416													✓					
19.	Kleinrechner	Microcomputer	3,343													✓					
20.	Programm	Program	3,335													✓					
21.	Beschreibung	Description	3,166																		✓
22.	Umweltschutz	Environment Protection	3,085																		✓
23.	Datentechnik	Data Processing Technology	3,060													✓					
24.	Muster	Pattern	3,034		✓				✓												
25.	EDVA	Electronic Data Processing Facility	3,018													✓					
26.	Metallurgie	Metallurgy	2,992											✓							
27.	Optik	Optics	2,922													✓					
28.	Personalcomputer	Personal Computer	2,722													✓					
29.	IBM	IBM	2,635													✓					
30.	Kernkraftwerk	Nuclear Power Plant	2,584																✓		
	⋮	⋮	⋮																		
1991.	Schwermetall	Heavy Metal	57											✓							
1992.	Schwingquarz	Oscillating Crystal	57													✓					
1993.	Soman	Soman	57								✓									✓	
1994.	Temperaturverteilung	Temperature Distribution	57																✓		
1995.	Turbinenschaufel	Turbine Blade	57												✓						
1996.	Umkehrosmose	Reverse Osmosis	57	✓															✓	✓	
1997.	Verformung	Deformation	57																		✓
1998.	Verkehr	Traffic	57																	✓	
1999.	Waermedaemmung	Heat Insulation	57																	✓	
2000.	Wolfram	Wolfram	57								✓										

Note: This tables shows the 2,000 most common keywords in TDB11 and their sectoral allocation. List of sectors: 1. Food and Tobacco, 2. Textiles and Clothing, 3. Leather Products, 4. Woodworking, 5. Paper, Printing, and Publishing, 6. Furniture, Jewelry, and Music Instruments, 7. Coking and Petroleum, 8. Chemicals, 9. Rubber and Plastics, 10. Glass, Ceramics, and other non-Metalic Minerals, 11. Metalworking, 12. Machine Building, 13. Office Appliances, Computers, and Electronics, 14. Automobiles, 15. Mining, 16. Utilities–Energy and Water Supply.

Table A-2: Top 20 Informants, 1968 - 1989

Code Name	Registration	Pieces of Information	Reliability	First Active Year	Last Active Year
(1)	(2)	(3)	(4)	(5)	(6)
FROEBEL	XV/6603/80	5,344	A	1982	1989
SEEMANN	XV/2768/76	4,963	A	1970	1989
KOREN	XV/1967/64	4,257	A	1973	1987
IRMGARD KRUEGER	XV/436/70	3,287	A	1970	1989
ZENTRUM	XV/78/71	2,686	A	1969	1989
DR. GROSZ		2,630	A	1969	1974
RING		2,485	A	1968	1978
HERZOG	XV/4483/86	2,328	A	1974	1989
LORENZ	XV/4070/70	1,933	A	1971	1989
SCHNEIDER	XV/3074/78	1,902	B	1969	1989
JUERGEN		1,640	A	1969	1989
OPTIK		1,472	A	1969	1989
HARTMANN		1,326	A	1969	1987
PICHLER	XV/6412/82	1,157	A	1982	1989
ALFRED	XIV/14/69	1,139	A	1970	1989
ERICH	XV/47/68	1,070	A	1971	1988
BERT	XV/3478/65	1,038	A	1977	1989
WEBER		979	A	1969	1988
JACK	XV/2001/73	944	A	1973	1987
PETER	XII/2399/71	908	A	1969	1989

Note: Reliability is measured by the mode of the recorded assessments. An "A" denotes "reliable" (*zuverlässig*), a "B" denotes "trustworthy" (*vertrauenswürdig*), a "C" denotes "not checked" (*nicht überprüft*), a "D" denotes "questionable" (*fragwürdig*), and an "E" denotes "double agent" (*Doppelagent*). Only values A, B and C appear in the data.
*, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A-3: Industrial Espionage and Productivity - Non-overlapping Observations

	Log TFP			Log Output per Worker		
	Baseline spec	Patents gap	Lagged gap	Baseline spec	Patents gap	Lagged gap
	(1)	(2)	(3)	(4)	(5)	(6)
Inflow/Y	-0.036*	-0.046**	-0.048***	-0.028	-0.041*	-0.042*
	(0.020)	(0.020)	(0.016)	(0.019)	(0.020)	(0.020)
Patents/Y Gap		0.105***	0.005		0.136***	0.044
		(0.030)	(0.033)		(0.032)	(0.042)
Log TFP Gap			-0.567***			
			(0.134)			
Log Output/Worker Gap						-0.478***
						(0.139)
P-value WB	0.036	0.030	0.004	0.076	0.046	0.094
Beta	-0.713	-0.914	-0.959	-0.532	-0.784	-0.807
Adj R2 (within)	0.34	0.39	0.59	0.32	0.41	0.54
Obs	80	80	80	80	80	80

Note: Sample based on 3-year intervals and non-overlapping observations for the years 1973, 1976, 1979, 1982, and 1985. All regressions include time- and industry-specific fixed effects. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values, relating to the Inflow/Y estimate, from (Cameron et al., 2008) clustered wild bootstraps using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

Table A-4: Industrial Espionage and Productivity - Yearly Intervals

	Log TFP			Log Output per Worker		
	Baseline spec	Patents gap	Lagged gap	Baseline spec	Patents gap	Lagged gap
	(1)	(2)	(3)	(4)	(5)	(6)
Inflow/Y	-0.041***	-0.040***	-0.029***	-0.043***	-0.042***	-0.030**
	(0.008)	(0.007)	(0.009)	(0.009)	(0.008)	(0.011)
Patents/Y Gap		0.067*	-0.071		0.094***	-0.036
		(0.033)	(0.046)		(0.032)	(0.058)
Log TFP Gap			-0.261***			
			(0.040)			
Log Output/Worker Gap						-0.227***
						(0.043)
P-value WB	0.026	0.008	0.302	0.038	0.042	0.548
Beta	-0.475	-0.464	-0.337	-0.490	-0.475	-0.344
Adj R2 (within)	0.11	0.11	0.25	0.13	0.14	0.24
Obs	304	304	304	304	304	304

Note: Sample based on yearly intervals for the period 1970 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log TFP gap between West and East Germany over the period t to t+1 in columns (1) to (3) and the change in the log output per worker gap over the period t to t+1 in columns (4) to (6). Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values, relating to the Inflow/Y estimate, from (Cameron et al., 2008) clustered wild bootstraps using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

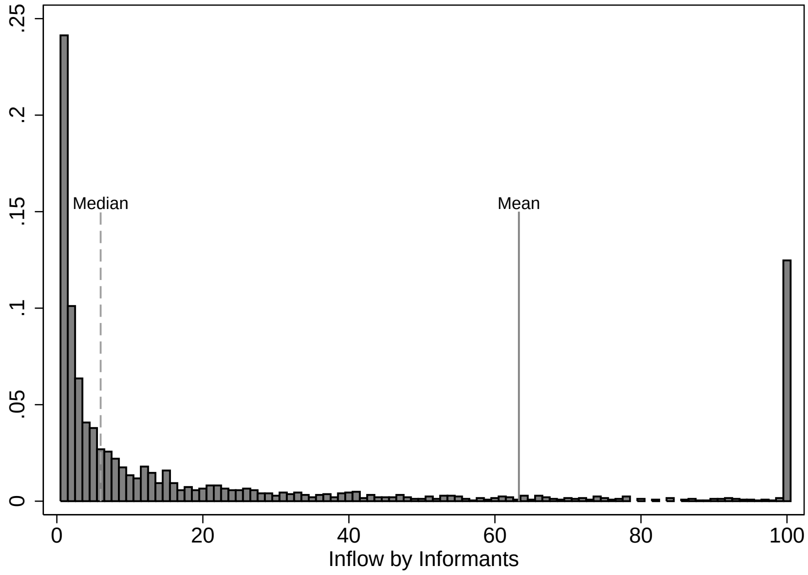
Table A-5: Robustness - Log Output per Worker

	Main spec	Weighted by output	No weights	No IT	Sector trends	Trade gap	Trade & High-tech	Capital/Labor gaps
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inflow/Y	-0.039**	-0.069*	-0.036**	-0.025	-0.047***	-0.037**	-0.039	-0.044***
	(0.015)	(0.034)	(0.015)	(0.022)	(0.012)	(0.016)	(0.031)	(0.013)
Patents/Y Gap	0.011	0.022	0.030	0.053	0.072	0.017	0.043	0.001
	(0.028)	(0.051)	(0.035)	(0.062)	(0.077)	(0.029)	(0.101)	(0.023)
Log Output/Worker Gap	-0.515***	-0.730***	-0.539***	-0.548***	-1.200***	-0.521***	-0.494***	-0.492***
	(0.100)	(0.181)	(0.100)	(0.109)	(0.107)	(0.102)	(0.150)	(0.095)
Imports/Y Gap						-0.002	-0.003	
						(0.002)	(0.002)	
Capital/Y Gap								0.027***
								(0.007)
Labor/Y Gap								-0.152
								(0.103)
P-value WB	0.104	0.108	0.126	0.252	0.002	0.102	0.192	0.018
Beta	-0.738	-0.697	-0.503	-0.235	-0.906	-0.708	-0.757	-0.834
Obs	240	240	240	225	240	234	234	240

Note: Sample based on 3-year intervals and overlapping observations for the period 1969 to 1989. All regressions include time- and industry-specific fixed effects. The dependent variable is the change in the log output per worker gap between West and East Germany over the period t to t+3. Column (1) restates our main results from column (6) of Table 2. In column (2), observations are weighted by the average sector-specific gross value added. In column (3), observations are unweighted. In column (4), we exclude the IT sector from the estimation sample. In column (5), we include sector-specific linear time trends in the specification. In column (6), we include the gap in the sector-specific import/output ratio between West and East Germany as an additional control variable. In column (7), we additionally include interactions of sector dummies with the difference between West and East Germany in a) the share of high tech imports in total imports and b) the share of high tech imports imported from CoCom countries. In column (8), we include the gap in the capital/output and employment/output ratios between West and East Germany as additional control variables. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values, relating to the Inflow/Y estimate, from (Cameron et al., 2008) clustered wild bootstraps using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

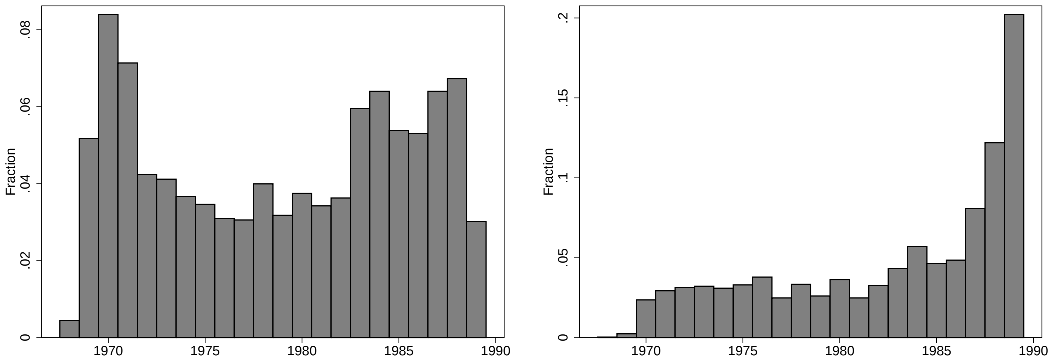
Appendix B Figures

Figure B-1: Inflow Distribution Across Informants



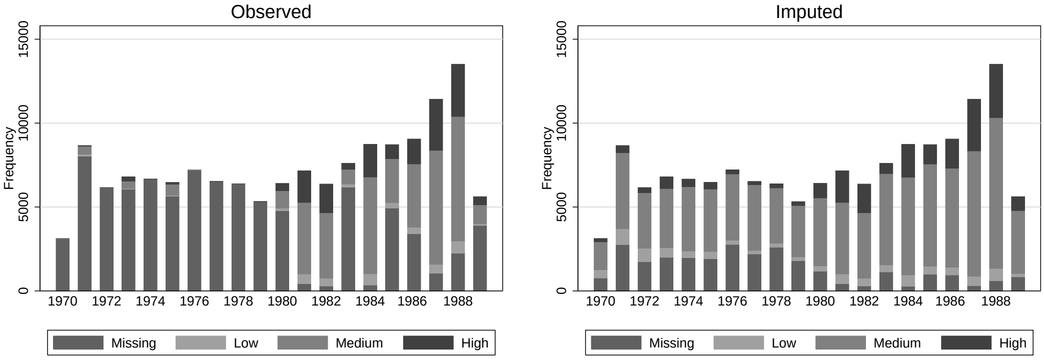
Note: The figure shows the distribution of the total number of pieces of information received from individual informants. Observations are censored at a value of 100.

Figure B-2: First and Last Active Year



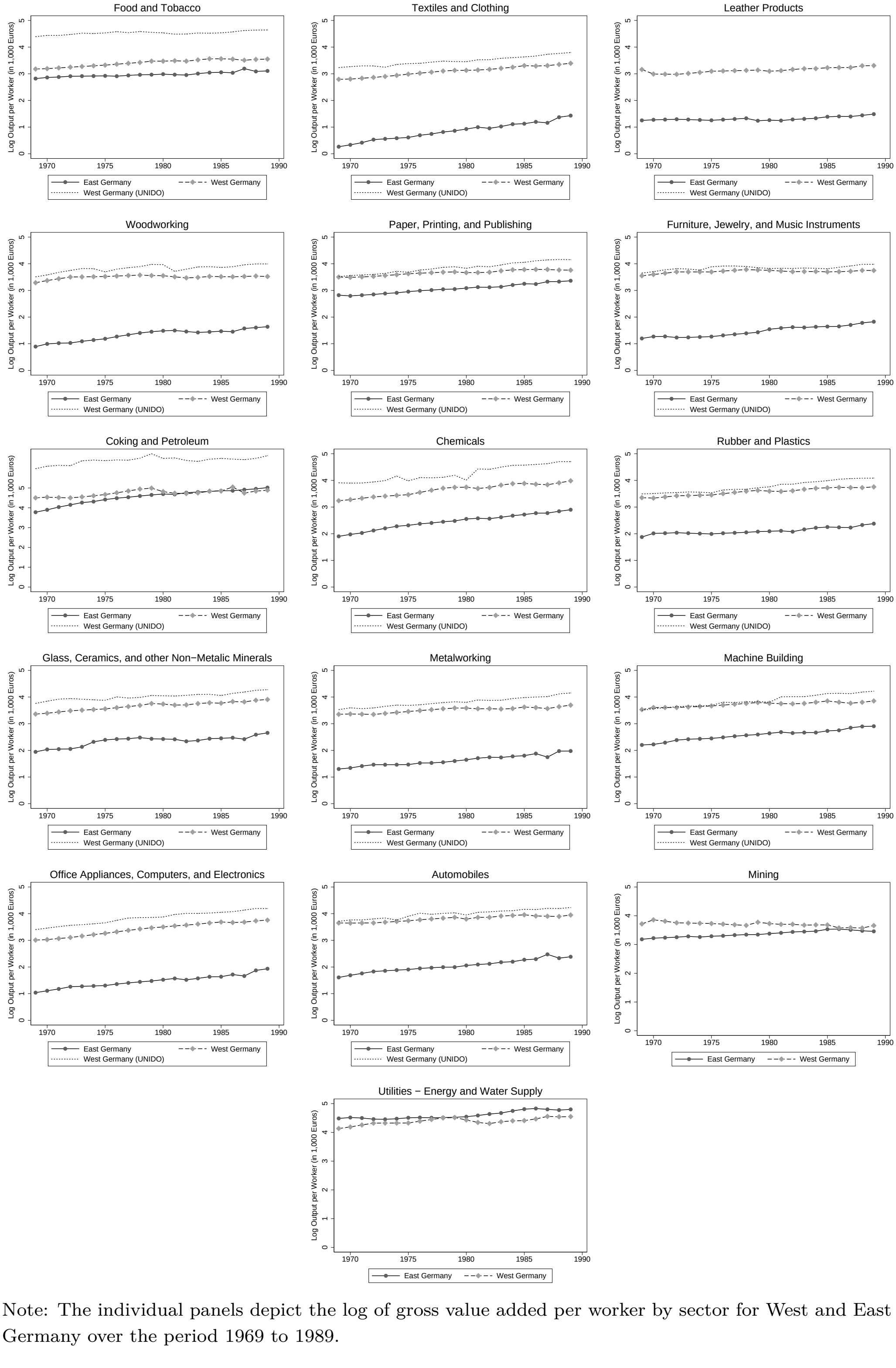
Note: The figure shows the distributions of the first (left panel) and last year (right panel) in which individual informants are observed in the data.

FIGURE B-3: DISTRIBUTION OF QUALITY ASSESSMENTS



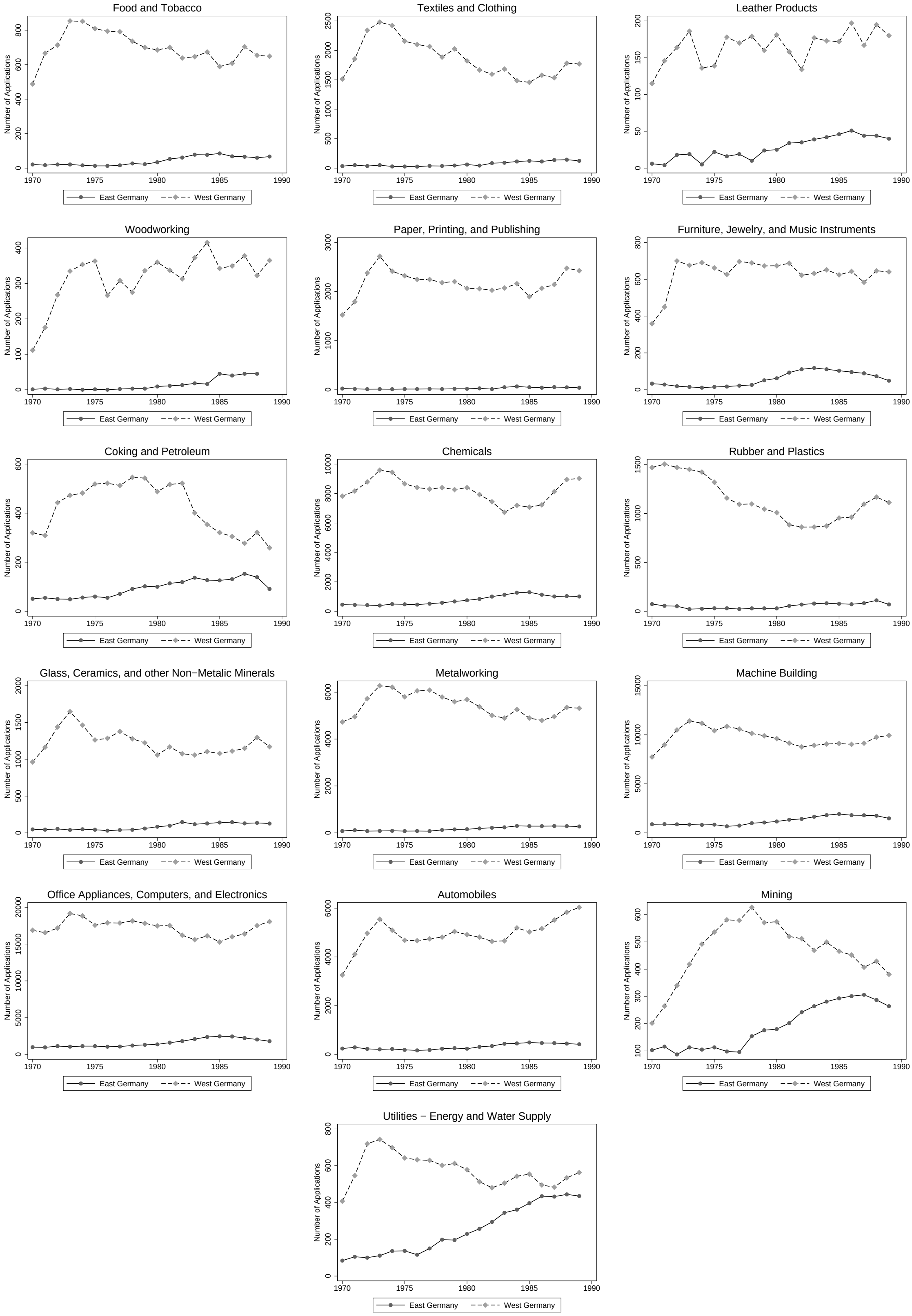
Note: The figure shows the distribution of quality assessments by year, both as observed in the data (left panel) and after imputing missing observations using the average quality assessments of the informant generating the information (right panel). "Low" comprises assessments of 0 to 2, "Medium" assessments of 3, and "High" comprises assessments of 4 to 5.

FIGURE B-4: LOG GVA PER WORKER BY SECTOR



Note: The individual panels depict the log of gross value added per worker by sector for West and East Germany over the period 1969 to 1989.

Figure B-5: Patent Applications by Sector



Note: The individual panels depict the number of patent applications by sector for West and East Germany over the period 1970 to 1989.