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FROM SOCIALIST SHOWCASE TO MEZZOGIORNO? LESSONS ON THE ROLE OF TECHNICAL CHANGE FROM EAST GERMANY'S POST-WORLD WAR II GROWTH PERFORMANCE

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ABSTRACT

In this paper we emphasize the contribution of technical change, broadly defined, towards productivity growth in explaining the relative East Germany-West Germany performance during the post-World War II era. We argue that previous work was excessively focused on physical capital investments determining productivity differentials, which consequently led to an overestimation of the East German performance during the Socialist era, and an overly pessimistic assessment of the East German prospects of catching up with West Germany during the post-reunification era. We show, first, that the rates of technical change in the manufacturing industries of East German states were significantly below those in Western states, helping to account for the fact that East Germany was not the socialist showcase for which it was frequently taken before German reunification. Second, we demonstrate that the rates of technical change in the East German states have been considerably higher than those in the West since German reunification. This suggests that the Mezzogiorno prediction for East Germany--that it will stay persistently behind West Germany as does Italy's South relative to its North--, based on an analysis of the need for physical capital accumulation alone, will prove too pessimistic.

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1. Introduction

How long will it take until East European economies will be similarly rich as the countries in the West of Europe? Barro (1991a) argued that, based on his own estimates from US states, it would take about 70 years until three-quarters of the per capita income gap in the specific case of East and West Germany would be eliminated[1] this would mean that East Germany would become a German Mezzogiorno, similar to Italy's South which persistently stays behind its North.

How well was East Germany doing during its socialist period before German reunification? In 1987, two years before the Berlin Wall came down, the Deutsche Institut fuer Wirtschaftsforschung (DIW) in Berlin-West, which has been most consistent in tracking the East German productivity performance, estimated that the ratio of East German to West German labor productivity in the industrial sector was ca. 50% (Report 1987, p.390), which, compared to other socialist countries, would have made East Germany the socialist showcase economy.

It is, with the benefit of hindsight, easy to see that both of these estimates were way off: Right before German reunification, the relative labor productivity of East Germany's manufacturing sector was not 50%, but ca. 25% of the West German level.[2] At the same time, the developments of East German GDP per capita between 1991 and 1995 suggest that it

[1]In Barro and Sala-i-Martin (1991), the authors predict that it will take 35 years until half of the initial income per capita difference between East and West Germany will have disappeared, p.154; these two estimates are equivalent. They are based on equation (2.4) and an estimate of λ of 2%. Barro did not stand alone with his pessimism; Hughes-Hallett and Ma (1993), e.g., estimate 30-40 years to full convergence. See also Sinn and Sinn (1992) for a review of other predictions.

[2]A level of productivity of 25% for 1989 seems plausible, see the references in Hughes-Hallett and Ma (1993), and Sinn and Sinn (1992), Ch.2. Akerlof et al. (1991) even assume a productivity level of less than one sixth for GDR manufacturing in 1989. The estimates are usually projections based on officially published data for the second half of 1990 or 1991. According to Arbeitskreis (1995), the average manufacturing labor productivity of East German states relative to West German states was 28.6% in 1991 (average Eastern relative GDP per capita was 31.23% [ibid]).

will take East German states on average not 70, but 20 years or less until it has reached three-quarters of the per capita GDP of West Germany. For labor productivity in the manufacturing sector, we estimate only about ten years until East Germany has reached three-quarters of the West Germany level.[3] Why is it that the East German productivity levels even at the end of the socialist era in Germany were overestimated by 100%? And why did Barro apparently overestimate the time to converge for East Germany by a factor of three? In this paper, we argue that ignoring differences in the rate of technical change–in the sense of Solow (1957)–as a factor determining productivity growth is at the heart of why these estimates are off by a factor of two and three, respectively.

This is because Barro's post-reunification prediction is based on a model of physical capital accumulation where all economies experience the same exogenous rate of technical change. But East Germany's rate of technical change can be much higher than West Germany's while new production and management techniques are adopted, and even more generally, because the economic agents now face the different incentive structures of a market economy. Further, technical change is at least to a certain degree not embodied in capital goods, which implies that it is not enough to compare rates of physical capital investments of East and West Germany to estimate how large the difference in the rates of technical change are. In this paper, therefore, we propose a Solow-Swan model of growth with differential rates of technical change; in this model, the rates of physical capital accumulation and technical change are independent from each other, and can also take on different values for different economies.

We will estimate the model using data on East and West German regions (*Laender* for the

[3]These estimates are obtained by calculating the speed of catch-up between the average East and West German state between 1991-95 (see section 4.2 below), and extrapolating it into the future.

West, *Bezirke* in the East) during East Germany's socialist era (1949-89). First of all, there are practical reasons for that, as a formal statistical analysis is hard to conduct with only five years of post-reunification data. Second, a comparative analysis of East and West during that period might be of interest in its own right. Ultimately, however, an analysis of East and West German regions during that era is the appropriate way of estimating the model because both today's overly pessimistic assessment of East Germany's growth prospects ('Mezzogiorno'), and the excessively optimistic estimates of East Germany's growth performance during its socialist era ('Showcase') can be attributed to ignoring the consequences of differences in the rates of technical change between economies. We show below that East German rates of technical change were below those in the West, which, if ignored,[4] explains why East Germany's achievements during its socialist era had been overestimated. In a nutshell, placing less emphasis on physical capital accumulation by accounting for differences in the rate of technical change can both explain the apparent East German 'Showcase' phenomenon before re-unification and suggest why a 'Mezzogiorno' scenario for East Germany in the post-reunification era is extremely unlikely.

This paper is related to work on income convergence across countries or regions using the framework of the Solow-Swan model of growth, including Barro (1991b) and Mankiw, Romer, Weil (1992) who consider cross-sections, as well as De Gregorio (1991) and Islam (1995) who use panel data analysis. The estimation here is more general in the sense that we allow, corresponding to the argument above, for differences in the rates of technical change across economies. Our analysis for the post-reunification era builds on the literature on the measurement of TFP

[4]For evidence on this, see Report (1987) and the studies cited therein.

growth, going back to Solow (1957).

The paper is also related to recent work specifically on East Germany, including Boltho et al. (1996), Burda and Funke (1993), and Hughes-Hallett and Ma (1993).[5] Boltho et al. attempt to answer the question of whether East Germany will remain Germany's Mezzogiorno by studying the circumstances which led to the Mezzogiorno problem proper, in Italy's South versus its North, before making comparisons with East Germany. Although criticizing the work by Barro and Sala-i-Martin (1991) in several respects, Boltho et al. conclude within that framework that Italy's South did not converge to its North between 1928 and 1991. Based on a variety of factors such as innovative policy design, a history of entrepreneurship, and wholesale administrative reform, Boltho et al. are cautiously optimistic that East Germany will not be a Mezzogiorno case.[6]

Both Hughes-Hallett and Ma and Burda and Funke are studies of the prospects of East Germany in the post-reunification period which are explicitly tied to a specific formal framework. The former base their predictions on simulations with the IMF's MULTIMOD model, stressing almost exclusively physical capital investments as the way to close the productivity gap between East and West. Therefore, Hughes-Hallett and Ma reach qualitatively similar conclusions as Barro (1991a) on the East-West catch-up time. In contrast, and similar to the views proposed here, Burda and Funke find the prediction that it will take 70 years until East Germany has caught up (to 75%) with West Germany to be overly pessimistic. Burda and Funke's model emphasizes the high mobility of human capital within Germany after reunification, and show

[5] See also the work by Akerlof et al. (1991), Ritschl (1996), and the overview in Sinn and Sinn (1992).

[6] While it is clear from this that Boltho et al.'s analysis of East Germany incorporates more elements than what is captured in the framework analyzed to study Italy's South, we note that Boltho et al. do not consider their convergence regressions as estimating a particular model either, p.4. This is due to Boltho et al.'s objections to the Barro and Sala-i-Martin (1991) approach.

evidence on the convergence of productivity between East and West. Burda and Funke, however, do not estimate their growth model with high capital mobility with both East and West German data.[7]

Taken together, there are few studies which estimates East Germany's relative economic performance along the lines of a formal growth model;[8] even fewer authors have integrated the analyses of Germany's pre- and post-reunification era, and no study isolates the effect of differences in the rate of technical change[9] as a critical factor, together with physical capital investment, in making long-term predictions on East Germany's economic prospects.

The remainder of the paper is as follows. Section 2 presents the Solow-Swan model with differences in the rate of technical change, and derives the estimating equation. In section 3, we give some background on the two parts of Germany which existed separately between 1949 and 1989, and discuss the data used in this paper. Estimation results are presented in the central section 4 of the paper; we first estimate and discuss results for the period until 1989, prior to German re-unification, before turning to evidence on the developments since 1989. Section 5 concludes.

[7]Moreover, while human capital mobility might be relevant to some extent, it cannot be the full story, because evidence in Sinn and Sinn (1992) and Ritschl (1996) shows that East Germany was relatively well endowed with skilled labor at the time of German reunification.

[8]At the same time, to conduct this analysis in a formal growth model implies that we will abstract from certain elements in the current East German economic situation. The applicability of this approach in the face of some particular aspects of the East German situation is discussed in section 5 below.

[9]Among the work which mentions this issue are Sinn and Sinn (1992), Boltho et al. (1996), and much of the work cited there. However, much of that work is not based on a structural model of economic growth, which makes it difficult to both isolate the exact mechanisms at work as well as to empirically verify them.

2. The Model

2.1. Developing an Estimation Equation in the Augmented Solow-Swan Model

We employ a standard Solow-Swan model of growth where the exogenous rate of productivity growth is allowed to vary between economies. Let output be produced according to $Q(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha}$, $0 < \alpha < 1$, then it is well-known that, in the neighborhood of the steady-state, output per worker $q(t)$ follows (see the appendix)

$$\ln\left[\frac{q\,(t_2)}{q(t_1)}\right] = (1 - e^{-\lambda\,\Delta})\left\{\frac{\alpha}{1-\alpha}\ln\left[\frac{s}{n+g+\delta}\right] + \ln\,A(0) - \ln q(t_1)\right\} + g(t_2 - t_1\,e^{-\lambda\,\Delta}) \quad (2.1)$$

Here, s is the savings rate, n the growth rate of the labor force; g is the rate of technical change, $A(t)$ is a productivity parameter capturing the level of technology, δ is the rate of depreciation, $\Delta \equiv t_2 - t_1$, and the parameter $\lambda \equiv (1 - \alpha)(n + g + \delta)$ has been termed the speed of convergence. The term $\left\{\frac{\alpha}{1-\alpha}\ln\left[\frac{s}{n+g+\delta}\right]\right\}$ is the log of steady-state output per efficiency unit of labor. Early work based on equation (2.1) regressed per capita income growth of a cross-section of countries on a constant and initial per-capita income. A negative coefficient on $\ln q(t_1)$ was then interpreted as evidence for convergence in the sense that, ceteris paribus, initially poorer economies grow faster. However, not all sets of countries generated a negative coefficient on $\ln q(t_1)$. Barro (1991b) and Mankiw, Romer, Weil (1992) then coined the concept of 'conditional convergence': by controlling for differences in savings and labor force growth rates (s and n), these authors restored the earlier finding that initially poorer countries grow faster than initially richer countries.[10]

[10]Note that allowing for differences in n or s across economies implies that λ, given its definition, is economy-specific as well, and hence, so is β, the regression coefficient on initial income. Nevertheless, the convergence

By construction, these studies can capture only the effect that output per worker goes up as the capital-labor ratio rises; this is called the "capital-deepening effect". It is a maintained assumption in these studies that g, the rate of technical change, is identical across all economies. This is problematic for two reasons: If the rate of technical change is economy-specific and not orthogonal to the other regressors, this will bias the estimated coefficients. The bias is the standard omission-of-variable bias. More importantly, the assumption of identical rates of technical change effectively shuts off the mechanism that differences in the rates of technical change are driving differences in per capita growth rates. Even in and of itself, therefore, it is interesting to see both the capital-deepening as well as the technical change at work in one model, because only that will allow to estimate their relative importance.

In this paper we argue that ignoring differential rates of technical change is the fundamental reason why the East German productivity gap relative to West Germany was underestimated during the socialist era. At the same time this is the reason why the prospects of East Germany after re-unification are underestimated. Therefore, we extend the specification (2.1) so as to allow for regional-specific rates of technical change.

2.2. Identifying Assumptions

In equation (2.1), we specify

$$(1-e^{-\lambda\Delta})\left\{\frac{\alpha}{1-\alpha}\ln(s)+\ln A(0)\right\}=c_1+\varepsilon_{it},\;\;\forall i,t;\;\;i=1,...,I;\;\;t=1,...,T,$$

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literature has usually constrained the coefficient β to be the same for all economies; to ensure comparability with earlier results, we will do the same.

where i indexes a region, and t indexes time. The term c_1 is a constant, and ε_{it} is an i.i.d. disturbance with $E[\varepsilon_{it}] = 0$ and $Var[\varepsilon_{it}] = \sigma_\varepsilon^2$, reflecting random shocks which are uncorrelated across individual regions and across time, like the local weather conditions in a region.

Two assumptions are being made. First, we posit that all German regions shared an identical initial technology level $A(0)$ at the beginning of the period of observation. This is justifiable, see UN (1949), Stolper (1960), and Boltho et al. (1996). Second, we postulate that the savings (and investment)[11] rates of all regions were identical and time-invariant. This assumption is simply necessary to do this analysis; there is no investment data at a regional level for East Germany during the pre-reunification era.[12]

Further, we assume that, in (2.1),

$$g(t_2 - t_1\, e^{-\lambda\,\Delta}) - (1 - e^{-\lambda\,\Delta})\frac{\alpha}{1-\alpha}\ln{(n + g + \delta)} = g_i\, \pi_{i\,t} - \omega_i \ln{(n + g_i + \delta)}, \qquad (2.2)$$

with $\pi_{it} = (t_2 - t_1\, e^{-\lambda\,\Delta})$ and $\omega_i = (1 - e^{-\lambda\,\Delta})\frac{\alpha}{1-\alpha}$.

Although the labor force growth rates n were clearly not time-invariant and identical across individual regions, the assumption appears to be valid if East and West are compared as blocks over the entire period.[13] Allowing the rate of labor-augmenting technical progress to be region-

[11]The German regions were open relative to each other (at least within West and within East), not closed, as the basic Solow-Swan model assumes. It is well-known that, with perfect capital mobility between economies, the Solow-Swan model predicts instantaneous convergence of per capita GDP; but Barro, Mankiw, and Sala-i-Martin (1995) show that the qualitative convergence properties carry over to a world in which capital mobility is only partial.

[12]Keller (1997) presents relevant data on this and other assumptions made below: there was little variation among West German regional investment rates at a given point in time, and that they were in general falling before 1989. The national East German investment rates, as published in the official statistics, were usually as high as, or even higher than, West German investment rates. The efficiency of East German investment was likely to be lower, though, especially for the 1970s and 1980s. Keller (1997) shows that the main estimation results for the pre-reunification era hold even if it were true that the effective East German investment rates were falling behind the West German ones during the the 1970s and 1980s.

[13]On the one hand, labor force growth between 1955-1961–the Berlin Wall was built in 1961–was, due to

specific, g_i, in equation (2.2) is the main emphasis of this paper.[14] The estimation will rely on a linear approximation of (2.2), with

$$g_i\,\pi_{it} - \omega_i \ln(n + g_i + \delta) = c_2 + \upsilon_t + \mu_i \ , \tag{2.3}$$

where c_2 is a constant.[15] The term υ_t captures influences on the development of output per worker which are common to all regions in Germany. The last term, μ_i, is region-specific and time-invariant. It measures the rate of regional technical change above or below the mean in the sample. Therefore, solving the left hand side of (2.1) for $\ln q(t_2)$, the estimating equation is given by

$$\ln q(t_2) = \chi + \mu_i + \upsilon_t + \beta \ln q(t_1) + \varepsilon_{i,t}, \tag{2.4}$$

with $\chi = c_1 + c_2$, $\upsilon_t = h(\pi_{it})$, $\beta = e^{-\lambda\Delta}$, and $\mu_i = f(g_i)$, where $f'(.) > 0$.

Equation (2.4) is a dynamic panel model where the group fixed effects μ_i identify differences in the rate of technical change across economies. Equation (2.4) contains therefore two independent effects of why economies might grow at different rates: first, there is the well-known capital-deepening effect, related to the convergence of the economies to their steady-state. In the estimation, this is captured by the β parameter. For $\beta < 1$, growth of economies with higher values of $q(t)$ will be lower than for those with lower values of $q(t)$, which is the condi-

outmigration, lower in the East. On the other hand, hours worked came down much slower in East Germany. In addition, women's labor force participation rose much faster in the East. In combination, these two effects suggest that there was no big East-West difference of labor force growth rates as a whole; see Keller (1997).

[14]The factors π_{it} and ω_i are indexed by region i because if the rate of technical change g_i is region-specific, then $\lambda = \lambda_i$ from the expression for λ above. The expression holds as long as Δ, the length of a subperiod, is constant. For values of n, δ, π_{it}, Δ, and ω_i in the relevant range, the expression in (2.2) is increasing in g_i.

[15]To obtain this linear approximation, we assume that $g_i = g + o_i$, $\pi_{it} = \pi_i + \rho_t$, and $\mathrm{Corr}(o_i, \rho_t) = 0$. For a time-varying subperiod length Δ, Δ_t as will be the case in the estimation below, we hypothesize in addition that $\omega_{it} = \omega_i + \xi_t$, with $\mathrm{Corr}(o_i, \xi_t) = 0$.

tional convergence prediction emphasized by Barro and Mankiw, Romer, Weil. Figure 1 shows the case where all economies display the same rate of technical change. Under these circumstances, all economies (two are shown) converge to a path which has the same slope (same g_i). Second, in the model of equation (2.4), economies can also exhibit steady-state growth (which is solely technical change) at different rates; this corresponds to the μ_i being different across economies. This is shown in Figure 2, where different slopes in the steady-state growth paths indicate different rates of technical change, related to μ_i. In that case, it is possible that although the economies, call them A and B, converge to their respective growth paths, and therefore undergo capital-deepening in the conditional convergence sense, the two economies can converge to steady-state growth paths which have different slope. Hence, it is possible to have conditional convergence and absolute divergence at the same time.[16]

3. Data

The study is based on German regional data from the post World War II era. Between 1949 and 1989, there existed both the Federal Republic of Germany (West Germany) and the German Democratic Republic (East Germany). With German reunification in 1989, the German Democratic Republic ceased to exist. West Germany consists of eleven states (*Laender*),[17] whereas the latter was arranged into fifteen regions called *Bezirke*.[18] The total area of West Germany

[16]Of course, we could redefine the concept of conditional convergence so that it encompasses differences in the rate of technical change. In this case, however, it would be possible to question the overall significance of the concept of conditional convergence–if what we are primarily interested in is the relative growth performance of econmies.

[17]The Laender are Schleswig-Holstein, Niedersachsen, Nordrhein-Westfalen, Hessen, Rheinland-Pfalz, Saarland, Baden-Wuerttemberg and Bayern. In addition, there are three city states: Hamburg, Bremen, and Berlin-West.

[18]These were Berlin-East, Cottbus, Dresden, Erfurt, Frankfurt (on the river Oder), Gera, Halle, Karl-Marx-Stadt (now renamed Chemnitz), Leipzig, Magdeburg, Neubrandenburg, Potsdam, Rostock, Schwerin, and Suhl.

is ca. 248,000 square kilometers, whereas East Germany had an area of ca. 108,000 square kilometers. See Figures 3 and 4 for the location of the regions in the pre-reunification era. After 1989, the administrative structure of East Germany reverted back to the five states which had existed until 1945.[19] Because the former fifteen Bezirke are, with small exceptions (see the dotted lines in Figure 4), uniquely attributable to one of the five East German states (and East Berlin was merged with West Berlin), the continuity of this analysis of regional productivity dynamics over the point of German reunification is guaranteed.

3.1. Pre-reunification Data

The data sources for West German regions during the pre-reunification period is Statistisches Bundesamt (1990), with the series *Bevoelkerungsstruktur und Wirtschaftskraft der Bundeslaender.* For East German regions, it is less clear which data source to use. This is primarily because the East German statistical office overstated, either directly or indirectly–by direct falsification, or by labeling economic quantities with Western names although Eastern methodology did actually differ from the one applied in the West–the East German economic achievements. Consequently, one might consider relying on Western estimates of the East German economic performance. There are a number of reasons, however, why this is both futile as well as unnecessary.

First of all, Western estimates of East Germany output per capita at any given point during the communist era were varying considerably, even when largely similar methods were applied. A study by Wharton Associates (1986), for instance, estimated for 1980 a GDP per

[19]These states are Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt, and Thueringen.

capita of 45% of the West German level. But for a World Bank publication, Collier (1985) estimated that East German GNP per capita in 1980 was 70% of the West German level; this is no less than 77.7% higher than the Wharton estimate (never mind the GDP-GNP difference). Second, Western estimates, even if they came from the same source, have been revised frequently (usually downwards), showing the degree of uncertainty involved. Consider the estimates by researchers at the DIW in Berlin-West: Wilkens estimated in 1976 (see Wilkens 1981) that in 1970, East Germany's GNP per worker in the industrial sector was ca. 70% of West Germany's. This contrasts with the DIW study for Report (1987), which gives 48% as the relative productivity level for 1970–a downward revision of more than twenty percentage points. From this and other examples which could be cited, it appears that Western estimates of East Germany's economic performance are very uncertain with respect to the time at which the estimates were made. In addition, the raw data for Western estimates of East German economic performance was the official East German statistics: no independent data collection to speak of was permitted.

If East German official data is deemed to be unreliable, however, another possibility would be to wait until recalculated figures of historical East German productivity according to Western methods are becoming available. The German Federal Statistical Office has investigated whether it is possible to revise the results of the GDR statistics according to West German concepts (Statistisches Bundesamt 1991, 1993). According to Statistisches Bundesamt (1991), there is no possibility that East German relevant data were directly falsified by the reporting enterprises, or by the ministries and statistical offices in the process of aggregating the data. Of course, this does not imply that official East German statistics are as such comparable to

West German figures. However, if, as these studies indicate, official East German statistics can be used for a historical recalculation, this would imply that the statistics could not have been forged by very complex or arbitrary techniques. At the same time, given that the recalculation project has not been completed yet (and will not, for the foreseeable future), in the following we will propose independent estimates of East German statistics during its socialist era.

The output data we are using is the gross industrial product per worker (GIPW), taken from Statistisches Amt/DDR (1990). The reason why we compare the dynamics of GIPW, as opposed to GDP per worker, is that services data on a regional level cannot be obtained for East Germany. However, we will be able to incorporate growth through structural shifts in the composition of output by conditioning on the share of employment in the agricultural sector, also from Statistisches Amt/GDR (1990).

For a comparison of industrial product dynamics between East and West German regions, two problems must be addressed: (1) Relative to Western figures, East German GIP figures are inflated through double counting at each intermediate step of production (e.g., Stolper 1960). (2) In East German statistics, the main mechanism of overstating real economic growth was to understate inflation. This was done for ideological reasons–inflation is not supposed to exist in a system where prices are nominally frozen. For several reasons (see the discussion in Budde et al. 1991), however, had inflation been calculated in the East in the same way as this was done in the West, it would have been much higher in East Germany than officially reported.[20]

[20]One mechanism has recently been exemplified by Hoelder, the director of the German Federal Statistical Office: He reports that the index of retail prices rose, according to East German statistics, over the years 1980-89 by only 0.1% annually. While this number is calculated correctly, and consistent with the prices of the products quoted in East German statistics, it encompasses only the change in prices for "comparable goods", but not so-called "new" goods. When the increase in the price index was recalculated according to West German methods–which adjust for changes in the basket of goods over time–annual inflation was on average 12.3%. (Quoted in Budde et al. 1991, pp.91ff.).

Point (1) implies that in Eastern statistics, GIP is not equivalent to value added, but conceptually the same as Western turnover ("Umsatz"). Therefore, we use West German turnover and East German GIP data in this study.[21] Point (2) requires to make an assumption of what the East German real rate of growth was had inflation been computed for 1955-89 as it had for West Germany. Equivalently, we can ask by how much the real rate of growth was overstated in the East.

Because we want to prevent an understatement of the growth achievements in Eastern regions, we adjust the rate of growth of real GIPW in the East downward by 25%, uniformly across all regions and over all years. We consider this as the upper bound of any estimate of East German industrial product growth which is consistent with the post-reunification evidence on the East-West productivity gap in 1989, as discussed above. Depending on whose productivity gap estimates for 1989 one accepts, the adjustment of real growth in East Germany should be even larger than 25%.[22]

Although an across-the-board downward revision of official East German figures is common practice for studies on the East German economy during this era,[23] it is to some degree arbitrary even ex-post, because the 1989 estimates on the productivity gap between East and West varied substantially (see above). The sensitivity analysis in Keller (1997), therefore, allows for alternative adjustments of East German real growth to assess whether the particular adjustment

[21] Thanks are due to T.N. Srinivasan for suggesting this approach.

[22] Winiecki's (1986) pre-reunification analysis, which turned out to be consistent with most estimates of the ex-post productivity gap in 1989, suggests that between 1951-73, the actual growth of the East German net national product was only 55% of the official figures; hence, a 45% downward adjustment, as opposed to the 25% which we propose here. Another way of looking at the proposed adjustment is to compute what the equivalent rate of inflation to a 25% downward adjustment of growth is. Making this calculation, we find that it implies an equivalent rate of inflation of 1.17% per year; with the official rate of inflation equal to zero, the rate of 1.17% is much lower than the average rate of inflation in West German regions over this period, with 2.74%.

[23] Melzer (1980), p.76, e.g., reports that the DIW estimates of the GDR performance in the late 1970s relied on an adjustment of official East German annual growth figures by two percentage points.

used here is driving qualitative results, and finds that this possibility can be excluded. Lastly, because East and West German GIPW levels in 1955 were not comparable–West German levels were higher, but we do not know exactly by how much–there is no loss in placing the average East German region at par with the average West German region. Summary statistics of the data we use are shown in Table 1.

The pre-reunification period is divided into six subperiods with a length of five years each, and the subperiod of 1985-88, with three years.[24] We believe that working with five-year long subperiods of smoothed time series is a compromise between a subperiod long enough so that transitional growth effects can be identified, and at the same time not too short so that cyclical or outlier effects might have no strong impact on the estimation results. In addition to that, we have smoothed the data by employing three-year moving averages in order to reduce the distorting effects of outliers and short-run movements.

The first eleven regions in Table 1 are Western *Laender*, the last fifteen were the Eastern *Bezirke* until German reunification. The first column shows the gross industrial product per worker (GIPW) in 1955. The second column shows the GIPW in 1985, the initial year of the last subperiod. The last column in Table 1 shows the share of the labor force working in the agricultural sector by industry, averaged over the whole pre-reunification period. From that it is clear that, on average, the structural change away from agriculture was faster in the West than in the East.

[24]We exclude data for the year 1989 from the sample because of internal consistency reasons: By 1989, the former East German statistical office was strongly under the influence of West German concepts and politicians, causing a break with the pre-reunification tradition of data collection.

3.2. Post-reunification Data

To preserve the continuity of the analysis, we analyze also after German re-unification gross industrial production (not GDP). We calculate TFP growth series for both Eastern and Western states from data in Statistisches Bundesamt (1996) and Arbeitskreis (1995,1996) for the years 1991-1995; for 1990, the German statistical office did not publish official data for Eastern regions. In Arbeitskreis (1995, 1996), there are figures on the number of manufacturing workers for 1991-95, as well as on current price and constant price manufacturing value added, which we utilize as the output measure. This latter fact allows to compute state-specific deflators for the manufacturing industry. In Statistisches Bundesamt (1996), one finds current price gross investment in manufacturing (and mining) for the years 1991/2-1993/4. After computing constant price investment series using the output deflators, we use the value added and number of workers data to predict constant price gross investment for the year 1994/5.[25] We finally estimate capital stocks for the states between 1991 and 1995 using the perpetual inventory method.[26]

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[25] This is done in separate regressions for East and West German states; the main results of this section do not depend on that.

[26] The benchmark capital stock for 1991, k_{1991} is estimated in a standard way: $k_{1991} = \frac{inv_{1991}}{(g_{9194}+\delta)}$, where inv_{1991} is real gross investment in 1991, g_{9194} is the rate of growth of real investment between 1991 and 1994, and δ, the rate of depreciation, is set at 0.1. For the years $t = 1992 - 1995$, $k_t = (1-\delta)k_{t-1} + inv_t$. The main results do not depend on the particular choice of δ.

4. Estimation Results

4.1. Pre-reunification Period: Dynamic Panel Estimation

We will present estimates based on two different techniques: a linear least-squares dummy variable (LSDV) estimation, and the minimum distance (MD) estimation proposed by Chamberlain (1982). The LSDV procedure amounts to estimating a dummy for each economy and subperiod, as well as the slope coefficient β, by ordinary least squares (OLS). The estimation equation is (2.4) from above

$$\ln q(t_2) = \chi + \mu_i + v_t + \beta \ln q(t_1) + \varepsilon_{i,t},$$

where, for instance, for the 1955-60 subperiod, $q(t_2)$ is equal to the 1960 per worker output, and $q(t_1)$ is equal to the 1955 level. Hence, there is the complication that the right-hand side includes the lagged dependent variable. It is well known that this implies that OLS estimates of β and μ_i are inconsistent for any number of subperiods $T < \infty$ (see, e.g., Amemiya 1985, Hsiao 1986). Because in this study, T is only equal to 7, the OLS estimates of (2.4) are likely to be severely biased. However, Monte-Carlo methods can be used to assess the direction and the size of the bias (as a function of any 'true' β and T). With eleven states in West Germany and fifteen regions in the East, $N = 26$, and the number of subperiods $T = 7$. The results can be seen in Table 2a. Asymptotic standard errors are given in parentheses.

The LSDV estimation gives a coefficient β^b of 0.716, which is significant at a standard 5% level of significance. Because this estimate is biased, we use Monte Carlo experiments and response surface techniques to estimate the direction and extent of the bias.[27] Briefly, a limited number of Monte Carlo experiments for different values of 'true' β's and number of subperiods, T, result in different biases as a function of β and T. The response surface technique then allows the bias of the coefficient β in (2.4) to be estimated for any combination of (β, T). With this bias function, we can infer the unbiased estimate of β in (2.4) from the estimated coefficient 0.716 in Table 2a. We find the unbiased estimate of β to be equal to $\beta^{bc} = 0.973$, given in the last line of Table 2a.

The LSDV estimation together with bias correction might appear as not the preferred estimation technique, as it is indirect. Therefore, we also present an estimate of β from a MD estimation as proposed in Chamberlain (1982). This estimation technique is equivalent to limited information maximum likelihood, hence efficient relative to the class of estimators that do not impose a priori restrictions on the variance-covariance matrix of the errors. Therefore, the MD estimator can accommodate arbitrary patterns of serial correlation and unspecified heteroskedasticity. Its disadvantages are that it is computationally less robust, and it relies on the presence of a strictly exogenous variable.[28] In our context, we employ the share of employment in agriculture in the initial year of the subperiod as this exogenous variable. The results are shown in Table 2b.

As one sees from Table 2b, the β from the MD-estimation is significantly different from zero at any standard level of significance. The point estimate of 0.942 is close to the bias-corrected LSDV estimate of 0.973. The parameter λ–which governs the speed of convergence towards the steady-state growth path–implied by the estimate of 0.942 is equal to 1.27%. This is lower than

[27]These methods are described in detail in the appendix.

[28]The MD estimation procedure is laid out in the appendix.

the estimate by Barro and Sala-i-Martin (1992) of 2%., and, correspondingly, it would lead to an even longer estimated time until East Germany had caught up in the post-reunification era were we to use this estimated value of λ to make this prediction.

However, we have neglected so far the growth effects due to differences in the rate of technical change across regions, as captured by the μ_i's. In Figure 5 the twenty-six regional fixed effects for 1955-88 are shown, based on the bias-corrected LSDV slope estimate of 0.973.[29] By construction, these twenty-six values sum to zero. In the left part of Figure 5, we see the estimated μ_i for the West German regions; in the right part of the figure are the East German fixed effects. Note that only one μ_i is estimated to be negative in the West (or, in 9% of all cases), whereas for East Germany, we find nine out of fifteen (60%) to be negative. On average, a West German region has a μ_i of 0.02, whereas for the East, the average is equal to -0.015. This means for the specific case of East and West Berlin, for instance, that if East and West Berlin would start out at the same GIPW level, after five years the GIPW level in West Berlin would be about 4.5% higher than in East Berlin due to differences in the rate of technical change alone.

From these results, we reject the model given in Figure 1 where all economies converge to the same steady-state growth path, corresponding to the same rate of technical change across these economies. Instead, our estimation provides evidence in favor of the augmented Solow-Swan model of Figure 2. Suppose we abstract from differences in the rates of technical change *within* the East and the West of Germany during the period of 1955-88. Then the economy converging to the steeper steady-state growth path captures West Germany during the period

[29]The fixed effects calculated from the MD slope estimate of 0.942 are very similar to what is shown in Figure 5.

of 1955-88, whereas the East German economy has been converging to the steady-state growth path with the lower slope. It is clear from the figure that conditional convergence in the sense of capital-deepening was present in Germany between 1955-88 at the same time where the output per worker difference between East and West region was increasing.

Moreover, the finding of different rates of technical change in East and West Germany between 1955 and 1988 suggests that perhaps also in the post-reunification era, this effect is important in determining the dynamics of relative (East-West) output per worker. Specifically, we conjecture that technical change could well be faster in the East than in the West for a while, due to the adoption of new management techniques, a change in incentive structures, and disembodied technological change in general. This would lead to faster catch-up of the East as would be implied by the capital-deepening model with identical rates of technical change. To investigate this possibility, we estimate TFP growth in East and West German regions for the years 1991-95.

4.2. Post-Reunification Period: Growth Accounting Analysis

As before, our focus is on differences of the rates of technical change across economies. However, we cannot estimate these effects in the same way as for the pre-reunification era, because the identifying assumptions we have employed above no longer hold.[30] But because we have comparable data on capital and labor inputs in the production of all regions, we can estimate whether there have been differences in the rate of technical change across East and West German

[30]Both the initial level of technology $A(0)$, for time $0 = 1989$ (the year of re-unification) in Eastern regions was lower than in Western regions (see again Figure 4), and the rates of physical capital investments have been considerably higher in the East than in the West.

regions directly, following Solow's (1957) growth accounting method.[31]

Consider a constant returns to scale Cobb-Douglas production function for gross industrial product with exogenous technical change,

$$Q'(t) = A(t)K(t)^{\alpha}L(t)^{1-\alpha},\ 0 < \alpha < 1. \tag{4.1}$$

From equation (4.1), the standard growth accounting formula can be derived through taking log-differences; we define $\Delta x(t) = \ln X(t) - \ln X(t-1)$, then

$$\Delta a(t) = \Delta q'(t) - \alpha \Delta k(t) - (1-\alpha)\,\Delta l(t), \tag{4.2}$$

and $\Delta a(t)$ is the rate of TFP growth between period t and $t-1$, which captures in this context the rate of technical change. Assuming a value for $\alpha = 2/3$,[32] we have computed the rate of TFP growth for the eleven states which constituted West Germany before reunification in 1989, and for five states which were formerly East Germany, plus East Berlin. The results of this for the years 1991-1995 can be seen in Figure 6.

The five East German states, plus East Berlin, are on the right in Figure 6. It is clear from the graph that the TFP growth rates of these regions have been considerably faster than in the West, in particular during the early years after reunification. Table 3 gives average rates of TFP growth over 1991-95. As the last column in Table 3 indicates, the estimated rate of

[31]Our framework is still the Solow-Swan model with exogenous differences in the rates of technical change (with the minor caveat that above, technical change was assumed to be Harrod-neutral, whereas now, we assume it to be Hicks-neutral). What is different is the method we use to estimate differences in the rate of technical change.

[32]The qualitative results are identical if other plausible values for α, such as 0.6 or 0.7, are chosen.

TFP growth of the average East German region was 10.3 percentage points higher than for the average West German region. This clearly supports our conjecture that the rate of technical change in East Germany has been considerably above that of West Germany after 1989. It is also consistent with the model we estimated for the pre-reunification period above. Further, the development of TFP growth rates between 1991 and 95 also suggests that the difference in the rates of technical change between East and West German regions was highest in the year of 1990, when the Federal Statistical Office did not publish data for Eastern regions. Moreover, we can show that the rate of technical change in the East was not just higher because investment rates in physical capital were higher, which rejects the notion of technical change embodied in capital goods at least in its extreme form.[33]

5. Conclusions

In this paper, we have shown that the contribution of technical change in the overall growth performance of East Germany since World War II has been underemphasized by previous research, and argue that this has important implications for assessing East Germany's growth prospects today. Using estimation techniques and assumptions which build on the particular, laboratory-type nature of the East and West German economic development after 1945, we show that the rate of technical change has on average been faster in West, relative to East German regions, in Germany's the pre-reunification period. We claim that this is the reason why analyses which solely relied on the effects of physical capital accumulation have generally

[33]Consider a linear regression of TFP growth on capital stock growth and a constant, with annual data for the six East German states for 1991-95 (24 observations). We find a slope coefficient of -0.48 with a standard error of 0.319, and, hence, no statistically significant correlation.

failed to account for the extent to which East Germany had fallen behind West Germany's productivity level by 1989.

At the same time, employing growth accounting techniques, we demonstrate that the rates of technical change in the post-reunification period have been considerably higher in East than in the West between 1991 and 1995. We therefore argue that any analysis which does not allow for the possibility of technical change at differential speeds in East and West Germany will be mistaken in assessing future economic growth in East Germany, in the same way as the earlier estimates for the pre-unification era were wrong. According to our estimates, East Germany will not remain the German Mezzogiorno for 70 or 100 years (or forever). Instead, the performance of the East German economy suggests a period of 20 years or less until seventy-five percent of the West German output per capita level will be reached.

It is important to note that this analysis has its own limitations. After all, it is cast in a growth model which does not account for wage setting above labor's marginal productivity in East Germany. Neither does it capture the significant West German transfer payments and, in general, an activist government policy influencing economic outcomes. We agree with those who believe that this means that our time to catch-up forecast is associated with a high degree of uncertainty. However, we do not believe that it invalidate our central point that the dynamics of technical change will have to be analyzed independently from capital investment rates in order to make accurate predictions on East Germany's growth prospects.

In fact, taking into account the West German transfers to East Germany into account suggests further research should focus even more, not less, on technical change as opposed to physical capital investment, for the following reasons. Figure 7 shows the growth rates of capital stock and TFP for East and West German states between 1991-95. On the one hand, from the capital stock growth rates, it appears that the high annual transfers from West to East were at least in part coming at the expense of physical investment in West German regions. On the other hand, turning to the TFP growth rates, although these are much lower in the West than in the East, they are positive in all West German states. In addition, they are not far from the average TFP growth rates in West Germany in the decade before reunification. The difference between these two developments is at least in part due to the fact that physical capital investments are rival, whereas disembodied technical change is, to some degree, non-rival.

Lastly, although this paper focuses only on East and West German regions, differences in the rates of technical change are likely to be important in determining overall performance in other economies as well. Future research need answer the question of how to identify, measure, and estimate the contribution of technical change as an independent source of economic growth in a more general context.

A. Derivation of the empirical implications of the Solow-Swan model

We start out with

$$Q\,(t) = K\,(t)^{\alpha}\,(A(t)\,L(t))^{1-\alpha} \quad , 0 < \alpha < 1, \tag{A.1}$$

where Q is output, K physical capital, L labor, and A the level of technology, all functions of time, t. L and A are growing at the exogenously given rates n and g: $L(t) = L(0)e^{nt}$ and $A(t) = A(0)e^{gt}$. The model assumes that the savings rate s is constant. Defining $k_e \equiv K/(AL)$ and $q_e \equiv Q/(AL)$ as capital and output, respectively, per efficiency unit of labor, then k_e changes over time as

$$\dot{k}_e = s\,k_e^{\alpha} - (n + g + \delta)\,k_e. \tag{A.2}$$

Here, δ is the rate of depreciation. This has the solution $[k_e\,(t)]^{1-\alpha} = (1 - e^{-\lambda t})[k_e^*]^{1-\alpha} + e^{-\lambda t}[k_e(0)]^{1-\alpha}$, with the definitions of $k_e^* = [s/(n+g+\delta)]^{(1-\alpha)^{-1}}$ and $\lambda = (n+g+\delta)(1-\alpha)$, where k_e^* denotes the steady-state value of k_e. The steady-state value of q_e, denoted by q_e^*, is given by $q_e^* = [s/(n+g+\delta)]^{\alpha/(1-\alpha)}$. To obtain an expression which is linear in k_e (resp. q_e), perform a Taylor expansion of equation (A.2) which results in

$$\frac{d\,\ln q_e(t)}{d\,t} = \lambda\,[\ln q_e^* - \ln q_e(t)]\ . \tag{A.3}$$

The solution of equation (A.3) implies, after rearranging, that for some $\Delta = t_2 - t_1$,

$$\ln q_e(t_2) - \ln q_e(t_1) = (1 - e^{-\lambda\Delta})\,\ln q_e^* - (1 - e^{-\lambda\Delta})\ln q_e(t_1) \tag{A.4}$$

Substituting in for q_e^* and rewriting the equation in terms of output per capita $q \equiv Q/L$ gives equation (2.1) in the text.

B. Bias-Correction for the LSDV Model

B.1. The Monte Carlo Experiments

For a given region i,[34]

$$y_t = \beta_j \, y_{t-1} + u_t.$$

Here, $u_t \sim N(0, \sigma^2)$, β_j = 0.5, 0.6, 0.7, 0.8, 0.9, and we consider four different numbers of subperiods T_k, namely T_k = 6, 20, 50, and 150. We conduct 1000 experiments for each combination (β_j, T_k). The results are given in Table A, where the $\hat{\beta}_j$ column gives the average estimates from applying equation (2.4) above for a combination of 'true' parameter and number of subperiods (β_j, T_k). Control variates, denoted τ, are used to improve the accuracy of the simulations

$$\tau = T^{-\frac{1}{2}} \sum_{t=1}^{T} u_t \, y_{t-1}$$

Intuitively, the "naive" simulated LSDV estimator uses only the information that $E[u_t] = 0$, for all t, whereas the control variate-simulated LSDV estimator uses the specific value of u_t. This reduces the standard error of the point estimate, which can be thought of as increasing the number of simulations (to more than 12-fold, see the last column in Table A).

[34] See Davidson and McKinnon (1993).

B.2. The Bias Function (Response Surface)

The Monte-Carlo results show that the bias of the LSDV estimator is a function Ψ which depends on β_j, and T_k. The specific form of is unknown; we model $\Psi(\beta_j, T_k)$ as a function of a parameter vector $\boldsymbol{\eta}$ which will be estimated. The ith experiment generates an estimated bias ψ_i^e, $i = 1,..., 20$. A good approximation for $\Psi(.)$, with all variables standardized by the standard error of experiment (j,k), is (see Davidson and McKinnon 1993):

$$\psi_i^e = \eta_1 \left(\frac{\beta_j^0}{T_k}\right) + \eta_2 \left[\left(\frac{\beta_j^0}{T_k}\right)\left(1 - (\beta_j^0)^2\right)^{-\frac{1}{2}}\right] + \varsigma_i \tag{B.1}$$

where ς_i is an error term. This regression produces the following results: $\eta_1(s.e.) : -3.51$ (0.1), $\eta_2(s.e.) = 0.383$ (0.059), a F-statistic of 3388, and an adjusted R^2 of 0.997. From this, and the estimates of η_1 and η_2, we can solve for the "true" β^0.

C. The Minimum Distance Estimator

Chamberlain's (1982) MD estimator has, in the present context, the following form:

$$y_{i,t} = \beta\, y_{i,t-1} + \gamma\, x_{i,t} + \mu_i + \varepsilon_{i,t} \quad ,$$

where $x_{i,t}$ is an exogenous variable. The data has been transformed through the inclusion of time-fixed effects. In addition, it is assumed that

$$\begin{aligned} \mu_i &= \kappa_1 x_{i1} + \kappa_2 x_{i2} + \ldots + \kappa_T x_{iT} + \zeta_i \\ y_{i0} &= \theta_1 x_{i1} + \theta_2 x_{i2} + \ldots + \theta_T x_{iT} + \tau_i \end{aligned} \tag{C.1}$$

where $E[\zeta_i \mid x_{i1}, .., x_{iT}] = 0$, $E[\tau_i \mid x_{i1}, .., x_{iT}] = 0$. The first step is to express $y_{i,t}$, $t = 1, .., 7$, only in terms of y_{i0} and μ_i. Then y_{i0} and μ_i are also substituted for by the exogenous variables. This results in

$$\mathbf{Y} = \mathbf{\Pi}\,\mathbf{X} + \mathbf{u} \tag{C.2}$$

where $\mathbf{u}$ is the composite error term consisting of $\varepsilon_{i,t}$ only if we substitute from (C.1) the conditional expectations of y_{i0} and μ_i. Here, $\mathbf{Y} = (y_{i1}, y_{i2}, .., y_{i7})'$, $\mathbf{X} = (x_{i1}, x_{i2}, ..x_{i7})'$, and $\mathbf{\Pi}$ equals $\Pi_1 + \Pi_2 + \Pi_3$, with

$$\Pi_1 = \begin{bmatrix} \gamma & 0 & 0 & 0 & 0 & 0 & 0 \\ \beta\gamma & \gamma & 0 & 0 & 0 & 0 & 0 \\ \beta^2\gamma & \beta\gamma & \gamma & 0 & 0 & 0 & 0 \\ \beta^3\gamma & \beta^2\gamma & \beta\gamma & \gamma & 0 & 0 & 0 \\ \beta^4\gamma & \beta^3\gamma & \beta^2\gamma & \beta\gamma & \gamma & 0 & 0 \\ \beta^5\gamma & \beta^4\gamma & \beta^3\gamma & \beta^2\gamma & \beta\gamma & \gamma & 0 \\ \beta^6\gamma & \beta^5\gamma & \beta^4\gamma & \beta^3\gamma & \beta^2\gamma & \beta\gamma & \gamma \end{bmatrix}$$

and Π_2 and Π_3 given by

$$\Pi_2 = \begin{bmatrix} \beta \\ \beta^2 \\ \beta^3 \\ \beta^4 \\ \beta^5 \\ \beta^6 \\ \beta^7 \end{bmatrix} \theta' \qquad \Pi_3 = \begin{bmatrix} 1 \\ 1+\beta \\ 1+\beta+\beta^2 \\ 1+\beta+\beta^2+\beta^3 \\ 1+\beta+\beta^2+\beta^3+\beta^4 \\ 1+\beta+\beta^2+\beta^3+\beta^4+\beta^5 \\ 1+\beta+\beta^2+\beta^3+\beta^4+\beta^5+\beta^6 \end{bmatrix} \kappa' \ ,$$

where $\theta' = (\theta_1, .., \theta_7)$, and $\kappa' = (\kappa_1, .., \kappa_7)$. If the $x_{i,t}$ are strictly exogenous, one can estimate (C.2) by OLS. The matrix $\mathbf{\Pi}$ has 49 elements which are nonlinear functions of the underlying 16 coefficients β, γ, θ', and κ'. We denote these by ϕ. MD estimation then amounts to finding the optimal ϕ by imposing the restrictions in $\mathbf{\Pi}$ and minimizing

$$\hat{\phi} = \arg\min(vec\,\Pi - g(\phi))' A_N^{-1} (vec\,\Pi - g(\phi)) \quad ,$$

where $g(\phi)$ is the vector valued function mapping the elements of ϕ into vec Π, and A_N^{-1} is the optimal weighing matrix as proposed by Chamberlain. The estimation relies on its consistent sample analog, which is the inverse of

$$\hat{\Omega} = \tfrac{1}{N} \textstyle\sum_i^N \left[(y_i - \hat{\Pi}\, x_i)\ (y_i - \hat{\Pi}\ x_i)' \otimes S_x^{-1} (\, x_i\, x_i'\,)\, S_x^{-1} \right] \ ,$$

$$\text{where } S_x = \tfrac{1}{N} \textstyle\sum_{i=1}^N x_i\, x_i' \ .$$

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TABLE 1: Summary Statistics by Region

Region	GIPW in 1955 in 1000 DM (1980 West)	GIPW in 1985 in 1000 DM (1980 West)	∅ Share of Agriculture in the Labor Force (per cent)
Schleswig-Holstein	60.92	187.66	10.25
Niedersachsen	59.36	202.53	12.9
Nordrhein-Westf.	53.79	181.06	4.34
Hessen	48.22	151.95	7.25
Rheinland-Pfalz	51.34	190.63	12.71
Baden-Wuerttbg.	46.61	156.04	9.3
Bayern	45.07	153.35	15.08
Saarland	33.29	157.35	3.39
Hamburg	87.7	496.29	1.3
Bremen	73.28	243.97	1.21
Berlin-West	44.48	239.15	0.35
Berlin-East	55.97	189.28	1.25
Cottbus	43.57	119.63	15.98
Dresden	48.82	158.29	10.03
Erfurt	44.36	152.71	16.03
Frankfurt/Oder	72.11	253.9	21.9
Gera	48.29	191.97	12.63
Halle	63.38	174.5	12.59
Karl-Marx Stadt	41.7	148.69	7.22
Leipzig	51.27	147.61	10.28
Magdeburg	59.73	173.11	20.15
Neubrandenburg	60.18	119.45	35.62
Potsdam	63.87	180.71	20.86
Rostock	59.34	154.51	19.68
Schwerin	71.09	141.15	28.91
Suhl	40.08	127.25	11.64

Table 2a: Results for Transitional Growth Effects with LSDV Estimation

$\beta^b : \ln q(t_1)$	biased	0.716
$(s.e.)$	estimate	(0.061)
R^2		0.961
No. of observations		182
$\beta^{bc} : \ln q(t_1)$	estimate after	0.973
$(s.e.)$	bias correction	

TABLE 2b: Results for Transitional Growth Effects with MD Estimation	
$\beta : \ln q(t_1)$	0.942
(*s.e.*)	(0.26)
γ : coefficient on exog. variable	−0.834
(*s.e.*)	(0.04)
No. of observations	182

TABLE 3: Post-Reunification TFP Growth Rates

	1991/2	1992/3	1993/4	1994/5	∅ 1991-95
Eastern Regions	0.254	0.077	0.104	0.052	0.122
Western Regions	-0.005	-0.021	0.07	0.032	0.019
Difference (East-West)	0.259	0.098	0.034	0.02	0.103

TABLE A

β_j	T_k	$\hat{\beta}_j$ / (s.e.)	Equivalent No. of Simulations using control variates
0.5	6	0.225 / (0.0026)	1382
0.5	20	0.422 / (0.0013)	3151
0.5	50	0.467 / (0.8×10^{-3})	6766
0.5	150	0.49 / (0.5×10^{-3})	12685
0.6	6	0.293 / (0.0027)	1208
0.6	20	0.511 / (0.0013)	2762
0.6	50	0.567 / (0.8×10^{-3})	5353
0.6	150	0.59 / (0.4×10^{-3})	10140
0.7	6	0.363 / (0.0027)	1082
0.7	20	0.604/ (0.001)	2095
0.7	50	0.663 / (0.7×10^{-3})	4347
0.7	150	0.688 / (0.4×10^{-3})	9578
0.8	6	0.428 / (0.0029)	1066
0.8	20	0.694 / (0.0011)	1642
0.8	50	0.76 / (0.6×10^{-3})	2783
0.8	150	0.787 / (0.3×10^{-3})	6175
0.9	6	0.5 / (0.0027)	1009
0.9	20	0.776 / (0.001)	1177
0.9	50	0.855 / (0.5×10^{-3})	1752
0.9	150	0.886 / (0.3×10^{-3})	3889

Figure 1
Convergence to the Same Steady-State Growth Path

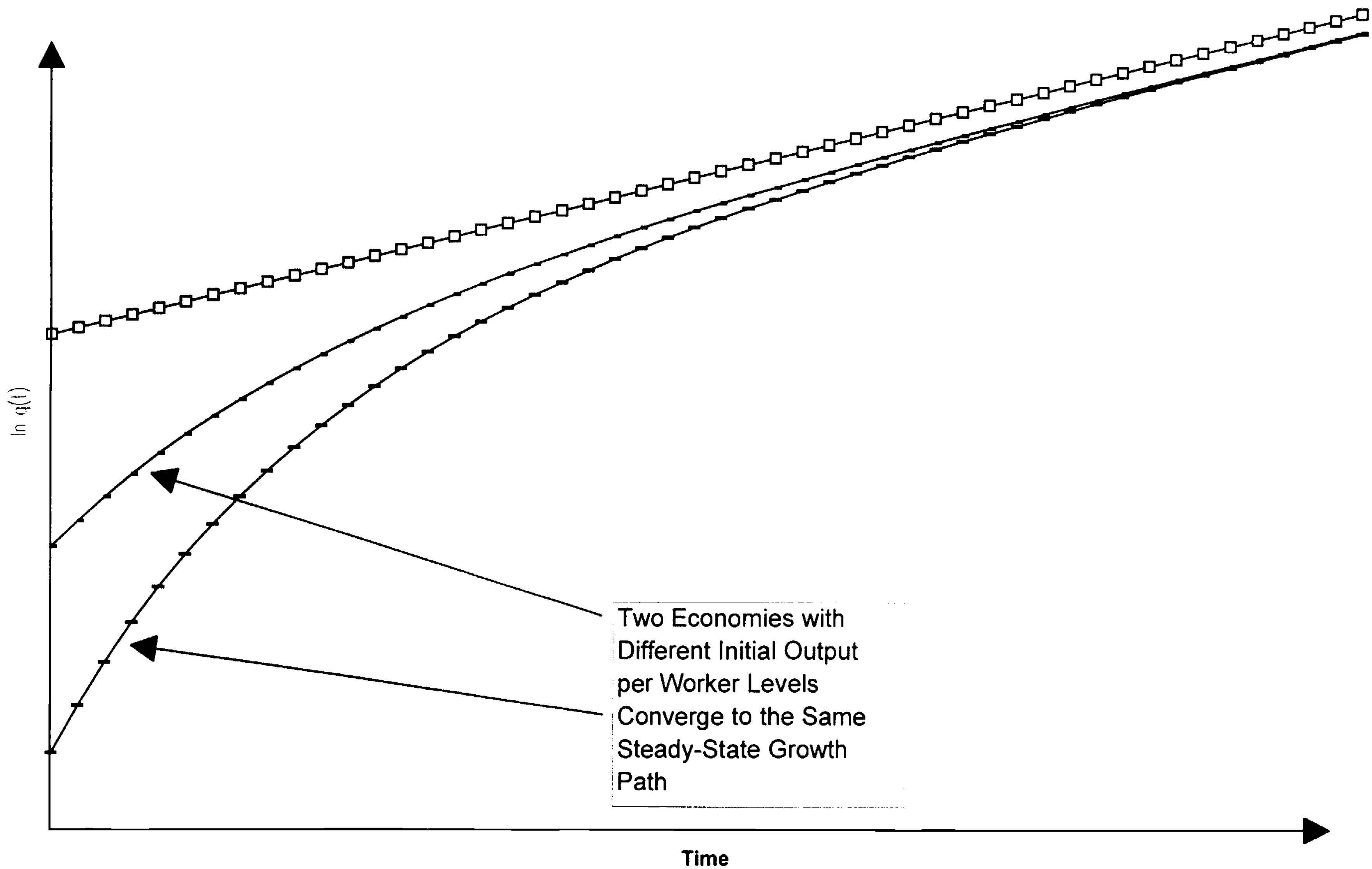


Figure 2

Convergence to Growth Paths with Different Rates of Technical Change

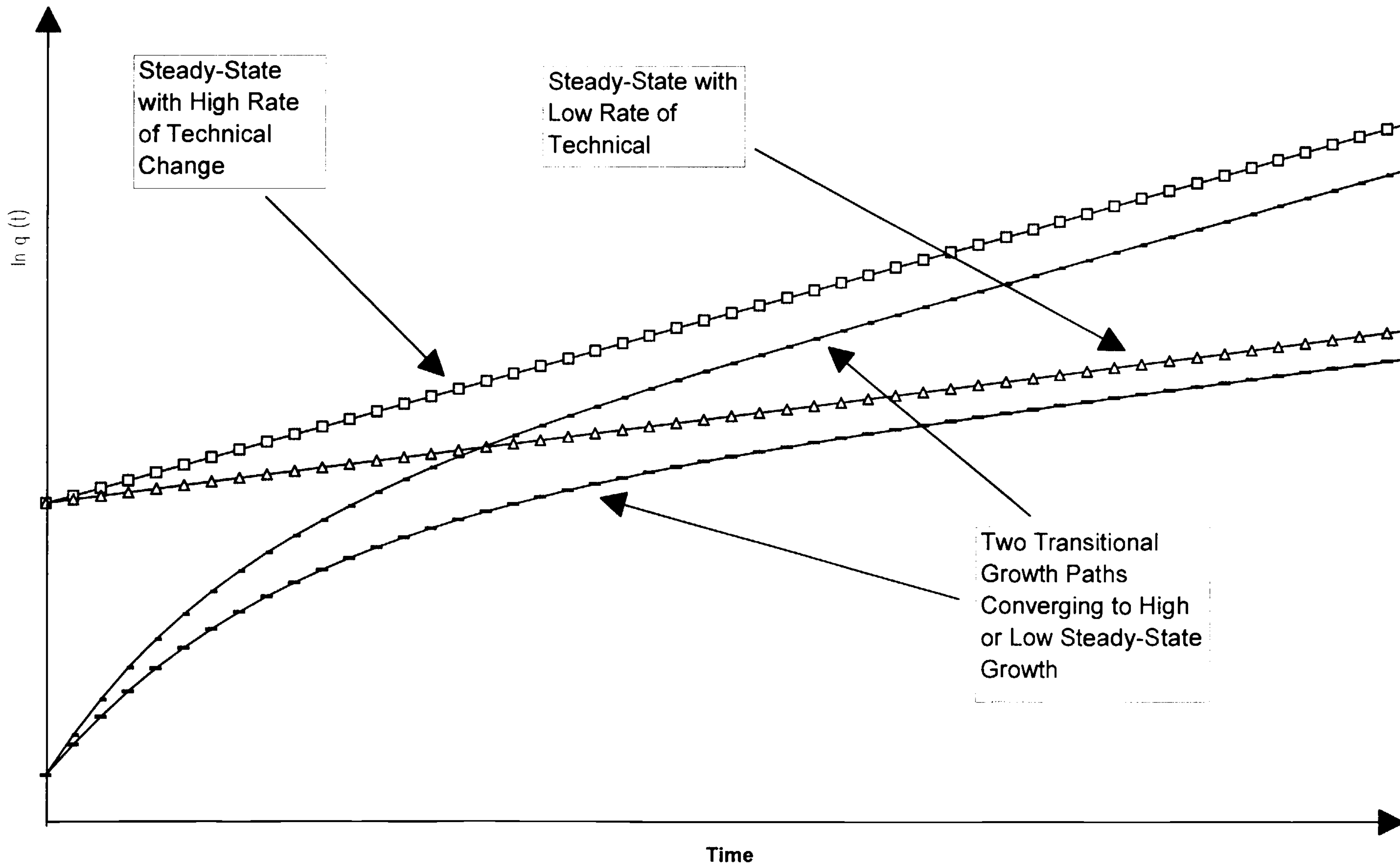
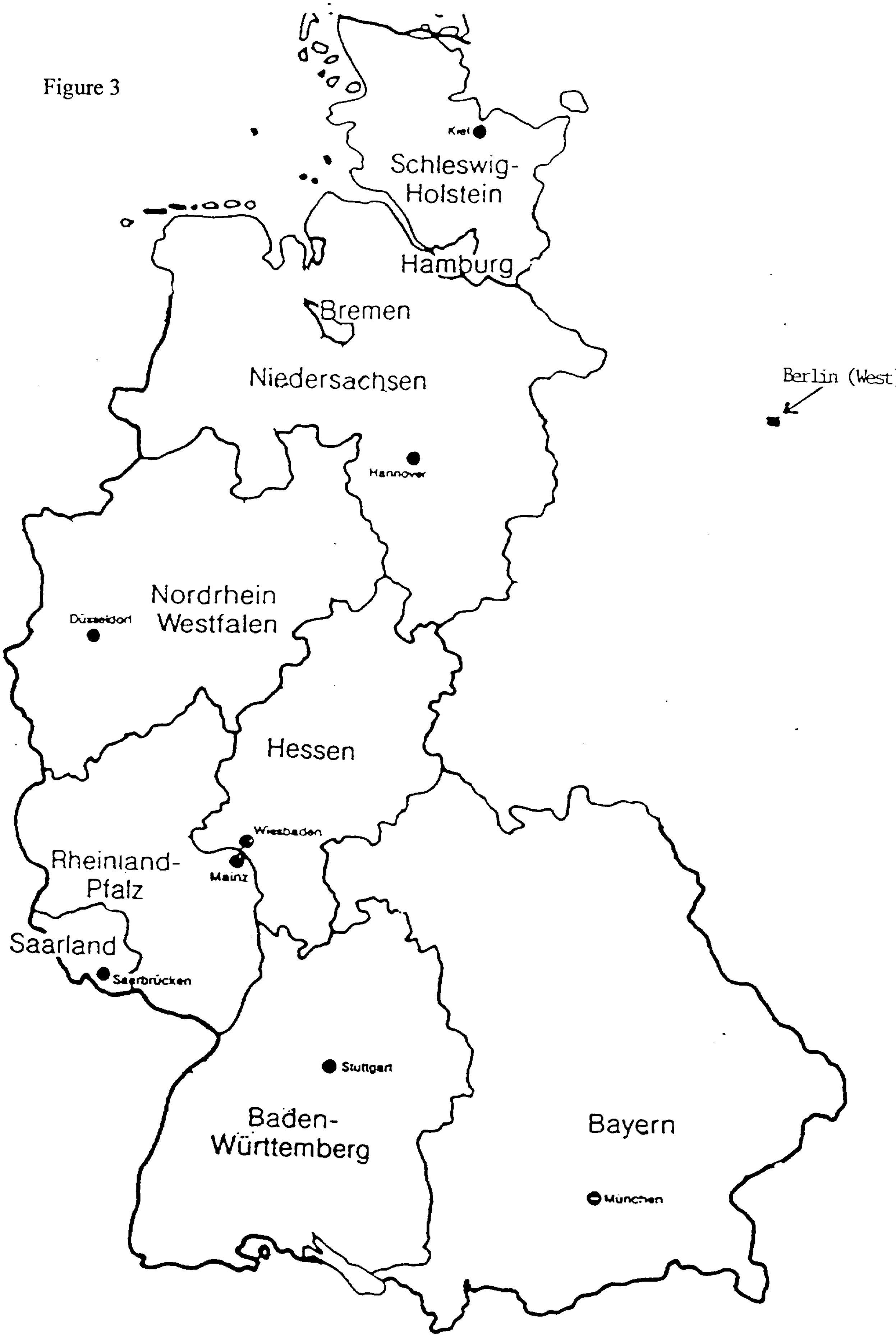


Figure 3



Schleswig-
Holstein
Hamburg
Bremen
Niedersachsen
Hannover
Nordrhein
Westfalen
Hessen
Wiesbaden
Mainz
Rheinland-
Pfalz
Saarland
Stuttgart
Baden-
Württemberg
Bayern
Munchen
Berlin (West)

1 :	Rostock	Mecklenburg-Vorpommern
2 :	Schwerin	
3 :	Neubrandenburg	
4 :	Potsdam	Brandenburg (BR)
5 :	Frankfurt/Oder	
6 :	Cottbus	
7 :	Magdeburg	**Sachsen-Anhalt (S-A)**
8 :	**Halle**	
9 :	**Erfurt**	Thueringen (TU)
10 :	Gera	
11 :	Suhl	
12 :	Dresden	Sachsen (S)
13 :	Leipzig	
14 :	Karl-Marx-Stadt (Chemnitz)	
15 :	Berlin-East}	(One state with Berlin-West)

Figure 4

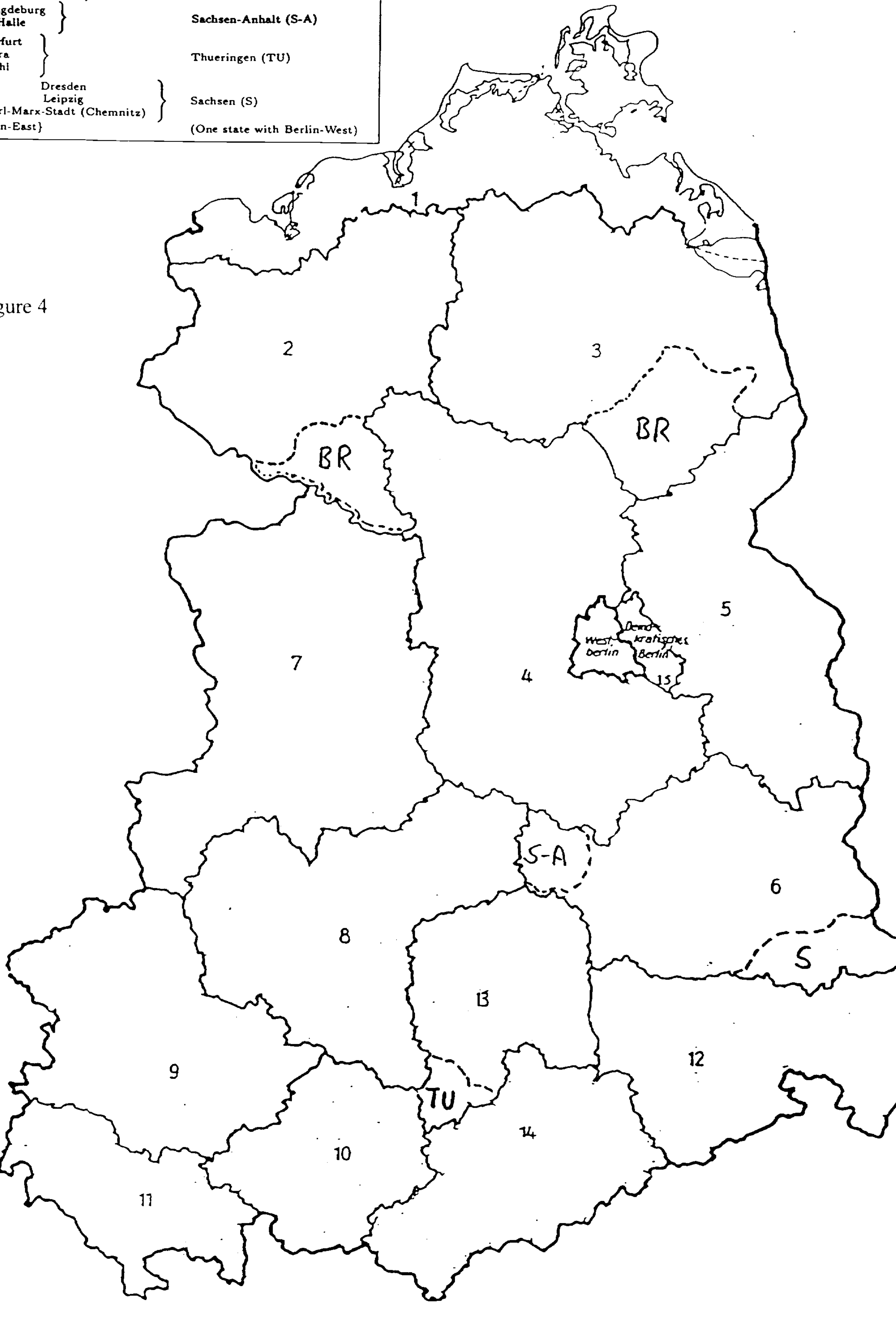


Figure 5
Rates of Technical Change in German Regions, 1955-88

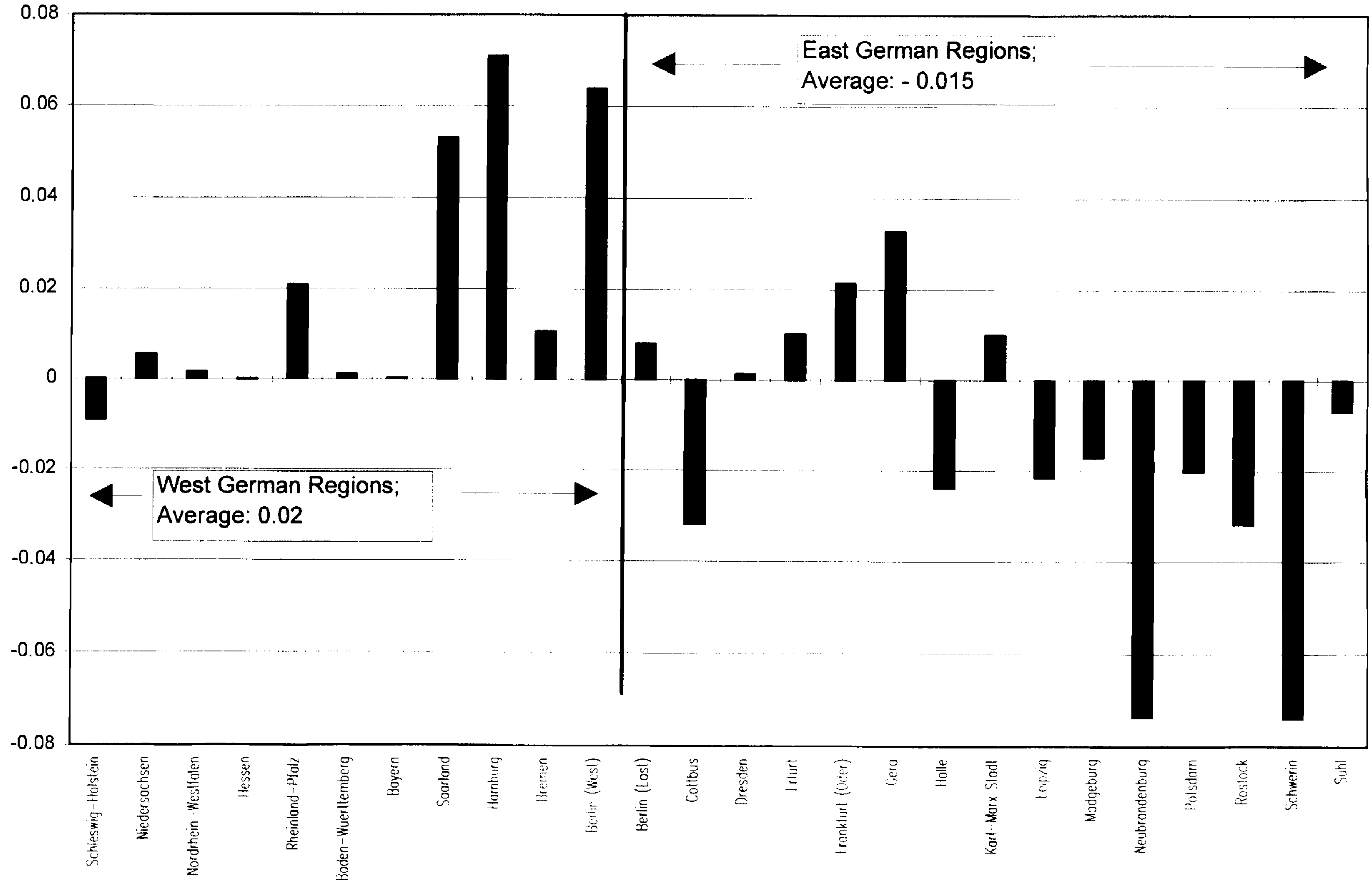


Figure 6
Total Factor Productivity Growth in German States, 1991-1995

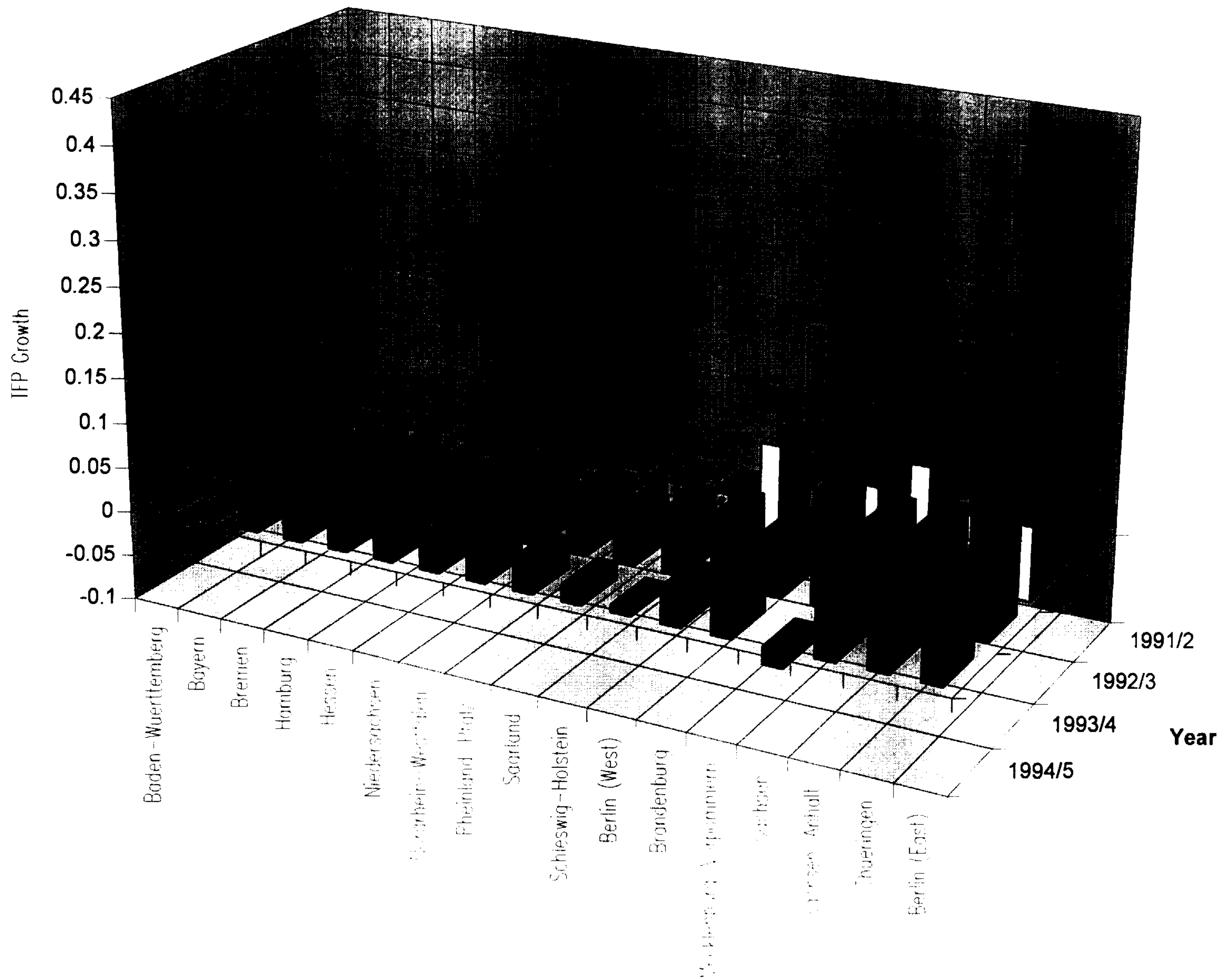


Figure 7
Comparison of TFP and Capital Stock Growth Rates by Region, Averages 1991-95