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Is East Germany Catching Up? A Time Series Perspective

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Is East Germany Catching Up?

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Abstract

This paper assesses whether the economy of East Germany is catching up with the West German region in terms of welfare. While the primary measure for convergence and catching up is per capita output, we also look at other macroeconomic indicators such as unemployment rates, wage rates, and production levels in the manufacturing sector. In contrast to existing studies of convergence between regions of reunified Germany, our approach is purely based upon the time series dimension and is thus directly focused on the catching up process in East Germany as a region. Our testing setup includes standard ADF unit root tests as well as unit root tests that endogenously allow for a break in the deterministic component of the process. In our analysis, we find evidence of catching up for East Germany for most of the indicators. However, convergence speed is slow, and thus it can be expected that the catching up process will take further decades until the regional gap is closed.

Keywords: East Germany, Catching up, Convergence, Unit root tests
JEL classification: C12; C32; O11; O47

Zusammenfassung

Dieser Beitrag untersucht den Aufholprozess Ostdeutschlands gegenüber Westdeutschland bezüglich des Wohlstandsniveaus. Betrachtet wird dabei das Produktionsniveau pro Kopf sowie andere makroökonomische Indikatoren wie Arbeitslosenquoten, Löhne und Produktionsniveaus des Verarbeitenden Gewerbes. Im Gegensatz zu anderen Konvergenzstudien, die Regionen des vereinigten Deutschlands analysieren, verwendet der hier herangezogene Ansatz ausschließlich die Zeitreihendimension und konzentriert sich damit direkt auf den Aufholprozess Ostdeutschlands als eine Region. Die hier angewendeten empirischen Ansätze sind zum einen standardmäßige Einheitswurzeltests nach Dickey-Fuller und zum anderen Einheitswurzeltests, die einen Strukturbruch in den deterministischen Komponenten des Prozesses zulassen. In dieser Studie finden sich Anhaltspunkte eines ostdeutschen Aufholprozesses für einen Großteil der betrachteten Indikatoren. Allerdings ist die Konvergenzgeschwindigkeit langsam; dies lässt erwarten, dass der Aufholprozess weitere Jahrzehnte andauern wird, bis sich die Lücke schließt.

Schlüsselworte: Ostdeutschland, Aufholprozess, Konvergenz, Einheitswurzeltests
JEL-Klassifikation: C12; C32; O11; O47

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1 Introduction

Nineteen years after German reunification, the eastern region and former communist part still lags behind the German western region in terms of economic performance. Lower per capita income and product as well as considerably higher unemployment still characterizes the situation of the geographic area of the former German Democratic Republic.

In this paper we study the process of convergence and catching up of East Germany (former GDR) compared with West Germany (former GER). The main focus lies on the different patterns of growth between the two German regions. We investigate whether disparities in welfare tend to diminish over time or whether they persist. Different indicators are analyzed: differences in per capita output, unemployment rates, nominal wages and manufacturing production. Our approach is empirical and relies on standard reduced form equations of the underlying processes. So we do not develop a theoretic model explicitly. However, the underlying structural model is a neoclassical growth model.[1]

We employ time series tests of convergence and catching up to investigate the impact of shocks to relative differences in the regional indicators. Moreover we ask whether regional differences tend to diminish over time along a well defined catching up process. Basically, the catching up hypothesis states that the lagging region (East Germany), with relative low initial income and productivity levels, will tend to grow more rapidly than the region with relative high income and productivity. Throughout, this analysis takes a pure time series perspective where data at a quarterly and monthly frequency are used for convergence tests. Standard unit root tests as well as tests that allow for an endogenous structural break are used in this analysis.

Other studies that investigate the catching up process for East Germany or test for convergence in reunified Germany include Barrell and te Velde (2000), Funke and Strulik (2000), Kosfeld and Lauridsen (2004), Juessen (2009), Hall and Ludwig (2006), Kosfeld, Eckey and Dreger (2006). Most of them rely on disaggregate approaches that employ cross-section data. Examples are Kosfeld and Lauridsen (2004) and Kosfeld et al. (2006) who both test for convergence of labour productivity and

[1] See Barro and Sala-i-Martin (1992) and Mankiw, Romer and Weil (1992) for a formal derivation of an empirical neoclassical growth-convergence equation from theoretical models.

of per capita income across regional labour markets with spatial econometric techniques. Juessen (2009) uses nonparametric methods to test for convergence of GDP per worker and per capita. A potential shortcoming of disaggregate approaches to convergence is that one normally estimates an average speed of convergence between all regions. This is generally not the convergence speed between East Germany and West Germany, only under rather unrealistic assumptions.

The overall evidence of convergence within Germany is quite heterogeneous. While Barrell and te Velde (2000) as well as Kosfeld et al. (2006) find evidence of convergence – at least during the nineties - Kosfeld and Lauridsen (2004) and Juessen (2009) support the idea of persistent inequality among German regions.

Our approach is different from those above since we use the time series dimension to test for convergence and catching up. If there is evidence of catching up we are also able to estimate the convergence speed of East Germany toward West Germany. The empirical tests employed here are similar to Bayer and Juessen (2007) who conduct a time series approach to regional unemployment rates of the German Laender, however, their analysis is restricted to West German regions only.

In this analysis we do not only investigate convergence of per capita output as it is mostly done in this line of research. We seek to get a broader picture by investigating the convergence properties of additional macroeconomic indicators. Besides regional disparities in per capita income also regional differences in regional unemployment rates receive much attention in the political debate. The problem of persistent unemployment disparities have been analyzed by Blanchard and Katz (1992) for the US. But there is some evidence that regional differences in employment patterns are a more persistent phenomenon in Europe than in the US. So it is interesting to see how unemployment disparities between East and West Germany evolve over time and whether there is some evidence that local discrepancies decline. Normally, one would expect that large local labor market disparities cannot persist within one relative homogeneous country due to regional mobility. However, at first sight the German experience seems to contradict this view. We also look at regional differences in manufacturing production. This indicator has the advantage that it is minor affected by interventions of the public sector. Furthermore, we look at nominal wage rates. Since when the general economic performance, i.e. labor productivity, displays the tendency of catching up, one also suppose that wages do.

Our results can be summarized as follows. For per capita output differences we find some evidence of a catching up process. So East German per capita output displays a gradual catching up to the West German during 1995-2008. For relative unemployment rates our test procedure identifies a structural break of relative unemployment rates in the year 2002. Since then the difference in unemployment rates have declined. For wages in the manufacturing industry we find that catching up

has come to a halt in 1995 and the relative difference in wage rates have persisted until today. Per capita manufacturing production displays a catching up process, but manufacturing output in East Germany is still at a very low level compared to the western region.

The rest of the paper is organized as follows. Section 2 introduces the basic convergence framework. Section 3 describes the different approaches to test for convergence. Section 4 gives an overview of the data set. Section 5 presents the results for different indicators and tests. Section 6 concludes.

2 Methodology

Convergence is one of the essential predictions of Solow's (1956) neoclassical growth model. Regardless of initial endowments; once country- or regional specific determinants are controlled for, economies are heading for their steady state. This theory predicts that lower income countries grow faster than higher income countries and vice versa. For this reason convergence should inevitably occur.

An extensive literature has investigated whether economies or regions converge as predicted by neoclassical models. Those early contributions such as Baumol (1986), Barro (1991), Barro and Sala-i-Martin (1991; 1992) rely on cross section tests of convergence. The cross-sectional relationship between the growth rates of output per capita is examined over some period of time and the initial level of per capita output. However, the cross-section approach may be faced with two potential drawbacks. Firstly, it may neglect important heterogeneities among different countries and regions, particularly regarding the speed of convergence. Secondly, it works with the null hypothesis that no countries are converging and the alternative that all countries do. Thus a grouping of some economies and a sophisticated comparison is not possible.[2] Obviously, in our situation where we investigate convergence between two regions a cross-section approach is not feasible.

We follow the time-series notion of economic convergence as outlined by Bernard and Durlauf (1996) and further specified by Maeso-Fernandez (2003). The time series approach of convergence of per capita output has become increasingly popular; see Carlino and Mills (1993), Bernard and Durlauf (1995), Evans and Karras (1996), Loewy and Papell (1996) and Li and Papell (1999) for interesting contributions.

[2] For further objection see Evans and Karras (1996). Bernard and Durlauf (1996) show that cross-sectional tests tend to spuriously reject the null of no convergence when economies have different long run steady states.

In line with Bernard and Durlauf (1996) we differentiate between two basic concepts of convergence: 1. Convergence as catching up and 2. Convergence as equality of long-term forecasts at a fixed time. Basically, we can deal with both concepts in a time series context. The first definition is particularly useful when looking at countries or regions that are expected to be far away from their steady state value. This holds true for East Germany, that can be viewed as a transition economy after unification. This implies that we expect East Germany to be well described by a catching up process. Formally this can be expressed as

$$E\left(y_{i,t+T} - y_{j,t+T} \middle| I_t\right) < y_{i,t} - y_{j,t}, \tag{1}$$

where y_i is real log output of country i and y_j is log real output of country j. I_t denotes the information set available at t. In this specification country j is supposed to catching up with country i. This implies that the initial endowments in country i (e.g. in terms of per capita output) are strictly higher than in country j.

The second definition of convergence means that the long-run forecast of output differences (or any other measure) tend to zero whenever the forecasting horizon tends to infinity. More formally, this definition implies

$$\lim_{s\to\infty} E\left(y_{i,t+s} - y_{j,t+s} \middle| I_t\right) = 0. \tag{2}$$

However, this statement can be further relaxed by allowing that long-run forecasts of the expected difference tend to a constant that is different from zero. This is often referred to as conditional convergence (see Evans and Karras, 1996).[3] Whereas the stronger statement of equation (2) is denoted as absolute convergence. Generally, the second definition of convergence implies that differences in the variables under consideration have to be stationary.

Although the catching up concept of convergence is less stringent because it does not involve a long-run equilibrium, it is more closely related to the concept of β-convergence (that is often tested by cross sectional regressions). A further assumption of convergence definition 1 involves the catching up process to be deterministic. This is not necessarily the case for long run convergence. The deterministic nature of catching up implies that the gap between two economies shrinks at a constant rate (see Maeso-Fernandez, 2003; Brueggemann and Trenkler, 2007).[4] Empirically,

[3] This allows for different steady state level defined by a fixed constant. This may be due to differences in regional characteristics such as demographics, regional policy and agglomeration effects.

[4] This means that the existence of a time trend alone does not necessarily imply convergence. Additionally, the time trend must lead to a reduction in the differences of the observed variables. Otherwise, when differences tend to increase over time there is evidence of divergence.

we can test whether differences of macroeconomic indicators between two countries can be well described by a linear trend. Furthermore, we also allow for structural breaks. This can lead to different episodes in the form of convergence process when breaks in the constant or in both the constant and the time trend are allowed for. Whenever a break in the time series has occurred, the actual convergence concept is defined after the last break has been observed.

The test of convergence implies the observed gap to be (trend) stationary. The rejection of a unit root is therefore a necessary, but not sufficient condition for convergence. Further it is also required, when a time trend is present, that the gap shrinks as time goes by (which then implies catching up). In the absence of a unit root, the deterministic term indicates what form of convergence is present. Without a constant and a linear time trend we talk of absolute convergence, whereas a constant implies conditional convergence. A linear time trend indicates catching up, whenever this implies that differences tend to diminish.

3 Unit Root Tests of Convergence

The concept of time series convergence allows us to formulate testable hypotheses about the stochastic behavior of the data series under consideration. Given this methodology we can ask whether the (log-) difference of an indicator between the two German regions contains a unit root or whether it can be described as a stationary (or trend stationary) process. This can be tested by standard unit root tests.

3.1 Standard Unit Root Tests

The most frequently applied formal unit root test is still the one of Dickey and Fuller (1979) - the augmented Dickey-Fuller (ADF) test.[5] This methodology consists of the statistical model

$$\Delta\left(y_{w,t}-y_{e,t}\right)=d_t+\left(\rho-1\right)\left(y_{w,t-1}-y_{e,t-1}\right)+\sum_{k=1}^{K}\phi_k\Delta\left(y_{w,t-k}-y_{e,t-k}\right)+u_t, \quad (3)$$

[5] As a robustness check we also consider additional unit root tests. These are the Phillips-Perron (PP) test, the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS) and the Elliot-Rothenberg-Stock (ERS) test. While the PP test is similar to the ADF except for the way autocorrelation is taken into account, the KPSS reverse the null hypothesis. The ERS test is considered because its power properties are preferable under certain conditions compared to the ADF test when deterministic components are present.

where $y_{w,t}$ and $y_{e,t}$ denote the macroeconomic variable for West and East Germany, respectively. d_t contains all deterministic components and u_t is an *i.i.d.* error term. The optimal lag length K is based upon a general-to-specific approach with a maximal lag length K_{max} where lags are then reduced until a prespecified significance level.[6] The null hypothesis of a unit root rests on $\rho = 1$, with $\rho < 1$ the alternative hypothesis of no unit root. The parameters of equation (3) can be simply estimated by OLS. But, standard critical values from a t-distribution are inappropriate and are therefore adjusted according to MacKinnon (1996) and depending on the specification for d_t.

As stated above, convergence requires the absence of a unit root. The deterministic term d_t determines the exact convergence definition. The term deterministic part can be decomposed as $d_t = \mu + \beta t$. Without a constant and a linear time trend ($\mu = 0, \beta = 0$) we talk of absolute convergence. A constant ($\mu \neq 0, \beta = 0$) implies conditional convergence. A linear time trend $\beta \neq 0$ indicates a catching up process, whenever this implies that the gap shrinks as time goes by.

3.2 Unit Root Tests with Structural Breaks

The ignorance of possible structural breaks in the deterministic components of the unit root tests can lead towards false non-rejection of the unit root hypothesis. So Perron (1989; 1990) strongly recommends to correct for changes of the deterministic components. As choosing an arbitrary exogenous break date due to visual inspection of the data has been strongly criticized (Christiano, 1992; Banerjee, Lumsdaine and Stock, 1992), we employ a data-dependent method as proposed by Zivot and Andrews (1992). Instead of taking the structural break as given, it takes into account the uncertainty of estimating the break date.[7] We stick to different versions of this test. First, only a break in the constant is considered. Second, we also allow for a break in both the constant and the slope of the linear trend.

In its most generalized form (which implies a break both in the intercept and trend) we can formulate the deterministic part of the test as

$$d_t = \mu + \beta t + \theta DU_t(\lambda) + \gamma DT_t(\lambda), \tag{4}$$

[6] According to Perron and Ng (1996) this strategy may be superior compared to information criteria in finite samples to determine the optimal lag length K. For quarterly data we choose $K_{max} = 5$, for monthly data $K_{max} = 13$. We assume a significance level of 5%.

[7] There are also tests available that test for two or more break points. But since our time span is generally rather short (around 15 years) we do only allow for one potential break point. Considering more than one break also increases potential problems of overfitting.

where

$\lambda = T_B/T$ represents the break fraction (or breakpoint);

$DU_t(\lambda) = 1$ if $t > T\lambda$, 0 otherwise;

$DT_t(\lambda) = t - T\lambda$ if $t > T\lambda$, 0 otherwise.

Besides the deterministic part, the structure equals the standard ADF test as in equation (3). Now the parameters μ, β, θ, γ, λ, ρ and ϕ_j's have to be estimated. This is done in two steps. First, the model is estimated sequentially for every potential break date T_B. Second, the breakpoint λ is chosen in order to minimize the t-statistic for the estimate of ρ and therefore the break takes place when it is most likely. Similar to the ADF test all remaining parameters are estimated and the unit root hypothesis is rejected if the absolute t-statistic for ρ is larger than the adjusted critical values provided by Zivot and Andrews (1992).

From the significance tests of the estimated parameters θ and γ we can directly infer whether a structural break is present. As with the ADF test, the deterministic components also determine which concept of convergence is actually present. For deciding about the notion of convergence what matters is the deterministic component after the estimated trend point.

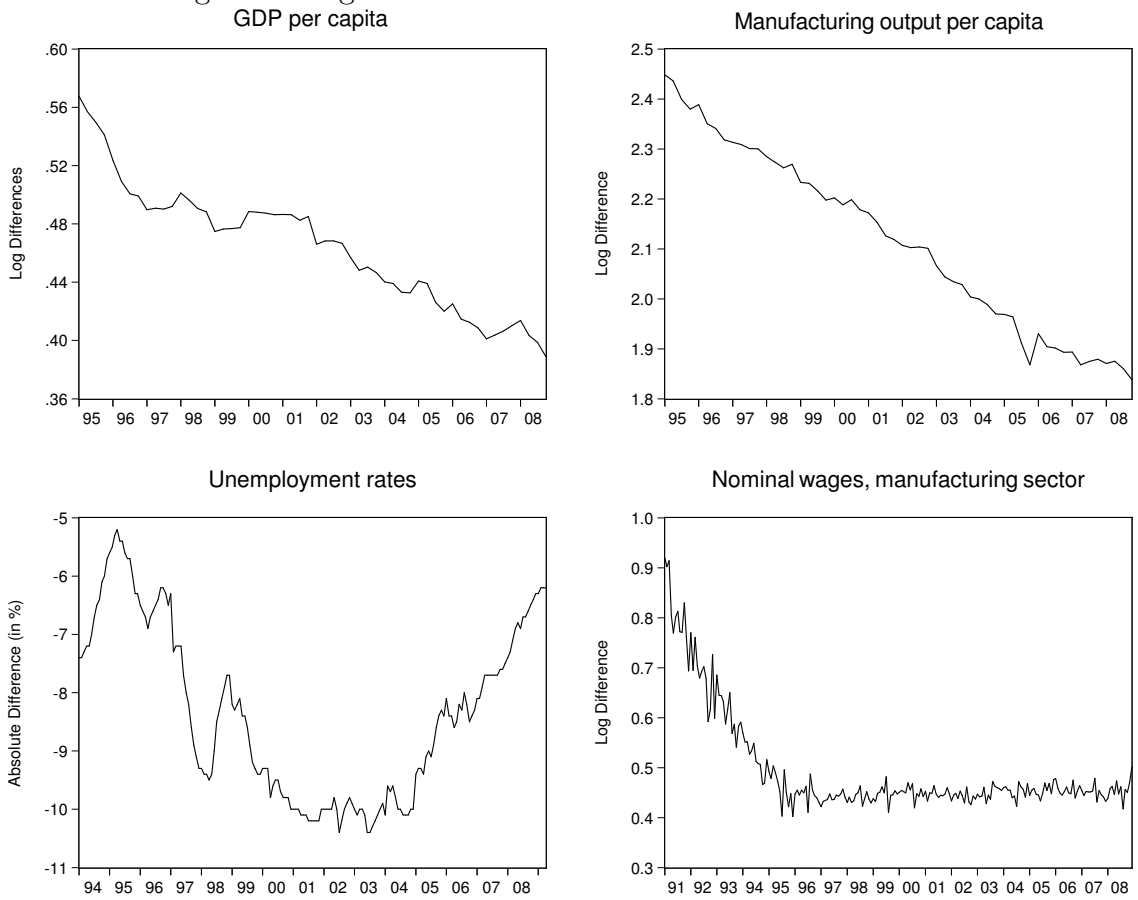
4 Data

Our main indicator to measure convergence and catching up between West and East Germany is real Gross Domestic Product (GDP) per capita, which is one of the standard measures of prosperity in a particular region. To construct quarterly data of GDP per capita we use a data base provided by the Halle Institute for Economic Research (IWH) which publishes quarterly seasonally unadjusted GDP for East Germany (excluding Berlin).[8] Data from this source are available since 1995:1. GDP for West Germany is computed by subtracting East German GDP from the aggregate country GDP as published by the Federal Statistical Office (Statistisches

[8] See Brautzsch and Ludwig (2002) for a methodological background. The data set is regularly updated and available under `http://iwhd:3129/c/start/prognose/prognose.asp?lang=e`.

Bundesamt). To work out the GDP per capita series, we divide each indicator by the population of the respective region.[9]

Figure 1: Regional differences of macroeconomic indicators



Source: Deutsche Bundesbank, Federal Statistical Office, IWH

For investigating convergence we look at the difference of the indicator in its natural logarithm. Since we use seasonally unadjusted data we also observe seasonality in the difference. But neglecting seasonal components in unit root tests may result in

[9] Data of the population of East and West Germany is obtained from the national accounts data base from the German Laender. We have converted population data from yearly to quarterly frequency by linear interpolation.

low power and bad size properties of the test (see Hassler and Demetrescu, 2005). For these reasons we remove the seasonality by seasonal adjustment.[10]

To get a broader picture of the catching up process of East Germany we also have a look at other macroeconomic indicators. Since most indicators are only available at a yearly frequency (with approximately 15 observations, which is obviously too short for this test methodology), we only have the choice along a very reduced variable set. Three series are investigated: unemployment rates, nominal wages in the manufacturing industry sector (defined as per man-hour worked) both observed at monthly frequency and per capita manufacturing production as a quarterly series.[11]

Figure 1 displays all four time series which show quite different characteristics. The differences in GDP per capita can be characterized by a falling trend although with different speeds of adjustment. After a slowdown in the adjustment speed at the end of the nineties, it accelerate again at the beginning of the century. In 2008, East Germany's GDP per capita still amounts to only 69% compared to that in the Western part.

The differences in unemployment rates between West and East Germany can be characterized by a rise from 1995 to 2001. At the beginning of the century the average unemployment rate in East Germany was more than ten percentage points higher in comparison with West Germany. Until 2005 the gap in unemployment rates has narrowed. For manufacturing industry wages we observe a falling trend until 1995/1996. Afterwards the differences have been approximately stable. In 2007 the average hourly wage rate in East Germany production sector accounts for only 62% of those of West Germany. Manufacturing production displays a relatively stable trend since 1995. But the level of gross value added is still relatively small compared to the West. In 2007 it accounts for just 15% (in terms per capita real terms) of those in West Germany.

[10] We use ARIMA-X12 as provided by EViews 6.0. Alternatively, we also augmented the unit root tests by seasonal dummy variables which leads to qualitatively the same results as the seasonal adjustment procedure. The sample period is 1995q1-2008q4.

[11] Monthly seasonally adjusted unemployment rates as well as the index of nominal wage rates (defined as per man-hour worked) are taken from the data base of the Deutsche Bundesbank (keys: US02CC, US0CC2, US08RB, US0RB8). The information about wage levels are taken from the Federal statistical office (Fachserie 16 Reihe 2.3). Manufacturing production is seasonally unadjusted data that was adjusted using ARIMA-X12. One break due to methodological changes has been removed form this data series. The index series has been obtained from German regional statistical offices. The reference level of the production values are obtained form an input-output table for Germany. As with per capita output, we divided this series by a quarterly interpolated population measure. All data series are available on request.

5 Results

In this Section we present the results of formal tests of convergence as discussed in Section 3. We apply a standard ADF test as well as the Zivot and Andrews' unit root test which allows for one potential structural break. These procedures are used to investigate four macroeconomic time series and their specific characteristics.

5.1 GDP per Capita

First we apply a standard ADF-type unit root test for relative per capita output. We restrict ourselves to report the test that includes both a constant and a time trend, since the visual inspection implies a falling trend in this time series. So under the alternative hypothesis of the test the time series is trend stationary (and thus includes a deterministic time trend).

Table 1: Augment Dickey-Fuller-test for GDP per capita

Indicator	K	μ	β	$\rho - 1$	p-value
Relative GDP per Capita	0	0.1094^{***}	-0.0005^{***}	-0.2131	0.0934
		(0.0356)	(0.0002)	(0.0664)	

Notes: Standard errors in parentheses. ***: 1%, **: 5% and *: 10% significance level. K denotes the optimal lag length chosen with a sequencial procedure. p-values are computed as one-sided values which are provided by MacKinnon (1996)

The ADF test as displayed in Table 1 does reject the unit root hypothesis for relative per capita output, but only at a significance level of 10%. So there is evidence in favor of a deterministic trend in this time series which indicates catching up.[12]

Next we additionally allow for a potential break in the time series and apply Zivot and Andrews' unit root test as outlined in Section 3.2. Table 2 reports the results of this test methodology. Two kinds of breaks are inspected: a break in the intercept and a break both in the intercept and the time trend. For both specifications, the unit root is not rejected. Although there is some evidence of a structural break in the level (but not in the time trend) the null hypothesis (unit root) is not rejected. Thus allowing for an endogenous break does not support the view of catching up. Once we accept the view of catching up in per capita output of East Germany, the evidence for a break in the deterministic components is weak.

[12] We also applied other unit root tests. The PP test confirms the results based on the ADF test and rejects the unit root hypothesis at a 10% significance level. The KPSS test does not reject for any standard significane level which suggests that the series is stationary. Also the EPS test reports evidence in favor of stationarity. This test rejects the hypothsis of a unit root even at the 1% level.

Table 2: Zivot-Andrews test for relative per capita output

Indicator	Break type	K	Break date	μ	β	θ	γ	$\rho - 1$	Test–statistic
Relativ GDP per Capita	Intercept	0	1999q4	0.1705***	−0.0010***	0.0097***	–	−0.3246	-4.5303
				(0.0387)	(0.0002)	(0.0032)	–	(0.0717)	
	Intercept + Trend	0	2002q4	0.1186***	−0.0003	−0.0056*	−0.0003	−0.2367	-3.7028
				(0.0343)	(0.0002)	(0.0031)	(0.0002)	(0.0639)	

Critical values (Intercept only): 0.01 = −5.34, 0.05 = −4.8 and 0.1 = −4.58
Critical values (Intercept and Trend): 0.01 = −5.57, 0.05 = −5.08 and 0.1 = −4.82

Notes: Standard errors in parentheses. ***: 1%, **: 5% and *: 10% significance level. K denotes the optimal lag length chosen with a sequencial procedure.

5.2 Other Macroeconomic Indicators

We turn now to other welfare indicators which are available at a monthly or quarterly frequency in order to investigate whether these variables indicate convergence or catching up between the two German regions. Again we apply an ADF-type unit root test as well as the Zivot-Andrews tests which allow for one potential break point.

Table 3: Augmented Dickey-Fuller tests for remaining indicators

	Intercept only				with intercept and time trend				
Indicator	K	μ	$\rho - 1$	p-value	K	μ	β	$\rho - 1$	p-value
Unemployment rates	4	−0.1150	−0.0140	0.5629	2	−0.0889***	0.00036**	−0.0055	0.9807
		(0.0830)	(0.0098)			(0.0102)	(0.0003)	(0.0102)	
Manufacturing wages	11	0.0754***	−0.1708	0.0000	11	0.0588***	0.00008**	−0.1582	0.0000
		(0.0135)	(0.0297)			(0.0148)	(0.0000)	(0.0298)	
Manufacturing output	1	0.0237	−0.0179	0.5932	0	0.9613***	−0.00433***	−0.4015	0.0339
		(0.0278)	(0.0131)			(0.2667)	(0.0012)	(0.1097)	

Notes: Standard errors in parentheses. ***: 1%, **: 5% and *: 10% significance level. K denotes the optimal lag length chosen with a sequencial procedure. p-values are computed as one-sided values which are provided by MacKinnon (1996)

Table 3 displays the results of ADF tests for relative unemployment rates, nominal wages in the manufacturing industry and manufacturing production. For relative unemployment rates ADF tests indicate no evidence of convergence or catching up irrespective of whether we allow for a linear trend or not . But for nominal wages we can reject the unit root hypothesis, so there is evidence of conditional convergence. However, when the time trend is included (which is only marginally significant) there is some evidence of conditional divergence since the time trend has a positive sign. For manufacturing production we can reject the unit root at a 5% significance level when allowing for a deterministic time trend. This indicator displays catching up along a linear trend. So manufacturing production has steadily grown faster in the East German region.

When we allow for a break in the deterministic components the results change slightly (see Table 4). The differences are most pronounced for relative unemployment rates, where we can reject the unit root – at least at the 5% level – by allowing

for a change both in the intercept and the time trend. The break can be identified to emerge in May 2002. Thus, relative unemployment rates can be characterized by two episodes: a period of deterministic divergence until 2002M5 followed by a period of catching up. With our testing methodology we cannot identify the reasons of this dramatic change. Nevertheless, we suspect that this is not primary result of a relative higher labor demand in Eastern Germany, but it may be a consequence of demographic characteristics of the population as well as of migration from the eastern part to the west.

The evaluation of relative wages in the manufacturing sector can be also described by two different episodes: a period of catching up of relative wages, where the East German wages increased relatively faster compared to the west. This catching up process suddenly stops in the middle of the nineties. The Zivot-Andrews test identifies the break point in June 1994. After this date both East and West German wages have increased together in percentage terms. Thus, no further catching up process can be observed until more recently.

For the remaining indicator, manufacturing production, the ADF test indicates a trend stationary behavior of relative production. Nevertheless, for this series the Zivot-Andrews test also identifies a break point in 2005. This indicates a change of the slope of the deterministic trend during the last two years. In this case it seems that the catching up process has slowed down somewhat. However, this break happens at nearly the end of the sample, so these findings should be carefully interpreted. Since actual data are still subject to revisions, this result may vanish after further corrections. For the basic assessment (unit root or trend stationary behavior) it is not so relevant as to whether we allow for a break or not. However, for policy purposes it may be of great interest as to whether and why the catching up speed of the eastern manufacturing sector has lowered in recent time.

5.3 Convergence Speed

Our test results indicate that there is an ongoing catching up process of East Germany toward West Germany. For three of four indicators, namely per capita output, unemployment rates and manufacturing production we find a closing gap of regional differences. However, as shown in the previous subsections the convergence speed may be different through time and for unemployment rates we observed a period where the regional indicators diverge. When we concentrate on those variables where a catching up process is found, we can also study the speed of convergence. These are given by the parameters associated with the deterministic trend (see also Figure 2). If we further assume that the convergence speed stays constant throughout the future, which implies no further breaks in the deterministic terms, we can compute

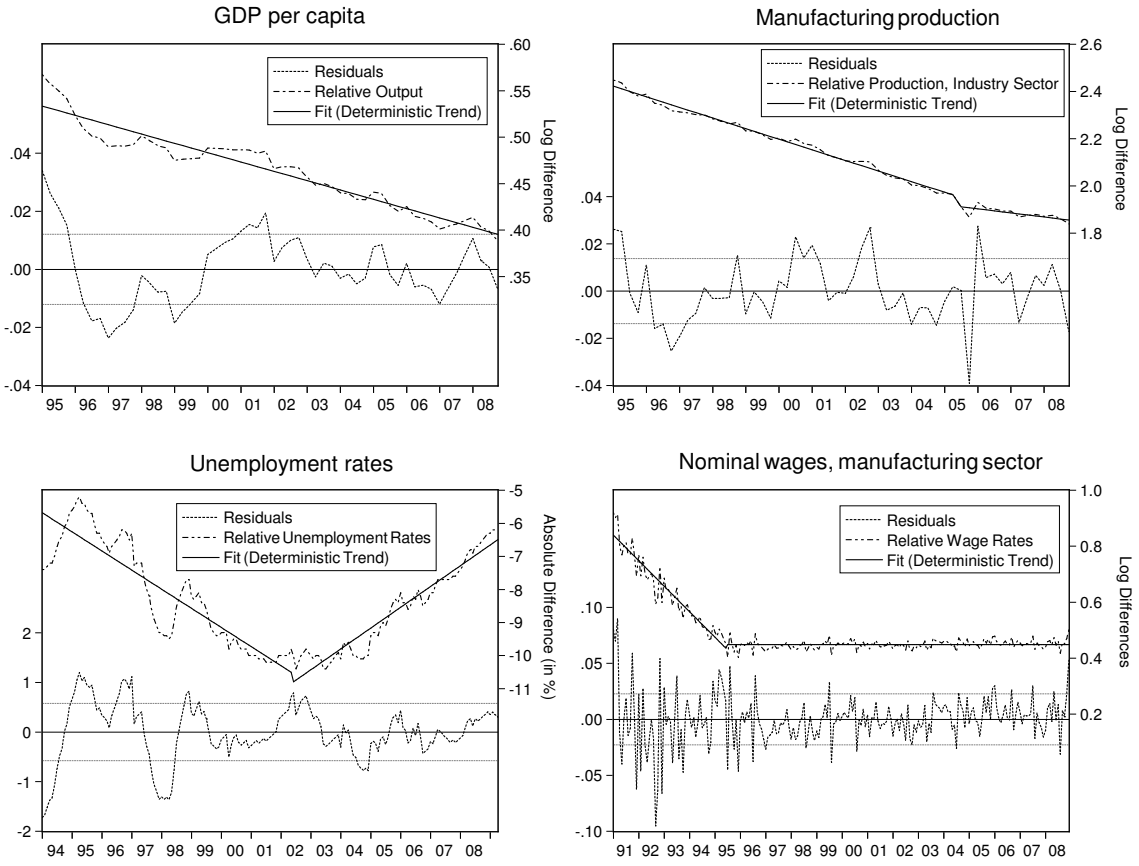
Table 4: Zivot-Andrews tests for remaining indicators

Indicator	Break type	K	Break date	μ	β	θ	γ	$\rho - 1$	Teststatistic
Unemployment rates	Intercept	11	1997M1	-0.2458^{***}	0.0017^{***}	-0.2126^{**}	–	-0.0299	-2.0633
				(0.0985)	(0.0004)	(0.0709)	–	(0.0145)	
	Intercept and trend	4	2002M5	-0.7340^{***}	-0.0073^{***}	-0.0226	0.0148^{***}	-0.1374	-5.1479
				(0.1467)	(0.0015)	(0.0543)	(0.0029)	(0.0267)	
Manufacturing wages	Intercept	11	1993M7	0.1631^{***}	0.0001^{**}	-0.0038	–	-0.3034	-6.5743
				(0.0297)	(0.0000)	(0.0095)	–	(0.0461)	
	Intercept and trend	11	1994M6	0.4238^{***}	-0.0032^{***}	-0.0354^{***}	0.0033^{***}	-0.5820	-6.9548
				(0.0694)	(0.0007)	(0.0097)	(0.0007)	(0.0837)	
Manufacturing output	Intercept	0	2007q2	1.3953^{***}	-0.0065^{***}	0.0255^{***}	–	-0.5755	-4.9178
				(0.2864)	(0.0013)	(0.0084)	–	(0.1170)	
	Intercept and trend	0	2005q2	1.8788^{***}	-0.0086^{***}	-0.0378^{***}	0.0054^{***}		-6.3325
				(0.2989)	(0.0013)	(0.0098)	(0.0012)	(0.1222)	

Critical values (Intercept only): 0.01 = −5.34, 0.05 = −4.8 and 0.1 = −4.58
Critical values (Intercept and Trend): 0.01 = −5.57, 0.05 = −5.08 and 0.1 = −4.82

Notes: Standard errors in parentheses. ***: 1%, **: 5% and *: 10% significance level. K denotes the optimal lag length chosen with a sequencial procedure.

Figure 2: Regional differences of particular indicator together with (broken) deterministic trends and corresponding residuals



Source: Deutsche Bundesbank, Federal Statistical Office, IWH

the expected time until absolute convergence is reached. However, this assumes that steady states of both regions are the same, which is not necessary the case and cannot be tested for. But still, it seems informative to ask when the gap between East and West Germany will be closed given the actual speed of convergence.

Table 5 displays the convergence speeds of the various macroeconomic indicators. If one agrees with the view that the regional gap in per capita output follows a deterministic trend which implies catching up, the average convergence speed is 1% per year. This value is significantly below the socalled "golden rule of convergence" which suggests a convergence speed of 2% as a usual benchmark speed of convergence between different regions. Given an average convergence speed of 1%, it would take

Table 5: Convergence speed

	ADF			Zivot-Andrews					
				Before break			After break		
		Con. speed			Con. speed			Con. speed	
	S-State	in %	in years	S-State	in %	in years	S-State	in %	in years
GDP per capita	–	1.00	49	–	–	–	–	–	–
Unemployment rates	–	–	–	–	–	–	–	–	10
Manufacturing wages	0.61	–	–	–	3.04	5	0.64	–	–
Manufacturing production	–	4.40	52	–	4.49	53	–	2.21	94

Notes: S-State indicates the long-run equilibrium which can be computed only in the case of conditional convergence. The convergence speed is given in annualized percentage terms. Convergence in years is the time it will take until the regional gap between East and West Germany will be closed, given the actual gap at the end of the sample.

additional 49 years until the gap between East and West Germany will be closed (assumed that the convergence speed remains constant). For relative unemployment rates we do not display a yearly convergence speed in percentage terms since we find this measure difficult to interpret. But we do report the expected time it takes until unemployment rates will be equal across East and West Germany. This will take addtional ten years until the existing gap will be equal to zero. Since for nominal wage rates in the manufacturing industry we find evidence of conditional convergence, no further catching up can be observed. But this also implies that we can report the long-run equilibrium of this gap which is 61% and 64% for the model without a break and for the period after the break point, respectively. Convergence speed of per capita manufactering production has been remarkebly fast. Once no break is taken into account it is above 4% per year. But as reported in the pervious subsection there is evidence of a structural break which implies that the catching up process has slowed down more recently. The convergence speed after the detected break is not significantly different from 2% that is often found as convergence speed for income. This suggests that catching up in the manufactering sector is more pronounced than in other sectors. However, one should also remember that the gap in this sector is exceptionally wide. What is also interesting is the fact that the time for closing the gap is twice as large when a structural break is taken into account.

6 Conclusions

This paper addressed the issues of convergence and catching up of East Germany. We employed a time series perspective and tested hypothesis with econometric techniques. Standard ADF unit root tests as well as unit root tests that allow for one endogenously determined break point were run for some welfare indicators. For regional per capita output there is some evidence of catching up, which implies that the gap between East and West Germany – in terms of per capita output - narrows. Further evidence for catching up was found for eastern manufacturing production

and unemployment rates. Nominal wages in the manufacturing sector for East Germany have displayed no tendencies of catching up to the western level since the mid nineties.

Concerning the convergence speed we find heterogeneous results. While unemployment rates may adjust after about ten years, the gap in relative per capita GDP closes at a lower rate. Here, it may take half a century until equality of regional welfare is reached (when actual convergence rates are presumed). For the relative importance of the manufacturing sector the catching up process may be even longer.

While we have characterized the convergence and catching up process of East Germany from an empirical side, we left many important aspects aside. First, it may be interesting to look more closely at the estimated break dates and ask what caused these changes. Second, an interesting topic for future research is to investigate why the catching up process of nominal wages have come to a halt. It would be interesting whether this also holds for other sectors and whether it also applies for real wages or purchasing power. Generally, we are optimistic that our results can contribute to lively debate about the transition process of East Germany and we hope to provide a starting point for more theoretical work that is able to investigate the ongoing processes in the required detail.

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