ECONSTOR
Make Your Publications Visible.

A Service of

ZBW Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Czarnitzki, Dirk

Working Paper

Extent and Evolution of the Productivity Gap in Eastern Germany

ZEW Discussion Papers, No. 03-25

Provided in Cooperation with:
ZEW - Leibniz Centre for European Economic Research

Suggested Citation: Czarnitzki, Dirk (2003) : Extent and Evolution of the Productivity Gap in Eastern Germany, ZEW Discussion Papers, No. 03-25, Zentrum für Europäische Wirtschaftsforschung (ZEW), Mannheim

This Version is available at:
https://hdl.handle.net/10419/23957

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

Discussion Paper No. 03-25

Extent and Evolution of the Productivity Gap in Eastern Germany

Dirk Czarnitzki

ZEW

Zentrum für Europäische Wirtschaftsforschung GmbH

Centre for European Economic Research

Discussion Paper No. 03-25

Extent and Evolution of the Productivity Gap in Eastern Germany

Dirk Czarnitzki

Download this ZEW Discussion Paper from our ftp server:

ftp://ftp.zew.de/pub/zew-docs/dp/dp0325.pdf

Die Discussion Papers dienen einer möglichst schnellen Verbreitung von neueren Forschungsarbeiten des ZEW. Die Beiträge liegen in alleiniger Verantwortung der Autoren und stellen nicht notwendigerweise die Meinung des ZEW dar.

Discussion Papers are intended to make results of ZEW research promptly available to other economists in order to encourage discussion and suggestions for revisions. The authors are solely responsible for the contents which do not necessarily represent the opinion of the ZEW.

Non–technical Summary

Since the German re–unification in 1990, the German government tries to foster the transition process of the Eastern German economy by means of different kinds of policy instruments. However, the vast majority of firms in Eastern Germany has been newly founded after 1990 and hence these firms are smaller than Western German companies on average, and a large share of them is struggling to survive. The still underdeveloped infrastructure and, additionally, the breakdown of the eastern European markets possibly hamper a positive development of Eastern Germany. From the macroeconomic point of view, the situation in the Eastern German producing sector is alarming: The re–unification has been followed by a phase of catching up in value added compared with Western Germany from 1991 to 1996. Since 1997, the growth rates of the Eastern German producing sector have dropped below the ones of Western Germany.

This study investigates whether this macroeconomic picture holds at the microeconomic level. The question arises if most firms in Eastern Germany suffer disadvantages in productivity or if there is just another misallocation present: for example, unfavorable factor combinations in production or not reaching the minimum efficiency scale due to the small firm size. The traditional approach of analyzing productivity is to estimate production functions. I suggest an alternative method to identify productivity gaps. In the special case of Eastern Germany, 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 suitable Western German control observations for every Eastern German company which have the same characteristics like size, industry classification, assets, 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 has therefore the advantage that no production function has to be specified and no assumptions on functional forms have to be imposed. It allows to estimate the differences 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 to 2000. The estimation results broadly confirm the macroeconomic picture: the catching–up of Eastern German productivity was largest in the first

years after the re–unification and has been declining since then, and a significant gap still remains in recent years. However, the matching does also allow to identify variables which influence the size of the gap to Western German firms. In more detail, the analysis shows that innovators in Eastern Germany perform worse than non–innovative firms: In relation to the Western German control group, the estimation discovers a higher gap for innovating firms. Although innovating firms show a higher productivity than non–innovators, they perform relatively worse with respect to their control group. Moreover, ownership structure is an important topic. If an Eastern German firm belongs to a group with a Western German or foreign parent company, it has a higher productivity than stand–alone companies on average. This result does even hold 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 companies does not destroy this finding. The gap between those two groups within Eastern Germany remains significant. In contrast to the result that the gap between the East and the West closes over time, the gap between these firms slightly increases over time. This diverging development points to 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 of the group members is provided.

Extent and Evolution of the Productivity Gap in Eastern Germany[1]

by

Dirk Czarnitzki

May 2003

Abstract

Since the German re–unification in 1990, Eastern Germany is a transition economy. After a phase of catching up of productivity with respect to Western Germany from 1991 to 1996, the growth rates in the producing sector have dropped below the Western German ones since 1997. This study investigates whether this macroeconomic picture holds at the microeconomic level. For the special case of Eastern Germany, I suggest to identify productivity gaps by a comparison with Western Germany 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 or firm ownership are taken into account. The macroeconomic facts are broadly confirmed: a significant gap still remains in recent years. Moreover innovators in Eastern Germany perform worse than their Western German pendants and firms owned by Western German or foreign companies perform better than Eastern German owned ones.

Keywords: Productivity Gap, Eastern Germany, Non–parametric Matching

JEL–Classification: C14, D24

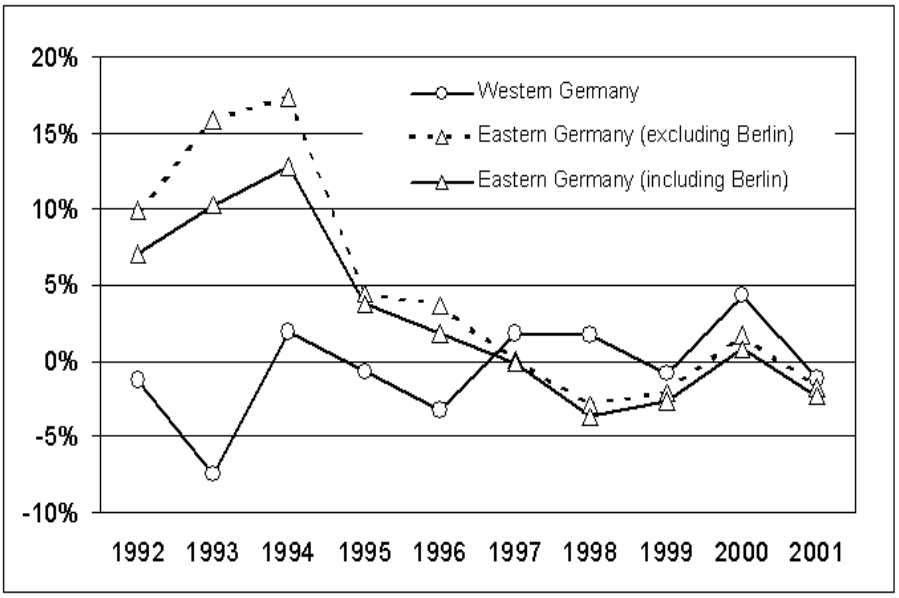
Address: Centre for European Economic Research (ZEW)
Department of Industrial Economics and International Management
P.O.Box 10 34 43
68034 Mannheim
Germany
Phone: +49/621/1235–158
Fax: +49/621/1235–170
E-Mail: czarnitzki@zew.de

[1]I would like to thank Lutz Bellmann, Herbert Buscher, Bernd Fitzenberger, Reinhard Hujer, Georg Licht, and Christian Rammer for helpful comments as well as Nora Külls and Mark Shore editorial assistance.

1 Introduction

Since the German re–unification in 1990, the economy of Eastern Germany is in transition from a planned economy to a market economy. The optimistic hypothesis that a second "Wirtschaftswunder" as after the second world war in Western Germany will occur in Eastern Germany after 10 years turned out to be falsified. While the productivity growth in Eastern Germany has been large in the early years, the growth rates dropped under the Western German ones in 1996 and remain low since then (see Figure 1). The catching–up process of the Eastern German economy to the Western standard is stagnating and the productivity gap remains large. The Eastern German aggregate productivity (GPD 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, the East–West ratio is stabilizing around this level since then. In 2002, it has been 58.4% (Source: Sinn, 2003).

Figure 1:
Growth rates of value added in the producing sector



Source: Arbeitskreis VGR der Länder, Statistisches Landesamt Baden–Württemberg

These discouraging macroeconomic facts are possibly partly due to the lack of large companies in Eastern Germany. While the large "combines" of the former German Democratic Republic had been closed down or separated into several smaller companies, most firms have been newly

founded after the re–unification. These are therefore smaller than Western German firms on average, and presumbly 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 have possibly also hampered a more positive development of Eastern Germany. Besides the problem of the lack of industrial companies, it is unclear how much of the productivity gap is due to other factors within the firms' production process. Examples are poor capital stocks, the lack of human capital ("know how"), the misallocation of production factors, the lack of innovative products, or inefficient management (cf. Ragnitz, 1997, for example). The purpose of this paper is to analyze whether the macroecomic picture holds at the microeconomic level, i.e. at the firm level, and to shed some light on the reasons of the persisting productivity gap.

The traditional approach of 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 the transition economy of Eastern Germany, 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 has, therefore, the advantage that no production function has to be specified and no assumptions on functional forms have to be imposed. It allows to estimate 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 to 2000. The matching also allows to identify single variables which may influence the productivity. Besides the central factors 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 third section, and the

fourth section discusses the empirical analysis.

2 Brief Review of the Literature

Since an important publication on the economic aspects of the Eastern German transformation process in 1991 (Sinn and Sinn, 1991), a lot of studies were 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 dicsuss the "iron law of convergence" which predicts a rate of convergence of roughly 2% between regions. Several studies have applied such growth theoretic models to Eastern Germany, and some have argued that the convergence of Eastern Germany will be faster due to different reasons (see, among others, Burda and Funke, 1995, or in contrast to this Hughes Hallet et al., 1996, as depressing forecast on Eastern Germany's future performance).

More recently, Burda and Hunt (2001) state 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 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: 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) do also point out that rather 'soft factors' like managerial issues and the integration of the plant or firm into the company or group respectively are more important than structural fators like tangible assets and so on.

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: 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 turn up when subsidies are reduced and structures relying upon subsidized capital input are no longer sheltered from market competiton. In contrast, Dietrich (1997) writes a main reason for the productivity gap is the circumstance that production in Eastern Germany is less capital–intensive (cf. also Ragnitz, 1997 and 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 the competitiveness are revealed, e.g. lower product quality, strategic orientation of firms or in marketing.

There are also two studies which use data from the Mannheim Innovation Panel as done here. 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 with both product and process innovations has been substantially larger than for 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 productivity growth of 7 to 8%.

Another study, closely related to this paper, is Fritsch and Mallok (1994). They apply the matched pair methodology, although not in 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 value added per employee in comparison to Western Germany. 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 63% on average. 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 responible 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 besides other more conventional characteristics like firm size, sectors, firm age and fixed capital.

3 Econometrics

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, or Heckmann et al., 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 from unknown reasons internal to the 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 both German regions is closing over time and whether it still exists in recent years. A parametric regression on productivity which includes

just a dummy for Eastern German firms may possibly be too restrictive to capture this difference carefully, especially when Eastern and Western German companies differ strongly in other important characteristics, like firm size etc. 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 individuals or firms, respectively:[2]

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

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 $S = 0$ the non–treated individuals (Western German firms). YC is the potential productivity which had been realized if the Eastern German firms ($S = 1$) would be Western German ones. The problem is obvious: while the outcome of the treated individuals in case of treatment, $E(YT|S = 1)$, is directly observable, this is not the case for the counterpart. What would these individuals have realized if they had not received the treatment, $E(YC|S = 1)$, is a counterfactual situation which is not observable and, therefore, has to be estimated. In this case, the potential outcome is constructed from a control group of Western German firms.[3] 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, 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,

[2]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.

[3]There exist other approaches in the treatment literature like a before–after comparison of treated firms, and a difference–in–difference estimation, where treated and not treated firms are compared before and after the treatment (see Heckmann et al., 1999, for example).

participation and potential outcome are independent for individuals 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 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.

Estimation of the counterfactual

A weight w_{ij} is defined with respect to X for each Eastern German firm i which assignes 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 Czarnitzki, 2001, Czarnitzki and Fier, 2002, Almus and Czarnitzki, 2003). 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 downweights observations with respect to their distance to X_i. h is the bandwidth parameter. The weights are obtained by a non–parametric regression that is 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. The minimization problem to obtain 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 resulting estimator equals

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

Instead of a single X, several characteristics of the individuals 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 chosen. 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

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

where k is the number of variables included in X.

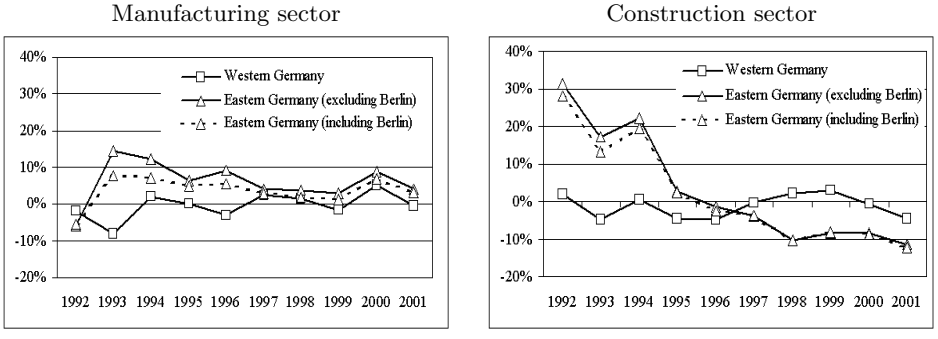
The Nadaraya–Watson kernel regression is performed for every Eastern German firm in the sample, that is, an estimate of the potential productivity for each i is constructed from the entire sample of Western German firms. Once the samples have been balanced by the kernel matching procedure,

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.

4 Empirical Study

As a simple break–up of the macroeconomic data available from the federal statistical office (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, the growth rates in Eastern Germany fall below the Western German ones in the mid nineties in both manufacturing and construction. The reason is quite clear in the construction sector: after a phase of impressive growth from 1992 to 1994 due to the demand pull after the re–unification, the construction firms were not able to cope with the decrease in public demand for new housing. Why the performance of Eastern Germany does also decline 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 do influence the productivity besides labor and capital?

Figure 2:
Growth rates of value added in manufacturing and construction



Source: Arbeitskreis VGR der Länder, Statistisches Landesamt Baden–Württemberg

4.1 Data and empirical modeling

Most information is taken from the Mannheim Innovation Panel (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 for 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 has of course been a part West–Germany, although it is located in the eastern part of the country. Berlin is even 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 Germany or as Western Germany, I decided to drop firms located in this city from the analysis completely.

A sample of 15,279 observations on manufacturing firms from the years 1993 to 2000 can be used. Table 1 displays the distribution of observations over the period under review.

Table 1:
Sample of manufacturing firms

Year	Western Germany	Eastern Germany	Total
1993	1562	649	2211
1994	1549	590	2139
1995	1181	429	1610
1996	1240	513	1753
1997	1110	458	1568
1998	1208	483	1691
1999	1030	448	1478
2000	1054	446	1500
Total	10913	4366	15279

Source: Mannheim Innovation Panel — Manufacturing Sector

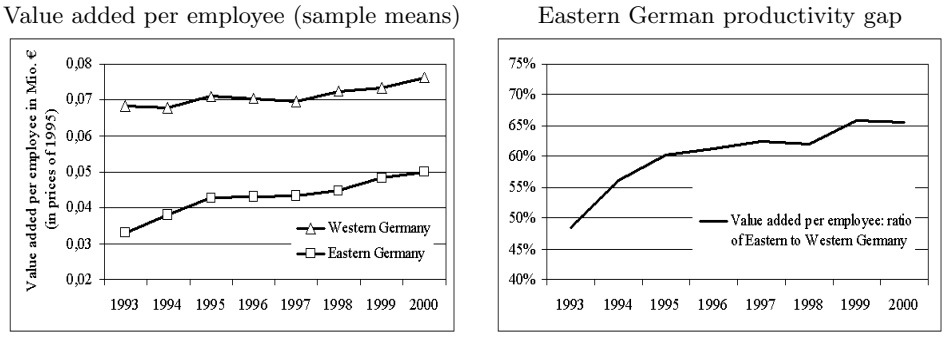
The dependent variable is value added per employee in Mio. €

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

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 Eastern German firms are catching up only slowly to the Western German productivity level since the mid–nineties. The right–hand side of Figure 3 shows the ratio of the Eastern German value added per employee to the Western German one (based on the sample means). In 2000 there is still a gap of 35%.

Figure 3:
Value added per employee in the MIP (manufacturing sector)



Source: Mannheim Innovation Panel — Manufacturing Sector

Unfortunately, the MIP does not contain identical information for all years and therefore, I will perform two different estimations. The first estimations covers the whole period from 1993 to 2000, but does not contain the full set of exogenous variables as considered in the following subsection. 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.

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 recent three years is considered to be innovative.[4]

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 needed to enter new markets and to compete on domestic and foreign markets. Of course, firms with highly skilled staff is expected to be able to produce the knowledge necessary to develop new products or introduce new processes. The most straightforward measure for human capital would be the formal qualification of employees, but it is a well–known fact that the formal qualification in the former GDR has, on average, been higher than in Western Germany. The share of graduates in Eastern German firms is still higher than in Western German ones. However, the actual qualification of such graduates may well be below the Western German standard. On one hand, the human capital of older employees from the former GDR may be outdated from the perspective of today's job specifications. On the other hand, there is an oversupply of formally highly skilled people in Eastern Germany due to the high rates of unemployment which results in rather high qualification patterns in Eastern German firms. However, the jobs these people are actually employed for, 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. I had calculated the share of graduates as indicator for the firms' human capital stock. 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 (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.

Therefore, I use the knowledge stock of firms as an alternative variable. This is approximated by the stock of patents, because as described above a closely related topic to human capital is innovation. The use of knowledge stocks as important assets of firms has become popular since a seminal study

[4]See Eurostat and OECD, 1997, for the exact definition.

of Griliches (1981) who investigated how firm values are comprised of the stock of physical assets and of intangible assets, i.e. of the 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. Usually, the knowledge stock is measured as the stock of past R&D expenditure or as patent stock, sometime weighted by citations (see Hall et al. 2001). In this paper, the information on the knowledge stock is taken from the patent database of the German Patent and Trademark Office. This database allows to derive the patent stock (PS_t) from firm–individual time–series on patent applications since 1980. See OECD (1994) for a comprehensive discussion on the use of patents as science and technology indicators. An alternative measure would be the R&D stock, but it is not possible to derive the R&D stock from the data available (firm–year observation on R&D expenditure), because many firms are only observed once in the MIP sample. For the calculation of firm–individual R&D stocks long time–series information on annual R&D expenditures would be required. On one hand, the R&D stock is a more general measure of knowledge. It is known that patent counts underestimate the innovation potential of firms because not every research result is patented due to limitations in patentability of new knowledge and the firms' preference for secrecy and lead time advantages as a protection for their intellectual property (see e.g. for the United States: Levin et al., 1987, Cohen et al., 2000; or for Germany: König and Licht, 1995). On the other hand, R&D may be a noisy measure of innovation potential because not every research activity must be successful and lead to usable results for the firm. If patents are considered as a measure for the knowledge stock, one issue should be clarified: One could choose either patent applications or patents granted. In Germany, the number of patent applications in 1999 (2001) is, for example, 61,283 (64,151) but only 15,008 (14,707) patents were granted (Source: German Patent Office, 2000, 2001). Using only patent grants as a measure of knowledge stocks would therefore cause a severe downward bias. Moreover, patent applications will be closer to the time of original knowledge production, but the time lag between patent applications and grants may be large. Therefore, I prefer to use the stock of patent applications instead of patents granted because it indicates a stock of useful research results, at least from the particular firm's point of view. Even if a number of filed patents is not granted, the technological knowledge behind them could be used for the development of innovative processes and products.

The stock of applications is calculated by the perpetual inventory method as

$$PS_t = (1 - \delta)PS_{t-1} + PA_t.$$

PA_t is the number of patent applications in period t and δ is the annual depreciation of the knowledge capital which is set to 0.15 (see also Hall, 1990). As the patent series is available since 1980 and the sample under consideration begins in 1993, the starting value PS_{1980} is set to zero for all firms. The bias possibly emerging from this assumptions reduces over the years due to depreciation and should be negligible in the 1990's.[5] 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.

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, the belonging to a larger group may enhance the flow of knowledge spill–overs 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 the access to a well functioning distribution network and thus a 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 spill–overs from knowledge flows and access to markets, Eastern German subsidiaries are only exploited. The empirical analysis is expected to shed some light on these opposing arguments.

[5] 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.

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. For it, the firm size is used, the distribution over sectors, the population density of the district and whether the firm is innovating, that is the firm has at least introduced a new product or implemented a new process in recent 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.[6]

Table 2:
Mean Values prior to the matching[a]

Variable	Year[b]	Western Germany	Eastern Germany
Employees	1993	.50	.18***
(in 1,000)	2000	.33	.11***
Population	1993	7.58	5.11***
density	2000	6.96	4.60***
Innovation	1993	.68	.66
dummy	2000	.60	.62
Value added per	1993	.07	.03***
employee (Mio. €)	2000	.08	.05***

Note: *** (**, **) indicate that the Eastern German mean differs from the Western German one at a significance level of 1% (5, 10%).
a) The firm distribution over sectors differs significantly before the matching.
b) Obs. in 1993 (2000): 1,530 (1,042) in Western and 638 (445) in Eastern Germany.

Table 3 presents the same statistics after the matching procedure. The samples of Eastern Germany and its estimated control group are now 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 has been about € 0,026 Mio. per employee on average before the matching in 2000, it reduces to € 0,019 Mio. after the matching procedure. Thus, about 27% of the observed productivity gap in 2000 can be attributed to possible disadvantages of Eastern Germany in factors like firm size, the sectoral composition, innovation and districts' characteristics. Figure 4 shows the evolution of the productivity over time and compares it before and after the matching.

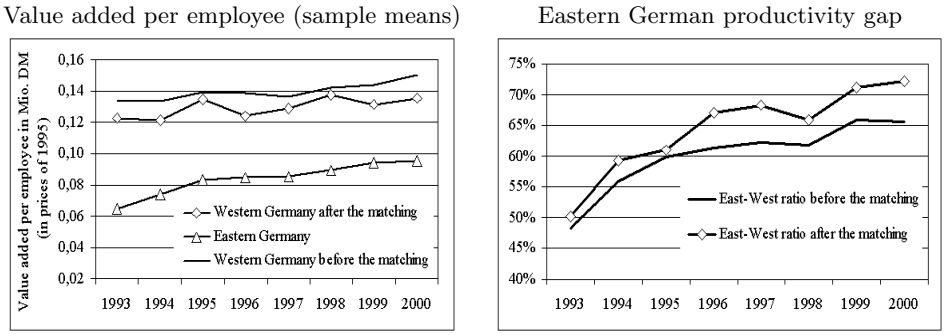
[6]The tests for the years in between are not presented, but yield the same results.

Table 3:
Mean Values after the matching[a]

Variable	Year[b]	Western Germany	Eastern Germany
Employees	1993	.17	.18
(in 1,000)	2000	.13	.11
Population	1993	5.35	5.11
density	2000	4.80	4.60
Innovation	1993	.65	.65
dummy	2000	.62	.62
Value added per	1993	.07	.03***
employee (Mio. €)	2000	.07	.05***

Note: *** (**, **) indicate that the Eastern German mean differs from the Western German one at a significance level of 1% (5, 10%).
a) The firm distribution over sectors is identical in both groups.
b) Obs. in 1993 (2000) in both groups: 638 (445)

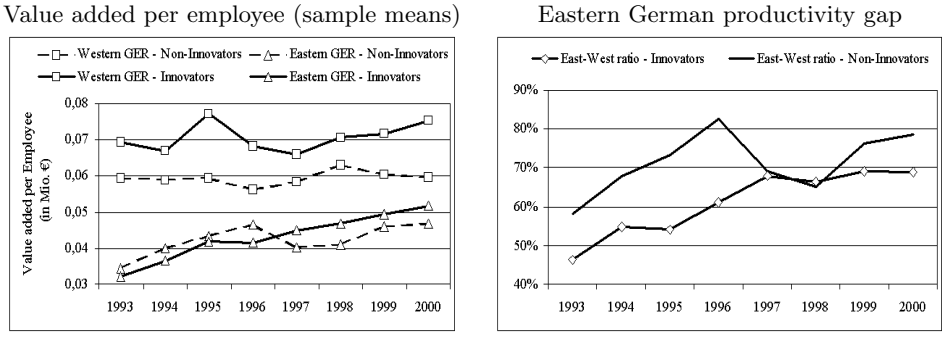
Figure 4:
Value added per employee after matching by firm size, industry classification and regional characteristics



The matching does now allow to analyze the remaining productivity gap in more detail. Are there groups of firms which do perform better or worse than average? A remarkable result is obtained by dividing the sample into innovating firms and non–innovating ones. Recall that the innovation dummy has been included in the matching function. As Figure 5 shows the Eastern German 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 the Western German firms do. 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 better than innovative firms. However, this may change in the future as the East–West ratio of non–innovative firms is quite volatile. Figure 5 (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 reasonable knowledge stocks become more and more able to produce new products which reach the quality requested by consumers.

Figure 5:
Value added per employee of innovators and non–innovators



4.3 Basic analysis — Only young firms

In a further step, the sample is restricted to firms which are existing for ten years at most. The vast majority of firms in Eastern Germany has been newly founded after the German reunification and is therefore younger than ten years. It may be possible that young firms have not been able to utilize learning curve effects yet and show a lower productivity. Table 4 displays that even the subsamples of young firms differ in size and productivity between Eastern and Western Germany prior to the 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 5 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 are possibly to young to have a similar productivity as Western German firms is not striking. Young Eastern German firms have a lower productivity than their matched controls from the West.

Table 4:
Mean Values prior to the matching[a] — Young firms

Variable	Year[b]	Western Germany	Eastern Germany
Employees	1993	.31	.18***
(in 1,000)	2000	.22	.11***
Innovation	1993	.72	.66
dummy	2000	.59	.65
Value added per	1993	.07	.03***
employee (Mio. €)	2000	.08	.05***

Note: *** (**, **) indicate that the Eastern German mean differs from the Western German one at a significance level of 1% (5, 10%).
a) The firm distribution over sectors differs significantly before the matching.
b) Obs. in 1993 (2000): 250 (176) in Western and 614 (224) in Eastern Germany.

Table 5:
Mean Values after the matching[a] — Young firms

Variable	Year[b]	Western Germany	Eastern Germany
Employees	1993	.15	.18
(in 1,000)	2000	.10	.11
Innovation	1993	.66	.66
dummy	2000	.65	.65
Value added per	1993	.06	.03***
employee (Mio. €)	2000	.07	.05***

Note: *** (**, **) indicate that the Eastern German mean differs from the Western German one at a significance level of 1% (5, 10%).
a) The firm distribution over sectors is identical in both groups.
b) Obs. in 1993 (2000) in both groups: 614 (224)

4.4 Extended Analysis

The previous estimations show that is is not possible to explain the productivity gap only by 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, the capital stock (as intensity: tangible assets per employee) and the 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 have at least one and 46% of Western German firms. Moreover, I include the size of the patent stock as described above (PS).

Table 6:
Mean Values prior to the matching[a]

Variable	Year[b]	Western Germany	Eastern Germany
Employees	1994	.35	.12***
(in 1,000)	1998	.31	.13***
Capital	1994	.04	.04
intensity	1998	.04	.05***
Patent Stock	1994	.44	.17***
dummy	1998	.46	.29***
Patent Stock	1994	7.15	.67***
	1998	6.78	1.61***
Value added per	1994	.07	.04***
employee (Mio. €)	1998	.07	.04***

Note: *** (**, **) indicate that the Eastern German mean differs from the Western German one at a significance level of 1% (5, 10%).
a) The firm distribution over sectors differs significantly before the matching.
b) Obs. in 1994 (1998): 1,507 (580) in Western and 1,171 (469) in Eastern Germany.

Table 7:
Mean Values after the the matching[a]

Variable	Year[b]	Western Germany	Eastern Germany
Employees	1994	.12	.12
(in 1,000)	1998	.12	.13
Capital	1994	.04	.04
intensity	1998	.06	.05
Patent Stock	1994	.17	.17
dummy	1998	.27	.29
Patent Stock	1994	.73	.67
	1998	1.23	1.61
Value added per	1994	.06	.04***
employee (Mio. €)	1998	.07	.04***

Note: *** (**, **) indicate that the Eastern German mean differs from the Western German one at a significance level of 1% (5, 10%).
a) The firm distribution over sectors is identical in both groups.
b) Obs. in 1994 (1998) in both groups: 580 (469)

As Tables 6 and 7 show, the inclusion of the 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 questionable 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. Within the Eastern German firms it is possible to distinguish stand–alone companies from those which belong to a group with a Western German or foreign parent company. 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 the poor access to markets. Bellman et al. (2002) did already state 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 broken up into stand–alone companies from Eastern Germany and into firms which belong to a group with a Western German or foreign parent company. Table 8 shows the productivity gap from the perspective of Eastern German firms. The result is interesting: although the productivity gap is shrinking between 1994 and 1998, the difference in value added per employee to the matched controls is diverging for both groups. While the gap differs only a little in 1994 between stand–alone companies and firms which belong to a Western German or foreign group (€ 0.005 Mio., significant at the 10% level only) it is larger in more recent time. In 1998, the difference in the gap amount already to € 0.015 Mio.

Table 8:
Productivity gap of Eastern German firms after the matching

Variable	Year[b]	Stand–alone companies	Subsidiaries
Diff. in value added			
per empl. to matched	1994	.04	.04*
controls (Mio. €)	1998	.03	.01***

Note: *** (**, **) indicate that the means differ at a significance level of 1% (5, 10%).
b) Obs. in 1994 (1998): 451 (365) stand–alone and 129 (104) group companies.

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 will thus select highly productive firms. Therefore, I consider the ownership as endogenous variable in the final analysis and consider a propensity score matching as proposed by Rosenbaum and Rubin (1983). Then, the belonging to a group can actually be interpreted as a 'treatment'. For this case, I only use Eastern German firms from

the sample and match those which belong to a Western German or foreign group with stand–alone companies from Eastern Germany. A probit model on the ownership status is estimated and the resulting propensity scores are used as matching criterion. The sample from Eastern Germany (1994 to 1996 and 1998) contains 464 firms that belong to a Western German or foreign group 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 the capital intensity as matching criteria in the probit model. Age, the number of patents and the innovation dummy have no significant effect on the group dummy. Table 9 shows the mean values before the matching. The group firms are larger, have a higher capital intensity and a higher share has at least one patent filed. Moreover the value added per employee is higher as well. This already shows that the group variable should be considered as endogenous. It seems that actually potential 'winners are picked' if one agrees to consider 'winners' as knowledge intensive firms as indicated by the capital intensity and the patent dummy.

Table 9:
Productivity of stand–alone firms versus group members prior to the matching[a]

Variable	Year[b]	Stand–alone companies	Firms belonging to group
log(Employees/1000)	1994	-3.15	-2.13***
	1998	-3.21	-2.01***
Capital intensity	1994	.03	.05***
	1998	.04	.07***
Patent Stock dummy	1994	.15	.29***
	1998	.24	.45***
Propensity Score	1994	-1.10	-.40***
	1998	-1.16	-.29***
Value added per employee (Mio. €)	1994	.03	.05***
	1998	.04	.06***

Note: *** (**, **) indicate that the means differ at a significance level of 1% (5, 10%).
a) The firm distribution over sectors differs significantly before the matching.
b) Obs. in 1994 (1998): 493 (378) stand–alone and 140 (110) group companies.

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 € 0.014 Mio. in 1994 and to € 0.016 Mio. in 1996 and both differences are significant. In contrast to the finding that the productivity gap closes, this development is different. The value

added per employee among Eastern German firms is diverging, although only slightly. The companies which belong to a group with a Western German or foreign parent company show a higher productivity in more recent years. This underpins the hypothesis that the ownership generates positive spillovers with respect to managerial skills or simply to a better access to markets. It does not seem that the subsidiaries of Western or foreign enterprises are just exploited as "sweat–shops" by their parent companies.

Table 10:
Productivity of stand–alone firms versus group members after the matching[a]

Variable	Year[b]	Stand–alone companies	Firms belonging to group
log(Employees)	1994	-2.10	-2.13
(in 1,000)	1998	-2.01	-2.01
Capital	1994	.05	.05
intensity	1998	.08	.07
Patent Stock	1994	.29	.29
dummy	1998	.44	.45
Propensity	1994	-.42	-.40
Score	1998	-.33	-.29
Value added per	1994	.04	.05***
employee (Mio. €)	1998	.05	.06***

Note: *** (**, **) indicate that the means differ at a significance level of 1% (5, 10%).
a) The firm distribution over sectors is identical in both groups.
b) Obs. in 1994 (1998) in both groups: 580 (469)

5 Conclusion

In this paper, I analyze the productivity gap of Eastern German firms in comparison to Western German firms. In general, the microeconometric study confirms the macroeconomic facts. The 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 catching up process has slowed down in recent years.

I have proposed to use an econometric matching procedure to analyze the productivity gap in Eastern Germany in more detail. If one agrees to use comparable Western German firms as benchmark for productivity, this estimation method does directly address the question, 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 come up with following key results: innovative firms from Eastern Germany exhibit a higher gap to their control firms from Western Germany than non–innovative firms. The Eastern German firms better catch up with the low 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 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 does still exist in 2000. Another interesting results which emerges from the comparison of different firm categories is the importance of firm ownership. If an Eastern German firm belongs to a group with a Western German or foreign parent company, it will have a higher productivity than stand–alone companies on average. This result does even hold 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 those two groups within Eastern Germany remains significant. In contrast to the result that the gap between the East and the West closes over time, the gap between these firms does slightly increase over time. This diverging development points to 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 of the group members is provided.

References

Almus, M. und D. Czarnitzki (2003), The effects of public R&D subsidies on firms' innovation activities: The case of Eastern Germany, *Journal of Business and Economic Statistics* 21(2), 226-236.

Barrell, R. and D.W. te Velde (2000), Catching–up of East German labour productivity in the 1990s, *German Economic Review* 1(3), 271–297.

Bellmann, L. and M. Brussig (1998), Ausmaß und Ursachen der Produktivitätslücke ostdeutscher Betriebe des verarbeitenden Gerwerbes,

Mitteilung aus der Arbeitsmarkt– und Berufsforschung 4/1998, 648–660.

Bellmann, L., P. Ellguth and R. Jungnickel (2002), Produktivität in auslandskontrollierten Betrieben Ostdeutschlands, in L. Bellmann (ed.), *Die ostdeutschen Betriebe in der internationalen Arbeitsteilung*, Beiträge zur Arbeitsmarkt- und Berufsforschung 263, 85–110.

Bergemann, A., B. Fitzenberger und S. Speckesser (2001), Evaluating the Employment Effects of Public Sector Sponsored Training in East Germany: Conditional Difference–in–Differences and Ashenfelters's Dip, mimeo, Universität Mannheim.

Berndt, E.R. (1991), *The practice of econometrics*, Reading, MA: Addison–Wesley.

Blundell, R. and S.R. Bond (2000), GMM estimation with persistent panel data: an application to production functions, *Econometric Reviews* 19(3), 321–340.

Burda, M. and J. Hunt (2001), From reunification to economic integration: productivity and the labor market in Eastern Germany, *Brookings Papers on Economic Activity*, 2/2001, 1–92

Burda, M. and M. Funke (1995), Eastern Germany: can't we be more optimistic?, *ifo Studien* 41(3), 327–354.

Cohen, W., R. Nelson and J. Walsh (2000), *Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent or not*, NBER Working Paper 7552, Cambridge.

Czarnitzki, D. (2001), Die Auswirkungen der Forschungs– und Technologiepolitik auf die Innovationsaktivitäten ostdeutscher Unternehmen, *Schmollers Jahrbuch (Journal of Applied Social Sciences)* 121(4), 539-560.

Czarnitzki, D. and A. Fier (2002), Do innovation subsidies crowd out private investment? Evidence from the German Service Sector, *Applied Economics Quarterly (Konjunkturpolitik)* 48(1), 1–25.

Deutsches Patent– und Markenamt (German Patent and Trade Mark Office) (2000), *Jahresbericht 2000 (Annual Report 2000)*, München.

Deutsches Patent– und Markenamt (German Patent and Trade Mark Office) (2001), *Jahresbericht 2001 (Annual Report 2001)*, München.

Dietrich, V. (1997), Kapitalausstattung und Produktivitätsrückstand im ostdeutschen Unternehmenssektor, *Wirtschaft im Wandel 7/1997*, 6–10.

Eurostat and OECD (1997), *OSLO–Manual — Proposed guidelines for collecting and interpreting technological innovation data*, Paris.

Falk, M. and F. Pfeiffer (1998), Auswirkungen von Innovationen auf Lohn– und Produktivitätsangleichung zwischen ost– und westdeutschen Unternehmen, in: M. Fritsch, F. Meyer–Krahmer and F. Pleschak (eds.), *Innovationen in Ostdeutschland: Potentiale und Probleme*, Heidelberg, 145–167.

Falk, M. and F. Pfeiffer (1999), Innovationen und Produktivitätswachstum ostdeutscher Unternehmen 1992–1995, in: L. Bellmann, S. Kohaut, und M. Lahner (eds.), *Zur Entwicklung von Lohn und Beschäftigung auf der Basis von Betriebs– und Unternehmensdaten*, Nürnberg, 77-98.

Fritsch, M. and J. Mallok (1994), Die Arbeitsproduktivität des industriellen Mittelstandes in Ostdeutschland — Stand und Entwicklungsperspektiven, *Mitteilungen aus der Arbeitsmarkt– und Berufsforschung* 1/1994, 53–59.

Griliches, Z. (1981), Market value, R&D and patents, *Economics Letters* 7, 183–187.

Griliches, Z. and J. Mairesse (1998), Production functions: the search for identification, in: Steinar Strom (ed.), *Econometrics and economic theory in the twentieth century: The Ragnar Frisch Centennial Symposium*, New York: Cambridge University Press, 169–203.

Hall, B.H. (1990), The manufacturing sector master file: 1959–1987, *NBER Working Paper Series* No. 3366, Cambridge, MA.

Hall, B.H. (2000), Innovation and market value, in: R. Barrell, G. Mason and M. O'Mahony (eds.), *Productivity, Innovation, and Economic Performance*, Cambridge.

Hall, B.H., A. Jaffee and M. Trajtenberg (2001), Market value and patent citations: A first look, Working Paper No. E01–403, University of California at Berkeley.

Heckman, J.J., H. Ichimura and P. Todd (1997), Matching as an econometric evaluation estimator: evidence from evaluating a job training program, *Review of Economic Studies* 64(4), 605–654.

Heckman, J.J., H. Ichimura and P. Todd (1998), Matching as an econometric evaluation estimator, *Review of Economic Studies* 65(2), 261–294.

Heckman, J.J., R.J. LaLonde and J.A. Smith (1999), The economics and econometrics of active labor market programs, in: Ashenfelter, O. und D. Card (eds.), *Handbook of labor economics*, Amsterdam, 1865-2097.

Hitchens, D.M.W.N., K. Wagner and J.E. Birnie (1993), *East German Productivity and the Transition to the New Economy — Comparisons with West Germany and Northern Ireland*, Aldershot: Avebury.

Hughes Hallett, A., Y. Ma and J. Mélitz (1996), Unification and the policy predicament in Germany, *Economic Modelling* 13, 519-544.

Janz, N., G. Ebling, S. Gottschalk und H. Niggemann (2001), "The Mannheim Innovation Panels (MIP and MIP–S) of the Centre for European Economic Research," *Schmollers Jahrbuch (Journal of Applied Social Sciences)* 121(1), 123–129.

Klodt, H. (2000), Industrial policy and the East German productivity puzzle, *German Economic Review*, 1(3), 315–333.

König, H. and G. Licht (1995), Patents, R&D and Innovation: Evidence from the Mannheim Innovation Panel, *ifo Studien* 41, 521–543.

Levin, R.C., A.K. Klevorick, R.R. Nelson and S.G. Winter (1987), Appropriating the returns from industrial research and development, *Brookings Papers on Economic Activity* 3/1987, 783–820.

OECD (1994), *The measurement of scientific and technological activities — Using patent data as science and technology indicators: patent manual 1994*, Paris.

Pagan, A. and A. Ullah (1999), *Nonparametric Econometrics*, Cambridge: Cambridge University Press.

Quehenberger, M. (2000), Ten years after: Eastern Germany's convergence at a halt?, *EIB Papers* 5(1), 117–133.

Ragnitz, J. (1997), Zur Produktivitätslücke in Ostdeutschland, *Wirtschaft im Wandel 7/1997*, 3–4.

Ragnitz, J. (1999), Warum ist die Produktivität ostdeutscher Unternehmen so gering? Erklärungsansätze und Schlussfolgerungen für den Konvergenzprozess, *Applied Economics Quarterly (Konjunkturpolitik)* 45(3), 165–187.

Rosenbaum, P.R. and D.B. Rubin (1983), The central role of the propensity score in observational studies for causal effects, *Biometrika* 70, 41–55.

Rothfels, J. (1997), Die ostdeutsche Wirtschaftsstruktur und die Produktivitätslücke, *Wirtschaft im Wandel 13/1997*, 15–19.

Rubin, D.B. (1977), Assignment to treatment group on the basis of a covariate, *Journal of Educational Statistics* 2, 1–26.

Silverman, B.W. (1986), *Density Estimation for Statistics and Data Analysis*, London.

Sinn, H.W. (2003), The laggard of Europe, *CESifo Forum 4*, Special Issue No. 1.

Sinn, G. and H.W. Sinn (1991), *Kaltstart*, Tübingen: Mohr (also available in English (1993): *Jump Start*, Cambridge, Mass.: MIT Press.

Smolny, W. (2002), Produktivitätsanpassung in Ostdeutschland: Bestandsaufnahme und Ansatzpunkte einer Erklärung, forthcoming in *Jahrbücher für Nationalökonomie und Statistik*.