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 between West and East Germany. Based on a data set that comprises the entire flow of information provided by East German spies over the period 1969-1989, 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 particularly strong in sectors that are closer to the West German technology frontier and in which constraints to the import of goods and services are particularly pronounced. Finally, our findings suggest 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

In the 6th century AD, two Nestorian monks successfully smuggled silkworm eggs, possibly hidden in bamboo canes, into the Byzantine Empire from China. 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 (Laiou, 2002; Norwich, 1990). 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).

In the period following the end of the Second World War, industrial espionage again became key to state development as the Communist bloc aimed to soak up much of the West's technological advantage through covert means. Via agents in the West, technologies underlying 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 has received little attention in economics. Undoubtedly, the secret nature of the practice obscures its economic significance which according to one US government report amounts to "billions of dollars per year, constituting a serious national security concern."[2]

In this paper, we analyze the relationship between state-sponsored industrial espionage and technological progress. The centerpiece of our empirical analysis is a data set that comprises the entire recorded stock of information East German foreign intelligence sources gathered and forwarded to the responsible East German Ministry for State Security (MfS, commonly referred to as the Stasi)during the period 1968-1989. This unique data base, 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 MfS, the code names of their sources, a list of keywords describing each item's content, and, for a subset, a numerical quality assessment. To operationalize this wealth of data, we use the keywords provided to attribute each piece of information to one of 16 industry sectors. We then merge the obtained information flows to

[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

industry-specific 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 1969 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 West and East 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 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 0.9 standard deviation narrowing of the TFP gap between West and East Germany. These results are robust to a number of controls, specifications, and the existence of alternative channels of technology transfer. We also employ an instrumental variable strategy in which we utilize only information accruing from informers who already existed at the beginning of the sample period. In doing so, we avoid endogeneity resulting from the selective placement of new agents based on the preferences of the East German government. We further show evidence that industrial espionage in East Germany tended to crowd out investments in regular, overt, R&D.

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 important strands of the economics literature. In economic history, the role of secrecy has been investigated with a focus on its adverse consequences. For example, Harrison and Zaksauskiene (2016), using Hoover Archives data on the Soviet Lithuania KGB, find evidence of adverse selection as a result of KGB counter-intelligence activities, resulting in a "systematic exclusion of talented, potentially disloyal citizens from selection for management". Secrecy can also lead to substantial transaction costs, as Harrison (2013) shows following new secrecy regulation enforced by Stalin after 1949 which prevented Gulag prisons from disclosing their locations. Furthermore, secret information often requires duplicated systems of accounting for secrets, increasing administrative burdens (Harrison, 2008). Finally, Lichter et al. (2015), exploiting discontinuities at state borders in Germany, 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.

Our work also relates to the existing empirical literature investigating the role of R&D in explaining productivity growth (Griliches, 1980; Griliches and Lichtenberg, 1984; Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Coe and Helpman, 1995; Eaton and Kortum, 1999). The literature tends to find relatively large estimates of the return to R&D, but both the empirical as well as the theoretical literature has been silent on the role of industrial espionage. Recently, a US Government report to Congress stated even though "[e]conomic espionage inflicts costs on companies that range from loss of unique intellectual property to outlays for remediation"..."no reliable estimates of the monetary value of these costs exist".[3] Undoubtedly, the clandestine nature of industrial espionage is to blame for this knowledge gap, and so our study is the first to break this seal of secrecy.

[3] "Foreign Spies Stealing US Economic Secrets in Cyberspace, Report to Congress on Foreign Economic Collection and Industrial Espionage, 2009-2011", October 2011, Office of the National Counterintelligence Executive, http://www.ncsc.gov/publications/reports/fecie_all/Foreign_Economic_Collection_2011.pdf

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

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), in which Western countries agreed 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, events during the 1950s in East Germany resulted in both substantial intelligence reform and an unprecedented chance to place informers in West Germany. While the workers' uprising in 1953 and a serious defection led the foreign intelligence agency to be brought in under the MfS, the significant migration of East Germans to West Germany up until the construction of the Berlin Wall in 1961 allowed the MfS to expand its intelligence network in the West, thus setting the foundation for a comprehensive infiltration of key centers of power in the Federal Republic of Germany. The Stasi's infiltration of West German political, military, and intelligence spheres is today widely known, as is its internal repressive nature (Koehler, 2000). The extent of Stasi's industrial espionage has been much less covered, with one exception being the work of Macrakis (2008), who through archival research provides a historical overview combined with several examples, 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 (*Hauptverwaltung Aufklärung*, HVA), led by the now legendary 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 spies. 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 subsequently a lot of effort was 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).

Illicit technology transfer from West to East was a contentious issue at the time and especially the US was becoming increasingly concerned over technology leaks to the Soviet bloc. 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 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 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 and earned half a million marks in ten years from his career as a Stasi informant.

Meanwhile, Western intelligence activities in East Germany remained by most accounts behind that 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, MfS officials have often boasted of the degree to which the Western intelligence sources in East Germany were, in fact, double agents, with one MfS general putting that number at around 90 percent (Schmidt-Eenboom, 2009). It is therefore conceivable that, even in the instances where Western espionage activities were successful in East Germany, they were unlikely to have been in the economic sector, and even more unlikely to be related to substantive technology transfer 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 MfS 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".[4] According to Macrakis (2008), internal estimates by the MfS suggested that its industrial espionage had saved the East German industry about 75 million marks in R&D costs.

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 versus open R&D may act as substitutes.

3 Data

The empirical analysis in this paper relies on a number of different data sources, two of which are 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*).[5] In addition, we use data recently published by Heske (2013) on inputs, output and productivity in different economic sectors in both West and East Germany. In the following, we will describe these two main data sources in 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*, TDB11), which comprises records about each piece of information that East German spies passed on to the Stasi between 1968 and 1989. Overall, a total of 189,725 pieces of information were received over this time period, with an annual average inflow of 8,624 items.[6] Figure 1 displays the distribution of this flow of information over time. While the annual inflow was on a declining trend since 1971, this pattern reversed thereafter, with a record 15,658 pieces of information received in 1988, the last year before the collapse of the Berlin wall.

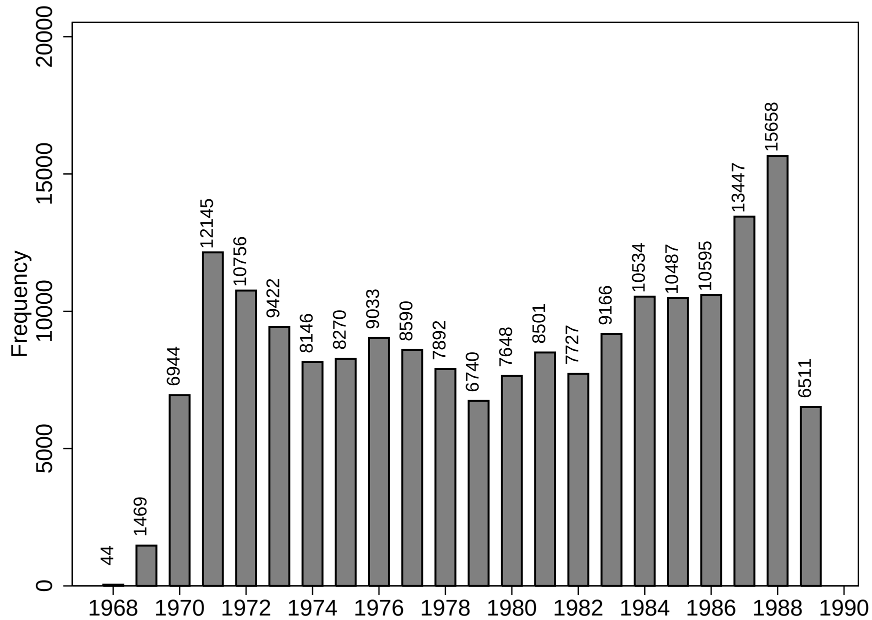
Upon arrival at the Stasi, the content of each piece of information was described by means of one or several, often highly specific, keywords. In total, the database comprises 143,005 distinct keywords,

[4]"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

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

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

Figure 1: Information Inflow, 1968-1989



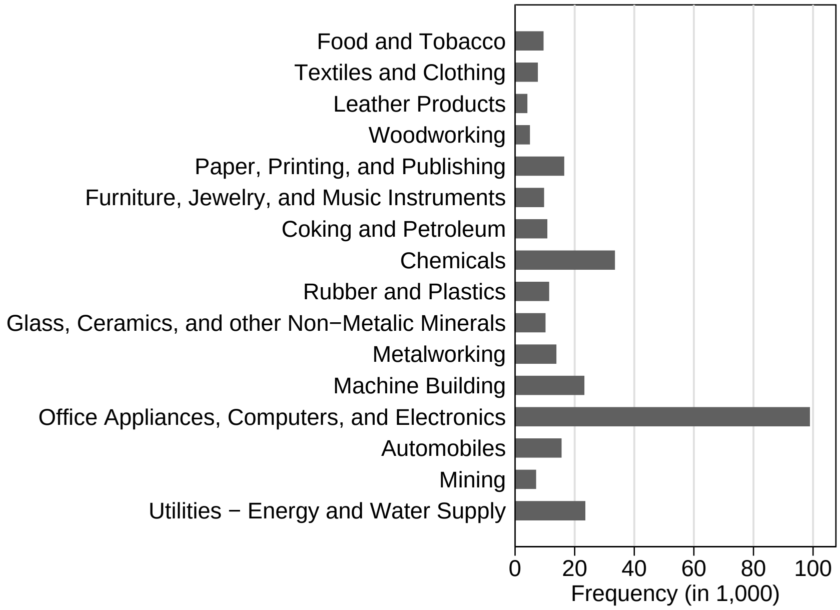
Note: Figure shows the annual inflow of information received by the HVA between 1968 and 1989. Data for 1968 incomplete.

68.5 percent of which are only used once throughout the entire period.[7] On average, each piece of information is described by 5.6 distinct keywords but the distribution is right skewed, 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 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 55.0 percent of these keywords to at least one of the 16 sectors for which we have information on inputs, output, and productivity.[8] Note that a given keyword can relate to more than one sector. After the allocation of the 2,000 most common keywords, the vast majority of the 186,655 total 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.

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

[8]The remaining 45.0 percent are either not classifiable (80.9 percent) or refer to other sectors of the economy (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).

Figure 2: Sectoral Distribution of Information



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

Figure 2 shows the (unweighted) sectoral distribution of the 151,854 pieces of information that could be allocated to at least one of the 16 sectors of analysis over the period 1968 to 1989. In line with historical accounts, the sector *Office Appliances, Computers and Electronics* constituted by far the most important sector for industrial espionage, with 98,886 pieces of related information in total, followed by the sectors *Chemicals* (33,458), *Utilities* (23,501) and *Machine Building* (23,182).

Of the 151,854 pieces of information included in our final estimation sample, 40.7 percent were qualitatively assessed upon arrival at the Stasi and allocated into one of six numerical categories, ranging from 0 to 5.[9] High quality ratings were relatively rare, with only 5.7 and 1.5 percent of the information inflow receiving a rating of 4 and 5, respectively, and 64 percent of all evaluated items receiving a rating of 3. Looking at the providers of these pieces of information, the TDB11 reveals, based on their assigned code names, 2,453 distinct informants. 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, was the top informant 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

[9] The quality information is relatively sparse before 1981.

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. It is interesting to see, though, that 20.2 percent of informants were still active in the final year of our data, 1989, the year when the Berlin wall came down.

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 constituted a challenging task, not least because West and East Germany followed different national accounting standards throughout the pre-unification period.[10]

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*.[11]

Heske (2005, 2009, 2013) builds on these initial findings but makes four important contributions. First, he translates all values of output and investment into constant *Mark* with respect to a base year, taking account of the complex issues arising from the qualitative upgrading of existing and introduction of new products.[12] 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

[10] 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 in 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.

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

[12] 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.

extends the time horizon to the earlier period 1950 to 1970, for which the existing data basis, however, was significantly more limited. Finally, and crucially for our analysis, he constructs separate time series for specific 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-3 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 utilities 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 SZS. 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 between 1969 and 1989.[13]

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, in particular R&D investments which have been shown to be important drivers of productivity growth. Unfortunately, there are no consistent data series available of sector-specific R&D investments for both West and East Germany over our observation window 1969 to 1989. To proxy for both countries' own R&D activities, we therefore use sector-specific patent applications (scaled by industry output). The source of our West German patent data is the database for online searches on patent publications (DEPATISnet), which is maintained by the German patent office (*Deutsches Patent- und Markenamt*). From this database, we extracted the annual number of patent applications (*A-, B1- and C1-Schriften*) 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. In cases, in which a given IPC would pertain 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*

[13] 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.

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 (1970-1989), 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 BFSR (*Büro für Schutzrechte*) (1980-1989), and the number of university cadres working in R&D (1986-1989). To construct sector-specific outcomes, we assign each state combine to one of our 16 industry sectors and sum the innovation outcomes across combines operating in the same sector. Figure B-4 in the appendix shows the number of patent applications by sector in West and East Germany.

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.[14] We convert the SITC revision 2 format of the trade data to the ISIC2 codes system of the Heske data using the concordance constructed by Muendler (2009). Following Cameron et al. (2005), we construct a measure of the relative import intensity between West and East Germany, defined as the difference in the West and East German ratios of industry imports from the whole world divided by output, respectively.

4 Empirical Framework

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.

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

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

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

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. 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

[14]The data set is available at the UC Davis Center for International Data http://cid.econ.ucdavis.edu/wix.html.

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 $\lambda_j \equiv \lambda^W_j - \lambda^E_j$, $\pi_j \equiv \pi^W_t - \pi^E_t$ and $\mathbf{X}_{jt} \equiv \mathbf{X}^W_{jt} - \mathbf{X}^E_{jt}$, leads to our main estimation equation

$$\Delta a_{j,t+1} = \rho S^E_{jt} + \eta r_{jt} - \theta a_{jt} + \mathbf{X}'_{jt}\mathbf{\Phi} + \lambda_j + \pi_t + \varepsilon_{jt}, \tag{3}$$

where $a_{jt} \equiv \ln(A^W_{jt}) - \ln(A^E_{jt})$, $r_{jt} \equiv R^W_{jt}/Y^W_{jt} - R^E_{jt}/Y^E_{jt}$, 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 identical ($\eta^W = \eta^E = \eta, \theta^W = \theta^E = \theta$, 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 yearly sector-specific TFP shocks μ_{jt} that would pertain to both West and East Germany respectively.

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 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. As East Germany's industrial espionage was to such a large extent driven by trade embargoes which West Germany did not suffer from, taken together this suggests that 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).[15]

As there are no direct measures of sector-specific TFP available over the time period considered, we use the Heske data to back out measures of sector-specific TFP by means of a standard growth accounting exercise. As a starting point, we assume that the production functions in equation (1) are

[15] 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^E_{jt} directly.

Cobb-Douglas, so that

$$Y^i_{jt} = A^i_{jt}(K^i_{jt})^\alpha (L^i_{jt})^{1-\alpha}$$

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 capita and the capital-labor ratio, respectively.[16] Unfortunately, as in many industry level data sets, 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 (see in particular Caselli 2005), we generate estimates of the capital stock in each industry sector using the perpetual inventory equation

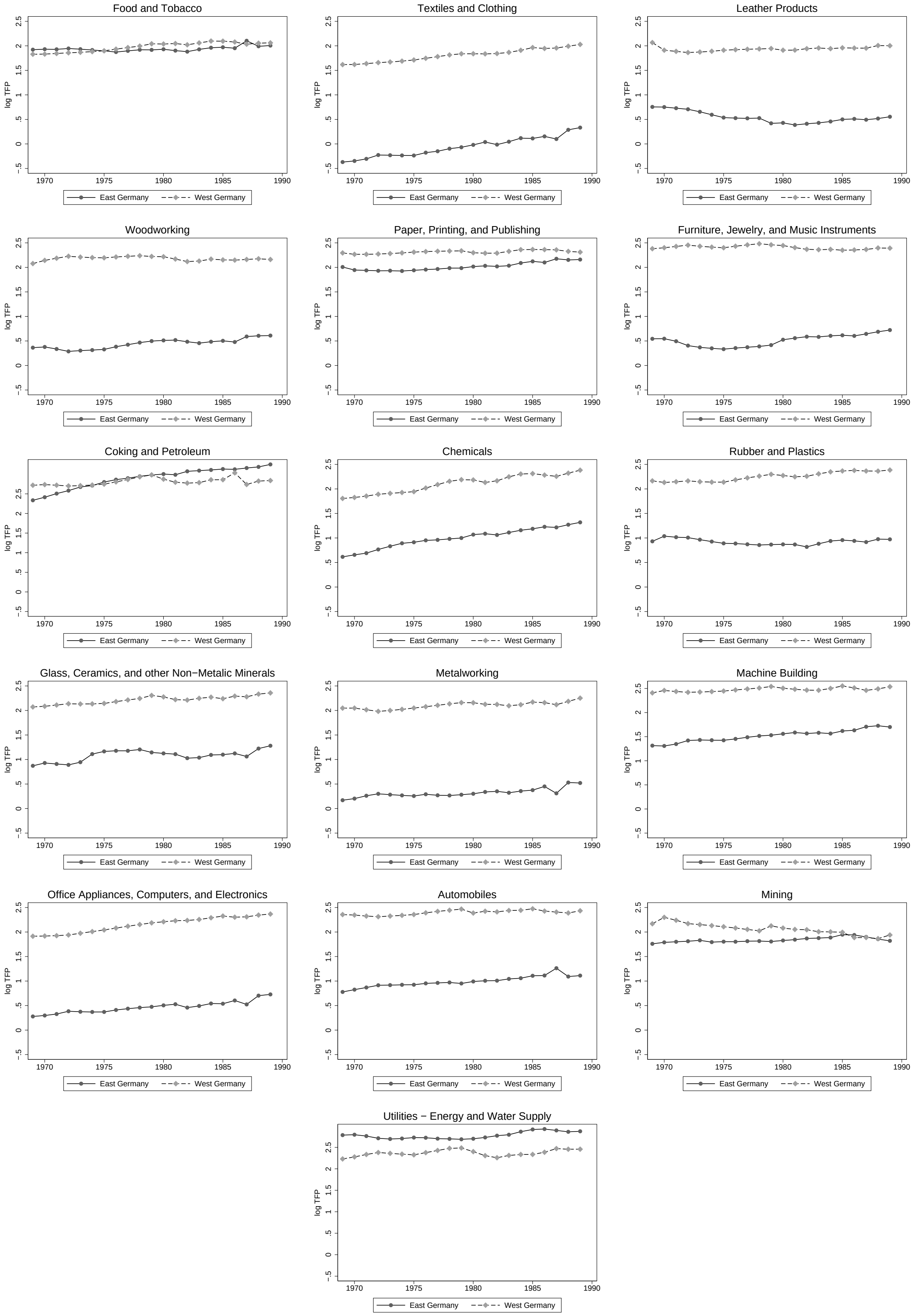
$$K_{jt} = I_{jt} + (1-\delta)K_{jt-1},$$

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 important sectors such as Textiles and Clothing, Metalworking, and Office Appliances, Computers, and Electronics.

[16] 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.

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%.

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, we believe 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 TFP gaps over a three-year period (so between t and t+3) to the average annual inflow of information from industrial espionage and the cumulative investments in R&D over the previous three years (so between t-3 and t) as the main regressors of interest, both scaled by the sector-specific output in period t.[17] To exploit the available data as efficiently as possible, and 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. We present both conventional standard errors clustered at the sectoral level and p-values calculated using the wild 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 also 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 specifications and specifications in which we weight observations by the average output in each sectors.

5 Results

5.1 Main Results

In Table 1, we present the main results of the effect of industrial espionage on the TFP gap between West and East Germany as specified in equation (3), using three-year overlapping observations in Panel A and non-overlapping observations in Panel B. Focussing on Panel A, 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 and economically meaningful effect of industrial espionage on the TFP gap. A one standard deviation increase in the information flow per 1 million euros of output of 0.467 reduces the gap in log TFP between West and East Germany by 4.5 percentage points. In column (2), we add the initial log TFP gap as an additional control variable which leads to a small increase in magnitude of our main parameter of interest to -0.137. 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 findings of Griffith et al. (2004), we find evidence for technology transfer as a source of productivity growth for countries behind the technological frontier. Column (3) represents our preferred specification, where we now introduce 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

[17]Results based on annual observations are consistent with our main findings and highly significant, but smaller in magnitude.

Table 1: Industrial Espionage and Total Factor Productivity

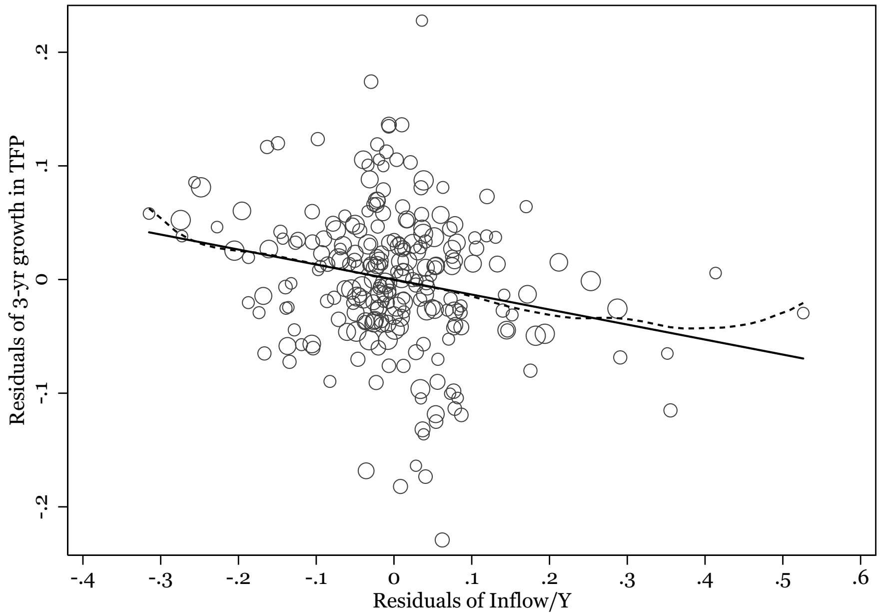
	Outcome is log difference in West/East TFP ratio between t and $t+3$								
Specification	Baseline spec	Patents gap	Lagged gap	Weight by output	No weights	Trade ctrls	FRG R&D	FRG R&D and patents	Sector trends
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Panel A: Three-year, overlapping					
Inflow/Y	-0.096*	-0.137***	-0.129***	-0.206**	-0.131***	-0.130***	-0.103*	-0.111	-0.123***
	(0.047)	(0.030)	(0.031)	(0.086)	(0.037)	(0.029)	(0.055)	(0.068)	(0.034)
TFP gap		-0.571***	-0.597***	-0.788***	-0.572***	-0.605***	-0.598***	-0.627***	-1.215***
		(0.082)	(0.098)	(0.175)	(0.092)	(0.080)	(0.118)	(0.117)	(0.098)
Patents/Y gap			-0.023	-0.022	-0.006	-0.010		-0.027	-0.025
			(0.018)	(0.035)	(0.022)	(0.017)		(0.022)	(0.071)
Imports/Y gap						-0.031**			
						(0.013)			
FRG R&D/Y							0.030	0.070	
							(0.792)	(0.838)	
P-value WB	0.040	0.002	0.002	0.046	0.008	0.002	0.272	0.264	0.012
Beta	-0.651	-0.927	-0.875	-0.733	-0.640	-0.922	-0.732	-0.788	-0.837
Adj R2 (within)	0.31	0.55	0.55	0.58	0.54	0.59	0.59	0.59	0.70
Obs	240	240	240	240	240	225	168	168	240
				Panel B: Three-year, non-overlapping					
Inflow/Y	-0.076	-0.146**	-0.077	-0.113	-0.116	-0.110	-0.109	-0.071	-0.024
	(0.104)	(0.063)	(0.099)	(0.129)	(0.084)	(0.107)	(0.112)	(0.112)	(0.171)
TFP gap		-0.554***	-0.636***	-0.780***	-0.547***	-0.694***	-0.480*	-0.568**	-1.187***
		(0.117)	(0.103)	(0.222)	(0.098)	(0.133)	(0.229)	(0.217)	(0.239)
Patents/Y gap			-0.104*	-0.104*	-0.056	-0.083		-0.102	-0.109
			(0.051)	(0.056)	(0.054)	(0.058)		(0.074)	(0.139)
Imports/Y gap						-0.052			
						(0.036)			
FRG R&D/Y							-0.929	-0.328	
							(2.595)	(3.015)	
P-value WB	0.518	0.118	0.422	0.316	0.236	0.292	0.346	0.472	0.866
Beta	-0.470	-0.901	-0.475	-0.410	-0.537	-0.699	-0.683	-0.444	-0.150
Adj R2 (within)	0.17	0.39	0.43	0.47	0.42	0.46	0.32	0.36	0.62
Obs	80	80	80	80	80	75	56	56	80

Note: All regressions include time- and industry-specific fixed effects. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values from the (Cameron et al., 2008) cluster wild bootstrap using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

investments. The inclusion of this additional control variable is important since 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. This positive correlation between R&D investments and the inflow of information from industrial espionage would lead to a downward bias in our parameter of interest if the former were not adequately controlled for. Indeed, the impact of our espionage variable decreases somewhat when moving from column (2) to column (3) but remains economically meaningful and highly significant, both using the standard cluster-robust standard errors reported in parentheses, and p-values from Cameron et al. (2008)'s wild bootstrap-clustering.

The remaining columns in Panel A of Table 1 show that our main result is robust to a number of changes in the estimated specification. In column (4), we weight each observation with the average

Figure 4: Industrial Espionage and Productivity



Note: The figure plots residualized differences in TFP growth rates between West and East Germany against residualized sector-specific inflows of information. The underlying specification corresponds to column (3) of Table 1. Circles are proportionate to the square root of the average workers in an industry. The solid black line represents a simple regression line whereas the dashed line represents the fit from a linear local polynomial estimator.

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 a third to -0.206. In contrast, not weighting at all leaves the estimated effect almost unaffected as shown in column (5). In column (6), we add the gap in sector-specific import intensities between West and East Germany as a further control variable with again little effect on the estimated impact of industrial espionage on TFP gaps. In column (7), we drop the patents gap variable and instead include actual sector-specific West German R&D investments in the specification, measured as a share of output. Since data on R&D investments only exist for West Germany and a reduced set of sectors, including this variable reduces the sample size by almost a third, and so the ensuing estimates remain similar in magnitude but – unsurprisingly – less precisely estimated. In column (8), we continue to include West German R&D investments but now reintroduce the patents gap variable as well. Finally, in column (9), we add industry-specific linear trends, which leaves the main result once more unchanged. In Panel B of Table 1, we report results for the same set of specifications based on non-overlapping observations, which reduces the sample by two thirds. However, the key estimates all have the same sign and are of similar magnitude as their counterparts in Panel A, albeit less precisely estimated.

Figure 4 visualizes the relationship between industrial espionage and changes in the log TFP gap between West and East Germany by plotting their residualized values that correspond to our preferred specification in column (3) of Table 1. There is a clear downward sloping relationship between information inflows and relative changes in TFP gaps. More 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.

In Table A-3 in the appendix, we rerun all regressions but with the West-to-East output per worker gap as the dependent variable rather than the log TFP gap. The results closely mirror those of Table 1, consistent with a narrowing productivity gap driving a narrowing output per worker gap between West and East Germany.

5.2 Robustness Checks

In Table 2, we add further controls beyond those included in our main specification, which we restate for comparison in column (1). In column (2), we include the West-to-East gaps in capital and labor intensities, respectively. In column (3), we control for the West-to-East gap in the distance to the domestic frontier, defined as the highest level of TFP across all domestic sectors in a given year. In column (4), we exclude all observations pertaining to the sector *Office Appliances, Computers and Electronics*, which was of specific interest to the East Germany government (see section 2) and which comprises by far the biggest share of the overall information received (compare Figure 2). As in the previous two columns, our parameter of interest remains relatively unchanged. In column (5), we control for future industrial espionage in period $t + 4$ which can be interpreted as a type of placebo test. The insignificant estimate suggests that future espionage does not predict contemporary changes in the TFP gap, which is to be expected unless espionage activities and productivity improvements are jointly determined by some unobserved common factors.

In column (6), we further interact the West-to-East gap in high-technology imports and high-technology imports from members of CoCom signatory countries, all measured as shares of total imports, with each industry dummy.[18] These industry-import-share interactions serve as additional controls for potential technology transfers through trade, by allowing East (relative to West) Germany's ability to import advanced technologies to have a differential effect on different industries over time.[19] The inclusion of these interaction terms leads to somewhat larger effects of information inflows from espionage on changes in the log TFP gaps, with a point estimate of -0.182 compared to our benchmark estimate of -0.129.

One potential concern with our analysis thus far is that the results could be confounded by time-varying state-led economic priorities that jointly affect the intensity of industrial espionage and the efforts to close productivity gaps with West Germany in particular industries. By controlling directly for the gap in the number of patent applications as a proxy for R&D investments, we already hope to capture much of the East German government's changing preferences for certain sectors. Another way to deal with this issue is to assume that informants who are already active sources at the beginning of the sample period, as well as the information they provide, are exogenous to this type of time-varying

[18] 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.

[19] A key concern underlying the CoCom-imposed embargo was the use of dual-purpose technologies, i.e. those that could be used in multiple industries. Although this centered mostly on civilian technologies that could have military uses, it is straightforward to extend this idea to one type of technology having use in multiple civilian industries. The products that are counted as "high-technology" are given by the SITC codes provided in Gibbons (1979).

Table 2: Robustness

Outcome is log difference in West/East TFP ratio between t and $t+3$							
	Main ctrls	CB spec	Domestic frontier	Excl IT	Future inflow	Trade trends	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inflow/Y	-0.129***	-0.137***	-0.129***	-0.124**	-0.151***	-0.182***	-0.114***
	(0.031)	(0.025)	(0.026)	(0.051)	(0.036)	(0.059)	(0.041)
TFP gap	-0.597***	-0.503***	-0.593***	-0.599***	-0.609***	-0.765***	-0.597***
	(0.098)	(0.109)	(0.095)	(0.097)	(0.088)	(0.174)	(0.087)
Patents/Y gap	-0.023	-0.027	-0.022	0.007	-0.011	0.000	-0.024*
	(0.018)	(0.018)	(0.016)	(0.030)	(0.024)	(0.036)	(0.013)
Capital intensity gap		-0.056					
		(0.143)					
Labor intensity gap		0.357*					
		(0.171)					
Domestic frontier gap			0.011				
			(0.142)				
Future inflow					0.109		
					(0.079)		
P-value WB	0.002	0.002	0.002	0.070	0.004	0.006	
Beta	-0.875	-0.927	-0.871	-0.402	-1.021	-1.244	
F-stat							141.5
Obs	240	240	240	225	224	236	240

Note: All regressions include time- and industry-specific fixed effects. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values from the (Cameron et al., 2008) cluster wild bootstrap using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

preferences. This assumption can be justified given the highly intricate process of recruiting, training and placing of informants in suitable objects, and the great difficulties in subsequently shifting them to different sectors. In column (7), we exploit this idea and instrument the inflow of information received between period t-3 and period t with the corresponding inflow of information received from informants who already existed at the beginning of the sample period in 1970. As reported at the bottom of column (7), the first stage is strong, with an F-stat for the excluded instrument of 141.5. Our parameter of interest decreases somewhat in magnitude relative to the baseline specification, from -0.129 to -0.114, which may point towards some degree of endogeneity in the baseline OLS model. However, the difference between both estimates is not statistically significant.

5.3 Mechanisms

In Table 3, we allow for West and East German lagged TFP and patents per output to appear separately in the regression, essentially testing the restrictions leading to equation (3). We also use the two countries' respective TFP growth rates as separate outcomes instead of solely looking at the growth in their TFP gap. Comparing columns (1) and (2), the inclusion of separate East and West German TFP levels and patent intensities has relatively little bearing on the main result for the log TFP gap as an outcome, suggesting that the assumption of equal coefficients η_{it}^{E}, η_{it}^{W}, and θ_{it}^{E}, θ_{it}^{W}

Table 3: Mechanisms

	Δ log TFP						Δ Patents		
	FRG/GDR		GDR		FRG		FRG/GDR	GDR	FRG
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Inflow/Y	-0.129***	-0.074**	0.106***	0.063**	-0.023	-0.011	0.575**	-0.202**	0.018
	(0.031)	(0.030)	(0.027)	(0.025)	(0.016)	(0.025)	(0.221)	(0.071)	(0.044)
TFP gap	-0.597***		0.387***		-0.210***		-0.034		
	(0.098)		(0.079)		(0.067)		(0.186)		
Patents/Y gap	-0.023		0.029		0.006		-0.309***		
	(0.018)		(0.018)		(0.015)		(0.030)		
TFP(GDR)		0.586***		-0.497***		0.089		0.001	-0.083
		(0.096)		(0.092)		(0.102)		(0.133)	(0.055)
TFP(FRG)		-0.678***		0.251		-0.426***		-0.054	0.105
		(0.104)		(0.154)		(0.142)		(0.197)	(0.061)
FRG patents/Y		-0.130**		0.049		-0.081		-0.302***	-0.030
		(0.052)		(0.062)		(0.060)		(0.066)	(0.040)
GDR patents/Y		-0.122*		0.067		-0.054		-1.034***	0.170**
		(0.059)		(0.047)		(0.066)		(0.114)	(0.060)
P-value WB	0.002	0.030	0.008	0.028	0.190	0.638	0.260	0.206	0.919
Beta	-0.875	-0.503	0.978	0.578	-0.207	-0.104	1.622	-0.758	0.103
Adj R2 (within)	0.55	0.56	0.43	0.46	0.64	0.67	0.66	0.65	0.89
Obs	240	240	240	240	240	240	239	239	240

Note: All regressions include time- and industry-specific fixed effects. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values from the (Cameron et al., 2008) cluster wild bootstrap using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

respectively in equation (3) is rather innocuous.[20] Moreover, what drives the relationship between East German industrial espionage and the TFP gap is the positive effect on East German log TFP as reported in columns (3) and (4) rather than the effect on West German log TFP shown in columns (5) and (6), which is close to zero and statistically insignificant.

The last three columns of Table 3 report results when we switch the outcome variable to three-year changes (between t and t+3) in the patent intensity gap between West and East Germany. Strikingly, industrial espionage appears to widen the gap in relative patent intensity, with East Germany lagging further behind. As illustrated by columns (7) and (8), this finding is again driven entirely by a reducing effect of industrial espionage on East Germany's patenting activities. This result is consistent with reports in Macrakis (2008) of industrial espionage essentially crowding out overt R&D, as the skills and procedures required in the former were quite different from those required in the latter.

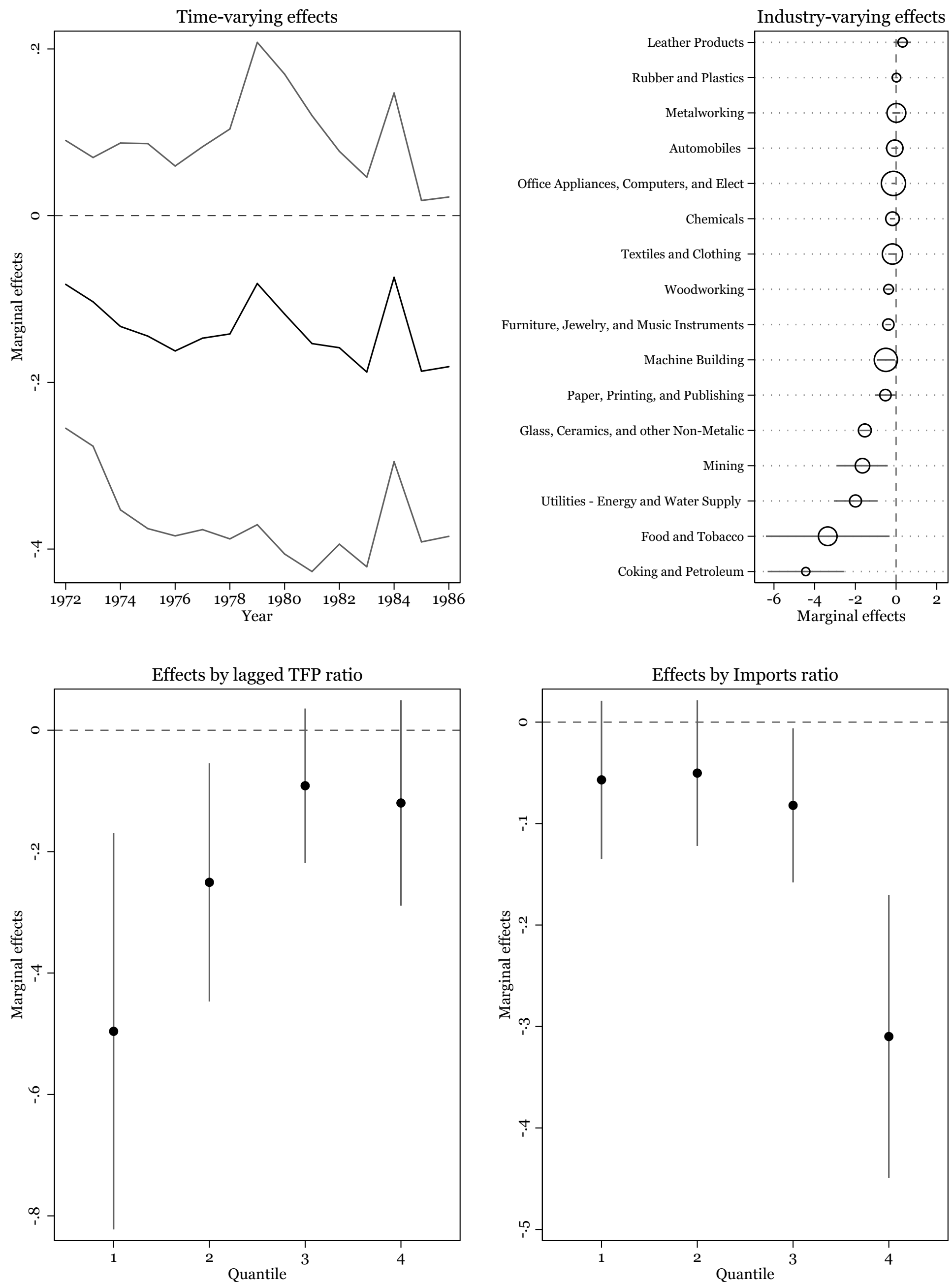
5.4 Heterogeneity

In Figure 5 we investigate heterogeneous effects along a number of dimensions. The upper left-hand panel allows varying effects of industrial espionage by year, yielding estimates that, at least after 1976, are very similar in magnitude and not significantly different from each other. The upper right-hand graph, correspondingly, allows differential effects of industrial espionage by sector. Here, 12 of the 16

[20]Note, however, that the sign of the coefficients 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.

industries exhibit negative effects, with a number of smaller ones having very large effects, but most of the major industries exhibiting magnitudes roughly similar to the baseline result.

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 following; year-fixed effects (upper left); industry fixed effects (upper-right), quartiles in the initial TFP gap (lower left), and quartiles in the imports ratio (lower right). Confidence intervals are constructed from standard errors clustered by industry. Circle area in observations in upper-right graph is proportional to industry size (measured by average workers).

The lower panels of Figure 5 instead allow the effects of industrial espionage to vary by the West-to-East log TFP gap (left) and the West-to-East log import intensity gap (right) in period t. While the former relates to the empirical 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), the latter allows us to examine the effect of industrial espionage along a measure of relative import barriers. If industrial espionage served as a form of technology transfer when regular channels, such as trade, are unavailable, we would expect larger estimates in cases where, all else equal, the gap between West and East German import intensities are larger.

Figure 5 reveals that both with respect to the initial log TFP gap and the log import intensity gap, the estimates for different quartiles are negative and not significantly different from the baseline results. However, the effects of industrial espionage are somewhat larger among observations where the initial log TFP gap was smaller and where the initial import intensity gap was higher. Overall, these findings suggests that industrial espionage was somewhat more effective in narrowing the productivity gap in cases where East Germany was not too far behind West Germany and where its ability to import products from abroad was severely hampered.

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 in which they occur. This relates both to the external setting faced by East Germany during the Cold War, as well as the appropriateness of East German institutions for secrecy.

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 whereas 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, where 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 technology. 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 not necessarily so. As such, any limit of external validity in the case of Cold-War-era East Germany needs to be traded off against the unique opportunity it represents to estimate the economic returns to industrial espionage.

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Appendix A Tables

Table A-1: Keyword Allocation

				Sector																	
Rank	Original Keyword	English Translation	Freq.	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.

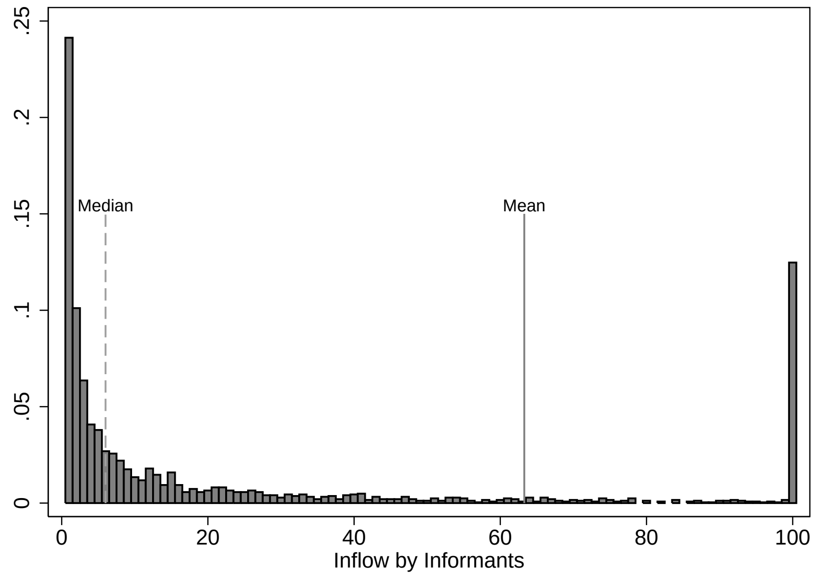
Table A-3: Industrial Espionage and Output per worker

Outcome is log difference in West/East Output per worker ratio between t and $t+3$									
Specification	Baseline spec	Patents gap	Lagged gap	Weight by output	No weights	Trade ctrls	FRG R&D	FRG R&D and patents	Sector trends
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Three-year, overlapping									
Inflow/Y	-0.070*	-0.105**	-0.108**	-0.192*	-0.101**	-0.106**	-0.077	-0.075	-0.142***
	(0.037)	(0.046)	(0.042)	(0.094)	(0.043)	(0.039)	(0.077)	(0.078)	(0.035)
Output per capita gap		-0.532***	-0.523***	-0.735***	-0.546***	-0.525***	-0.568***	-0.562***	-1.209***
		(0.086)	(0.102)	(0.182)	(0.101)	(0.083)	(0.100)	(0.102)	(0.110)
Patents/Y gap			0.008	0.016	0.018	0.017		0.007	0.039
			(0.023)	(0.040)	(0.026)	(0.023)		(0.022)	(0.073)
Imports/Y gap						-0.027**			
						(0.011)			
FRG R&D/Y							-0.634	-0.650	
							(0.719)	(0.720)	
P-value WB	0.024	0.050	0.044	0.090	0.140	0.022	0.574	0.648	0.002
Beta	-0.450	-0.679	-0.696	-0.659	-0.479	-0.712	-0.501	-0.488	-0.919
Adj R2 (within)	0.31	0.52	0.51	0.53	0.48	0.55	0.61	0.61	0.71
Obs	240	240	240	240	240	225	168	168	240
Panel B: Three-year, non-overlapping									
Inflow/Y	-0.045	-0.123*	-0.063	-0.093	-0.098	-0.099	-0.057	-0.024	-0.058
	(0.098)	(0.061)	(0.095)	(0.128)	(0.077)	(0.102)	(0.103)	(0.107)	(0.159)
Output per capita gap		-0.541***	-0.617***	-0.758***	-0.542***	-0.691***	-0.514**	-0.584**	-1.181***
		(0.110)	(0.105)	(0.223)	(0.098)	(0.110)	(0.206)	(0.205)	(0.222)
Patents/Y gap			-0.093	-0.085	-0.042	-0.073		-0.087	-0.066
			(0.053)	(0.059)	(0.058)	(0.058)		(0.073)	(0.145)
Imports/Y gap						-0.057			
						(0.034)			
FRG R&D/Y							-1.317	-0.761	
							(2.627)	(2.881)	
P-value WB	0.638	0.108	0.470	0.360	0.178	0.346	0.562	0.810	0.640
Beta	-0.268	-0.726	-0.373	-0.320	-0.439	-0.600	-0.332	-0.137	-0.342
Adj R2 (within)	0.19	0.39	0.41	0.43	0.36	0.45	0.37	0.39	0.61
Obs	80	80	80	80	80	75	56	56	80

Note: All regressions include time- and industry-specific fixed effects. Standard errors clustered at the sectoral level in parentheses. *P-value WB* denotes p-values from the (Cameron et al., 2008) cluster wild bootstrap using 1,000 replications. *Beta* denotes the standardized coefficient of Inflow/Y in terms of standard deviations.

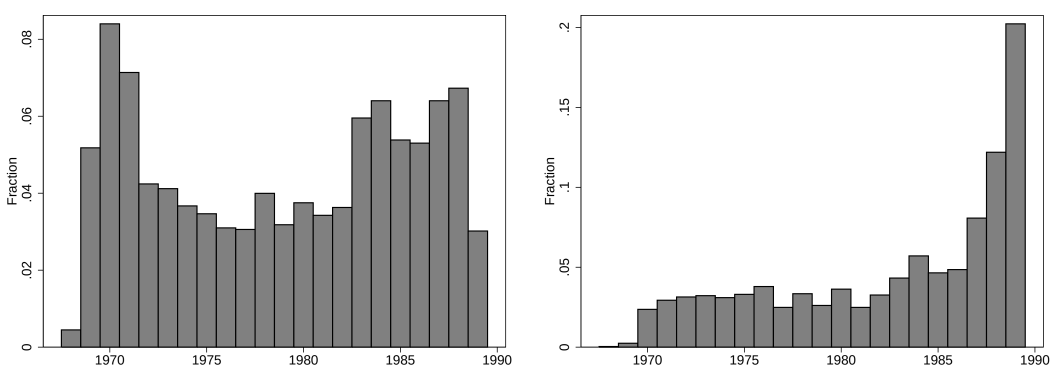
Appendix B Figures

Figure B-1: Inflow Distribution Across Informants



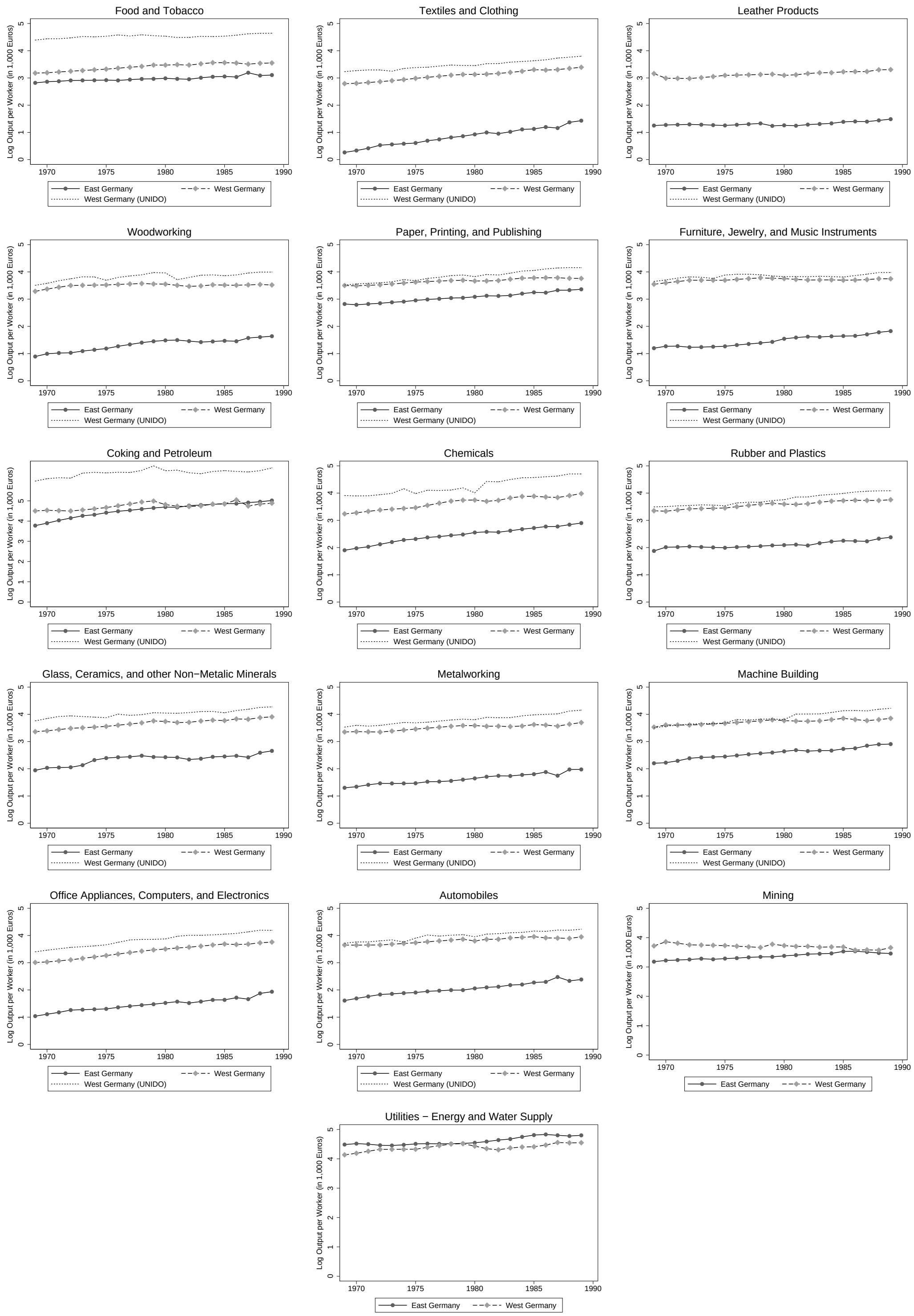
Note: The figure shows the distribution of the total number of pieces of information received from individual informants. Observations are censored at a value of 100.

Figure B-2: First and Last Active Year



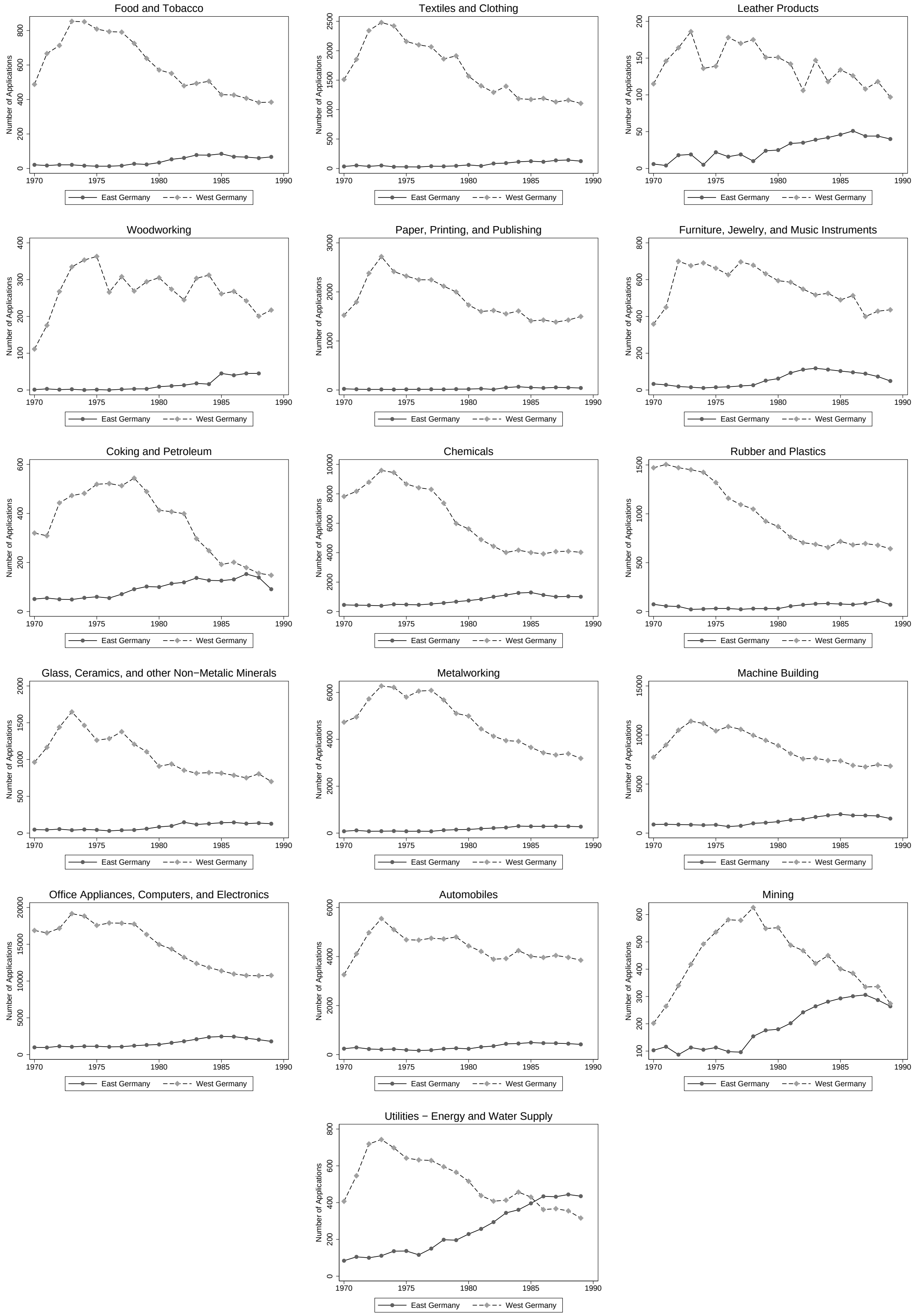
Note: The figure shows the distributions of the first (left panel) and last year (right panel) in which individual informants are observed in the data.

Figure B-3: 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-4: 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.