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TFP Convergence in German States since Reunification: Evidence and Explanations

Michael C. Burda*
Battista Severgnini*²

* Humboldt-Universität zu Berlin, Germany
*² Copenhagen Business School, Denmark

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TFP Convergence in German States since Reunification: Evidence and Explanations*

Michael C. Burda
Humboldt University Berlin, CEPR and IZA

Battista Severgnini
Copenhagen Business School

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Abstract

A quarter-century after reunification, labor productivity in eastern Germany continues to lag systematically behind the West. Denison-Hall-Jones point-in-time estimates point to large gaps in total factor productivity as the proximate cause, and auxiliary measurements which do not rely on capital stock data confirm a slowdown in TFP growth after 2000. Strikingly, capital intensity in eastern Germany, especially in industry, has overshot values in the West, casting doubt on the embodied technology hypothesis. Indeed, TFP growth is negatively associated with rates of expenditures on both total investment and plant and equipment. The best candidates for explaining the stubborn East-West TFP gap are the low concentration of managers in the East and the insufficient R&D expenditure, rather than the concentration of firm headquarters and R&D personnel.

Key Words: Productivity, regional convergence, German reunification

JEL classification: D24, E01, E22, O33, O47

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1 Introduction

A quarter-century after reunification, living standards in the new German states have largely converged to those of former West Germany, with income disparities across eastern and western households resembling those found within the richer western half of the country.[1] The convergence of average incomes stands in stark contrast to that of labor productivity, which continues to lag behind the West. The market value of output per capita in the East in 2014 was only about 75% of the German average including Berlin, and only 71% when Berlin is excluded. On the basis of productivity per employed person, the latter measure is somewhat higher at 79%; on a per-hour basis, it drops to 76%. After an initial post-unification decade of strong output and productivity growth, the convergence process of the new German states has stalled, leaving Eastern income convergence to be financed by long-term regional transfers.[2]

The German reunification episode thus continues to pose a challenge to economists. Under ideal conditions for economic integration - free trade, capital and labor mobility, and similar human capital endowments and economic institutions - the productivity of regions should converge, albeit slowly, at a rate determined by the mobility of capital and labor and the savings rate of the regions as well as the productivity of capital.[3] In the German case, regional integration took place under ideal conditions in which language, cultural, institutional and legal differences were of second order importance. While per-capita GDP growth in the immediate aftermath of unification was remarkable, it slowed after 2000 below rates of total factor productivity (TFP) growth in leading western states. Why has East-West convergence stalled?

In this paper, we present evidence on the existence and persistence of regional productivity differences across East and West Germany. We document the role of TFP and its evolution over time. In particular, we show evidence of conditional convergence in the East to a lower level of total factor productivity in the second half of the the post unification episode. We address doubts about problems typically associated with TFP growth measurement, especially the quality of productive capital stock data. By using TFP measurements which are free of capital stocks, we are able to deconstruct

[1]By 2012, average consumption per capita in Eastern Germany excluding Berlin had reached 87% of the national average, while in Berlin and Saarland it was 88% and 96%, respectively; within Western Germany, residents of Lower Saxony only enjoyed 89% of average per capita consumption in Bavaria.

[2]Source: *Arbeitsgemeinschaft Volkswirtschaftliche Gesamtrechnung der Länder*, 2014

[3]On the basis of purely model-theoretic considerations, Barro (1991) and Acemoglu and Zilibotti (2001) show that capital formation alone implies convergence in productivity of 2% per annum.

the stalled convergence episode. We find that, if anything, eastern German regions have seen an overaccumulation of capital relative to output, even if residential and nonresidential structures are excluded. Because it is unlikely that technology or institutions can account for different levels of conditional convergence across the German *Bundesländer*, we focus in our econometric work on agglomeration, exports, the presence of large firms, small firms, and startups as well as human capital endowments, using data extracted from this purpose from a large dataset of establishment-level data (*Querschnittsmodell der LIAB Daten*) as well as publicly available data sources. Our results point to an influence of firm size, but not headquarters, on productivity; we also do not find evidence that agglomeration, urbanization or population density matters. We do find a significant influence of the concentration of managers and technical personnel as well as a negative influence of the investment rate. The latter finding supports the view that investment is a substitute for, rather than a complement, to multifactor productivity, at least in the current context.

The paper is organized as follows. Section 2 frames the scientific relevance of the German unification episode and presents evidence on disparate regional productivity developments between Eastern and Western Germany on the basis of point-in-time TFP level estimates using the Denison-Hall-Jones decomposition (Denison (1962), Hall and Jones (1999)). Section 3 assesses the robustness of our findings using three measures of TFP growth as well as relative TFP levels in the German states. In Section 4, we present an econometric analysis of the level and dynamics of TFP levels. Section 5 concludes with an interpretation of our findings and some tentative policy conclusions.

2 Labor Productivity and Total Factor Productivity after German Unification

2.1 The east-west productivity gap, a quarter century later

As it was virtually unanticipated, German unification presents a unique natural experiment for a number of important economic hypotheses. Early on, it was recognized as an episode of intense regional economic integration (Collier and Siebert (1991) and Burda (1990, 1991) with significant labor productivity differentials between East and West at the outset, when output was measured at market prices (Akerlof et al. (1991)). A capital-poor East integrating with a capital-rich west initiated a mobility race between the two regions (Burda and Hunt (2001) and Burda (2008)) in which migration was strongly responsive to push and pull factors, yet in a demographically sensitive fashion (Hunt (2006)). A number of factors make the German unification episode an attractive laboratory for economic hypotheses: uniform and standardized data collection methods implemented early on, a common legal institutional framework and underlying economic system and ultimately, highly similar but by no means identical preferences of households (Alesina and Fuchs-Schuendeln (2007)).

Under conditions of economic integration, productivity per unit of labor input should converge faster than rates predicted by the neoclassical growth model (e.g. Barro and Sala-i-Martin (1990)). This is because movements of capital and labor act to equalize factor returns and, in the case of otherwise identical production technologies, capital-labor ratios across regions (Burda (2006)). Figure 1 presents the trajectory of GDP per employee in the new states individually as well as the West German average and shows that, despite an initial surge, labor productivity in the eastern states continues to lag systematically behind that of their western counterparts, even 25 years after unification. The trajectory of the Berlin-Brandenburg as an intermediate outcome is solely due to the presence of West Berlin; Brandenburg taken alone is little different from the other eastern German States.

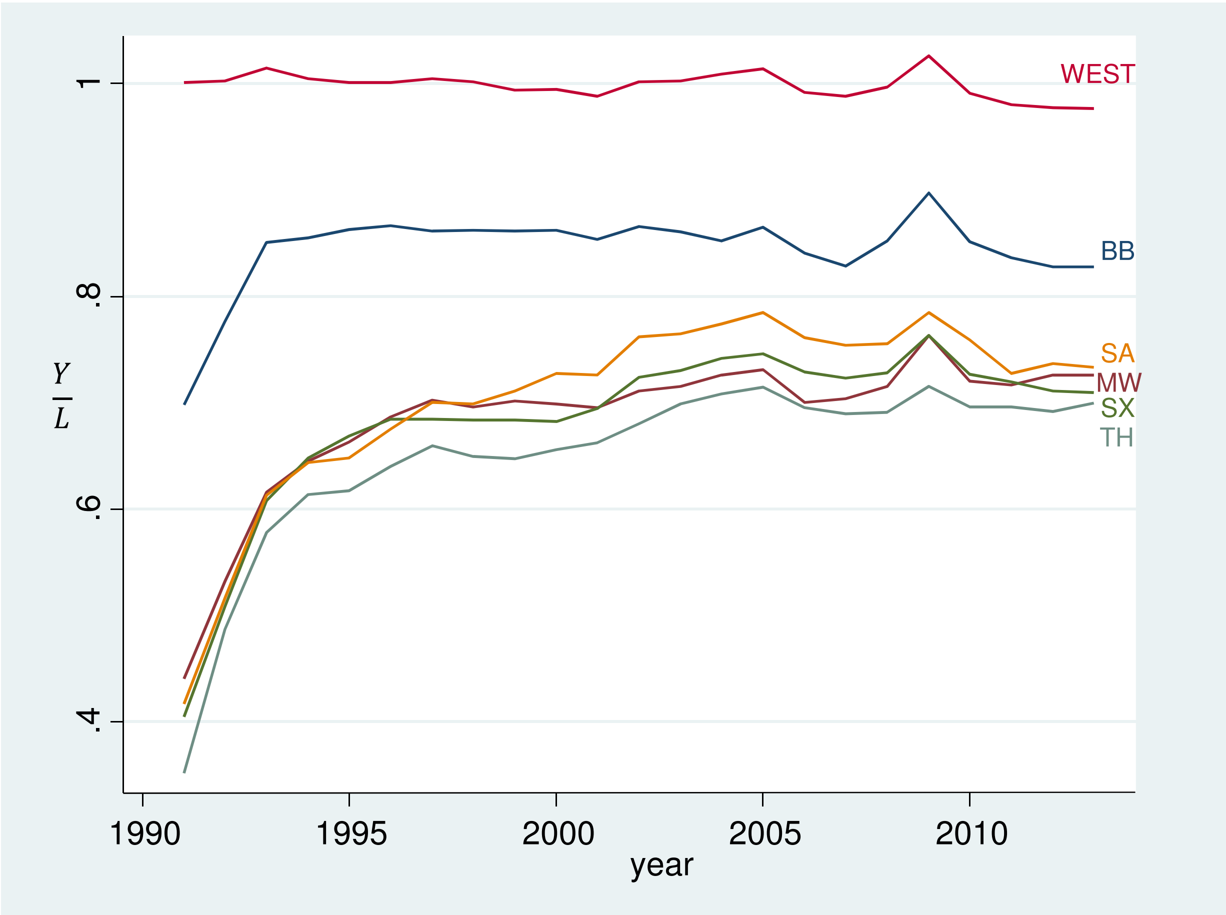
We document the regional labor productivity differences in more detail in Table 1, using a more accurate hourly productivity measure in 13 "region-states", measured as gross domestic product in nominal terms per hour in 2014.[4] The region-states correspond to the Bundesländer, except that the city-states Berlin, Bremen and Hamburg have been merged with the states which surround them. The total economy exhibits significant differences which are in excess of the usual measures of income per capita and have given rise to controversial discussions about a "*Mezzogiorno* syndrome" in eastern Germany.[5]

[Table 1 about here]

[4]Due to a lack of hours data in the new states from the 1990s, our subsequent econometric work will use employed persons rather than hours. Details on the data used in this research can be found in the Appendix.

[5]While these regional differences are significant and economically interesting, they are by no means unusual. Germany has a surface area comparable to the US region of New England plus the states of New York and New Jersey. Among those states, annual GDP per civilian employed person ranged in 2010 from $135,000 in Connecticut and New York to $78,000 and $82,000 in Vermont and Maine respectively. This is much more dispersed than the extreme values in Germany (71,000 in Hessen versus 49,000 in Mecklenburg-West Pomerania). What makes the German episode so interesting is the apparent history-dependence of these differences, especially considering that parts of Eastern Germany were the most productive regions before the Second World War.

Figure 1: **Labor productivity, espressed as a fraction of Baden-Württemberg's, 1993-2013**



Source: Authors' calculations based on Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen. BB: Berlin / Brandenburg. MW: Mecklenburg-West Pomerania. SX: Saxony. SA: Saxony-Anhalt. TH: Thuringia. WEST: West Germany.

2.2 Proximate causes of East-West productivity differences

What could be the source of persistent regional differences in labor productivity in Germany more than a quarter-century after unification? A natural first reaction to this question is to look for structural reasons, i.e. compositional effects. The last three columns of Table 1 reveal significant and systematic differences in productivity per employed person between eastern and western Germany. While the West continues to dominate the East in manufacturing, construction and other "productive sectors", yet it is less clear for services - in which the public sector plays a large role. It is not true at all, however, in agriculture, forestry and fishing, where an hour worked in (eastern German) Saxony-Anhalt or Mecklenburg-West Pommerania is *twice* as productive as in the rich western states of Bavaria or Hesse. Yet even in these states, only 2% of total GDP derives from agriculture,, forestry and fishing. Much more significant in the East is the low-productivity public sector, which continues to play a much larger role in the East, while the share of high value-added services remains modest.

To see whether heterogeneity and changing sectoral composition can account for some or all of the flagging productivity growth in Eastern Germany, we disaggregated value added per capita into six sectoral activities using definition common to the sample period 1991-2014.[6] Holding constant the fraction of employment in each of the six sectors at 1991 levels, we find that aggregate labor productivity per person in Eastern German states excluding Berlin would have been consistently *lower* than observed levels, meaning that sectoral change has in fact accelerated convergence. Yet quantitatively the level difference is never more than 6% and has been declining steadily since the early 2000s; this conclusion also holds when employment shares in 2000 are used instead. Furthermore, the distribution of the labor productivity gap is fairly uniform across the important sectors: Structural change - or a lack of it - cannot be the main suspect for flagging Eastern German productivity since 2000.

The neoclassical response to the productivity puzzle lies in the endowment of physical capital. Indeed, most analyses of the unification episode assume that the eastern states had access to the same production function and operate with the same physical, institutional and political infrastructure, human capital endowments, and technical sophistication available in the western states. Put differ-

[6] The categories are agriculture, forestry and fishing; productive industries (manufacturing, mining, quarrying, and energy; construction; trade, hospitality and transport; finance and business services; public services and private household services.

ently, total factor productivity was identical in both halves of Germany from an early date. This assumption was defensible *a priori* on a number of grounds: Human capital endowments of formal education in eastern and western Germany were very similar (Burda and Schmidt (1997)) and migration patterns following the fall of the wall suggest that a large fraction of human capital was transferable (Fuchs-Schündeln and Izem (2012)) Nevertheless, it may be an enormous leap of faith to assume that all determinants of the aggregate production were identical from the outset.[7] In the sections which follow, we address directly this issue by constructing measures of TFP levels and growth rates from several perspectives to judge whether total factor productivity is consistently lower in Eastern Germany, twenty five years later.

2.3 Assessing TFP levels using the Denison-Hall-Jones decomposition

With a point-in-time decomposition we begin our analysis of regional German labor productivity with an approach described by Hall and Jones (1999), which can be traced back to Christensen, Cummings, and Jorgenson (1981) and ultimately Denison (1962).[8] Under the assumption of identical constant returns production technology and an appropriate benchmark, improvement in the efficiency in the aggregate use of productive factors can be summarized in a convenient way. Hall and Jones (1999) used this method to point out the limitation of human capital in accounting for differences between developed nations and those of, say, sub-Saharan Africa.

Consider a constant returns production function expressing output in period t (Y_t) as resulting from production factors capital (K_t) and labor (L_t) as well as Harrod-neutral (labor augmenting) technology (A_t):

$$Y_t = K_t^{\alpha} \left(A_t L_t\right)^{1-\alpha} \tag{1}$$

with $0 < \alpha < 1$, Rewrite (1) in intensive form expressing labor productivity as a function of capital intensity (the capital coefficient) as follows:

$$\frac{Y_t}{L_t} = A_t \left(\frac{K_t}{A_t L_t}\right)^{\alpha} = A_t \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}}$$

[7]Another variant would be to assume an identical production function with more structure, leading to a different interpretation of total factor productivity and implying conditional convergence to different steady states. We discuss this argument in more detail in Section 4.

[8]This technique is also referred to in the literature as development accounting (Caselli (2005) and Hsieh and Klenow (2010)).

Assuming that capital can be measured, output per worker can be accounted for as the product of a term involving the observable capital intensity of production $\left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}}$ and unobservable labor augmenting technical progress A_t. Over longer periods the former can be linked in a natural way to the investment rate (the ratio of investment I to Y).[9] The Denison-Hall-Jones procedure expresses differences in labor productivity in region or economy i to some "frontier" benchmark (superscript F) as

$$\frac{(Y/L)_t^i}{(Y/L)_t^F} = \frac{A_t^i}{A_t^F}\left(\frac{(K/Y)_t^i}{(K/Y)_t^F}\right)^{\frac{\alpha}{1-\alpha}}$$

where the benchmark is normalized to equal 1 in each year.

Table 2 displays the Hall-Jones decomposition the year 2011 for the thirteen region-states, the eastern six and the western seven as aggregates, and Germany as a whole. The decomposition is normalized on the state of Baden-Württemberg, which serves as the benchmark for the analysis. A value of 0.33 is assumed for α. The data used, including the capital stocks, are described in the Appendix.

[Table 2 about here]

The first three columns immediately lead us two preliminary conclusions. First, TFP and labor productivity are highly positively correlated, as is consistent with current theory on the source of productivity differences. Second, TFP levels appear to represent the primary driver of the East-West differences; within East and West variance is dwarfed by the between variance. Figure 2 shows that during the first ten years following unification were characterized by rapid TFP catch-up, followed by a marked stagnation, while further convergence of labor productivity seems to be achieved via capital intensity. The two panels of Figure 2 present the time series of the contribution to labor productivity for TFP levels for each of the individual Eastern states, the West German average for the entire period. The first panel shows that the level TFP measures in East Germany slow down systematically around 1994. In contrast, the capital intensity of Eastern Germany has continued to rise. In fact, capital-output ratios as measured by the statistical agencies appear to have overshot their West German counterparts.

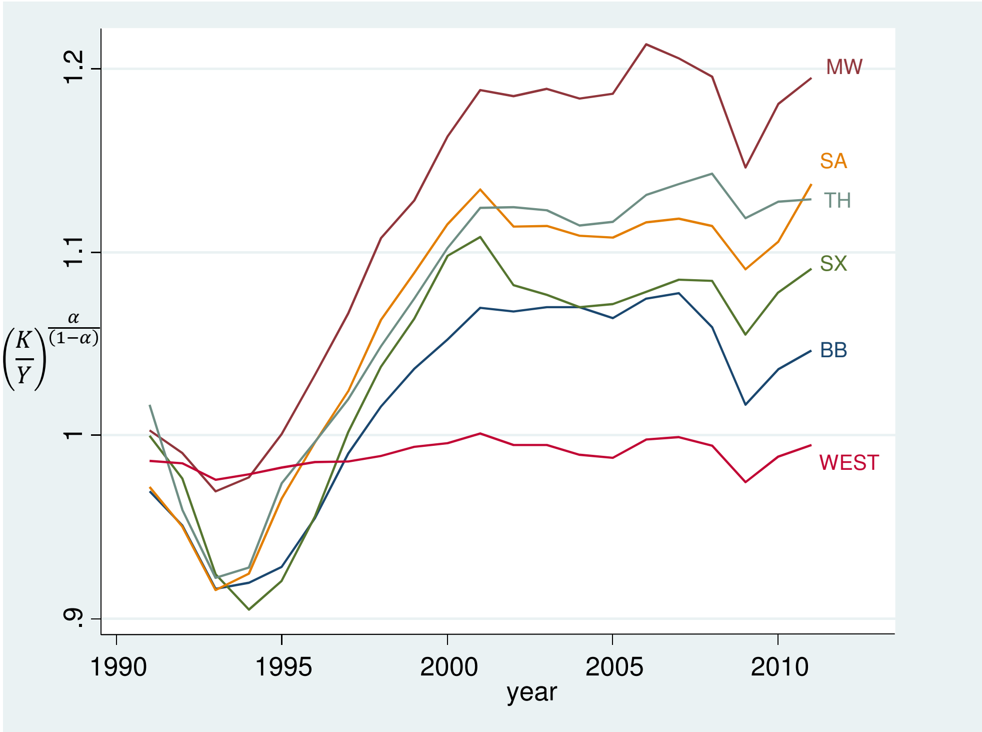
A natural suspicion is that our results may be an artifact of structural differences or structural

[9] In the steady state of a competitive economy, capital and output grow at the same rate, say g. If capital depreciates at rate δ ,then the steady state capital-output ratio is $(I/Y)/(g+\delta)$.

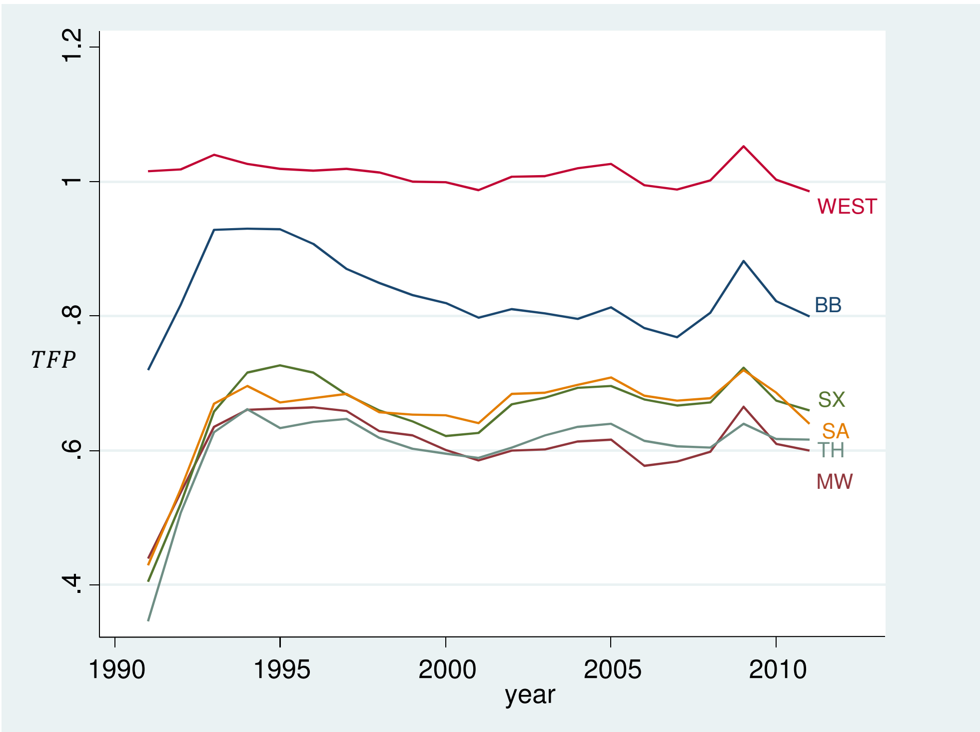
shifts. The former German Democratic Republic was highly industrialized with an underdeveloped service sector (see Collier and Siebert (1991), Burda and Hunt (2001)). In the remaining columns of Table 1, we decompose labor productivity in the three sectors of agriculture (agriculture, forestry, fisheries), industry (manufacturing, mining, energy) and services (business services, personal services, wholesale and retail trade, finance). The production sector dominates the movement in the total economy, with a more murky picture in services; moreover, the tables are turned in favor of the east in agriculture, where by far the most productive workers are located. The temporal behavior of these series (not reported) confirms the pattern in Table 2: TFP growth in the new states has slown to a trickle, and in particular for industry, the East appears more capital intensive than the West. Figure 3 plots for aggregate of western and eastern Germany, the contribution of capital and TFP according to the Denison-Hall-Jones productivity decomposition. It shows 1) a significantly larger variability of the components over time and 2) that eastern Germany has compensated for flagging TFP in the latter half of the sample with a significant increase in capital intensity (the capital coefficient).

Figure 2: **Denison-Hall-Jones Decomposition 1993-2011.**

Contribution of capital $(K/Y)^{\alpha/(1-\alpha)}$**.**

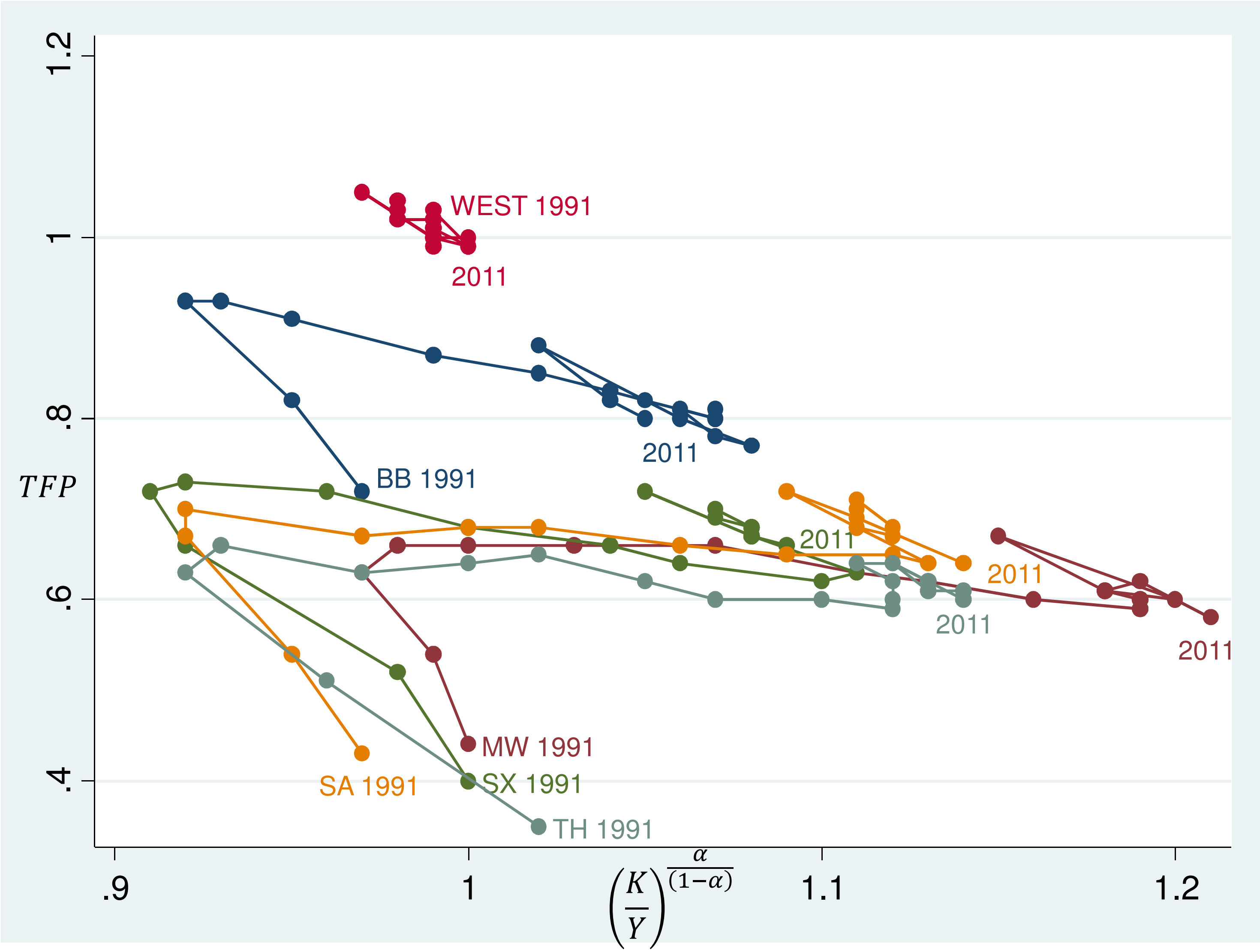


Contribution of total factor productivity (TFP)**.**



Source: Authors' calculations based on Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen. BB: Berlin / Brandenburg. MW: Mecklenburg-West Pomerania. SX: Saxony. SA: Saxony-Anhalt. TH: Thuringia. WEST: West Germany.

Figure 3: Contributions of capital and TPF in the East-West. Denison-Hall-Jones Decomposition 1993-2011.



Source: Figure Authors' calculations based on Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen. BB: Berlin / Brandenburg. MW: Mecklenburg-West Pomerania. SX: Saxony. SA: Saxony-Anhalt. TH: Thuringia. WEST: West Germany.

The finding that East Germany's capital intensity has overshot and exceeds that of the states of the former West Germany might reflect fundamental mismeasurement currently. The size and value of eastern Germany's capital stock was largely impossible to assess in the initial part of the sample, and was dominated by new investment for many years. Only over time will the decommissioning and obsolescence of equipment and structures render its capital stock increasingly like comparable to West Germany's. In order to corroborate the TFP growth slowdown in the East, we will now turn to robust TFP measurements which avoid the use of capital stock data (Burda and Severgnini (2014)).

3 Robust TFP Growth Measurement: Three measurements

3.1 Solow-Törnqvist residuals (ST)

In his seminal paper, Solow (1957) defined TFP growth as the difference between observable growth in output and a weighted average of growth in observable inputs. In his analysis, inputs were capital and labor, and the weights are the output elasticities of capital and labor. Under constant returns in production and competitive factor markets, output elasticities of capital and labor correspond to factor income shares, which may or may not change over time. This "Solow residual" captures growth not attributable to observable factor inputs; it does so solely on the basis of theoretical assumptions (constant returns to scale, perfect competition in factor markets), external information (factor income shares), and without particular statistical assumptions.[10] Because the Solow residual is straightforward and easy to compute, it is a standard measurement in productivity analysis. Over the half-century to follow, Denison, Jorgenson and others extended the TFP measurement paradigm to a larger set of production factors; nevertheless, they continued to find that the residual is the most important factor driving output growth.

Let a_t^{ST} be the rate of TFP growth as captured by the Solow concept. We will use the logarithimic Törnqvist index specification[11] for region i in time t:

$$a_{it}^{ST} = \Delta \ln Y_{it} - \bar{\alpha}_{it-1} \Delta \ln K_{it} - (1 - \bar{\alpha}_{it-1}) \Delta \ln L_{it} \tag{2}$$

[10]For more microeconometrically motivated methods, see e.g. Olley and Pakes (1996).

[11]This formulation is also attributed to Caves, Christensen, and Diewert (1982a,1982b).

where Y is gross value added as measured "gross domestic product" K is the capital stock at the beginning of the period, L_t is average employment over the period, and $\bar{\alpha}_{t-1} = \frac{\alpha_{t-1}+\alpha_t}{2}$ (see Törnqvist (1936)). Because data on income shares do not exist at the level of the *Bundesländer,* we will use a single common value across time and space to be specified below.

Using synthetic data, Burda and Severgnini (2014) show that the Solow residual is subject to considerable measurement error in short time series when the capital stock is poorly measured. In benchmark scenarios, about 40% of this error in short datasets is due to the estimated initial capital stock, while the rest is due to unobservable depreciation and capacity utilization. Measurement error in K_0 will be significant when 1) the depreciation rate is low and 2) the time series under consideration is short. For conventional rates of depreciation, errors in estimating the initial condition can have long-lasting effects on estimated capital stocks. It is widely recognized that the transformation led to systematic depreciation of physical, human and match capital.[12] In the case of Eastern German states, for which market-based estimates of the capital stock are only available since 1991, the problem of correctly measuring the contribution of that factor are likely to be significant. It is for this reason that we present two alternative measures of TFP growth proposed by Burda and Severgnini (2014).

3.2 Direct Substitution (DS)

In this and the following section, we describe two capital stock-free alternatives to the Solow residual elaborated in detail in Burda and Severgnini (2014). The DS measure relies on direct substitution and alternative assumptions to eliminate capital from the Solow residual calculation. Substitution of the perpetual inventory equation for the capital stock in (2) and rearranging, yields the DS measure, a_{it}^{DS} :

$$a_{it}^{DS} = \Delta \ln Y_{it} - \kappa_{t-1}\frac{I_{it-1}}{Y_{it-1}} + \alpha_{it-1}\delta_{it-1} - (1-\alpha_{it-1})\,\Delta \ln L_{it}. \tag{3}$$

where κ is the user cost of capital and δ_{it-1} is the depreciation rate applied to the capital stock in *Bundesland* i in period $t-1$ The DS approach, which eliminates the capital stock from the TFP calculation, will be a better measurement of TFP growth to the extent that 1) the capital stock is unobservable or poorly measured; 2) capital depreciation varies and is better measured from other sources; 3) the most recent increments to the capital stock is more likely to be completely utilized

[12]See Blanchard and Kremer (1997) and Roland and Verdier (1999) for theoretical models on capital depreciation during the transition process.

than older capital. The DS measure can be used to construct a total contribution of capital to growth as $\frac{\Delta Y_t}{Y_{t-1}} - a_t^{DS} - (1-\alpha_{t-1})\frac{\Delta L_t}{L_{t-1}}$. While the cost of capital may vary over the sample, credible data at the regional level are unavailable, so we will assume a single value for the purposes of TFP growth estimation. Similarly, we will assume a single rate of depreciation over space and time.

3.3 Generalized Differences (GD)

If an economy, region or sector is close to a known, stable steady state growth path, it may be more appropriate to measure total factor productivity growth as deviations from a long-run deterministic trend path estimated using the entire available data set, e.g. trend regression estimates, moving averages or Hodrick-Prescott filtered series (Hodrick and Prescott (1997)). Suppose that a region has attained, but fluctuates around a steady state path in which all observable variables grow at a common rate g. Denoting the deviation of variable X_t around its steady state value $\overline{X}_t$ by $\hat{X}_t$, it is possible to write the Solow decomposition as

$$\widehat{Y}_t = \widehat{A}_t + \alpha \widehat{K}_t + (1-\alpha)\widehat{L}_t. \tag{4}$$

and the perpetual inventory equation as

$$\widehat{K}_t = \frac{(1-\delta)}{(1+g)}\widehat{K}_{t-1} + \iota \widehat{I}_{t-1}, \tag{5}$$

where $\iota = \frac{\overline{(I/K)}}{(1+g)}$, and the capital elasticity $\alpha \equiv \frac{F_K K}{Y_t}$ and depreciation rate δ are constant, and $\overline{(I/K)}$ is constant in the steady state. If L is the lag (backshift) operator, premultiplication of both sides of (4) by $\left(1 - \frac{(1-\delta)}{(1+g)}L\right)$ and substitution of (5) results in

$$\left(1 - \frac{(1-\delta)}{(1+g)}L\right) a_t^{GD} = \left(1 - \frac{(1-\delta)}{(1+g)}L\right)\widehat{Y}_t - \iota\alpha\widehat{I}_{t-1} - \left(1 - \frac{(1-\delta)}{(1+g)}L\right)(1-\alpha)\widehat{L}_t \tag{6}$$

which as in the DS approach eliminates the capital stock from the measure. Assuming an initial condition, $\widehat{a}_0^{GD}$, the sequence $\{\widehat{a}_t^{GD}\}$ is recovered recursively for $t = 1, ..., T$ using

$$\widehat{a}_t^{GD} = \left(\frac{1-\delta}{1+g}\right)^t \widehat{a}_0^{GD} + \sum_{i=0}^{t-1}\left(\frac{1-\delta}{1+g}\right)^i \left[\widehat{Y}_{t-i} - \alpha\iota\widehat{I}_{t-1-i} - (1-\alpha)\widehat{L}_{t-i}\right]. \tag{7}$$

From the sequence $\{\widehat{a}_t^{GD}\}_{t=1}^T$ it is straightforward to recover the TFP growth measure $\{a_t^{GD}\}$, given an estimate of the initial condition, $\widehat{a}_0^{GD}$, and using the approximation $a_t^{GD} \approx \ln(\frac{A_t}{A_{t-1}})$.[13] Our estimate, based on the Malmquist index, is given by $\widehat{a}_0^{GD} = \ln\left(A_0/\bar{A}_0\right)$ and is computed in Burda and Severgnini (2014) as the geometric mean of labor productivity growth and output growth in the first period. The GD measure imputes the contribution of capital as $\frac{\Delta Y_t}{Y_{t-1}} - a_t^{GD} - (1-\alpha_{t-1})\frac{\Delta L_t}{L_{t-1}}$. As was the case for the DS measure, we assume a single values of δ, g and ι across geographic units and time.

3.4 Results

We now employ all three measures to study the sources of economic growth in the federal states of Germany (*Länder*) in the period following reunification. We revisit the findings of Keller (2000) and Burda and Hunt (2001), who estimated total factor productivity growth using either the conventional Solow residual measure or econometric techniques. Given the poor quality of capital stock data in the new states, especially for structures, the alternative DS and GD methods offer an additional perspective on TFP growth in a complex and changing environment. Reunification - due to both market competition and the revaluation of the east German mark - rendered about 80% of East German production noncompetitive (Akerlof et al. (1991)), and implied a large capital loss for existing equipment and business structures. At the same time, many buildings measured initially at minimal book value have since been returned to productive use, implying larger capital stock than conventionally measured. Depreciation rates and capacity utilization data do not exist at the state level, further compounding already severe measurement problems.

In Tables 3, and 4, we present Solow-Törnqvist residuals and our stock-free TFP measurements for both new and old German states for the period 1993-2011 and the two sub-periods 1993-2001 and 2002-2011. We also present the same calculations based on macroeconomic aggregates consisting of the Eastern states, the Western states and all of Germany. The Solow residual estimates employ an estimate of capital stocks provided by the German statistical agency (*Statistisches Bundesamt*). A constant capital share (0.33) was assumed for reasons related to data availability. For the DS method, the annual rental price of capital (κ) was set to a constant value over the entire period (0.11). For

[13]To see this note that: $a_t \approx \ln(\frac{A_t}{A_{t-1}}) = \ln(\frac{A_t/\overline{A}_t}{A_{t-1}/\overline{A}_t}) = \ln(\frac{(1+a)A_t/\overline{A}_t}{A_{t-1}/\overline{A}_{t-1}}) \approx \bar{a}_t + \ln(\widehat{A}_t) - \ln(\widehat{A}_{t-1})$, where $\bar{a}_t \equiv \ln\left(\frac{\bar{A}_t}{\bar{A}_{t-1}}\right)$ is the underlying trend growth rate. If TFP grows at constant rate a, then we have:
$a_t^{GD} \approx a + \ln(\widehat{A}_t) - \ln(\widehat{A}_{t-1}) = (1-\alpha)(g-n) + \ln(\widehat{A}_t) - \ln(\widehat{A}_{t-1})$.

the GD approach, the trends were constructed using H-P filter ($\lambda = 100$). For both approaches, a constant rate of capital depreciation δ equal to 5.52% per annum was used. The assumed steady state trend growth rate was average real output growth in each state over the entire period. Capacity utilization and depreciation at the *Bundesland* level is not available. Lacking sufficient data on hours worked, we used total employment as a measure of labor input.

We first turn to TFP growth estimates for the eastern and western states and Germany. The behavior of the DS measure is broadly consistent with that of the Solow residual, which indicate a slowdown of GFP growth after 2001, while the western states appear little changed in either direction. Our results are thus broadly consistent with the findings of Keller (2000), who used both econometric and conventional growth accounting techniques to estimate TFP growth rates in East and West Germany following unification. He finds an acceleration of East German TFP growth in the period 1990-1996. We also find a higher rate of TFP growth in the initial period (1993-2000), but we also find a significant slowdown in the latter period, starting in 1997. This slowdown is consistent with his hypothesis of TFP growth driven by diffusion from West to the East due to adoption patterns of embodied technologies.

The cross-sectional dimension of our TFP growth estimates for individual states can shed light on the appropriateness of the two alternative measures. The prior expectation is that measurement error should be most severe in the new states, given the limited statistical basis for computing capital stocks. Yet given the common institutional background and common access to technology, wide variation across space within the East or West during during these seven-year intervals is likely to be associated with measurement error. For the Eastern states, the unweighted standard deviation of the DS measure is slightly lower than that of the Solow-Törnqvist (ST) residual (0.545 versus 0.551); for the GD measure the standard deviation is much higher (0.970). Given initial conditions at reunification, the GD measure is thus likely to be inappropriate for the eastern German states. In contrast, the GD estimates for the western states are much more tightly distributed (standard deviation of 0.217 for a^{GD}, versus 0.365 and 0.401 for a^{ST} and a^{DS} respectively). A priori, the dispersion of TFP growth in the Western states is likely to be low, so the GD measure appears to provide a more credible estimate of the temporal evolution of TFP in the West, which is presumably close to its steady state growth path, than its Solow-Törnqvist counterpart.

The DS and GD estimates can be used to back out an implied growth contribution of capital, or, given a capital share, to the growth in the "true" (i.e. utilized) capital stock. These estimates are presented in Tables 5 and 6. They suggest a larger degree of fluctuation than otherwise implied by official capital stock estimates. The GD and DS measures reduce that mismeasurement to the extent that the utilization of more recent capital formation more closely tracks the "true" utilization rate. It is striking that both alternative measurements imply little contribution of growth in capital input to the evolution of East German GDP in the latter period, in contrast to the 1990s.

[Tables 3, 4, 5, 6, and 7 about here]

4 Accounting for differences in East-West TFP growth and levels

The last two sections established that 1) aggregate TFP levels in eastern German states remain persistently lower than in the West, and 2) convergence of TFP ground to a halt in all Eastern states after 2001. We also found that capital intensity has compensated for low total factor productivity, partially offsetting its effects on labor productivity in the eastern states. To learn more about factors behind these convergence dynamics, we present an econometric analysis of the level and the dynamics of TFP in our panel of German regions, using a convenient framework for understanding determinants of productivity growth in OECD countries (Griffith, Redding, and Van Reenen (2003, 2004)). This approach is a natural complement to the Denison-Hall-Jones analysis of TFP differences presented in Section 2, in the sense that it to explain TFP growth dynamics described in Section 3.

4.1 TFP growth regression specification

As a point of departure, we employ the following "convergence to the frontier" empirical framework which has been used by Griffith, Redding, and Van Reenen (2003, 2004) to study the role of R&D on TFP growth. The baseline specification takes the form

$$a_{it}^{ST} \left(= \ln \frac{A_{it}^{ST}}{A_{it-1}^{ST}} \right) = \beta_0 + \beta_1 a_{Ft}^{ST} + \beta_2 \ln \frac{A_{Ft-1}^{ST}}{A_{it-1}^{ST}} \tag{8}$$

$$+ \left(\beta_3 + \beta_4 \ln \frac{A_{Ft-1}^{ST}}{A_{it-1}^{ST}} \right) \ln \left(\frac{R\&D_{it-1}}{Y_{it-1}} \right) + \beta_5 Z_{it-1} + u_{it}$$

Equation (8) relates the growth in A^{ST}_{it}, the estimated level of total factor productivity (DHJ method) in the ith German region/state at time t, to the growth of the technological frontier (a^{ST}_{Ft}), to the distance to the frontier ($\ln \frac{A^{ST}_{Ft-1}}{A^{ST}_{it-1}}$), to other controls Z_{it}, to the intensity of R&D expenditure $\frac{R\&D_{it-1}}{Y_{it-1}}$, and to an interaction with the distance to the frontier $\ln\left(\frac{A^{ST}_{Ft-1}}{A^{ST}_{it-1}}\right)\ln\left(\frac{R\&D_{it-1}}{Y_{it-1}}\right)$, which affects the speed at which convergence occurs. u_{it} is a standard disturbance term with mean zero and finite variance.

This specification is derived and explained in detail in Griffith, Redding, and Van Reenen (2004) and will not be elaborated here. TFP dynamics of each state is a function of growth in the technological frontier, defined as the *Bundesland* with the highest estimated level, as well as the distance to that frontier, along the lines of the standard growth convergence literature. TFP growth is also affected by determinants contained in Z_{it}, as well as resources dedicated to research and development (R&D spending). Following Griffith et al. (2004) we distinguish between direct innovation effects of R&D spending (β_3) and the creation of "absorptive capacity" for adopting innovations at the frontier (β_4).

4.2 Data and Sources

The TFP series are the same ones described in previous sections. Public and private R&D expenditure data at the *Bundesland* level are from the German Federal Ministry of Education and Research.[14] Elements of Z were obtained from a number of different datasets. The *Establishment History Panel* (BHP), collected by the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB), tracks all German establishments with at least one employee liable for social security contributions (until 1999) and with at least one marginal part-time employee (after 1999).[15] From the BHP we extract for each *Bundesland* the total number of establishments (*establishments*), startups (*startup*), and employees liable for social security contributions (*employees*) in establishments of various sizes. In addition, we consider the number of technical workers (*technicians*), semi-professionals (*semiprofessionals*), professionals ($professionals$), and managers (*managers*).[16] Total and urban population in levels serve as controls for agglomeration

[14]The statistics can be found at the following link `http://www.datenportal.bmbf.de/portal/de/Tabelle-1.1.3.html`. Data are available for the years 1995, 1997, and for the period 1999-2013. For the missing years, we estimate the series using the growth rates of investment of private R&D.

[15]Additional information on the dataset can be found at the following link `http://fdz.iab.de/en.aspx`

[16]The job classification followed by IAB follows the classification introduced by Blosfeld (1985). In particular, professionals are defined as all the positions requiring a university degree (*Freie Berufe und hochqualifizierte Dienstleis-*

effects; total population (*population*) is taken from the *Statistisches Bundesamt*, while urban population (*population*100), defined as population for cities larger than 100,000 inhabitants is taken from several *Bundesland* and regional statistical offices. Descriptive statistics for the variables of interest are provided in the Appendix.

Given these sources, the elements of Z are the following: the ratio of startups to all establishments ($ratiostartup$), the fraction of establishments with less than 50 employees ($fractionest < 50$), the ratio of establishments with more than 250 employees to the total ($fractionest > 250$), population density ($\ln \frac{population}{km^2}$), degree of urbanization measured as fraction of total population living in cities with more than 100,000 inhabitants ($fractionurban$), the ratio of managers to total number of employees ($\frac{managers}{employees}$), the ratio of semiprofessional workers to the total number of employees ($\frac{semi\ professionals}{employees}$), the ratio of technicians to the total number of employees ($\frac{technicians}{employees}$).

4.3 OLS Results

Table 8 presents the first set of OLS regressions using Solow-Törnqvist residuals as the dependent variable (effectively, first differences of Denison-Hall-Jones estimates described in Section 2). The results are presented with robust standard errors. Relative to the first column, the second includes controls for the composition of employment; the third and fourth columns substitute annual time dummies for the growth of the technological frontier $\left(a_{Ft}^{ST} = \ln \frac{A_{Ft}^{ST}}{A_{Ft-1}^{ST}}\right)$. Consistent with findings elsewhere in the literature, all four specifications exhibit a positive and significant influence of distance to the frontier. In specifications (1) and (2), growth of the frontier has a similarly strong and statistically significant effect on *Bundesland* TFP growth. In the fifth and sixth columns of Table 8, we include the logarithm of R&D expenditure as well as its interaction with the distance to the frontier. The outcome, which is robust to many changes in specification, is that the direct effect is negative and significant taken in isolation, but as an interaction with the distance to the frontier is positive, implying that the most backward states profit the most from R&D spending. Looking at the indirect effect, at the mean distance in the sample (0.23), a 10% increase in R&D spending can be anticipated to have a 0.37% effect on TFP growth. For states that are closer than 40% to the frontier, the point estimates imply

tungsberufe), semi professionals considers jobs characterized by a specialization degree (*Dienstleistungsberufe, die sich durch eine Verwissenschaftlichung der Berufspositionen auszeichnen*), and managers are defined as employees in charge of either the production or the organizational processes (*Berufe, die die Kontrolle und Entscheidungsgewalt über den Einsatz von Produktionsfaktoren besitzen sowie Funktionäre in Organisationen*).

that additional R&D spending reduces TFP growth. Our findings are thus only partially consistent with Griffith et al. (2004), which is likely due to their aggregated (national) level of analysis.

[Table 8 about here]

Of the controls employed, the prevalence of startups and small establishments appear to have some positive effect, while in the preferred specification the presence of large establishments has a negative influence on TFP growth. Most striking are our findings for personnel structure in the *Bundesland*: while workers with technical training, semiprofessional status and university degrees have little consistent explanatory power, the presence of managers has a powerful and positive influence on TFP growth. In our preferred OLS specification, an increase in the ratio of managers to total employees of 0.1 (10 percentage points), or from the mean *Bundesland* of 2.64% to 2.90% will increase TFP growth by 0.65%.

In all specifications, the lagged investment rate is negatively associated with total factor productivity dynamics. This result is robust with respect to the measurement used.[17]

4.4 Robustness checks: Endogeneity concerns, alternative specifications, split samples

One concern, also raised by Griffith et al. (2004), is endogeneity of R&D spending or other variables on the right-hand side of the regression. Spending on research and development might react to variables which determine future TFP growth, but because these are omitted from the equation and possibly unobservable to the econometrician, will lead to endogeneity and biased coefficient estimates. For example, an important discovery today can cause an increase in research activity today and later, as a result of the spending, appear to ”cause” an increase in TFP tomorrow.

We deal with endogeneity in two different ways. First, following Griffith, Redding, and Van Reenen (2004) we instrument the R&D spending variable as a potentially endogenous covariate with lagged values, including the interaction with the TFP gap, under the orthogonality assumption that further lags are no longer correlated with spending. The Sargan test provides evidence on the validity of this assumption.

[17] Regressions using DS and GD measures are not reported but for DS were broadly similar; the GD measure, which assumes proximity to the steady state, is probably not appropriate for the episode under consideration.

A second perspective on robustness is to assume that the variables of interest are adequately captured by an error correction model (ECM) specification. This would be the case if log TFP at the frontier is integrated of order 1 and that one or more linear combinations of logarithms of *Bundesland* TFP, the frontier level, R&D spending, managerial and other personnel inputs, and other variables are stationary.[18] Exploiting nonstationarity of the relevant variables should deliver consistent estimates of the parameters of interest even if there is simultaneity of the type described above. Let X_{it} denote the deviation of the integrated variables from one particular cointegrating relationship. Following Griffith, Redding, and Van Reenen (2003, 2004), convergence patterns can be studied following error-correction formulation of the model above, somewhat specialized in the following form):

$$a_{it}^{ST} = \alpha_{0i} + \alpha_1 a_{it-1}^{ST} + \alpha_2 \left(\ln A_{it-1}^{j} - \beta X_{it-1} - (1+\gamma_i) \ln A_{Ft-1} \right) + \alpha_3 \Delta X_{it-1} + u_{it} \quad (9)$$

In this setup, the rate of change of TFP is modeled as an autoregressive process driven by stochastic shocks, changes in X (ΔX), which are represented by the variables Z and $\ln \frac{R\&D}{Y}$, and deviations of $\ln A_{it-1}^{ST}$ from its steady state value, which is given by $\beta X_{it-1} + \gamma_i \ln A_{Ft-1}$. This steady state corresponds to constant and equal growth rates of A_{it-1}^{j} and A_{Ft-1}, so it thereby expresses the steady state value of the former as a linear combination of common determinants X_{it-1}, including the frontier A_{Ft-1}, plus a state fixed effect captured by γ_i :

$$\ln A_{it-1}^{ST} = \beta X_{it-1} + \gamma_i \ln A_{Ft-1}^{ST} + \epsilon_{it}$$

The results of both the IV estimation and "nonstructural" ECM specifications are presented in Tables 9 and 10.

[Tables 9 and 10 about here]

Finally, the robustness of the results might be challenged if the data generating process for eastern and western German observations is fundamentally different. This is especially important for our findings concerning the effects of the frontier, management personnel, R&D spending and investment on TFP growth. As reported in Table 11, splitting the sample into East and West did affect the

[18]The series are too short for a Dickey-Fuller or related tests of integration or cointegration, so these results should be viewed as explorative.

precision of some estimates but the sign and the statistical significance of the OLS and IV estimates survive across most specifications.

[Table 11 about here]

5 Conclusion

In their widely cited study of international cross-country differences in output per worker, Hall and Jones (1999) stressed the role of social infrastructure, referring to institutions which encourage productive activities, i.e. the selling labor services and investing in human and physical capital with the expectation of appropriating gains from those activities. They can link a great deal of the cross-sectional variation in TFP to corruption and confiscatory taxation by governments, impediments to trade, the absence of rule of law, disruptive racial and ethnic diversity, and civil strife. Naturally TFP differences may also be due to other factors such as as regional agglomeration, Marshallian externalities, learning by doing, or even climate. In the case of post-unification Germany, however, persistent productivity gaps are unlikely due to regional variation in social infrastructure or human capital endowments or even weather. This makes the post-unification episode of particular scientific interest for uncovering the determinants of total factor productivity, a fundamental source of the wealth of nations.

Using a standard two-factor production function approach, we have shown that persistent East-West labor productivity differentials are due to a significant TFP gap in the East. Most of this gap can be attributed to manufacturing, construction and other production sectors; the difference is less pronounced in services and even reversed in agriculture, where east German labor is significantly more productive. Yet the evolution of TFP convergence cannot be attibuted to structural shifts over the period. Strikingly, capital intensity in eastern states has overshot values in the West. Our findings are confirmed using measures which do not depend on capital stocks, with the slowdown beginning roughly a decade after reunification. It is noteworthy that eastern German capital intensity is higher than in the West, and that level TPF is negatively correlated with capital intensity in both eastern and western German states, albeit with significantly less variability over time and space in the latter.

Econometric analysis of TFP growth using the framework associated with Griffith, Redding, and

Van Reenen (2004), Aghion and Griffith (2005) and Nicoletti and Scarpetta (2003) confirm a significant role for growth at the technological frontier and distance to the frontier, but also show that of the two channels or "faces" of R&D spending, only the absorptive capacity channel is operative in East German context, helping backwards states the most. This finding is true even in "only West" regressions. This is also supported by unreported regressions in which we used US TFP data for the frontier. Consistent with our descriptive evidence, investment rates are robustly associated with lower TFP growth, *ceteris paribus*. In one interpretation, this is a signal of mismeasurement error; in another, physical capital is a substitute for TFP with the latter having a causal role. While we do not find a role for firm headquarters (Ragnitz (1999)), we do find a positive, robust and significant association of TFP growth with the density of managers, consistent with agency theory and new empirical evidence from the US relating productivity to monitoring and selective personnel policies (Kalnins and Lafontaine (2013)). Factors such as agglomeration, small firms, new startups contribute positively, and the prevalence of large firms negatively, to the evolution of TFP.

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Table 1: **Hourly productivity in German regions, 2014 (nominal GDP/hour, in euros)**

Region/State	Total Economy	Agriculture	Industry	Services
Baden-Württemberg	53.42	16.43	56.64	44.32
Bavaria	52.93	14.96	54.89	45.69
Berlin / Brandenburg	43.56	21.20	44.55	38.27
Lower Saxony / Bremen	48.31	18.85	53.32	40.92
Hamburg / Schleswig-Holstein	53.27	16.85	54.28	47.23
Hessen	55.19	15.86	52.41	49.27
Mecklenburg-West Pomerania	36.80	28.56	35.53	32.64
North Rhine-Westphalia	51.52	18.96	51.39	44.97
Rheinland-Palatinate	48.35	21.89	50.77	41.25
Saarland	48.42	14.46	50.64	40.70
Saxony	37.52	19.62	36.49	32.90
Saxony-Anhalt	38.38	29.95	39.87	32.47
Thuringia	35.65	21.84	33.10	31.92
Eastern Germany including Berlin	39.56	23.82	38.49	34.91
Western Germany excluding Berlin	52.00	17.27	53.70	44.87
All Germany	49.66	18.49	51.08	42.93

Source: *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen, Reihe 1, Band 1.*
Note: Agriculture refers to farming, forestry and fishing.

Table 2: **Denison-Hall-Jones decomposition of labor productivity in German region-states, 2011, relative to Baden-Württenberg**

Region/State	Total Economy			Agriculture			Industry			Service		
	$\frac{Y}{L}$	$\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}}$	TFP	$\frac{Y}{L}$	$\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}}$	TFP	$\frac{Y}{L}$	$\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}}$	TFP	$\frac{Y}{L}$	$\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}}$	TFP
Baden-Württemberg	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bavaria	1.01	1.05	0.95	0.98	1.12	0.87	1.01	1.02	0.99	1.03	1.03	1.00
Berlin / Brandenburg	0.84	1.05	0.80	0.94	1.03	0.91	0.84	1.29	0.65	0.89	0.94	0.94
Lower Saxony / Bremen	0.91	1.01	0.90	1.36	0.88	1.55	0.96	1.10	0.87	0.93	0.95	0.98
Hamburg / Schleswig-Holstein	1.04	0.99	1.05	0.98	1.01	0.97	0.95	1.13	0.84	1.14	0.87	1.30
Hessen	1.07	0.95	1.13	0.99	1.07	0.93	0.95	1.05	0.91	1.15	0.87	1.33
Mecklenburg-West Pomerania	0.72	1.20	0.60	1.69	0.94	1.79	0.59	1.66	0.36	0.79	1.05	0.76
North Rhine-Westphalia	0.96	0.93	1.03	1.34	0.87	1.53	0.94	1.10	0.85	1.00	0.86	1.16
Rheinland-Palatinate	0.89	1.08	0.82	1.22	0.80	1.52	0.94	1.08	0.87	0.89	1.06	0.84
Saarland	0.89	1.04	0.86	0.86	1.13	0.76	0.91	1.13	0.80	0.90	1.01	0.89
Saxony	0.72	1.09	0.66	1.16	0.91	1.28	0.68	1.52	0.45	0.75	0.99	0.76
Saxony-Anhalt	0.73	1.14	0.64	1.80	0.90	1.99	0.72	1.56	0.46	0.74	1.03	0.72
Thuringia	0.70	1.13	0.62	1.29	0.89	1.44	0.66	1.42	0.46	0.72	1.07	0.68
Eastern Germany including Berlin	0.76	1.09	0.69	1.33	0.93	1.42	0.72	1.45	0.50	0.80	0.99	0.81
Western Germany excluding Berlin	0.98	0.99	0.99	1.13	0.97	1.16	0.97	1.06	0.92	1.02	0.94	1.08
All Germany	0.94	1.01	0.93	1.17	0.96	1.21	0.93	1.12	0.83	0.98	0.95	1.03

Source: Authors' calculations based on *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen.*

Table 3: **TFP growth in German federal states: A comparison of three measures. 1993-2011.**

	ST	**DG**	**GD**
East Germany	**0.8**	**0.7**	**0.3**
Berlin / Brandenburg	0.5	0.4	0.4
Mecklenburg-West Pomerania	1.0	0.3	0.4
Saxony	1.4	1.1	0.4
Saxony-Anhalt	1.2	0.7	0.2
Thuringia	1.3	0.8	0.2
West Germany	**0.5**	**0.5**	**0.5**
Baden-Württemberg	0.6	0.6	0.5
Bavaria	0.9	0.7	0.5
Hesse	0.3	0.6	0.5
Lower Saxony / Bremen	0.3	0.3	0.5
North Rhine-Westphalia	0.4	0.5	0.4
Rheinland-Palatinate	0.2	-0.0	0.5
Saarland	0.5	0.4	0.5
Hamburg / Schleswig-Holstein	0.2	0.4	0.4
Germany	**0.5**	**0.5**	**0.4**

Source: Authors' calculations based on *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen.*

Table 4: **TFP growth in German federal states: A comparison of three measures. 1993-2001 and 2002-2011.**

	ST		**DS**		**GD**	
	1993-2001	2002-2011	1993-2001	2002-2011	1993-2001	2002-2011
East Germany	**1.0**	**0.7**	**1.1**	**0.2**	**0.0**	**0.6**
Berlin / Brandenburg	0.5	0.5	0.6	0.3	0.1	0.6
Mecklenburg-West Pomerania	1.3	0.7	0.7	-0.1	0.1	0.6
Saxony	2.1	0.9	1.9	0.3	0.2	0.6
Saxony-Anhalt	1.9	0.5	1.6	-0.0	-0.1	0.5
Thuringia	1.8	0.8	1.6	0.2	-0.5	0.8
West Germany	**0.4**	**0.5**	**0.6**	**0.4**	**0.4**	**0.5**
Baden-Württemberg	0.7	0.5	0.8	0.5	0.5	0.5
Bavaria	0.9	1.0	0.7	0.7	0.3	0.7
Hesse	0.8	-0.1	1.2	0.0	0.4	0.5
Lower Saxony / Bremen	-0.2	0.8	-0.1	0.6	0.3	0.6
North Rhine-Westphalia	0.2	0.5	0.5	0.6	0.4	0.5
Rheinland-Palatinate	-0.3	0.6	-0.4	0.3	0.2	0.7
Saarland	0.3	0.7	0.2	0.5	0.4	0.6
Hamburg / Schleswig-Holstein	0.8	-0.4	1.2	-0.4	0.6	0.3
All Germany	**0.5**	**0.5**	**0.7**	**0.4**	**0.3**	**0.6**

Source: Authors' calculations based on *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen.*

Table 5: **Growth accounting using the three methods. 1993-2011 (% per annum).**

		Solow-Törnqvist			**Direct Substitution**			**Generalized Difference**		
	GDP	**Contribution of**			**Contribution of**			**Contribution of**		
	Growth	**TFP**	**Labor**	**Capital**	**TFP**	**Labor**	**Capital***	**TFP**	**Labor**	**Capital***
East Germany	**2.0**	**0.8**	**-0.1**	**1.2**	**0.7**	**-0.1**	**1.3**	**0.3**	**-0.1**	**1.7**
Berlin / Brandenburg	1.3	0.5	0.1	0.7	0.4	0.1	0.8	0.4	0.1	0.9
Mecklenburg-West Pomerania	2.2	1.0	-0.1	1.4	0.3	-0.1	2.0	0.4	-0.1	2.0
Saxony	2.7	1.4	-0.0	1.2	1.1	-0.0	1.6	0.4	-0.0	2.3
Saxony-Anhalt	2.1	1.2	-0.4	1.3	0.7	-0.4	1.7	0.2	-0.4	2.3
Thuringia	2.7	1.3	-0.0	1.4	0.8	-0.0	1.9	0.2	-0.0	2.5
West Germany	**1.2**	**0.5**	**0.3**	**0.4**	**0.5**	**0.3**	**0.4**	**0.5**	**0.3**	**0.4**
Baden-Württemberg	1.3	0.6	0.3	0.4	0.6	0.3	0.4	0.5	0.3	0.5
Bavaria	1.9	0.9	0.4	0.6	0.7	0.4	0.7	0.5	0.4	1.0
Hesse	1.0	0.3	0.2	0.4	0.6	0.2	0.1	0.5	0.2	0.2
Lower Saxony / Bremen	1.1	0.3	0.4	0.4	0.3	0.4	0.4	0.5	0.4	0.2
North Rhine-Westphalia	0.9	0.4	0.3	0.3	0.5	0.3	0.1	0.4	0.3	0.2
Rheinland-Palatinate	1.0	0.2	0.4	0.3	-0.0	0.4	0.5	0.5	0.4	0.1
Saarland	1.0	0.5	0.3	0.2	0.4	0.3	0.4	0.5	0.3	0.2
Hamburg / Schleswig-Holstein	1.1	0.2	0.3	0.6	0.4	0.3	0.4	0.4	0.3	0.3
Germany	**1.3**	**0.5**	**0.3**	**0.5**	**0.5**	**0.3**	**0.5**	**0.4**	**0.3**	**0.6**

Note: Components may not add exactly due to rounding error.

* Imputed contribution conditional on TFP calculations described in text.

Source: Authors' calculations based on *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen.*

Table 6: **Growth accounting using the three methods. 1993-2001 (% per annum).**

	GDP Growth	Solow-Törnqvist Contribution of			Direct Substitution Contribution of			Generalized Difference Contribution of		
		TFP	Labor	Capital	TFP	Labor	Capital*	TFP	Labor	Capital*
East Germany	**3.0**	**1.0**	**-0.2**	**2.2**	**1.1**	**-0.2**	**2.1**	**0.0**	**-0.2**	**3.2**
Berlin / Brandenburg	1.6	0.5	-0.2	1.4	0.6	-0.2	1.2	0.1	-0.2	1.7
Mecklenburg-West Pomerania	3.7	1.3	-0.1	2.5	0.7	-0.1	3.1	0.1	-0.1	3.8
Saxony	4.3	2.1	-0.1	2.3	1.9	-0.1	2.4	0.2	-0.1	4.2
Saxony-Anhalt	3.8	1.9	-0.6	2.5	1.6	-0.6	2.8	-0.1	-0.6	4.5
Thuringia	4.4	1.8	0.0	2.6	1.6	0.0	2.8	-0.5	0.0	4.9
West Germany	**1.3**	**0.4**	**0.4**	**0.5**	**0.6**	**0.4**	**0.3**	**0.4**	**0.4**	**0.6**
Baden-Württemberg	1.5	0.7	0.4	0.4	0.8	0.4	0.3	0.5	0.4	0.7
Bavaria	1.9	0.9	0.4	0.7	0.7	0.4	0.8	0.3	0.4	1.3
Hesse	1.6	0.8	0.3	0.4	1.2	0.3	0.1	0.4	0.3	0.9
Lower Saxony / Bremen	0.7	-0.2	0.4	0.5	-0.1	0.4	0.4	0.3	0.4	0.0
North Rhine-Westphalia	1.0	0.2	0.4	0.4	0.5	0.4	0.1	0.4	0.4	0.2
Rheinland-Palatinate	0.6	-0.3	0.5	0.5	-0.4	0.5	0.6	0.2	0.5	-0.0
Saarland	1.2	0.3	0.4	0.4	0.2	0.4	0.6	0.4	0.4	0.3
Hamburg / Schleswig-Holstein	1.6	0.8	0.2	0.6	1.2	0.2	0.2	0.6	0.2	0.8
Germany	**1.5**	**0.5**	**0.2**	**0.7**	**0.7**	**0.2**	**0.6**	**0.3**	**0.2**	**1.0**

Note: Components may not add exactly due to rounding error.
* Imputed contribution conditional on TFP calculations described in text.
Source: Authors' calculations based on *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen.*

Table 7: **Growth accounting using the three methods. 2002-2011 (% per annum).**

		Solow-Törnqvist			**Direct Substitution**			**Generalized Difference**		
	GDP	**Contribution of**			**Contribution of**			**Contribution of**		
	Growth	**TFP**	**Labor**	**Capital**	**TFP**	**Labor**	**Capital***	**TFP**	**Labor**	**Capital***
East Germany	**1.0**	**0.7**	**0.1**	**0.3**	**0.2**	**0.1**	**0.7**	**0.6**	**0.1**	**0.3**
Berlin / Brandenburg	1.0	0.5	0.3	0.2	0.3	0.3	0.4	0.6	0.3	0.2
Mecklenburg-West Pomerania	0.9	0.7	-0.1	0.3	-0.1	-0.1	1.1	0.6	-0.1	0.4
Saxony	1.2	0.9	0.1	0.3	0.3	0.1	0.8	0.6	0.1	0.6
Saxony-Anhalt	0.5	0.5	-0.2	0.2	-0.0	-0.2	0.7	0.5	-0.2	0.2
Thuringia	1.1	0.8	-0.1	0.4	0.2	-0.1	1.0	0.8	-0.1	0.4
West Germany	**1.2**	**0.5**	**0.3**	**0.3**	**0.4**	**0.3**	**0.4**	**0.5**	**0.3**	**0.3**
Baden-Württemberg	1.2	0.5	0.3	0.4	0.5	0.3	0.4	0.5	0.3	0.4
Bavaria	1.9	1.0	0.4	0.5	0.7	0.4	0.7	0.7	0.4	0.8
Hesse	0.4	-0.1	0.2	0.3	0.0	0.2	0.2	0.5	0.2	-0.3
Lower Saxony / Bremen	1.4	0.8	0.4	0.2	0.6	0.4	0.4	0.6	0.4	0.4
North Rhine-Westphalia	0.9	0.5	0.2	0.2	0.6	0.2	0.1	0.5	0.2	0.2
Rheinland-Palatinate	1.2	0.6	0.4	0.2	0.3	0.4	0.5	0.7	0.4	0.1
Saarland	0.8	0.7	0.1	0.0	0.5	0.1	0.2	0.6	0.1	0.0
Hamburg / Schleswig-Holstein	0.6	-0.4	0.4	0.7	-0.4	0.4	0.6	0.3	0.4	0.0
Germany	**1.1**	**0.5**	**0.3**	**0.3**	**0.4**	**0.3**	**0.4**	**0.6**	**0.3**	**0.3**

Note: Components may not add exactly due to rounding error.

* Imputed contribution conditional on TFP calculations described in text.

Source: Authors' calculations based on *Statistische Bundesamt, Volkswirtschaftliche Gesamtrechnungen.*

Table 8: **Determinants of TFP Growth in German *Bundesländer*, OLS Regressions**

Dependent Variable: a^{ST}_{it}						
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln \frac{A^{ST}_{Ft-1}}{A^{ST}_{it-1}}$	0.24***	0.31***	0.24***	0.30***	0.90***	1.01*
	(0.05)	(0.06)	(0.05)	(0.05)	(0.33)	(0.33)
a^{ST}_{Ft}	1.12***	1.12***				
	(0.11)	(0.11)				
$\ln \frac{I_{t-1}}{Y_{t-1}}$	-0.28***	-0.30***	-0.26***	-0.20***	-0.24***	-0.17*
	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)
$ratiostartup_{t-1}$	-0.05	-0.03	0.27***	0.25***	0.14	0.16*
	(0.03)	(0.03)	(0.09)	(0.09)	(0.10)	(0.09)
$fractionest < 50_{t-1}$	-5.11***	-4.68***	-2.89*	-1.69	-1.01	-0.31
	(1.29)	(1.52)	(1.50)	(1.61)	(1.76)	(1.80)
$fractionest < 250_{t-1}$	-0.06	-0.16	-0.15	-0.21	-0.34*	-0.44*
	(0.20)	(0.21)	(0.18)	(0.19)	(0.20)	(0.23)
$\ln \frac{est_{t-1}}{km^2}$	0.16***	0.13**	0.06	0.06	0.05	0.07
	(0.04)	(0.05)	(0.06)	(0.07)	(0.07)	(0.08)
$\ln \frac{population_{t-1}}{km^2}$	0.07	-0.15	0.21	-0.21	0.25	-0.20
	(0.09)	(0.12)	(0.13)	(0.14)	(0.16)	(0.17)
$\ln fractionurban_{t-1}$	0.21	0.31**	0.07	0.16	0.14	0.22*
	(0.13)	(0.12)	(0.11)	(0.11)	(0.10)	(0.10)
$\frac{managers_{t-1}}{employees_{t-1}}$		4.16**		6.47***		6.49*
		(1.86)		(1.61)		(1.83)
$\frac{professionals_{t-1}}{employees_{t-1}}$		-0.06		-0.60		-0.52
		(0.68)		(0.86)		(0.98)
$\frac{semi\ professionals_{t-1}}{employees_{t-1}}$		0.06		0.51		1.06*
		(0.37)		(0.38)		(0.48)
$\frac{technicians_{t-1}}{employees_{t-1}}$		-1.29		0.05		0.58
		(0.87)		(0.74)		(0.99)
$\ln \frac{R\&D_{t-1}}{Y_{t-1}}$					-0.06**	-0.07*
					(0.03)	(0.03)
$\ln \frac{R\&D_{t-1}}{Y_{t-1}} * \ln \frac{A^{ST}_{Ft-1}}{A^{ST}_{it-1}}$					0.16*	0.16*
					(0.08)	(0.08)
Constant	4.37***	5.03***	1.67	2.43	-0.50	0.77
	(1.43)	(1.51)	(1.92)	(1.85)	(2.22)	(2.06)
R^2	0.61	0.63	0.75	0.77	0.78	0.80
Time dummies	NO	NO	YES	YES	YES	YES
No. of observations	234	234	234	234	208	208

Notes: Regression estimates are weighted by state GDP share in 1993. Bundesland fixed effects included in all regressions. *, **, and *** denote significance at 90%, 95% and 99% confidence levels respectively, on the basis of robust standard errors .

Table 9: **Determinants of TFP Growth in German *Bundesländer*, IV Regressions**

Dependent Variable: a_{it}^{ST}						
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln \frac{A_{Ft-1}^{ST}}{A_{it-1}^{ST}}$	0.23***	0.35***	0.31***	0.39***	1.40***	1.86***
	(0.08)	(0.09)	(0.07)	(0.08)	(0.50)	(0.64)
a_{Ft}^{ST}	1.10***	1.11***				
	(0.12)	(0.12)				
$\ln \frac{I_{t-1}}{Y_{t-1}}$	-0.24***	-0.26***	-0.28***	-0.21***	-0.28***	-0.17**
	(0.07)	(0.08)	(0.06)	(0.07)	(0.07)	(0.07)
$ratiostartup_{t-1}$	-0.06**	-0.01	0.12	0.13	0.09	0.14
	(0.03)	(0.02)	(0.09)	(0.09)	(0.09)	(0.09)
$fractionest < 50_{t-1}$	-1.63	-1.97	-2.07	-1.31	-0.28	0.47
	(1.88)	(2.41)	(1.97)	(2.03)	(1.87)	(1.91)
$fractionest < 250_{t-1}$	-0.24	-0.26	-0.23	-0.35*	-0.56***	-0.70***
	(0.18)	(0.19)	(0.16)	(0.19)	(0.22)	(0.25)
$\ln \frac{est_{t-1}}{km^2}$	0.08	0.11*	0.09	0.11	0.02	0.06
	(0.05)	(0.06)	(0.07)	(0.09)	(0.07)	(0.08)
$\ln \frac{population_{t-1}}{km^2}$	0.12	-0.13	0.16	-0.31*	0.40***	-0.02
	(0.10)	(0.11)	(0.14)	(0.16)	(0.14)	(0.18)
$\ln fractionurban_{t-1}$	0.17	0.16*	0.15	0.23**	0.12	0.22**
	(0.11)	(0.10)	(0.10)	(0.10)	(0.08)	(0.09)
$\frac{managers_{t-1}}{employees_{t-1}}$		4.62***		6.85***		6.02***
		(1.59)		(1.56)		(1.76)
$\frac{professionals_{t-1}}{employees_{t-1}}$		-0.58		-0.21		-0.37
		(0.59)		(0.83)		(1.10)
$\frac{semi\ professionals_{t-1}}{employees_{t-1}}$		0.55		0.81*		1.45**
		(0.39)		(0.46)		(0.72)
$\frac{technicians_{t-1}}{employees_{t-1}}$		-0.34		0.44		1.26
		(0.90)		(0.89)		(0.94)
$\ln \frac{R\&D_{t-1}}{Y_{t-1}}$					-0.10**	-0.14**
					(0.05)	(0.05)
$\ln \frac{R\&D_{t-1}}{Y_{t-1}} * \ln \frac{A_{Ft-1}^{ST}}{A_{it-1}^{ST}}$					0.27**	0.36**
					(0.12)	(0.15)
Constant	0.87	2.31	1.11	2.48	-2.02	-1.12
	(2.03)	(2.35)	(2.30)	(2.26)	(2.13)	(2.11)
R^2	0.65	0.68	0.77	0.79	0.79	0.79
Sargan (*p value*)	0.71	0.51	0.54	0.32	0.02	0.02
No. of observations	208	208	208	208	195	195

Notes: Regression estimates are weighted by state GDP share in 1993. Bundesland fixed effects included in all regressions. *, **, and *** denote significance at 90%, 95% and 99% confidence levels respectively, on the basis of robust standard errors . Instruments: $\ln \frac{A_{Ft-2}^{ST}}{A_{it-2}^{ST}}$ and $\ln \frac{A_{Ft-3}^{ST}}{A_{it-3}^{ST}}$ in all columns, $\ln \frac{R\&D_{t-2}}{Y_{t-2}}$ and $\ln \frac{A_{Ft-2}^{ST}}{A_{it-2}^{ST}} * \ln \frac{R\&D_{t-2}}{Y_{t-2}}$ in columns (5) and (6).

Table 10: **Determinants of TFP Growth in German *Bundesländer*, ECM Regressions**

Dependent Variable: a_{it}^{ST}								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
a_{it-1}^{ST}	0.20**	0.19**	0.06	0.07	0.10	0.13	-0.01	0.29
	(0.08)	(0.08)	(0.10)	(0.09)	(0.11)	(0.10)	(0.54)	(0.53)
$\ln A_{it-1}$			-0.24***	-0.35***			0.00	0.00
			(0.06)	(0.07)			(.)	(.)
$\ln A_{Ft-1}$	-0.67***	-0.67***						
	(0.11)	(0.11)						
a_{Ft-1}^{ST}	0.24**	0.32***			0.33***	0.46***	0.86***	1.29***
	(0.09)	(0.10)			(0.08)	(0.09)	(0.29)	(0.34)
$\ln \frac{I_{t-1}}{Y_{t-1}}$	-0.15*	-0.21**	-0.12*	-0.11	-0.17**	-0.09	-0.16*	-0.07
	(0.08)	(0.09)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
$\Delta \ln \frac{I_{t-1}}{Y_{t-1}}$	0.02	0.07	-0.07	-0.05	-0.04	-0.05	-0.05	-0.05
	(0.08)	(0.08)	(0.07)	(0.07)	(0.08)	(0.08)	(0.07)	(0.07)
$\frac{managers_{t-1}}{employees_{t-1}}$		4.10		6.44***		6.82***		7.62***
		(2.56)		(2.29)		(2.35)		(2.32)
$\Delta \frac{managers_{t-1}}{employees_{t-1}}$		2.70		-0.45		0.53		-0.71
		(3.43)		(2.66)		(2.71)		(2.67)
$\frac{professionals_{t-1}}{employees_{t-1}}$		-0.56		-0.58		-0.52		-0.12
		(1.03)		(1.12)		(1.20)		(1.20)
$\Delta \frac{professionals_{t-1}}{employees_{t-1}}$		-0.99		-0.73		0.06		0.26
		(0.94)		(2.15)		(2.27)		(2.41)
$\frac{semi\ professionals_{t-1}}{employees_{t-1}}$		0.10		0.54		0.80		1.06**
		(0.45)		(0.46)		(0.52)		(0.52)
$\Delta \frac{semi\ professionals_{t-1}}{employees_{t-1}}$		0.98		0.61		0.53		0.50
		(0.63)		(0.54)		(0.71)		(0.72)
$\frac{technicians_{t-1}}{employees_{t-1}}$		-2.28*		0.36		1.90		2.32*
		(1.18)		(1.01)		(1.22)		(1.18)
$\Delta \frac{semi\ professionals_{t-1}}{employees_{t-1}}$		-1.50		-0.73		-2.86*		-2.99**
		(1.76)		(1.32)		(1.49)		(1.44)
$\ln \frac{R\&D_{t-1}}{Y_{t-1}}$					-0.01	-0.02	-0.06**	-0.09***
					(0.01)	(0.01)	(0.03)	(0.03)
$\Delta \ln \frac{R\&D_{t-1}}{Y_{t-1}}$					-0.01	0.01	-0.01	0.03
					(0.02)	(0.02)	(0.04)	(0.04)
$\Delta \ln \frac{R\&D_{t-1}}{Y_{t-1}}$							0.14*	0.21**
							(0.08)	(0.08)
$\Delta \ln \frac{R\&D_{t-1}}{Y_{t-1}}$							0.02	-0.05
							(0.13)	(0.13)
R^2	0.30	0.33	0.68	0.70	0.72	0.74	0.73	0.75
Time dummies	NO	NO	YES	YES	YES	YES	YES	YES
N. of observations	221	221	221	221	195	195	195	195

Notes: Bundesland fixed effects included in all regressions. *, **, and *** denote significance at 90%, 95% and 99% confidence levels respectively, on the basis of robust standard errors .

Table 11: **Determinants of TFP Growth in western and eastern *Bundesländer***

Dependent Variable: a_{it}^{ST}						
	OLS		**IV**		**ECM**	
	WEST	**EAST**	**WEST**	**EAST**	**WEST**	**EAST**
$\ln \frac{A_{Ft}^{ST}}{A_{it-1}^{ST}}$	1.33**	1.85**	2.50***	3.05***	1.40**	1.21**
	(0.51)	(0.51)	(0.51)	(0.51)	(0.51)	(0.51)
$\ln \frac{R\&D_{t-1}}{Y_{t-1}}$	-0.07**	-0.19**	-0.16**	-0.33	-0.08	-0.29
	(0.04)	(0.05)	(0.07)	(0.07)	(0.52)	(0.07)
$\Delta \ln \frac{R\&D_{t-1}}{Y_{t-1}} * \ln \frac{A_{Ft-1}^{ST}}{A_{it-1}^{ST}}$	0.24*	0.33***	0.52**	0.67**	0.20	0.18
	(0.13)	(0.12)	(0.22)	(0.16)	(0.16)	(0.15)
$\Delta \ln \frac{I_{t-1}}{Y_{t-1}}$	-0.29**	-0.17**	-0.33**	-0.12	0.06	-0.42***
	(0.12)	(0.07)	(0.12)	(0.94)	(0.07)	(0.14)
$\frac{managers_{t-1}}{employees_{t-1}}$	4.54***	3.27	3.71*	1.90	3.49	8.72**
	(2.25)	(2.86)	(2.11)	(3.24)	(3.35)	(4.43)

Notes: Regression estimates are weighted by state GDP share in 1993. Bundesland fixed effects included in all regressions. *, **, and *** denote significance at 90%, 95% and 99% confidence levels respectively, on the basis of robust standard errors .

Appendix

Income and product account data used in this study are available for all 16 *Bundesländer* beginning in 1992: 11 Western Länder (Bavaria, Baden-Württemberg, Bremen, Hamburg, Hesse, Lower Saxony, North Rhine-Westphalia, Rhineland-Palatinate, Saarland, Schleswig-Holstein) and the 6 "new" Eastern states (Berlin, Brandenburg, Mecklenburg-West Pommerania, Saxony-Anhalt, Saxony, and Thuringia). Berlin/Brandenburg is the union of East and West Berlin, because the western half of Berlin, while under the protection and economic aegis of Western Germany until 1989, never enjoyed full status as a *Bundesland*. We employ the income and product accounts and capital stock estimates at the level of the federal states published by the Working Group for State Income and Product Accounts (*Arbeitsgemeinschaft Volkswirtschaftliche Gesamtrechnung der Länder*).[19] Table of descriptive statistics here:

[19] The data can be downloaded at the website `http://www.vgrdl.de/Arbeitskreis_VGR/ergebnisse.asp`. Capital stocks for the new states in the period 1991-1993 were computed by backcasting the perpetual inventory method from the 1994 estimates.

Growth accounting variables: Descriptive statistics

	Y	K	I	L
East Germany	**328.6**	**1077.0**	**82.2**	**7449.5**
	(21.9)	**(197.4)**	**(17.8)**	**(168.1)**
Berlin	87.9	258.8	14.3	1612.4
	(3.8)	(17.9)	(2.231)	(48.8)
Brandeburg	45.4	157.0	133.6	1055.2
	(45.5)	(38.9)	(3.1)	(26.3)
Mecklenburg-Western Pomerania	30.4	115.4	9.2	743.9
	(2.2)	(24.9)	(2.4)	(20.0)
Saxony	80.3	256.7	21.7	1952.8
	(7.2)	(54.3)	(5.0)	(37.2)
Saxony-Anhalt	44.3	150.3	12.144	1050.7
	(3.1)	(31.1)	(3.8)	(52.4)
Thuringia	40.4	138.5	11.6	1034.5
	(3.7)	(31.4)	(2.6)	(22.3)
West Germany	**1846.2**	**5404.9**	**317.4**	**31.6**
	(147.8)	**(390.7)**	**(35.0)**	**(1148.4)**
Baden-Württenberg	316.0	944.4	54.0	5408.8
	(28.1)	(67.5)	(6.6)	(215.2)
Bavaria	362.0	1227.4	74.1	6345.6
	(42.3)	(119.8)	(9.2)	(250.4)
Bremen	23.9	54.2	3.1	394.0
	(1.5)	(1.8)	(0.4)	(8.9)
Hamburg	82.8	158.8	14.7	1053.8
	(6.6)	(27.5)	(5.6)	(42.1)
Hesse	200.0	508.4	30.3	3043.9
	(13.9)	(32.3)	(4.2)	(80.8)
Lower Saxony	187.5	599.3	34.1	3511.7
	(13.0)	(40.1)	(3.0)	(136.9)
North Rhine-Westphalia	485.9	126.2	72.8	8333.2
	(32.0)	(67.5)	(6.9)	(300.7)
Rhineland-Palatinate	96.2	339.6	18.0	1778.1
	(6.1)	(20.4)	(1.3)	(82.5)
Saarland	26.4	88.8	4.5	494.9
	(2.2)	(3.9)	(0.5)	(16.9)
Schleswig-Holstein	65.7	221.8	12.1	1243.4
	(3.8)	(13.2)	(1.2)	(30.7)
Germany (in milions)	**21.7**	**6.48**	**39.9**	**39.1**
	(1.68)	**(5.80)**	**(2.4)**	**(1.08)**

Regression covariates: Descriptive statistics

	mean	std. error	min	max	N. of obs.
$\ln \frac{A_i^{ST}}{A_F^{ST}}$	2.80	0.15	2.56	3.06	234
$\frac{I}{Y}$	0.21	0.08	0.13	0.51	234
$ratio\ startup$	0.07	0.03	0.04	0.18	234
$ratio\ firm\ 50$	0.97	0.01	0.95	0.98	234
$ratio\ firm\ 250$	0.08	0.17	0.00	0.58	234
$\frac{firm}{km^2}$	3.54	1.74	0.87	8.83	234
$\frac{population}{km^2}$	241.03	117.55	70.15	530.04	234
$\frac{population100}{population}$	0.27	0.15	0.11	0.62	234
$\frac{managers}{employees}$	0.03	0.00	0.02	0.04	234
$\frac{professionals}{employees}$	0.02	0.00	0.01	0.03	234
$\frac{semi\ professionals}{employees}$	0.07	0.01	0.05	0.10	234
$\frac{technicians}{employees}$	0.04	0.01	0.03	0.06	234
$\frac{R\&D}{Y}$	0.02	0.01	0.01	0.05	208

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