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**Article**

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## TOTAL FACTOR PRODUCTIVITY IN GERMAN REGIONS

MICHAEL BERLEMANN AND  
JAN-ERIK WESSELHÖFT\*

### Introduction

When the two parts of Germany reunified 20 years ago, there was a widespread belief in a quick process of convergence (see Berlemann and Thum 2005). While some degree of convergence between East and West Germany was observed in the early years at least, the expectation of a quick and complete convergence in general turned out to be unrealistic.

Comparatively high levels of convergence can be seen with respect to the existing public infrastructure and the provision of housing (Krause *et al.* 2010). Salaries and wages have also shown a comparatively high degree of convergence (Brück and Peters 2009; Sinn and Sinn 2010; Fiedler and Fuchs-Schündelen 2011). German politics strongly supported this development by rapidly raising the wages of East German public service employees to a West German level. These politics were motivated by the expectation that living

conditions in the two parts of Germany would converge more quickly. However, the quickly rising wages were detrimental to East Germany's competitiveness and contributed significantly to high unemployment rates in East Germany (Sinn 2005; Brück and Peters 2010). As a result, East Germany still suffers from comparatively high levels of unemployment. According to the numbers published by the German Federal Statistical Office, the unemployment rate in East Germany amounted to 10.72 percent in 2011, while it was 6.36 percent in West Germany.

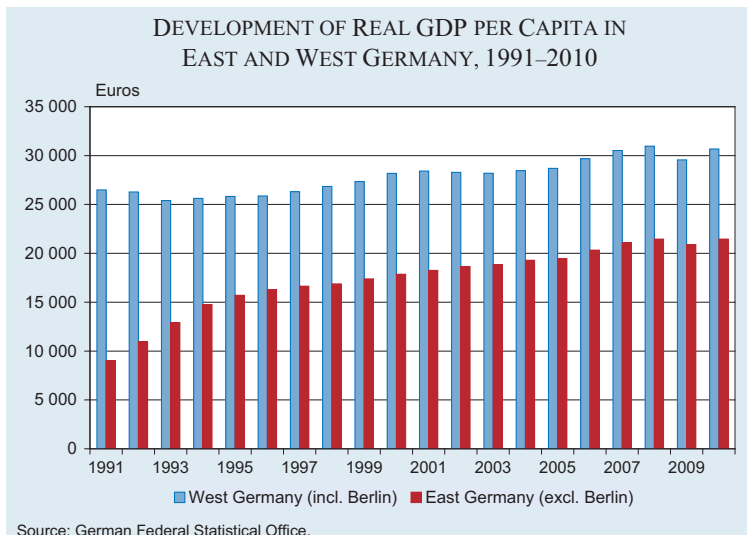
In the years immediately after German reunification, East Germany's per-capita GDP rose strongly, which quickly closed the gap between the two parts of Germany (see Figures 1 and 2). In the second half of the 1990s, however, this process decelerated. While East Germany's per-capita GDP reached 62.8 percent of the West German level in 1996, this percentage rose only slowly to 69.9 percent in 2010.

The differences between East and West Germany are considerably smaller when considering GDP per employee instead of per-capita GDP. In 2008, GDP per employee in East Germany reached at least 82 percent of the West German level (East Germany: 50,026 euros compared to West Germany: 61,027 euros). Nevertheless, even from this perspective a remarkable gap between the two parts of Germany exists. Moreover, as

Figure 3 reveals, there are also remarkable differences on the regional level (NUTS III).

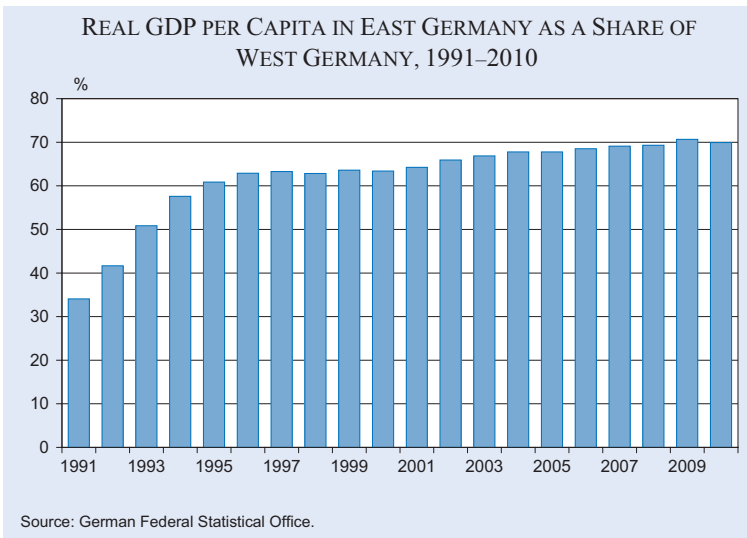
The question of which factors contribute to the differences in output per employee in East and West Germany, which remain significant, is an intriguing one. In general, it is assumed that the production technologies do not differ within one and the same country. If this effectively holds

Figure 1



\* Helmut Schmidt University Hamburg. The authors would like to thank CREDITREFORM, especially Michael Bretz and Hardy Gude, for the provision of firm data.

Figure 2



true, the observed differences must result from differences in the local supply of input factors. Differences in regional developments can then be exclusively attributed to differing levels of input factors.

However, the assumption that the technological level is the same in all regions is highly questionable.<sup>1</sup> Obviously, the technological levels in the two parts of Germany differed substantially at the time of German reunification. While it is plausible to expect that the technological gap decreased over the course of time, it

is less clear that this gap has completely disappeared. It is also questionable to assume that the development has been similar in all (East) German regions. Even under the assumption that all German regions had access to the same technology in principle, it is less clear that all regions had the factual capabilities of adopting them in an efficient manner.

In this paper we study – based on a newly constructed dataset of regional capital stocks – whether German regions differ in their technological levels. Based on these results, we analyze the share of the differences in German per-employee GDP can be attributed to differences in technology, and the share resulting from differences in the local supply of input factors.

**Total factor productivity and the Solow residual**

Total factor productivity (TFP) is the portion of output which can not directly be attributed to the amount of inputs used in the production process. The level of

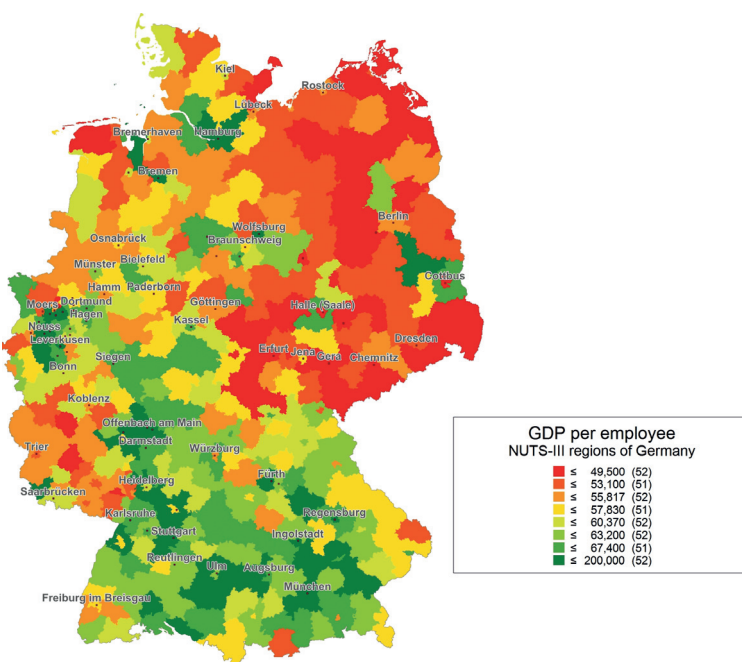
TFP thus determines how efficiently and intensely the available inputs are used in production. Let  $\chi$  be the level of TFP and  $f(L, H, K)$  the production function, depending on the input levels of ‘pure’ labour  $L$ , human capital  $H$  and physical capital  $K$ . Assuming a Cobb-Douglas production function with a Hicks-neutral technology, we have

$$(1) \quad Y = \chi \cdot L^{\alpha_L} \cdot H^{\alpha_H} \cdot K^{\alpha_K}$$

with  $\alpha_L$ ,  $\alpha_H$  and  $\alpha_K$  being the elasticities of the production factors. We allow for non-constant returns to scale by allowing  $\alpha_L + \alpha_H + \alpha_K$  to take any possible value. Taking logarithms allows rewriting the production function as

Figure 3

REAL GDP PER EMPLOYEE OF GERMAN NUTS-III REGIONS, 2010



Source: German Federal Statistical Office.

<sup>1</sup> Christopoulos and Tsionas (2004) come to a similar conclusion when studying the technological levels of Greek prefectures.

$$(2) \ln Y = \ln \chi + \alpha_L \cdot \ln L + \alpha_H \cdot \ln H + \alpha_K \cdot \ln K$$

Rearranging this equation allows us calculating TFP as

$$(3) \ln \chi = Y - \alpha_L \cdot \ln L - \alpha_H \cdot \ln H - \alpha_K \cdot \ln K$$

In order to be able to calculate the level of TFP it is necessary to know the level of the output, as well as the levels of all input factors. Moreover, we need to know the concrete values of  $\alpha_L$ ,  $\alpha_H$  and  $\alpha_K$ .

Solow (1956) proposed differencing the logarithmic production function with respect to time, yielding

$$(4) \Delta Y = \Delta \chi + \alpha_L \cdot \Delta L + \alpha_H \cdot \Delta H + \alpha_K \cdot \Delta K$$

Using time-series data  $\alpha_L$ ,  $\alpha_H$  and  $\alpha_K$  can be estimated using ordinary least square regression analysis. This information can then be used to calculate which part of the observed change in the output cannot be attributed to the change in the production factors  $L$ ,  $H$  and  $K$ . The remaining residual, the so-called 'Solow residual', is then a suitable measure of the underlying technical progress.<sup>2</sup>

Instead of deriving the rate of technical progress from the time-dimension, we make use of the cross-section dimension in the following.<sup>3</sup> We therefore employ regional data from German municipalities. Assuming  $\alpha_L$ ,  $\alpha_H$  and  $\alpha_K$  to be constant across all regions, we estimate these parameters from the equation

$$(5) \ln Y_i = \alpha_0 + \alpha_L \cdot \ln L_i + \alpha_H \cdot \ln H_i + \alpha_K \cdot \ln K_i + \varepsilon_i$$

where  $i$  is a region index. Using the estimation results we can then calculate a region  $i$ 's level of technology as

$$(6) \chi_i = \alpha_0 + \varepsilon_i$$

## Data

For our estimation approach we need regional data on production (as output variable), labour, human capital and physical capital. Data on production, labour and human capital are easily available for various years on the German municipality (NUTS-III) level. Capital stock data for Germany are available only on

the NUTS-I level. Since the necessary data to construct regional capital stock data is available only for the year 2008, we conduct a pure cross-section analysis in the following.

As an output variable we employ nominal GDP. The necessary data is provided by the German Federal Statistical Office.<sup>4</sup>

Following Eckey, Kosfeld and Türck (2004) we distinguish between two different sorts of labour input: low and high-qualified labour. The total number of employees is provided by the *Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR)* via the INKAR-database. This database also includes data on the share of high-qualified employees in each region.<sup>5</sup> Multiplying the total number of employees with the share of highly qualified employees delivers our human capital variable  $H$ . In order to derive the amount of 'pure' labour  $L$  we subtract the number of high qualified from the total number of employees. Figures 4 and 5 show the regional distribution of labour and human capital inputs for 2008.

As pointed out earlier, capital stock data for Germany from official sources is only available on the NUTS-I level. This data is again provided by the German Federal Statistical Office. The task to be solved is thus to develop a suitable method of allocating the capital stock to the NUTS-III level. In order to achieve this, we use information on the regional economic structure deduced from a private firm database, as well as data on gross fixed assets provided by the German Federal Statistical Office. The applied procedure is described below in greater detail.

On the NUTS-III level, detailed information on the structure of the local business is unavailable from official sources. We therefore use data provided by CREDITREFORM from their firm database. This database contains data on over 4 million businesses located in Germany and is highly representative for the population of German firms.<sup>6</sup> For every firm included in the database information on the industry classification code (WZ 2003, two digits) and the exact location (NUTS-III region codes) is available.

<sup>4</sup> More precisely, the regional data from the German Federal Statistical Office, we use in this paper, was collected and is published by the *Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder (AVGRdL)*.

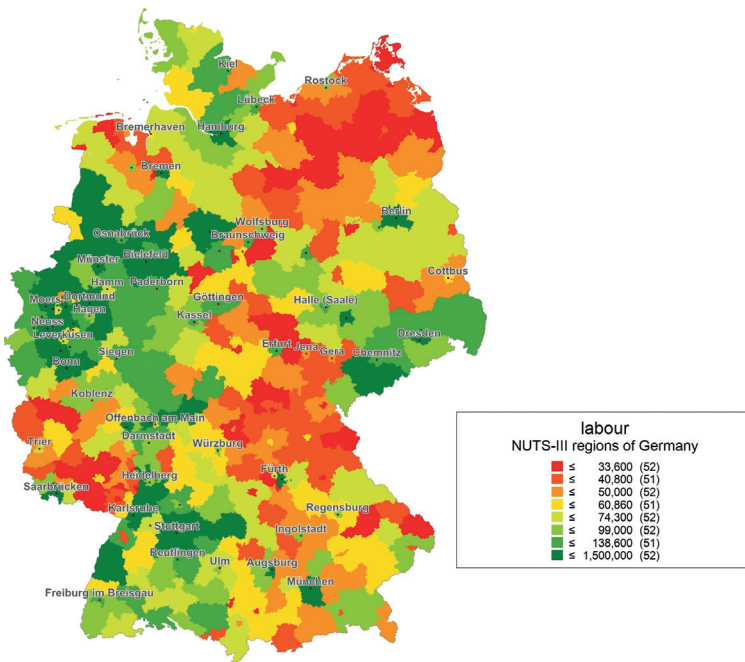
<sup>5</sup> The group of highly qualified employees consists of employees subject to social insurance contributions/civil servants who have passed an exam at a higher vocational school, a university of applied sciences or a university.

<sup>6</sup> Only very small firms are slightly misrepresented. However, since these firms typically accumulate little capital this is unproblematic.

<sup>2</sup> See also Felipe (1997) for a description of the approach.

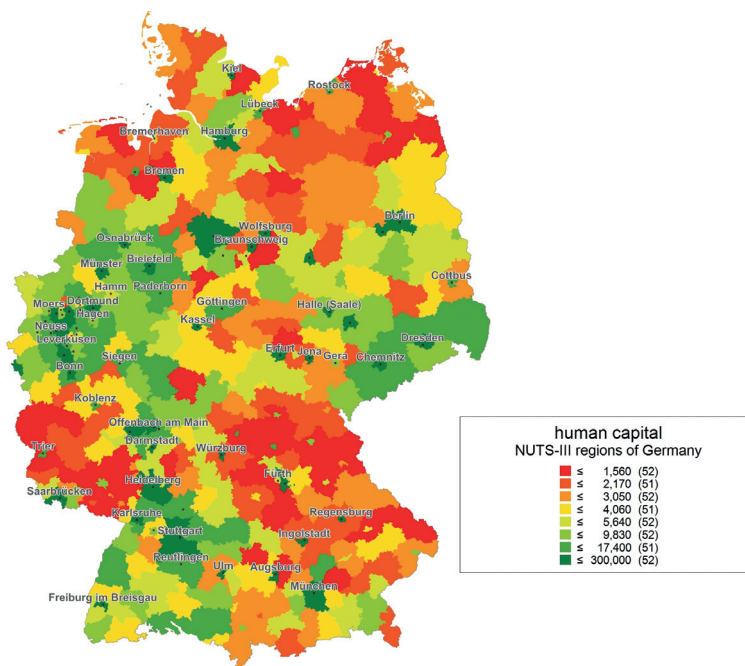
<sup>3</sup> We use cross-section data because of data restrictions, which are explained in the next section.

**Figure 4**  
LABOUR INPUTS IN GERMAN NUTS-III REGIONS, 2008



Source: German Federal Statistical Office.

**Figure 5**  
HUMAN CAPITAL INPUTS IN GERMAN NUTS-III REGIONS, 2008



Source: German Federal Statistical Office.

Using this information we can construct a branch vector for each of the 413 NUTS-III regions in Germany consisting of 21 different branches.

In addition to information on the sectoral structure of a region, we need information on the capital intensity of

different branches. In order to collect this sort of information we use data on gross fixed assets, which are provided by the German Federal Statistical Office in the WZ 2003 classification. Following Eckey, Kosfeld and Türck (2004), we exclude buildings from the fixed asset data. Average capital intensity  $c_j$  of branch  $j$  is then calculated by

$$(7) \quad c_j = \frac{\sum_{i=0}^{413} gfa_{i,j}}{\sum_{i=0}^{413} n_{i,j}}$$

with  $gfa_{i,j}$  being gross fixed assets (excluding buildings) and  $n_{i,j}$  being the number of firms in region  $i$  and branch  $j$ . Multiplying average capital intensity  $c_j$  of branch  $j$  by the number of firms of branch  $j$  located in region  $i$  delivers gross fixed assets in branch  $j$  and region  $i$ :

$$(8) \quad gfa_{i,j} = c_j \cdot n_{i,j}.$$

Summing up for all branches delivers gross fixed assets  $gfa_i$  of region  $i$ :

$$(9) \quad gfa_i = \sum_{j=1}^{21} gfa_{i,j}$$

In order to guarantee that the sum of regional capital stocks adds up to the capital stock of the referring state (NUTS-I level) as published by the German Federal Statistical Office, we calculate for each region  $i$  the share of gross fixed assets this region has in the gross fixed assets of the referring state  $B$ :

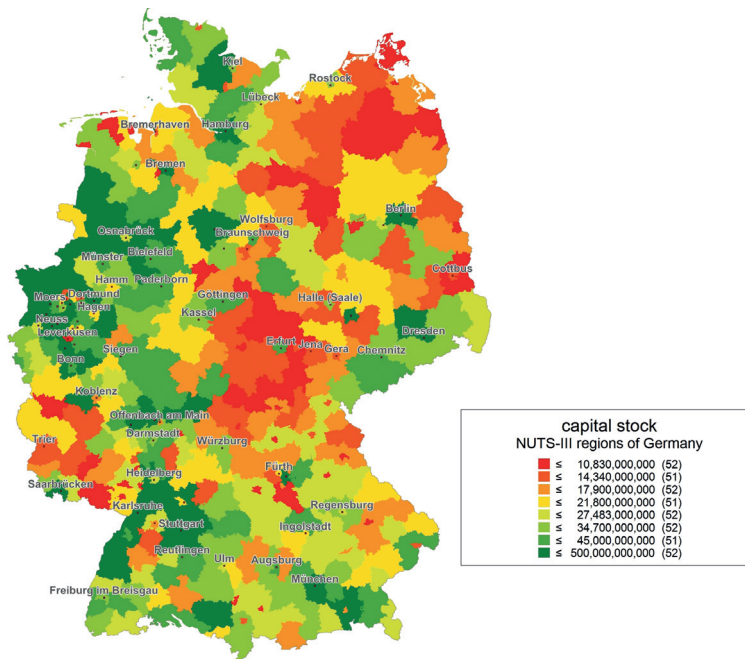
$$(10) \quad s_{i,B} = \frac{gfa_{i,B}}{\sum_{i=0}^{z_B} gfa_{i,B}}$$

with  $z_B$  being the number of municipalities belonging to state  $B$ . Multiplying these shares with the capital stock of the referring state  $B$  as published by the German Federal Statistical Office then delivers the capital stock of region  $i$ , located in state  $B$ :

$$(11) K_{i,B} = s_{i,B} \cdot K_B$$

Figure 6 shows the distribution of capital stocks among the German municipalities. East German regions on average have lower capital stocks. Moreover, cities and agglomeration centers tend to accumulate higher capital stocks.

**Figure 6**  
CAPITAL STOCKS OF GERMAN REGIONS, 2008



Source: Own calculations based on German Federal Statistical Office & CREDITREFORM.

**Estimation results**

Using the described data sources we can now estimate the production function for German regions. We estimate the equation

$$(12) \ln Y_i = \alpha_0 + \alpha_L \cdot \ln L_i + \alpha_H \cdot \ln H_i + \alpha_K \cdot \ln K_i + \varepsilon_i$$

using OLS and report White-heteroskedasticity-corrected standard errors. The estimation results are

shown in Table 1. The regression constant is positive and highly significant. The same holds true for the coefficients of the three considered input factors capital, labour and human capital. The regression explains almost 97 percent of the observed variability in regional nominal GDPs and thus has a high explanatory power.

Using the estimation results we can now calculate the Solow residual for each German municipality. Figure 7 visualizes the results. Obviously, the regions with higher technology levels are located in the south of Germany. According to our estimations, the 10 regions with the highest levels of technology are Munich, Erlangen, Wolfsburg, Fürth (county), Leverkusen, Ludwigshafen, Altötting, Frankfurt/Main, Fürth (city) and Starnberg. East German regions stand out as showing relatively low technology levels. The lowest technology levels result for Eisenach, Erzgebirge, Sächsische Schweiz/Osterzgebirge, Berlin, Halle/Saale, Ostvorpommern, Leipzig, Potsdam, Chemnitz and Erfurt. Thus, technology gaps seem to be an important factor in explaining the

obvious differences in per-employee GDP between East and West Germany.

It is interesting to look at which factors contribute the most to the existing differences in GDP per employee between East and West Germany: the differences in the available factor inputs capital, labour and human capital or the differences in the level of productivity. As reported earlier, East Germany's GDP per employee reached 82 percent of the West German level in

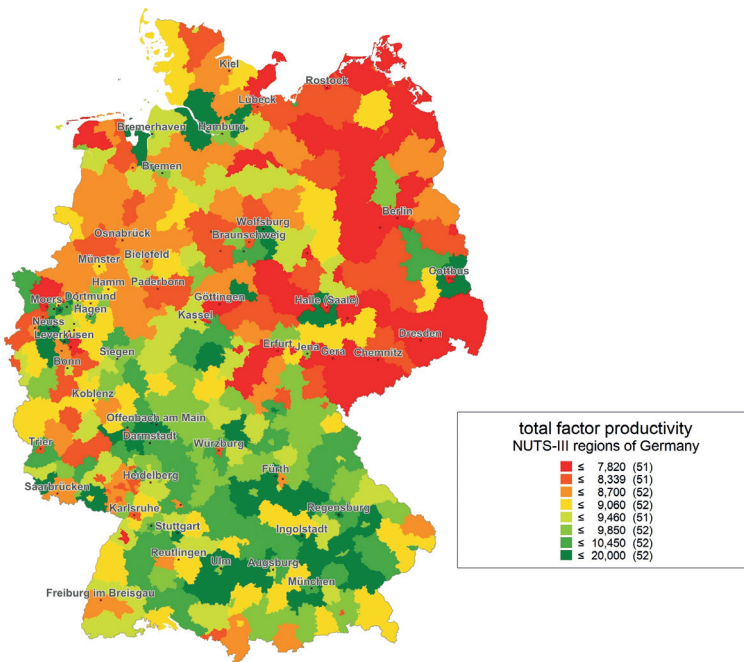
**Table 1**  
Estimated parameters of production function

Coefficient	estimated value	standard error	t-value
$\alpha_0$	9.1132***	0.3223	28.28
$A_L$	0.8006***	0.0414	19.32
$A_H$	0.1448***	0.0180	8.04
$A_K$	0.1229***	0.0236	5.21
Observations	413		
F-Value (p-value)	4008.563 (p<0.0001)		
Adj. R <sup>2</sup>	0.9669		

Note: We report White-corrected standard errors.

Source: Authors' own calculations.

**Figure 7**  
TECHNOLOGY LEVELS OF GERMAN NUTS-III REGIONS, 2008



Source: Own estimations.

2008. If East German regions were to increase their level of total factor productivity to the average level in West Germany, East Germany's GDP per employee would increase to 94.8 percent of the West German level. Thus, the differences in GDP per employee between East and West Germany are primarily due to differences in total factor productivity. While differences in the supply of input factors also play a role in explaining the empirical pattern, this factor is of considerably lower explanatory power.

**Marginal productivities**

Using the estimation results allows us to calculate the marginal productivities of capital, labour and human capital. The marginal productivity of capital can be derived by differencing the productions function with respect to capital

$$(13) \frac{\partial Y}{\partial K} = \chi \cdot L^{\alpha_L} \cdot H^{\alpha_H} \cdot \alpha_K \cdot K^{\alpha_K - 1} = \alpha_K \cdot \frac{\chi \cdot L^{\alpha_L} \cdot H^{\alpha_H} \cdot K^{\alpha_K}}{K} = \alpha_K \cdot \frac{Y}{K} = 0.1229 \cdot \frac{Y}{K}$$

Accordingly, we can calculate the marginal productivity of labour as

$$(14) \frac{\partial Y}{\partial L} = \alpha_L \cdot \frac{Y}{L} = 0.8006 \cdot \frac{Y}{L}$$

and the marginal productivity of human capital as

$$(15) \frac{\partial Y}{\partial H} = \alpha_H \cdot \frac{Y}{H} = 0.1448 \cdot \frac{Y}{H}$$

The regionally differing marginal productivities allow us to study the GDP effect of an additional unit of an input factor on the regional level.

Figure 8 shows the resulting regional marginal productivities of capital. In the regions pigmented green, additional capital will deliver the highest marginal productivity. While there is considerable variation in marginal capital productivities among the regions, there is no systematic difference between East and West German regions. On average, an additional euro of capital delivers an increase in nominal GDP of

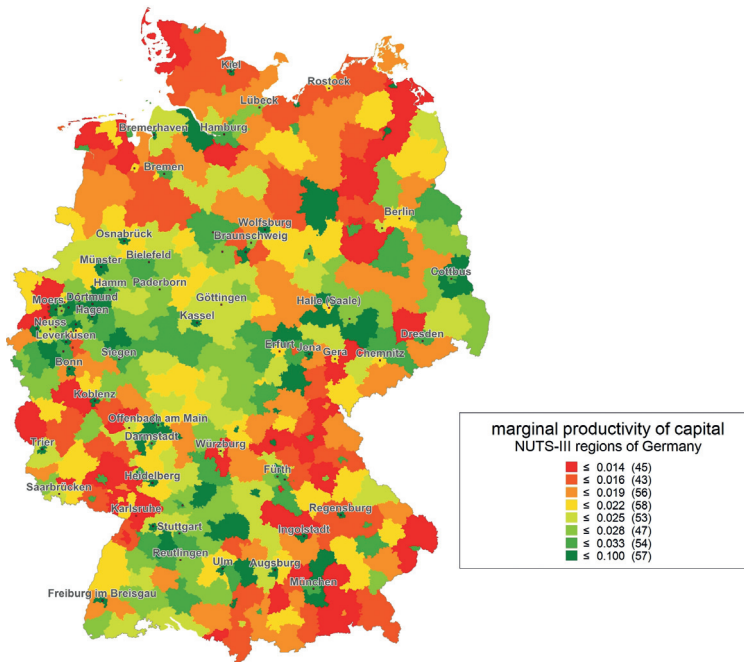
0.0246 euros in East Germany versus 0.0243 euros in West Germany. Capital delivers the highest marginal productivity in Wolfsburg (0.092 euros) and Leverkusen (0.084 euros), and the lowest productivity in Krefeld (0.007 euros) and Baden-Baden (0.008 euros). Capital productivity in general turns out to be high in agglomeration centers around large cities like Munich, Ulm, Stuttgart, Hamburg, Frankfurt and Düsseldorf and the Ruhr-Area. However, regions around larger East German cities such as Cottbus, Halle/Leipzig and Erfurt/Jena also exhibit high degrees of capital productivity.<sup>7</sup> Interestingly enough, marginal capital productivity turns out to be almost uncorrelated with the absolute level of capital.<sup>8</sup>

In Figure 9 we display the regional marginal productivities of labour. It is easy to see that labour productivity in East Germany is – on average – well below the West German level. While an additional unit of labour increases GDP on average by 44,294 euros in East Germany, in West Germany it increases GDP by 53,976 euros. The highest levels of marginal labour pro-

<sup>7</sup> Our results are broadly in line with findings of Eckey, Kosfeld and Türk (2004). Different from their results we find capital productivity to be high even in the Wolfsburg and Ingolstadt region. However, since the study of Eckey, Kosfeld and Türk (2004) uses older data (2000) and is conducted on a higher level of aggregation (job market regions) the results can only be compared with caution.

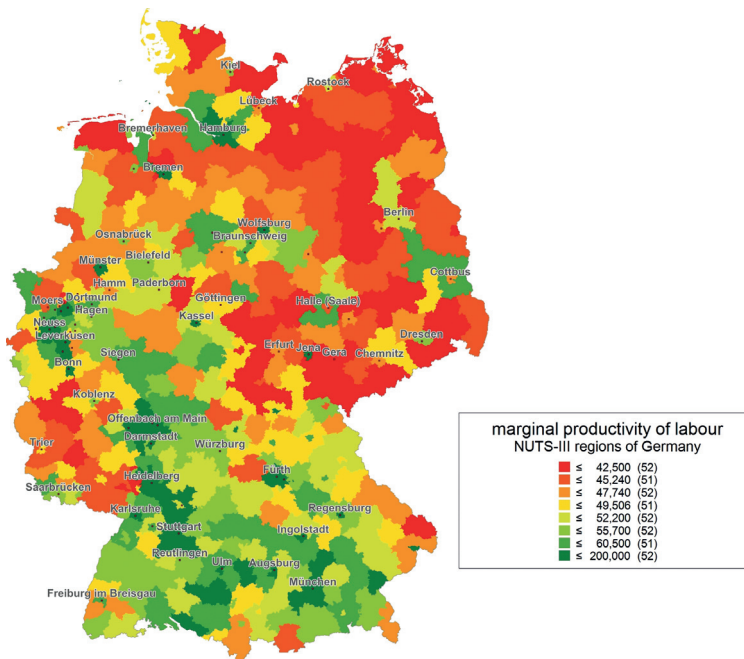
<sup>8</sup> The correlation coefficient between capital and marginal capital productivity is – 0.03.

**Figure 8**  
**MARGINAL PRODUCTIVITY OF CAPITAL IN GERMAN NUTS-III REGIONS, 2008**



Source: Own estimations.

**Figure 9**  
**MARGINAL PRODUCTIVITY OF LABOUR IN GERMAN NUTS-III REGIONS, 2008**



Source: Own estimations.

ductivity can be found in the Munich area (142,760 euros) and in Erlangen (131,010 euros), followed by Frankfurt/Main (110,230 euros), Düsseldorf (97,576 euros) and Wolfsburg (97,249 euros). In general, regions in South Germany in particular tend to

show high degrees of labour productivity. The lowest marginal productivities of labour can be found in Eisenach (32,860 euros), Ostvorpommern (36,117 euros) and Mecklenburg-Strelitz (36,189 euros). We again find no evidence of a negative correlation between the level of labour inputs and its marginal productivity. On the contrary, we find a small but positive correlation coefficient of 0.31.

Figure 10 illustrates the regional patterns of marginal productivities of human capital. We find the highest marginal productivity of human capital for Südwestpfalz (665,781 euros), Straubing-Bogen (504,755 euros) and Fürth County (501,989 euros). The lowest values result for Erlangen (18,169 euros), Jena (25,347 euros) and Darmstadt (25,431 euros). Two striking features are obvious. Firstly, the marginal productivities of human capital are much lower in East Germany. An additional, highly qualified employee delivers on average an additional GDP of 158,684 euros in West Germany, while the marginal effect in East Germany is only 99,219 euros and thus much smaller. Secondly, the effect of an additional highly qualified employee is typically small in cities.<sup>9</sup> Highly qualified employees are typically educated in cities with universities or universities of applied sciences. Significant shares of these people stay in the region where they were educated or move to other cities. Only a minority of high educated people moves to more rural areas. As a result, there is a significant shortage

of well-educated employees, especially in rural regions. This is in line with the finding of a negative

<sup>9</sup> This finding coincides with the results reported by Eckey, Kosfeld and Türk (2004).



(but still quite small) correlation coefficient of  $-0.35$  between the level of human capital and its marginal productivity.

## Conclusions

Two decades after German reunification significant differences in GDP per capita between East and West Germany still exist. To a somewhat lesser extent, this also holds true for GDP per employee. While it is often argued that this to be due to the lower levels of input factors such as capital, labour and human capital, we show that differences in the level of total factor productivity account for most of the remaining gap between East and West Germany. We also show that marginal capital productivity – on average – in East Germany is on almost the same level as in West Germany. However, East Germany exhibits comparatively low levels of marginal productivity of labour and particularly low levels of human capital.

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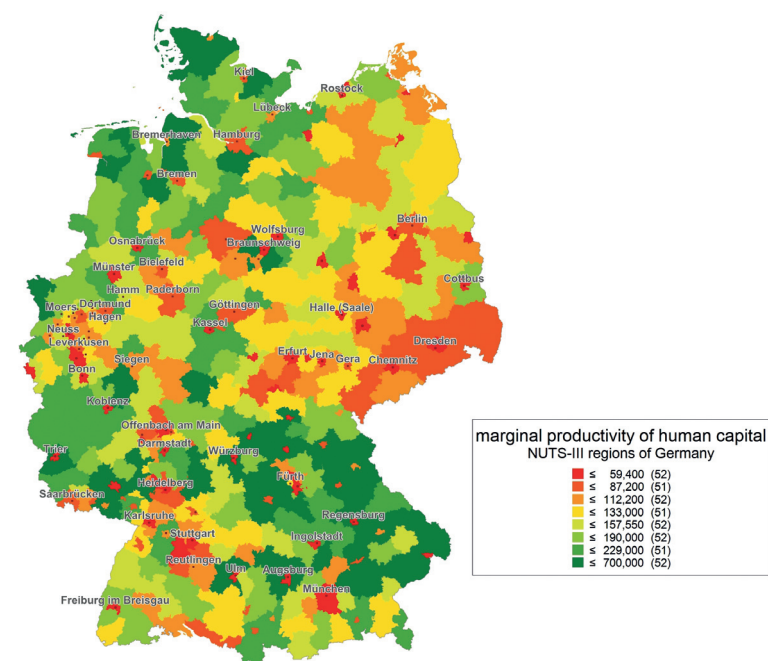
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Figure 10

### MARGINAL PRODUCTIVITY OF HUMAN CAPITAL IN GERMAN NUTS-III REGIONS, 2008



Source: Own estimations.