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The Extent and Evolution of Productivity Deficiency in Eastern Germany

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Abstract

Since the German re-unification in 1990, Eastern Germany has been a transition economy. After a phase of catching up in productivity with Western Germany from 1991 to 1996, growth rates in the producing sector have dropped below those in Western Germany since 1997. This study investigates whether this macroeconomic picture holds at the microeconomic level. For the special case of Eastern Germany, I suggest identifying productivity gaps by using comparable Western German firms as a "productivity benchmark". Applying an econometric matching procedure allows to study the productivity gap at the firm level in detail. Besides labor and capital, other factors like innovation and firm ownership are taken into account. The macroeconomic facts are broadly confirmed: a significant gap has remained in recent years. Moreover, Eastern German innovators perform worse than their Western German pendants, and firms owned by Western German or foreign companies perform better than those owned by Eastern German entities.

JEL Classification: C14, D24

Keywords: productivity gap, eastern germany, non-parametric matching

1. Introduction

Since the German re-unification in 1990, the economy of Eastern Germany has been in transition from a planned economy to a market economy. The optimistic hypothesis that a second "Wirtschaftswunder" similar to that which came about after the Second World War in Western Germany would occur in Eastern Germany within 10 years turned out to be false. While productivity growth in Eastern Germany was substantial in the early years, growth rates sank below those of Western Germany in 1997 and have remained low since then (see Figure 1). The catch-up process of the Eastern German economy to the Western standard is stagnating and the productivity gap remains wide. The Eastern German aggregate productivity (GDP per employable person) reached only 35% of the Western German level in 1991, but rose up to 60.6% of the corresponding western level in 1996. However,

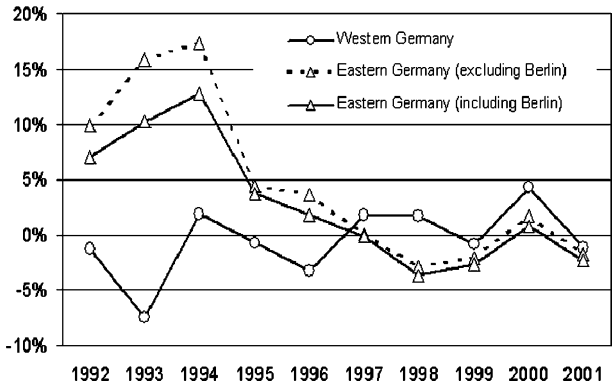

Figure 1. Growth rates of value added in the producing sector. Source: Arbeitskreis VGR der Länder, Statistisches Landesamt Baden-Württemberg.

the East–West ratio has stabilized at this level since then. In 2002, it was 58.4% (Source: Sinn, 2003).

These discouraging macroeconomic facts are possibly due in part to the lack of large companies in Eastern Germany. While the large "combines" of the former German Democratic Republic were closed down or separated into several smaller companies, most firms were newly founded after the re-unification. These are therefore smaller than Western German firms on average, and presumably still do not reach the minimum efficiency scale. Hence, many are struggling to survive. In the 1990s, the still underdeveloped infrastructure and, additionally, the breakdown of the eastern European markets also possibly hampered a more positive development of Eastern Germany. Besides the lack of industrial companies, it is unclear how much of the productivity gap is due to other factors within the firms' production processes. Examples can be seen in the region's poor capital stocks, lack of human capital ("know–how"), misallocation of production factors, lack of innovative products, and inefficient management (cf. Ragnitz, 1997, for example). The purpose of this paper is to analyze whether the macroeconomic picture holds at the microeconomic level, i.e. at the firm level, and to shed some light on the reasons behind the persisting productivity gap.

The traditional approach to analyzing productivity is to estimate production functions (see e.g. Berndt, 1991, ch. 9 for an overview, or Blundell and Bond, 2000; Griliches and Mairesse, 1998, for recent studies). In this paper I suggest an alternative method to identify productivity gaps. In the special case of Eastern Germany's transition economy, it is possible to use the Western German economy as a "productivity benchmark". If this is considered, one can apply a matching estimator to find a Western German "twin" for every Eastern German company which has the same characteristics like size, industry classification, innovation activities and so on. Matching methods are usually applied to estimate treatment effects, mainly in labor market research and, recently, also in industrial economics to evaluate the impact of technology policies on innovation. Matching is a non-parametric

approach and thus has the advantage that no production function has to be specified and no assumptions on functional forms have to be imposed. It allows estimation of the difference in productivity without any distributional assumptions. In this paper, I apply a non-parametric matching to eight cross-sections of the Mannheim Innovation Panel (MIP) referring to the years 1993–2000. The matching also allows the identification of single variables which may influence productivity. Besides the central factors of labor and capital, other variables like knowledge assets, innovation, firm ownership, etc. are considered.

The following section summarizes some results from previous studies on the topic. The econometric approach is presented in the Sections 3 and 4 discusses the empirical analysis.

2. Brief Review of the Literature

Since an important publication in 1991 on the economic aspects of the Eastern German transformation process (Sinn and Sinn, 1991), many studies have been conducted on this topic. In this paper, I focus on literature dealing with the productivity gap, but, as the main emphasis in this paper is the empirical application, the existing literature is only discussed briefly. One strand of literature is the application of macroeconomic growth theory. Some studies discuss the "iron law of convergence" which predicts a rate of convergence of roughly 2% of GDP per year between regions. Several studies have applied such growth models to Eastern Germany, and some have argued that the convergence of Eastern Germany will be faster due to various reasons (see, among others, Burda and Funke, 1995, or in contrast to this Hughes et al., 1996, for a depressing forecast on Eastern Germany's future performance).

More recently, Burda and Hunt (2001) stated among other findings that the productivity gap is constant across skill levels. Therefore, they look for other skill-neutral explanations, like an inferior infrastructure. Although some types of infrastructure are as good as those in Western Germany, they recommend continued investment in types of infrastructure which still lag behind. Moreover, Burda and Hunt hypothesize that a deficiency of business skills could reduce productivity at all skill levels. Although they do not provide original evidence on this, they recommend a further investigation of this topic. This is in line with Quehenberger (2000), who has emphasized that "[...] human capital with marketing experience may become the binding constraint for convergence to progress" (Quehenberger, 2000, p. 133). Barrell and te Velde (2000) also argue that further convergence may be embedded in the stock of human capital instead of further capital deepening. Bellmann and Brussig (1998) also point out that rather 'soft factors' like managerial issues and the integration of the plant or firm into the respective company or group are more important than structural factors like tangible assets.

Klodt (2000) even holds industrial policies responsible for the productivity gap. He criticizes the focus of public subsidization on capital formation in Eastern Germany. "The strategy of fostering of capital intensity hampered the

development of viable industrial structures based upon human capital-intensive and service-intensive products and production processes." (Klodt, 2000, p. 330). He concludes that the sectoral structure is distorted in favor of capital-intensive industries. In contrast, there is a low weight of human capital-intensive industries and a lack of intermediate services, which are essential for the provision of sophisticated industrial goods and higher growth rates. Klodt points out that the Eastern German industry composition resembles the structure of declining regions in Western Germany. He predicts that another wave of painful adjustment will present itself when subsidies are reduced and structures relying upon subsidized capital input are no longer sheltered from market competition. In contrast, Dietrich (1997) writes that a main reason for the productivity gap is the circumstance that production in Eastern Germany is less capital-intensive (cf. also Ragnitz, 1997, 1999). The weak export performance of Eastern German firms is, according to Ragnitz (1997), one main reason for the productivity gap. On one hand, the small start-up firms are especially hampered by higher entry barriers on international markets. On the other hand, disadvantages in competitiveness are revealed, e.g. lower product quality, strategic orientation of firms or in marketing.

There are also two studies which use related data (from the Mannheim Innovation Panel) to this paper. The focus of both studies is innovation. Falk and Pfeiffer (1998) estimate translog production functions and distinguish innovating and non-innovating firms from both Eastern and Western Germany. They find that in 1994 productivity growth of innovating Eastern German firms performing both product and process innovations was substantially larger than that of non-innovating (or only product innovating) firms from Eastern Germany. For Western German firms Falk and Pfeiffer do not find such differences. Falk and Pfeiffer (1999) investigate innovation-related productivity growth in Eastern Germany with slightly different tools in comparison to their previous study and with an additional wave of the MIP (up to 1995). They conclude that process innovations have led to a productivity growth of 7–8%.

Another study closely related to this paper was conducted by Fritsch and Mallok (1994). They apply the matched pair methodology, although not in the econometric sense. Fritsch and Mallok conducted interviews with 52 small and medium-sized Eastern German firms in 1992. For each interviewee they select a Western German counterpart with similar characteristics (size, industry classification, etc.). They conclude that the interviewed firms from Eastern Germany only reach 45.6% of Western German value added per employee. As one main reason Fritsch and Mallok identify the lower operating rate in Eastern Germany. While the Western German firms used about 90% of their production capacity in 1992, Eastern German interviewees only reached an average of 63%. However, even the construction of a scenario with a 100% operating rate only yields an Eastern–Western productivity ratio of 67.3% (see Hitchens et al., 1993, for a related study). Rothfels (1997) constructs similar scenarios at the industry level. She concludes that the different industry structures in Western and Eastern Germany are not responsible for the productivity gap, neither at the macroeconomic level nor at the sectoral level (manufacturing sector).

As Smolny (2002) points out there is no study that provides a comprehensive discussion of all possible determinants of the productivity gap. In this paper I focus on innovation and ownership structure in addition to other more conventional characteristics like firm size, sectors, firm age, and fixed capital.

3. Econometrics

3.1. Matching and Identification

The matching approach was originally developed to identify treatment effects when the available observations on individuals are subject to a selection bias. This typically occurs when participants differ from non-participants in observable and/or unobservable characteristics (see Heckman et al., 1999, 1997, for surveys). Popular economic examples are studies on the effects of active labor market policies. In this study, the matching estimator is not used to identify such policy effects. The aim is to separate differences based on observable characteristics between Eastern and Western German companies from the productivity gap emerging due to unknown reasons internal to each respective firm. The advantage over a parametric regression analysis is that one does not have to assume a functional form of the productivity equation. The matching is able to directly address the question "What could be expected from an Eastern German firm with given characteristics if it were a Western German firm?" The matching will be carried out for eight cross-sections of data at the firm level. Hence, it is possible to analyze whether the gap between the two German regions is gradually closing and whether it still existed in recent years. A parametric regression on productivity which includes just a dummy for Eastern German firms may be too restrictive to capture the finer regional differences, if companies differ strongly in important characteristics (for example, in firm size). A fully parametric estimation would require a functional form assumption that would possibly not be flexible enough to account for the dissimilarity between Eastern and Western German firms. The matching estimator individually balances the sample with respect to the variables included in the analysis for each observation from Eastern Germany.

The fundamental question can be illustrated by an equation describing the average treatment effect on the treated firms, respectively:[1]

$$E(\theta) = E(YT|S=1) - E(YC|S=1), \tag{1}$$

where YT is the outcome, in our case productivity, of the 'treatment group' Eastern German firms. The status S refers to the group: $S=1$ is the treatment group (Eastern Germany) and $S=0$ is the non-treated firms (Western German ones). The YC is the potential productivity which would be realized if the Eastern German firms ($S=1$) were in Western Germany. The problem is obvious: while the outcome of the treated companies in the case of treatment, $E(YT|S=1)$, is directly observable, this is not the case for its counterpart. What would these firms have

realized if they had not received the treatment, $E(YC|S=1)$, is a counterfactual situation which is not observable and has to be estimated. In this case, the potential outcome is constructed from a control group of Western German firms.[2] The matching relies on the intuitively attracting idea to balance the sample of Eastern German firms and a control group of comparable Western German firms. Remaining differences in the outcome variable between both groups are then attributed to the measure (Heckman et al., 1998), which means in this case the fact that firms are Eastern German ones.

Initially, the counterfactual cannot simply be estimated as average outcome of the non-treated firms, because $E(YC|S=1) \neq E(YC|S=0)$ due to the possible selection bias. The treated group and the non-treated group can be expected to differ from each other, except in cases of randomly assigned measures in experimental settings. Rubin (1977) introduced the conditional independence assumption (CIA) to overcome the selection problem, that is, participation and potential outcome are independent for firms with the same set of exogenous characteristics X. If this assumption is valid, it follows that

$$E(YC|S=1, X) = E(YC|S=0, X). \tag{2}$$

The outcome of the non-treated companies can be used to estimate the counterfactual outcome of the treated in case of non-treatment provided that there are no systematic differences between both groups. The treatment effect can be written as

$$E(\theta) = E(YT|S=1, X=x) - E(YC|S=0, X=x). \tag{3}$$

Conditioning on X takes account of the selection bias due to observable differences between treated and non-treated firms.

3.2. Estimation of the Counterfactual

A weight w_{ij} is defined with respect to X for each Eastern German firm i, which assigns a high weight to Western German firms j being similar in X and vice versa. The weights w_{ij} sum up to one. The 'treatment effect' for the Eastern German firm i is

$$YT_i - \sum_j w_{ij} YC_j. \tag{4}$$

The outcome of the Eastern firm i is compared to the weighted outcome of all Western German companies j. According to Heckman et al. (1998), matching estimators differ with respect to the weights attached to members of the comparison group. The extreme cases are to use all non-treated firms as control group or to pick just the most similar control observation. The latter case is called "nearest neighbor" matching. The weight would be equal to one for the most similar control observation and would be zero for all other cases. Nearest neighbor matching has already been applied in industrial economic literature to estimate the impact of

R&D subsidies on R&D investment at the firm level (see Almus and Czarnitzki, 2003; Czarnitzki, 2001; Czarnitzki and Fier, 2002). In this study, a kernel-based matching is applied. In contrast to the nearest neighbor matching, where only one control observation is assigned to each Eastern German firm, the entire group of Western German firms is used for every firm from Eastern Germany. Therefore, a non-parametric regression in the sample of Western German firms is performed to determine the weights for the potential productivity of an Eastern German firm. The weights are specified as

$$w_{ij} = \frac{K((X_j - X_i)/h)}{\sum_j K((X_j - X_i)/h)}. \tag{5}$$

The kernel K downweighs observations with respect to their distance to X_i. h is the bandwidth parameter. The weights are obtained by a non-parametric regression, a locally weighted average of the outcome of the Western German firms with similar characteristics. In this case, the Nadaraya–Watson kernel regression is applied.[3] The minimization problem for obtaining the non-treatment estimate for individual i is (see Pagan and Ullah, 1999, Section 3.2)

$$m(X_i) = \min_m \sum_j (YC_j - m)^2 K\left(\frac{X_j - X_i}{h}\right). \tag{6}$$

The estimator resulting from the first order condition equals

$$\sum_j \frac{K((X_j - X_i)/h)}{\sum_j K((X_j - X_i)/h)} YC_j = \sum_j w_{ij} YC_j. \tag{7}$$

Note that I impose the following restriction in the subsequent empirical analysis: firms j operating in a different sector than firm i always receive zero weight.

Instead of a single X, several of the firms' characteristics may be employed in the matching function. Therefore the Mahalanobis distance

$$MD_{ij} = (X_j - X_i)' \Omega^{-1} (X_j - X_i) \tag{8}$$

is used as the argument in the kernel function. Ω is the empirical covariance matrix of the vector X_j. Finally, the kernel function and the bandwidth have to be specified. I use the Gaussian kernel

$$K = \frac{1}{2\pi} \exp\left(-\frac{1}{2}\left(\frac{MD_{ij}}{h}\right)^2\right). \tag{9}$$

and the bandwidth h is chosen according to Silverman's (1986) rule of thumb as

$$h = k(0.9n^{-1/5})^2 \tag{10}$$

where k is the number of variables included in X.

The Nadaraya–Watson kernel regression is performed for every Eastern German firm in the sample, that is, an estimate of the potential productivity for each i is

constructed from the entire sample of Western German firms. Once the samples have been balanced by the kernel matching procedure, remaining differences in the outcomes are not due to previous heterogeneity in observable characteristics, but can be assigned to the treatment if no selection on unobservables occurs.

Due to the inclusion of many matching arguments, one has to deal with the "curse of dimensionality". If ones employs many variables in the matching function, it will become difficult to find appropriate controls. Rosenbaum and Rubin (1983) suggested using a propensity score, $P(X)$, as a single index, thereby reducing the number of variables included in the matching function to just one. They have shown that it is sufficient to use this single index to balance the samples with respect to all the covariates used. However, Rosenbaum and Rubin assumed that $P(X)$ is known. Heckman et al. (1998) have extended the Rosenbaum and Rubin framework to the case where the propensity score is unknown and has to be estimated. They show that neither of the methods (using the characteristics X in the matching functions or the propensity score $P(X)$) have a clear advantage over the other. They state that the appeal of the propensity score matching is just its simplicity in estimation. "In samples of the usual size of economics, cells will be small if matching is made on a high-dimensional X. This problem is less likely to arise when matching is on a single variable like P." (Heckman et al., 1998, p. 283). However, the disadvantage of the propensity score matching is that the researcher has to estimate a model describing the selection mechanism. This involves making distributional assumptions about error terms and a choice of some functional form, which can be subject to specification errors.[4] Consequently, I first apply a multivariate non-parametric matching technique as the control group will be reasonably large. In a more detailed analysis on ownership of Eastern German firms, I will use a propensity score matching due to the smaller size of the available control group.

4. Empirical Study

A simple breakdown of the macroeconomic data (see Figures 1 and 2) shows that one should distinguish the manufacturing sector and the construction sector within the producing sector. The focus of this study is Eastern German manufacturing. Although it becomes clear that the decline in the construction sector is to a large extent responsible for the macroeconomic picture as shown in Figure 1, the basic statement remains the same. As the time-series in Figure 2 reveal, construction sector growth rates in Eastern Germany fall below those of Western Germany in the mid nineties. In manufacturing, Eastern Germany realizes significantly higher growth rates from 1993 to 1996, but in 1997 and 1998 these rates are nearly identical in both regions. From 1999 to 2001, the growth rates in Eastern German manufacturing are marginally higher again. The reason for the decline is quite clear in the construction sector: after a phase of impressive growth from 1992 to 1994 due to the demand pull after re-unification, the construction firms were not able to cope with the decrease in public demand for new housing. Why the performance

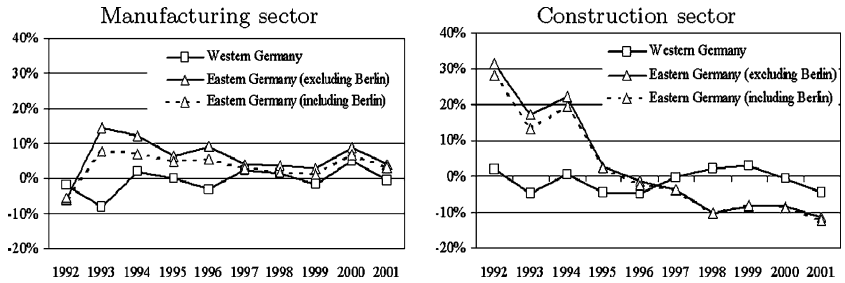

Figure 2. Growth rates of value added in manufacturing and construction. Source: Arbeitskreis VGR der Länder, Statistisches Landesamt Baden-Württemberg.

of Eastern Germany also declines in manufacturing is not as easy to explain, and remains an interesting question to investigate. Is the productivity of labor and capital stagnating in Eastern German manufacturing, and which factors influence productivity besides labor and capital?

4.1. Data and Empirical Modeling

Most information is taken from the MIP. The MIP is an annual German innovation survey conducted since 1992 by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry of Education and Research (BMBF). Firms surveyed in the MIP are selected by a stratified random sampling and are representative of the population in the manufacturing sector (and several service sectors) of the German economy (cf. Janz et al., 2001, for a description of the database).

It is unclear how the German capital, Berlin, should be treated in the data in the context of this study. West Berlin was, of course, a part of West Germany, although it is located in the eastern part of the country. Berlin is important in the macroeconomic figures (see Figures 1 and 2) when it is assigned to Eastern Germany. As it is not meaningful in this analysis to treat Berlin either as Eastern or Western German, I decided to drop firms located in this city from the analysis completely.

As Western Germany has some exceptionally huge firms for which definitely no counterparts exist in Eastern Germany, I drop such firms in the first place. Firms with more than 15,000 employees are excluded (159 firm-year observations). The remaining sample of 13,646 observations on manufacturing firms from the years 1993–2000 can be used. Table 1 displays the distribution of observations over the period under review.

The dependent variable is value added per employee in 100.000 €

$$\text{Value added per employee}_{it} = \frac{\text{Sales}_{it} - \text{materials}_{it}}{\text{employees}_{it}}.$$

Table 1. Sample of manufacturing firms.

Year	Western Germany	Eastern Germany	Total
1993	1530	638	2168
1994	1522	581	2103
1995	1160	420	1580
1996	1212	505	1717
1997	1082	440	1522
1998	1183	469	1652
1999	987	430	1417
2000	1042	445	1487
Total	9718	3928	13646

Source: Mannheim Innovation Panel—Manufacturing Sector

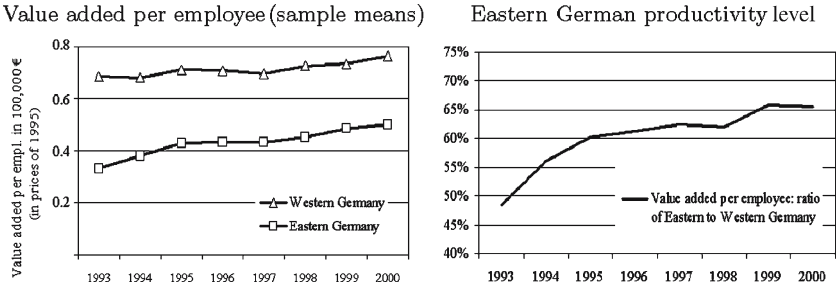

Figure 3. Average value added per employee in the MIP (manufacturing sector). Source: Mannheim Innovation Panel—Manufacturing Sector.

It is deflated by a price index for producer goods on a two-digit industry level. The sample confirms the macroeconomic picture: The left-hand side of Figure 3 shows the sample means of the firm-level observations in the MIP. The right-hand side of Figure 3 shows the ratio of the Eastern German value added per employee to that of Western Germany (based on the sample means). The Eastern German firms have been only slowly catching up to Western German productivity levels since the mid nineties. In 2000 there is still a gap of 35%. The t-tests reveal that the average value added per employee between Eastern and Western Germany differs significantly in each year (at the 1% level). This phenomenon is robust in more detailed analyzes as well: First, I performed non-parametric median tests instead of mean tests, because those are robust against the skewness of the size distribution. Second, I only considered younger firms (less than 10 years old), and, third, only small firms. In all cases the mean or median differences show a similar picture to Figure 3 and the productivity gap between Eastern and Western German firms is always significant at the 1% level in every period.

Unfortunately, the MIP does not contain identical information for each year and I will thus perform two different estimations. The first approach covers the whole period from 1993 to 2000, but does not contain the full set of exogenous variables

as considered in Section 4.2. Additionally, an estimation is conducted with the full set of variables, but this covers only selected years from the sample; that is, when all information is available in the MIP survey.

The main input factors of production are obviously labor and capital. Labor is measured as the number of employees and capital as tangible assets per employee (capital intensity). Eastern German firms are on average smaller than Western firms as indicated by both employees and fixed assets. Of course, the sectoral classification is captured by a set of dummy variables in the regressions. Firms from the control group which are engaged in a different sector than the particular Eastern German firm receive a weight equal to zero in the matching procedure. In addition, it is also controlled for regional characteristics. In order to distinguish companies in rural and urban locations, the corresponding district's population density is included as a covariate. Many Eastern German firms still rely on their regional market instead of seeking national or international market penetration. Hence, the geography could matter for the performance of such units. As the average population density in Eastern Germany is significantly lower than in Western Germany, this might also add to the productivity gap.

Moreover, the companies are distinguished with respect to innovation. As described in Section 2, innovative products and processes are often seen as a key factor of firm performance. An innovating firm is defined as proposed in the OLSO–Manual: A firm having introduced at least one product or process new to the firm within the last three years is considered to be innovative.[5]

Another important factor for productivity is the ownership of firms. It has often been hypothesized that firms which are owned by Western German or foreign companies develop differently compared to stand-alone Eastern German firms. On one hand, belonging to a larger group may enhance the flow of knowledge spillovers from more experienced enterprises to the newly founded and smaller Eastern German firms. Another important benefit for Eastern German firms which belong to a group could be access to a well-functioning distribution network and thus better access to markets. On the other hand, critics of the argument concerning foreign (and Western German) ownership often emphasize that the Eastern German firms are only used as "extended workbenches" or "sweat-shops". This would imply that instead of receiving positive spillovers from knowledge flows and access to markets, Eastern German subsidiaries are only being exploited. The empirical analysis is expected to shed some light on these opposing arguments.

As the reading of other studies suggests, human capital may be an important feature of successfully operating firms, especially with respect to innovation. As Klodt (2000) points out, Eastern German firms may suffer from an underprovision of human capital and may therefore not be able to produce highly sophisticated products and employ highly efficient processes, both of which are needed to enter new markets and to compete on domestic and foreign markets. Human capital, or the knowledge stock of firms, is approximated by the stock of patents because this reflects the (successfully) technological know how accumulated by a firm over time. The use of knowledge stocks as important assets of firms has become popular since the publication of a seminal study by Griliches (1981), who investigated

how firm values are comprised of the stock of physical assets and of intangible assets (their knowledge stock). Several studies were conducted on this topic (see Hall, 2000 for a survey). The results can be summarized as follows: a firm's stock of knowledge is an important asset even though it does not appear in its balance sheet. In this paper the information on knowledge stocks is taken from the patent database of the German Patent and Trademark Office. This database allows to derive the patent stock (PS_{it}) from firm-specific time-series on patent applications since 1980. See OECD (1994) for a comprehensive discussion on the use of patents as science and technology indicators.[6] The stock of applications is calculated by the perpetual inventory method as

$$PS_{it} = (1-\delta)PS_{it-1} + PA_{it},$$

where PA_{it} is the number of patent applications of firm i in period t and δ is the annual depreciation of the knowledge capital, which is set to 0.15 (see also Griliches and Mairesse, 1984, who have shown that the choice of the rate of obsolescence played only a very minor role in production function estimates). As the patent series has been available since 1980 and the sample under consideration begins in 1993, the starting value $PS_i, 1980$ is set to zero for all firms. The bias possibly emerging from this assumption decreases over the years due to depreciation, and should be negligible in the 1990s.[7] Of course, not every firm has filed a patent: 42% (26%) of Western (Eastern) German firms in the sample have a patent stock larger than zero. The average patent stock of firms with at least one application in the period under review is 7.6 (5.1) in Western (Eastern) Germany. The patent stocks in Eastern Germany are obviously smaller because most firms did not exist until the German re-unification in 1990.

In contrast to the knowledge stock approximated by patents, the most straightforward measure of human capital is the formal qualification of employees. However, it is a well-known fact that formal qualification in the former GDR has, on average, been higher than in Western Germany and this still persists. The actual qualification of such graduates may well be below the Western German standard. The human capital of older employees from the former GDR may be outdated from the perspective of today's job specifications, and there is an oversupply of formally highly skilled people in Eastern Germany due to high rates of unemployment. Thus, the jobs many people hold do not correspond to their skills. I have experimented with the formal qualification structure despite its deficiencies, but it turns out to be inappropriate in the matching procedure. If one tries to match the samples with respect to size and human capital, it turns out that the Eastern German firms ceteris paribus show a higher share of graduates than Western firms. Once the firm size and other basic characteristics (e.g. sectoral classification) are fixed, it is not possible to find proper matching firms with comparable shares of graduates in Western Germany. This indicates that the formal qualification may not reveal the actual qualification employed on the job in Eastern Germany. In order to overcome this problem, the patent stock is favored in the subsequent analysis.

Table 2. Mean values before and after matching[a].

Variable	Year[b]	Eastern Germany	Western Germany	Matched sample
Employees	1993	0.18	0.50***	0.17
(in 1000)	2000	0.11	0.33***	0.13
Population	1993	5.11	7.58***	5.35
density	2000	4.60	6.96***	4.80
Innovation	1993	0.66	0.68	0.65
dummy	2000	0.62	0.60	0.62
Value added per	1993	0.27	0.72***	0.68***
empl. (in 100,000 €)	2000	0.50	0.77***	0.68***

*** (**, **) indicate that the Eastern German mean differs from that of Western Germany at a significance level of 1% (5, 10%).

[a] The firm distribution over sectors differs significantly before matching, but does not differ between matched samples.

[b] Obs. in the original sample in 1993 (2000): 1,530 (1,042) in Western and 638 (445) in Eastern Germany.

4.2. Basic Analysis

The first matching procedure is carried out with only a few variables in order to cover the whole period from 1993 to 2000. In it, I consider firm size, the distribution over sectors, the population density of the district and whether the firm is innovating (that is, whether or not the firm has at least introduced a new product or implemented a new process in the last three years). Prior to the matching, the firms in Eastern and Western Germany are quite different. Firms differ in size, are located in differently characterized districts and the firm distribution is different over industries. See Table 2 for *t*-tests on mean differences for the years 1993 and 2000 before and after matching.[8]

After the matching routine, the samples of Eastern Germany and its estimated control group are well balanced with respect to the elements included in the matching function. The distribution over industries is now the same for both groups. However, the productivity gap remains. While it was an average of approximately € 26.35 thousand per employee before matching in 2000, it decreases to € 18.97 thousand after the matching procedure. Thus, about 27% of the observed productivity gap in 2000 can be attributed to Eastern German disadvantages in factors like firm size, sectoral composition, innovation and districts' characteristics. Figure 4 shows the evolution of productivity over time and compares productivity statistics from before and after matching.

The matching now allows the analysis of the remaining productivity gap in greater detail. Are there groups of firms which perform better or worse than average? A remarkable result is obtained by dividing the sample into groups of innovating and non-innovating firms. Recall that the innovation dummy has been included in the matching function. As Figure 5, shows the Eastern German

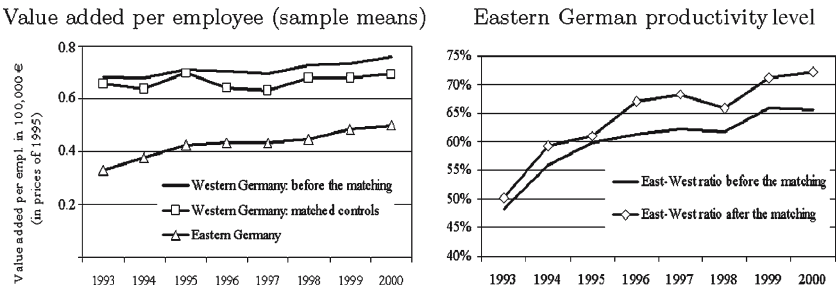

Figure 4. Average value added per employee after matching by firm size, industry classification and regional characteristics.

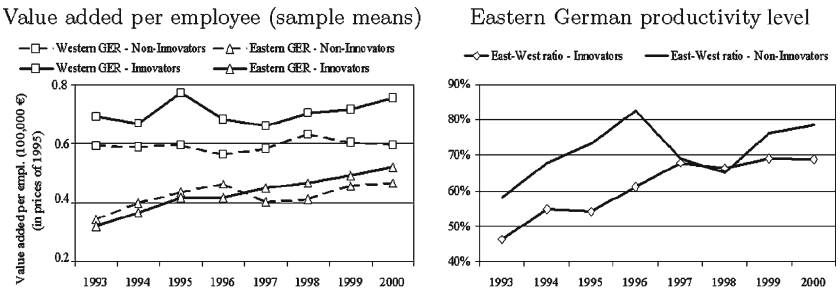

Figure 5. Average value added per employee after matching by innovators and non-innovators.

innovators perform worse than the non-innovating firms. It is important to note that this does not imply that innovation reduces productivity. Instead, the innovating firms are compared with innovative Western German firms which have a high productivity even compared to the Western German average. On the contrary, non-innovating Eastern German firms are compared to those from Western Germany whose results are below the Western German average. The results show that the Eastern German companies are not able to utilize their innovation activities to the same extent as the Western German firms. While the non-innovating firms do almost reach a productivity level of 80% of the matched controls, the innovating firms are at 70% in 2000. Non-innovating firms did catch up relatively well in comparison to innovating firms. However, this may change in the future, as the East–West ratio of non-innovating firms is quite volatile. Figure 5 (on the left-hand side) shows that since 1997 innovative Eastern German firms achieved a slightly higher value added per employee than non-innovating firms. Possibly, firms with considerable knowledge stocks become more and more able to produce new products which reach the quality demanded by consumers.

4.3. Basic Analysis—Only Young Firms

In a further step, the sample is restricted to firms which have existed for a maximum of 10 years. The vast majority of firms in Eastern Germany were newly

Table 3. Mean values before and after matching[a]—young firms.

Variable	Year[b]	Eastern Germany	Western Germany	Matched sample
Employees	1993	0.18	0.31***	0.15
(in 1000)	2000	0.11	0.22***	0.10
Innovation	1993	0.66	0.72	0.66
dummy	2000	0.65	0.59	0.65
Value added per	1993	0.32	0.65***	0.61***
empl. (in 100,000 €)	2000	0.50	0.76***	0.72***

*** (**, **) indicate that the Eastern German mean differs from that of Western Germany at a significance level of 1% (5, 10%).

[a] The firm distribution over sectors differs significantly before matching, but does not differ between matched samples.

[b] Obs. in the original sample in 1993 (2000): 250 (176) in Western and 614 (224) in Eastern Germany.

founded after the German reunification and are therefore younger than 10 years. It may be that young firms have not yet been able to utilize learning curve effects and exhibit a lower productivity. Table 3 shows that even the subsamples of young firms differ in size and productivity between Eastern and Western Germany prior to matching.

After balancing the sample of young firms with respect to size, industries and the innovation dummy both groups do not differ in these characteristics. However, as Table 3 shows, the difference in productivity between young firms from Eastern and Western Germany remains significantly different from zero. Even the argument that Eastern German companies may be too young to be as productive as Western German firms is not striking. Young Eastern German firms have a lower productivity than their matched controls from the West.

4.4. Extended Analysis

The previous estimations show that is is not possible to explain the productivity gap only by referencing differences in firm size, industry composition, regional characteristics and innovation. As the review of the literature in Section 2 suggests, other relevant factors are inputs like physical capital and human capital. Unfortunately, this analysis is only possible for a subsample of the years from 1994 to 1998 (excluding 1997) because not all information has been surveyed annually. The matching procedure is now carried out with the number of employees, sector controls, capital stock (as intensity: tangible assets per employee) and knowledge assets (that is, the patent stock). I include a dummy which indicates whether a firm has filed at least one patent; 23% of Eastern German firms and 46% of Western German firms have done so. Moreover, I include the size of the patent stock as described above (PS).

Table 4. Mean values before and after matching—extended analysis.[a]

Variable	Year[b]	Eastern Germany	Western Germany	Matched sample
Employees	1994	0.12	0.35***	0.12
(in 1000)	1998	0.13	0.31***	0.12
Capital intensity	1994	0.39	0.38	0.43
(100,000 €)	1998	0.48	0.38***	0.59
Patent stock	1994	0.17	0.44***	0.17
dummy	1998	0.29	0.46***	0.27
Patent stock	1994	0.67	7.15***	0.73
	1998	1.61	6.78***	1.23
Value added per	1994	0.38	0.68***	0.60***
empl. (100,000 €)	1998	0.45	0.72***	0.69***

*** (**, **) indicate that the Eastern German mean differs from that of Western Germany at a significance level of 1% (5, 10%).

[a] The firm distribution over sectors differs significantly before matching, but does not differ between matched samples.

[b] Obs. in the original sample in 1994 (1998): 1507 (580) in Western and 1171 (469) in Eastern Germany.

As Table 4 shows, the inclusion of capital stock and knowledge stock does not alter the basic result. The productivity gap remains significantly different from zero. However, it is noteworthy that the capital stock per employee is higher in Eastern Germany which is a result of the huge initiatives of the German government to foster the transformation process. It is still unclear why the Eastern German firms are not able to utilize this advantage. Even if the disadvantage in knowledge assets is taken into account (measured by patents), the matched control group still exhibits a higher value added per employee.

4.5. Firm Ownership

As final analysis, I consider firm ownership. Among the Eastern German firms it is possible to distinguish stand-alone companies from those associated with a group with Western German or foreign parent companies. If these firms are more productive than others, this would support the hypothesis that there is still a lack of human capital with respect to management and that a major problem of Eastern German firms could be poor access to markets. Bellman et al. (2002) already stated that foreign owned firms have a higher productivity than other firms. However, they did not control for firm heterogeneity as done here.

The matching results from above can be categorized into groups containing stand-alone companies from Eastern Germany and firms associated with group with Western German or foreign parent companies. Table 5 shows the productivity gap from the perspective of Eastern German firms. The result is interesting: although the productivity gap shrank between 1994 and 1998, the difference in value added per employee to the matched controls diverged between the two

Table 5. Productivity of Eastern German firms after matching.

Variable	Year[a]	Stand-alone companies	Subsidiaries
Diff. in value added per empl.	1994	0.23	0.18*
to matched controls (100,000 €)	1998	0.25	0.11***

*** (**, **) indicate that the means differ at a significance level of 1% (5, 10%).
[a] Obs. in 1994 (1998): 451 (365) stand-alone and 129 (104) subsidiaries.

groups. While the gap differs only slightly in 1994 between stand-alone companies and firms associated with Western German or foreign groups (€ 5.2 thousand, significant at the 10% level only), it has more recently been larger. In 1998, the difference in the gap already amounts to € 14.4 thousand (significant at the 1% level).

While this result is striking, it may be possible that this is not an exogenous phenomenon. It may be the case that the parent companies follow a "picking-the-winner" strategy and select highly productive firms. Thus, belonging to a group can actually be interpreted as a 'treatment'. In the following I consider ownership as an endogenous variable and perform a propensity score matching as described above in the methodological section. For this case, I only use Eastern German firms from the sample and match those associated which a Western German or foreign group with stand-alone companies from Eastern Germany. A probit model on ownership status is estimated and the resulting propensity scores are used as matching criteria. The sample from Eastern Germany (1994–1996 and 1998) contains 464 firms that are associated with Western German or foreign groups and 1652 control observations of stand-alone companies. As the control group is rather small, I include only the number of employees (in logs), the sectors, the patent dummy, and capital intensity as regressors in the probit model. Age, the number of patents and the innovation dummy have no significant effect on the group dummy. Table 6 shows the mean values before and after matching. The group firms are larger, have a higher capital intensity and a higher share has filed at least one patent. Moreover the value added per employee is higher as well. This already shows that the group variable should be considered as endogenous. It actually seems that potential 'winners are picked' if one agrees to consider 'winners' as knowledge-intensive firms, as indicated by the capital intensity and the patent dummy.

Balancing the sample leads to the estimation of the treatment effect, which is the difference in value added per employee between both groups. The difference in productivity amounts to € 14.1 thousand in 1994 and to € 15.5 thousand in 1998, and both differences are significant. In contrast to the finding that the productivity gap closes, this development shows that the value added per employee among Eastern German firms is diverging, although only slightly. The companies associated with a group with Western German or foreign parent companies show a higher productivity in more recent years. This underpins the hypothesis that ownership generates positive spillovers with respect to managerial skills, or simply to a better

Table 6. Productivity of stand-alone firms versus group members.[a]

Variable	Year[b]	Firms associated with a group	Stand-alone companies	Matched sample
log(Employees/1000)	1994	−2.13	−3.15***	−2.10
	1998	−2.01	−3.21***	−2.01
Capital intensity	1994	0.53	0.35***	0.45
(100,000 €)	1998	0.67	0.43***	0.79
Patent stock	1994	0.29	0.15***	0.29
dummy	1998	0.45	0.24***	0.44
Propensity	1994	−0.40	−1.10***	−0.42
score	1998	−0.29	−1.16***	−0.33
Value added per	1994	0.49	0.35***	0.35***
employees (100,000 €)	1998	0.63	0.40***	0.48***

*** (**, **) indicate that the mean of firms belonging to a group differs from that of stand-alone companies at a significance level of 1% (5, 10%).

[a] The firm distribution over sectors differs significantly before matching, but does not differ between matched samples.

[b] Obs. in 1994 (1998): 493 (389) stand-alone and 140 (111) group companies.

access to markets. It does not seem that the subsidiaries of Western or foreign enterprises are merely being exploited as "sweat-shops" by their parent companies. Note that this is not a phenomenon unique to Eastern Germany.[9] I conducted the same analysis for Western Germany, and matched Western German firms associated with a group with stand-alone companies. These both groups differ significantly in average firm size and knowledge assets, but not in capital intensity, as it is the case in the Eastern German sample. The productivity gap amounts to € 16.06 thousand (€ 16.99 thousand) in 1994 (1998). After matching, a significant gap remains in Western Germany, too. It is € 10.64 thousand (€ 12.11 thousand) in 1994 (1998). Thus, both Eastern and Western German firms associated with groups seem to benefit from spillovers, financial backup or access to better distribution networks and markets. However, it is noteworthy that the remaining productivity difference after matching in Western Germany is about 16% in 1998. In Eastern Germany, though, the average difference between firms associated with a group compared to the counterfactual situation of being a stand alone company amounts to 33%, which is almost as twice as high. The macroeconomic productivity gap due to group membership shows even more clearly in Eastern Germany, because only about 28% of firms in manufacturing belong to a group, whereas this figure is 50% in Western Germany.

5. Conclusion

In this paper, I analyze the productivity gap between Eastern and Western German firms. In general, the microeconometric study confirms the macroeconomic facts. The Eastern firms operating in the manufacturing sector are still lagging behind

Western German firms in terms of value added per employee. Although the productivity gap is closing, the catch up process has slowed in recent years.

I have proposed using an econometric matching procedure to analyze the productivity deficiency in Eastern Germany in more detail. If one agrees to use comparable Western German firms as a benchmark for productivity, this estimation method directly addresses the question of which productivity level one could expect from an Eastern German firm with given characteristics like industry classification, firm size, capital intensity, knowledge assets, innovations and age.

Several applications of the matching procedure show that the productivity gap remains significantly different from zero in all considered settings. I arrive at following key results: innovating firms from Eastern Germany are less productive in comparison to their control firms from Western Germany than non-innovating firms. Eastern German firms catch up faster with less productive firms from the West. Note that this does not imply that innovative firms are less successful in the East. In recent years they have exhibited a higher productivity than non-innovating firms but still suffer from a higher deficit in comparison to their Western German counterparts and possible competitors. However, for both firm groups a significant gap still existed in 2000. Another interesting result which emerges from the comparison of different firm categories is the importance of firm ownership. If an Eastern German firm is associated with a group with Western German or foreign parent companies, it is, on average, more productive than stand-alone companies. This result even holds true when the group variable is considered as endogenous, that is, when the parent companies follow a "picking the winner" strategy. Matching such Eastern German subsidiaries with stand-alone firms does not destroy this result. The gap between these two groups within Eastern Germany remains significant. In contrast to the result that the gap between the East and the West is gradually closing, the gap between these firms is actually increasing over time. This diverging development indicates the hypothesis of positive spillovers. Either managerial skills are mediated via the ownership structure, or simply a better access to markets due to a well-functioning distributional network between the group members is provided.

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Notes

1. In the following, I use the term 'treatment' as the literature origins in this field of research. However, it is not intended to interpret 'being an Eastern German firm' as treatment.

2. There exist other approaches in the treatment literature like a before–after comparison of treated units, and a difference-in-difference estimation, where treated and not treated units are compared before and after the treatment (see Heckman et al., 1999, for example).
3. Another popular choice would be, for example, the local linear regression. While the Nadaraya–Watson estimator fits a constant to the data close to X the local linear approximation fits a straight line (see Pagan and Ullah, 1999, Sections 3.2 and 3.3, or Fan, 1992).
4. If the propensity score is estimated non-parametrically, one again encounters the curse of dimensionality (see Heckman et al., 1998, p. 271).
5. See Eurostat and OECD (1997) for the exact definition.
6. An alternative measure would be R&D stock, but it is not possible to derive R&D stocks from the data available (firm-year observations on R&D expenditure) because many firms are only observed once in the MIP sample. For the calculation of firm-specific R&D stocks long time-series information on annual R&D expenditures would be required.
7. If a patent has been filed jointly by two or more applicants, the application is counted for both of them because the knowledge behind the patent should be available to each of the applicants.
8. The tests for the years in between are not presented but yield the same results.
9. This comment was made by one of the referees.

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