A distribution dynamics approach to regional income convergence in reunified Germany

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ABSTRACT

This paper presents an empirical study of income per worker (and per capita) convergence across German labor market regions during 1992 to 2002 using nonparametric techniques. There is evidence for a tendency towards convergence, i.e. regions that were poor in 1992 (East-German regions) established a higher relative income in 2002. It is an advantage of our approach that it allows to make predictions about the long-run distribution of regional incomes. We predict a persistent inequality among German regions. This result implies that the substantial regional policy expenditures made by the German government and the EU will not achieve their aim of equalization, and need therefore to be critically reviewed.

JEL-*classification*: C14, C23, O47, R11

Keywords: regional convergence, distribution dynamics, nonparametric econometrics, stochastic kernel, regional policy.

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1 Introduction

This paper presents an empirical study of income convergence across German labor market regions during 1992 to 2002 using the distribution dynamics approach to economic convergence first introduced by Quah (1993, 1996, 1997). This methodology studies how the *entire* cross-sectional distribution of relative income evolves over time and is therefore not limited to an analysis of single moments of the underlying income distribution as in the case of traditional $\beta-$ and $\sigma-$convergence approaches (Barro and Sala-i-Martin, 2004).

The convergence hypothesis states that poor economies catch up with rich ones. This topic is important in Germany because alleviating regional disparities is regarded as a fundamental objective for German policy, especially in light of East-West differentials in reunified Germany. At the heart of the debate about regional inequality stands a fundamental controversy about whether or not a process of economic homogenization has taken or will take place in reunified Germany. Recently, the Federal President of Germany, Horst Köhler, initiated a lively debate about whether it is possible to equalize "living conditions" between the two parts of the country. This debate is directly related to the issue of regional income convergence in reunified Germany and the present paper contributes statistical evidence to this debate.

Persistent disparities in income lead to wide disparities in welfare and can be a source of social tension (Bandyopadhyay, 2002). In order to mitigate regional inequalities, disadvantaged regions in Germany benefit from two major assistance programs, the European Structural Funds and the German "Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur" (GRW).

The main objective of EU regional policy is to promote the development of regions whose per capita GDP is below 75% of the EU average (Eckey, 2001). Approximately 70% of total EU regional expenditure is spent for narrowing regional income differences (Overman and Puga, 2002). Since 1994, the East German federal states are target-1 development areas, and they will receive subsidies totalling 19.229 million Euro until 2006 (Eckey, 2001).

The GRW is the guideline for German regional policy and advocates a supply-side policy supporting growth in order to reduce regional differences in living stan-

dards (Gerling, 2000). For the allocation of subsidies the GRW has defined 271 German regional labor markets ("Arbeitsmarktregionen"). This paper addresses regional convergence on the level of these labor market regions. Therefore, our descriptive analysis of the extent of regional convergence is associated with the most important regional policy program in Germany, the GRW.

A particular feature of our approach is that it allows to make predictions about the long-run distribution of regional incomes. This is an important aspect because it gives an idea on the long-run outcome *given* that convergence continues as it has in the last decade. In other words, we investigate what would happen to the German regional income distribution if the observed dynamics remained unchanged. Under the assumption that the development of the regional income distribution is affected by regional economic policy (i.e. the GRW) we can reformulate the question under study: Where will German regions end up if policy is unchanged?

As for most other convergence studies, the theoretical framework of the empirical analysis is the neoclassical growth model which suggests that regional per capita income within a country converge to the same long-run steady-state (see Magrini, 2004, Durlauf, Johnson, and Temple, 2005, for recent surveys of the large literature). However, regions are by no means small closed economies but are highly integrated by goods and factor movement. Hence, in a regional context the neoclassical growth model for closed economies does not appear to be the best framework for convergence studies. Barro, Mankiw, and Sala-i-Martin (1995) have extended the neoclassical growth model for partial factor mobility and show that the basic prediction of convergence is not altered in this setting. For an elaborate analysis of the role of labor mobility in the convergence process we refer to Razin and Yuen (1997).

The main results of this study are the following. We find evidence for a tendency towards convergence during the period we study, i.e. regions that were poor in 1992 established a higher relative income in 2002. The convergence process is driven mainly by the catching-up process of East German regions in relative terms.

Concerning the long-run distribution of regional incomes this study provides discouraging evidence. The ergodic density we calculate on the basis of our estimates is characterized by polarization which means that we are unable to predict long-run convergence among German labor market regions towards *equality*. In

other words, the long-run distribution of relative incomes shows clustering. This pattern is found to emerge for both income per worker and income per capita.

Moreover, the calculated ergodic distribution is similar to the actual observed distribution in 2002. Our estimates suggest that there will be a similar degree of (in)equality among German regions in the long-run as in comparison to the situation today.

These results are especially important with respect to the substantial regional policy expenditures taken in the past decade. According to our analysis, it is unlikely that German policy will prevent polarization in the regional income distribution even if transfers and subsidies will be continued in a comparable magnitude. Because the analysis shows that regional policy is unlikely to achieve its aim of long-run equalization it is argued that policy measures need to be critically reviewed.

The remainder of this paper is organized as follows. The literature is briefly discussed in Section 2. Section 3 introduces the data employed. The empirical analysis is presented in Section 4 and the last section concludes.

2 Literature

While it is quite clear in theory what economic convergence means, measuring convergence is not a trivial task. In recent years, a number of alternative strategies have been suggested, i.e. traditional cross-sectional regressions of $\beta-$ and $\sigma-$convergence, panel data models and time series tests.[1]

While there are several studies analyzing regional convergence in West Germany[2], empirical evidence regarding reunified Germany is scarce. A potential reason for this has been pointed out by Kosfeld, Eckey, and Dreger (2002) who state that regionally disaggregated data on economic growth are available only recently.

Most studies for reunified Germany are limited to an analysis of convergence between the Eastern and Western part of the country.[3] Although some authors are

[1] See the review of Magrini (2004) for a survey focusing on regional convergence studies.

[2] See Seitz (1995), Schalk and Untiedt (1996), Kellermann (1997), Bohl (1998), Funke and Strulik (1999) and Niebuhr (2001). In general, these studies do find evidence for both absolute and conditional income convergence in West Germany.

[3] See Hallet and Ma (1993), Burda and Funke (1995), Keller (1997), Funke and Strulik (2000)

more pessimistic than others about convergence, the general result is that "East German labor productivity has converged on that in West Germany more slowly than was initially thought but faster than would have been expected on the basis of studies of convergence such as Barro and Sala-i-Martin (1991)" (Barell and te Velde, 2000, p. 272).

Our paper is a contribution to the literature which addresses regional convergence in reunified Germany on a disaggregated geographic level (see Kosfeld, Eckey, and Dreger, 2002, and Kosfeld and Lauridsen, 2004).

Using a spatial econometric approach to $\beta-$convergence, Kosfeld, Eckey, and Dreger (2002) find clear evidence for both per capita income and labor productivity convergence during the period 1992 to 2000. Kosfeld and Lauridsen (2004) adopt a cross-sectional spatial econometric adjustment model which bases on the concept of spatial error-correction. They find only weak evidence for conditional convergence in the year 2000.

A shortcoming of the $\beta-$convergence approach is that by focusing on the average behavior of a representative region it suppresses the cross-section income dynamics one wishes to investigate (Quah, 1996, 1997). This criticism also holds for spatial econometric extensions of the $\beta-$convergence approach proposed by Kosfeld, Eckey, and Dreger (2002) and Kosfeld and Lauridsen (2004). One possibility to overcome the limits of the $\beta-$convergence method is to estimate the entire income distribution and its dynamics over time (Arbia, Basile, and Salvatore, 2003). Only this method allows to uncover empirical regularities such as persistence, polarization and the formation of convergence clubs. Since pronounced East-West disparities are a well-documented fact in reunified Germany (Barell and te Velde, 2000), it appears to be promising to adopt the distribution dynamics approach to Germany, which has not been done yet in the literature.[4]

and Barrell and te Velde (2000).

[4]Technically related studies for other countries are Andrade et al. (2004) (Brazil), Maza and Villaverde (2004) (EU), Kang (2004) (Japan), Magrini (2004) (EU), Johnson (2000) (US), Arbia, Basile, and Salvatore (2003) (Italy), Johnson (2005) (Penn World Tables), Bandyopadhyay (2002) (India), Mossi et al. (2003) (Brazil).

3 Data

The key variable in empirical growth studies is either GDP per capita and/or GDP per worker. Since most theoretical growth models are based on production functions, their implications relate more closely to GDP per worker than GDP per capita (Durlauf, Johnson, and Temple, 2005). In general, GDP per worker is a more accurate index of average productivity than GDP per capita (Jones, 1997). In contrast, GDP per capita can be interpreted as an indicator of regional welfare. The bulk of this paper focuses on income per worker and in the end results for income per capita are briefly summarized.

Germany's official statistics provide data on disaggregated administratively defined regions ("Kreise und kreisfreie Städte"). A regional economic analysis based on district data can be misleading because the borders of German districts are determined by political and historical rather than economic reasons (Eckey, 2001). For this reason we aggregate districts to local labor market regions which are the target areas for the German "Gemeinschaftsaufgabe Verbesserung der regionalen Wirtschaftsstruktur" (GRW). We use data for 439 German districts to define 271 labor market regions, so that center and hinterland of labor markets are adequately integrated on the basis of commuter flows. The time period ranges from 1992 to 2002.[5]

The raw GDP data on the district level stem from the National Accounts of the States ("Arbeitskreis Volkswirtschaftliche Gesamtrechnungen der Länder") compiled by the Statistical State Office Baden-Würtemberg and are measured in current prices. Regional price indices on the district level are not available. The labor force and population data on the district level are reported by the Federal Office for Building and Regional Planning ("Bundesamt für Bauwesen und Raumordnung").[6]

The key variable in our econometric analysis is regional relative income per worker. This means, regional income per worker data are normalized by dividing

[5] There are no data for 1993.

[6] All district data have been adjusted for changes in the boundaries of the districts which occurred during the period we study, i.e. all changes caused by the various "Kreisgebietsreformen" have been accounted for. The regional borders of the districts correspond to the spatial classification ("Gebietsstand") in 2001.

by the labor productivity of the German economy. This allows us to abstract from the growth of the German economy during the period under study. The normalization also accounts for common changes in inflation.[7]

Relative income per worker data have a natural economic interpretation as the fraction of total German income contributed by the ith region, if all regions had the same labor force (Bianchi, 1997).

We do not exclude any regions from the analysis, because outlying data points represent regions which performed either extremely well or poor. From an economic point of view it is not appealing to simply delete these observations (Quah, 1997). The complete sample consists of 271 German labor market regions which are observed for 10 years.

As a starting point, we document the regional disparities in relative GDP per worker, for 1992 and 2002. Figure 1 illustrates the apparent East-West disparities in reunified Germany. It is interesting to compare incomes in labor market regions with extreme values. If income per worker for Germany is normalized to equal 1, the average income in the five richest German regions is 1.31 in 1992 and 1.28 a decade later. The five poorest regions had an average of only 0.45 in 1992 and 0.65 times the German average in 2002. These numbers clearly illustrate that regional disparities are very pronounced in reunified Germany.

In order to get a first impression of the dynamics of regional inequalities we constructed a table (not reported) showing relative income per capita (and per worker), for 1992 and 2000, and ranked the regions in descending order in terms of their 1992 position. Then, we calculated the Spearman rank correlation coefficient in order to assess if the position in the league table of GDP in 1992 is a good predictor of that position a decade later. For GDP per capita, the coefficient takes a value of 0.94 and thus indicates a high degree of stability in relative positions. For GDP per worker, the Spearman rank correlation coefficient is 0.86 and hence indicates more mobility in relative positions.

In the remainder of the present paper it is analyzed if regional inequalities continue to persist, particularly if they do so after a decade of substantial regional

[7] We do not take a logarithmic transformation of the data because this transformation affects the shape of the density distribution of the original data (the relative income transformation is purely a scale transformation) (Bianchi, 1997). It turns out that our results are robust with respect to a logarithmic transformation.

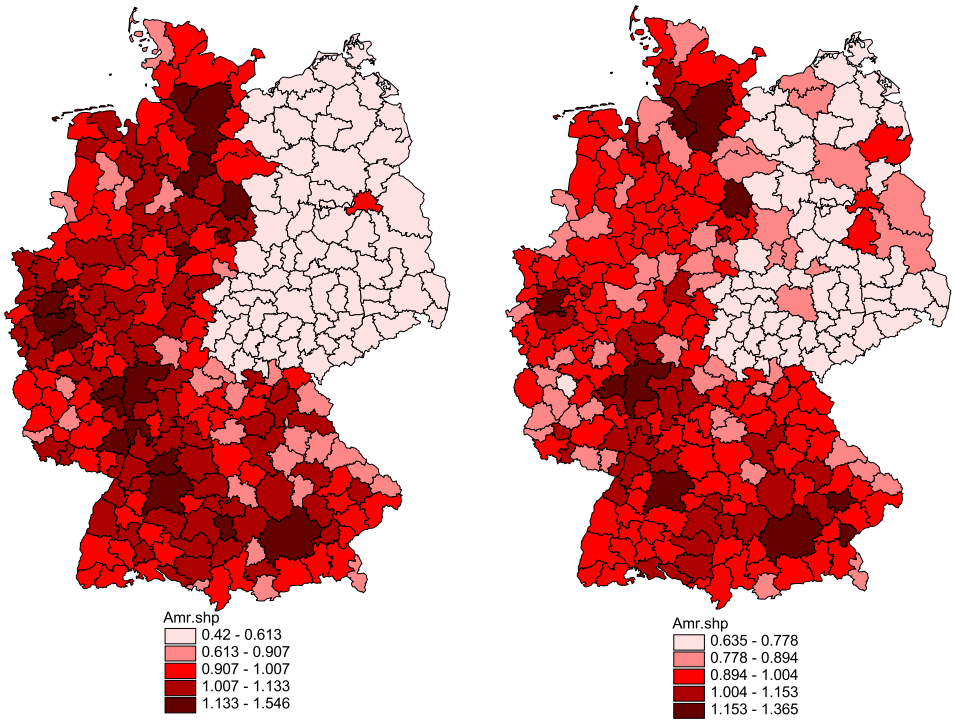

Figure 1: GDP per worker across German labour market regions, relative to the national average. Left: 1992, right: 2002.

policy expenditures.

4 Empirical analysis

The outline of the empirical analysis is as follows. In a first step we estimate *density functions* of relative income per worker for different years. This procedure is a way to test the convergence hypothesis by evaluating whether unimodality in the income distributions is present or not. For example, if we start with a bimodal (or multimodal) density in a given point in time, convergence implies a tendency of the distribution to move towards unimodality (Bianchi, 1997).

In a second step we estimate *transition probabilities* to analyze mobility within the income distributions. This means, we examine how a given individual of the distribution at a given point in time transits to another part of the distribution in the future.

In a third step we calculate the *ergodic* or invariant density of relative income implied by the estimated transition probabilities. This allows to make long-run predictions on the income distribution in reunified Germany.

4.1 Densities of relative income distributions

Nonparametric kernel techniques (see Silverman, 1986) are used to analyze the shape of the distribution of German relative labor productivity for two different years, 1992 and 2002.

We employ adaptive kernel methods with flexible bandwidth, which are especially useful to estimate multi-modal densities when a fixed bandwidth estimation may lead to undersmoothing in areas with only sparse observations and to oversmoothing in others.[8]

A two-step procedure is used to estimate the adaptive kernels. First, an initial (or pilot) estimate of the probability density function with fixed bandwidth is computed. Then, this pilot estimate is used to adapt the size of the bandwidth over the data points when computing the final kernel density. To illustrate, let λ_i denote the local bandwidth factor at each sample point which are proportional to the square root of the underlying density functions at the sample points:

$$\lambda_i = \lambda(x_i) = \left(G/\tilde{f}(x_i)\right)^{0.5} \tag{1}$$

where x_i are the data points, G is the geometric mean over all i of the pilot density estimate $\tilde{f}(x)$. The local bandwidths are then computed as $h_i = h \cdot \lambda_i$, where h is the fixed bandwidth of the pilot estimate.

A crucial point in nonparametric econometrics is the choice of the (pilot) bandwidth h. The larger the value of h, the smoother is the density estimate. Among several possibilities to select, we choose the smoothing parameter to be

$$h = 0.9An^{-1/5} \tag{2}$$

where $A = \min(\text{standard deviation, interquartile range}/1.34)$. This bandwidth criterion has been recommended by Silverman (1986, p. 48) and has been used by

[8] The following description of adaptive kernel methods is based on Van Kerm (2003).

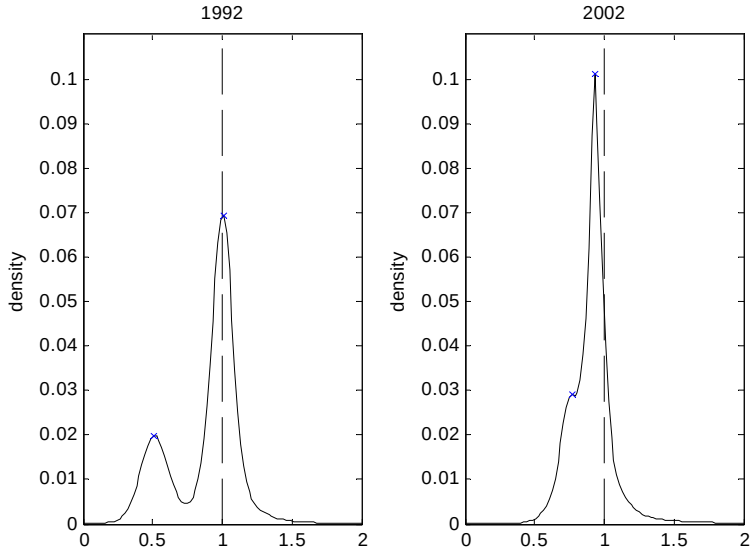

Figure 2: Densities of relative income per worker across 271 German labour market regions, 1992 and 2002.

almost all related studies.[9]

Figure 2 shows the estimated density functions of relative income per worker for the initial and final year of the sample period using a Gaussian kernel. We normalized the densities so that the areas under the graphs integrate to unity.

In 1992, the distribution of relative income is clearly bimodal. The first mode is at 0.51 and the second is at 1.01 times the German labor productivity. Regions in the productive cluster have twice the income of those in the other group.[10] In our setting, we suggest that the cluster of poor regions in 1992 is mainly formed by regions located in the new federal states because of their low income levels after German reunification (see Barrell and te Velde, 2000). We will examine this issue below.

A decade later, in 2002, the density has changed substantially. The two peaks of the distribution correspond to 0.77 and 0.93 times the German income per

[9]Different bandwith selection methods yield very similar results in our application.

[10]One could perform bootstrap multimodality tests as in Bianchi (1997) to formally test for two peaks, but we believe the figure speaks for itselves and there are no doubts about the presence of *exactly* two peaks.

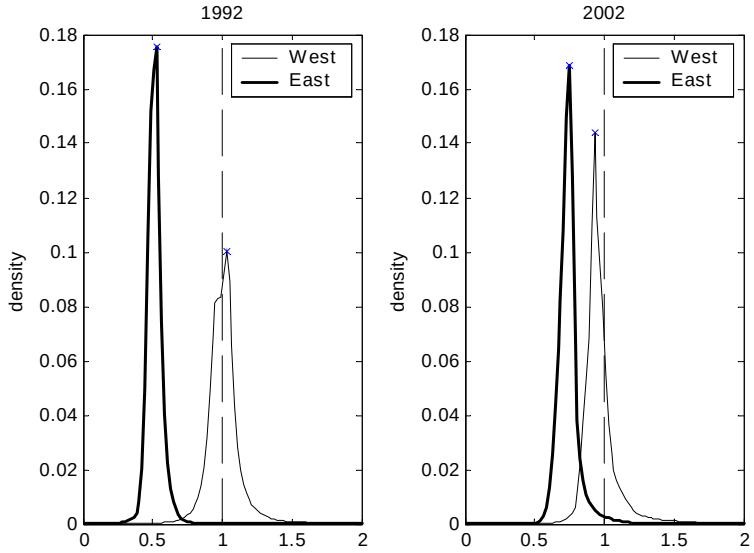

Figure 3: Densities of relative income per worker for West- and East German regions separately, 1992 and 2002.

worker. Now there is considerably weaker evidence for a clustering of the poor regions. It seems as if most poor regions have increased their relative income. The apparent convergence across German regions is reflected by the relative income distance between the peaks. In 1992, the relative income distance is 0.510 while it is 0.16 in 2002.

To illustrate further the convergence between German labor market regions, we compute the variances of the two distributions as

$$variance = \sum \left(z - \sum z \cdot f(z) \right)^2 \cdot f(z), \tag{3}$$

where z is the grid on the x-axis and $f(z)$ the normalized density of z. If there is convergence, the dispersion of the density will tend to fall over time.

In 1992, the variance of the distribution is 0.06 and it decreases to 0.03 a decade later. Hence, we conclude that the relative income distribution has become more equal over time.

Since we suppose that the observed tendency towards convergence in reunified

Germany is primarily driven by the catching-up process of the East German federal states, it is interesting to analyze the shape of the income distribution for West- and East Germany separately. This experiment allows us to assess if there is also convergence within the Western part of Germany.

Figure 3 shows the kernel-smoothed densities of relative income per worker for the Western and Eastern part of Germany separately. There are 204 West German and 67 East German labor market regions. We evaluated the density for West and East German regions at the same values, so that the two graphs can be compared in one figure.

Consider the densities for East German regional incomes first. In 1992, the peak of the distribution is at 0.53 times the German average. As expected, this mode roughly corresponds to the left peak in the income distribution for all German labor market regions as displayed in figure 2 and provides evidence that the cluster of poor regions in figure 2 is mainly formed by East German regions. In 2002, the distribution has shifted to the right; the peak is now at 0.75 times the German average. East German labor market regions have increased their relative income over time. However, most East German regions still have considerably lower productivity levels than the national average. This finding is well compatible with other studies, such as Barell and te Velde (2000).

The density for West German regions did not change very much. The peak corresponds to 1.03 times the German average in 1992 and decreases to 0.93 in 2002. Nearly the same peaks were obtained for the income distribution for all German regions as displayed in figure 2. This confirms the presumption that the West German regions cluster together in the center of the distribution for all German regions.

Again, the apparent convergence between the East and the West of Germany is reflected by the relative income distance between the peaks. In 1992, the relative income distance of the East and West German peaks is 0.510 while it is 0.18 in 2002.

4.2 Transition dynamics

So far we have analyzed the (external) shape of relative income distributions for two different years. Obviously, the densities have fluctuated but we could not say

anything on movements of individual regions in the income distribution. However, for describing convergence it is important to have information on how units move within the distribution. Generally, a broad range of intra-distribution dynamics is possible, for example, over time there are some initially rich regions falling behind; poor regions overtaking the rich; and groups of regions, beginning at similar levels of development, eventually diverging (Quah, 1996).

In this section we analyze intra-distribution mobility by developing a probability model of transitions which captures the distribution's law of motion. This means, we examine how a given individual of the distribution at time t (e.g. 1992) transits to another part of the distribution by the time $t + \tau$ (e.g. 2002).

One possibility to examine transition probabilities is to discretize the income space and then count the observed transitions out of and into distinct discrete cells of a Markov transition probability matrix (Quah, 1993). However, Bulli (2001) has shown that any arbitrary discretization of the state space alters the probabilistic properties of the data. A better approach is not to use a discretization at all but instead allowing the number of cells of the Markov transition probability matrix to tend to infinity (Quah, 1997). In this continuous case, the transition probability "matrix" becomes a stochastic kernel. In simple words, the kernel is a big non-negative matrix whose rows sum to unity, satisfying regularity conditions to ensure that a limiting distribution exists (Quah, 2001).

Assuming that the process describing the evolution of the distribution is time-invariant and first-order Markov, the relationship between the two distributions can be written as[11]

$$f_{t+\tau}(z) = \int_0^\infty g_\tau(z|x) f_t(x) dx \tag{4}$$

where $g_\tau(z|x)$ is the $\tau-$period ahead density of z conditional on x. In other words, the stochastic kernel $g_\tau(z|x)$ maps the distribution from period t to period $t + \tau$. It shows the probability that a given region transits to a certain state (rich or poor) of relative income *given* that it is in a certain state of relative income in the starting period.

As a starting point, we set $\tau = 10$ and estimate $g_{10}(y|x)$ using adaptive kernel

[11] This simplified presentation of Quah's (1997) methodology was proposed by Johnson (2000, 2005). It can also be found in Durlauf, Johnson, and Temple (2005).

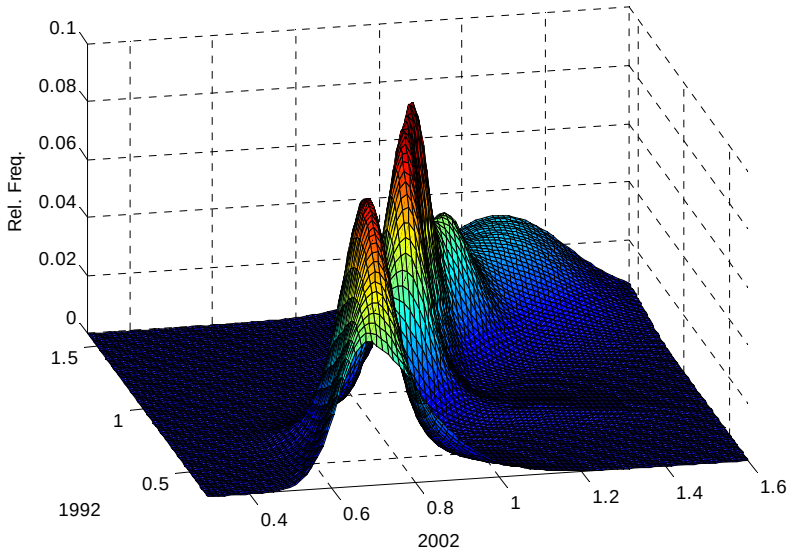

Figure 4: Bidimensional density, $g_{10}(y|x)$, transition 1992-2002.

methods. This means, x is relative income in 1992 and z is the same variable a decade later. First, we estimate the joint density of z and x. Then, we compute the marginal density of x by integrating over z. The ratio of the joint density to the marginal density provides the estimate of $g_{10}(z|x)$.

Figure 4 shows a three-dimensional plot of the estimated conditional density $g_{10}(z|x)$. The $z-$axis measures the density for each pair of points in the 1992-2002 space. The lines that run parallel to the 2002 axis reveal the probability of transiting from the corresponding point in the 1992 axis to any other point 10 years ahead. Note that the Markov interpretation is possible because on both axes the same possible values (the income states) are reported.

The dynamics of the regional income distribution can be seen more clearly from a contour plot of the surface of the bidimensional density. The lines in Figure 5 connect points at the same density on the three-dimensional graph.

To interpret the figure recall that one can recover the probability density function associated with any point in the 1992 axis by slicing across the figure from this specific point, parallel to the 2002 axis. This projection is similar to one single row of a Markov transition matrix in which all entries sum up to one (Andrade et

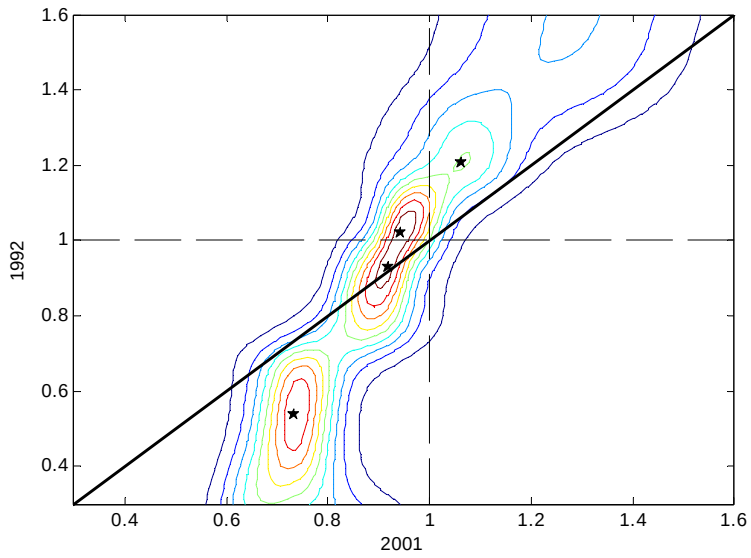

Figure 5: Contour plot of $g_{10}(y|x)$, transition 1992-2002.

al., 2004). If all mass were concentrated around the 45°-diagonal there would be complete persistence (no mobility) in the distribution.

Figure 5 tells that most of the mass of the conditional distribution lies *below* the 45° line for values of relative income *less* than 1 and *above* the line for values *greater* than 1. This means that regions with incomes below the German average in 1992 tend to have increasing relative income over the 10-year horizon. Similarly, regions with incomes above the average tend to have decreasing relative incomes. This pattern is consistent with convergence and confirms the results of our previous univariate density analysis.

The interesting question is to which level of relative income the regions are likely to converge. Examining the local maxima in the conditional distribution (indicated with stars) we suppose that most regions tend to congregate at lower relative income levels than the national average. In order to perform a more formal analysis of the long-run distribution of regional incomes we calculate the ergodic density implied by our estimates.

4.3 Long-run predictions

Given an estimate for $g_\tau(z|x)$ one can compute the implied long-run or ergodic density of relative incomes (so long as it exists). The long-run density, $f_\infty(z)$, is the solution to

$$f_\infty(z) = \int_0^\infty g_\tau(z|x) f_\infty(x) dx. \tag{5}$$

If there is long-run convergence towards German income per worker the ergodic density is strongly unimodal with a mean close to one. In contrast, multiple peaks in the ergodic distribution provide evidence for persistence of convergence clubs in the long-run. This means that some regions catch up with one another but only within particular subgroups (Baumol, 1986).

As a starting point, we calculate the ergodic density implied by $g_{10}(z|x)$ (transition between 1992 and 2002) by multiplying $g_{10}(z|x)$ with itself until the density has converged. This means, we project the observed transition probabilities further into the future.

An important aspect of the limiting distribution is that it is independent of initial conditions (Quah, 2001). Hence, the stationary distribution shows the probability of becoming a poor, middle or rich region independent of the starting value of relative income. Therefore, one has to keep in mind that the ergodic density does not allow inference which labor market regions form the different clusters (if there are any).

Moreover, we have to assume that the observed law of motion is stable over time. We should be aware of the fact that we can interpret the long-run density only as showing the likely outcome given that the realized transitions characterize future developments. Under the assumption that the law of motion is affected by regional policy we can interpret the time-invariance assumption as "unchanged" regional policy expenditures.

Figure 6 displays the ergodic density computed on the basis of $g_{10}(z|x)$. The distribution looks unimodal and the peak is at 0.92 times the German income per worker. This means, the probability is highest to become a below-average income region. The shape of the ergodic distribution provides evidence for long-run convergence of relative incomes in Germany because there are no convergence clubs apparent.

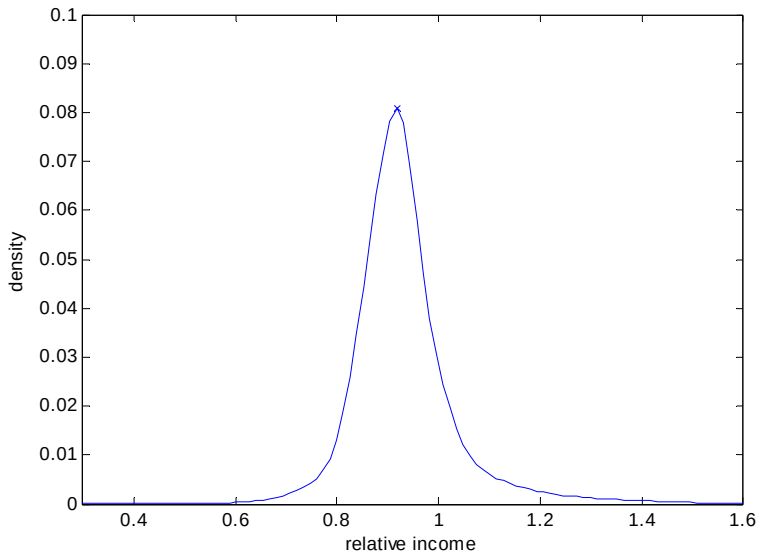

Figure 6: Ergodic density of relative incomes, $f_\infty(z)$, calculated on the basis of $g_{10}(z|x)$ (transition 1992-2002).

The variance of the ergodic density implied by $g_{10}(z|x)$ is 0.01. Since the variance of the actual density of relative income in 2002 is 0.03 we could be tempted to conclude that there will be more equality among German labor market regions in the long-run than today.

However, the computed long-run distribution is unlikely to be a realistic forecast because the estimation suffers from two major problems.

First, it is well-known that the catching-up process of East German regions slowed down considerably in the second half of the last decade (see Eckey, 2001 and Barell and te Velde, 2000 for a detailed discussion). Since we are interested in a long-run forecast, it is more convincing to exclude the first years after German reunification from the analysis, which were turbulent years after the political turn. The period 1995-2002 is characterized by more stability and hence observed transitions during this time should allow more realistic predictions about the long-run.[12]

The second problem is that we have computed the ergodic density on the basis of one observed transition for a longer time period (10 years) but with only rela-

[12]The following results do not change qualitatively if we analyze the period 1994-2002.

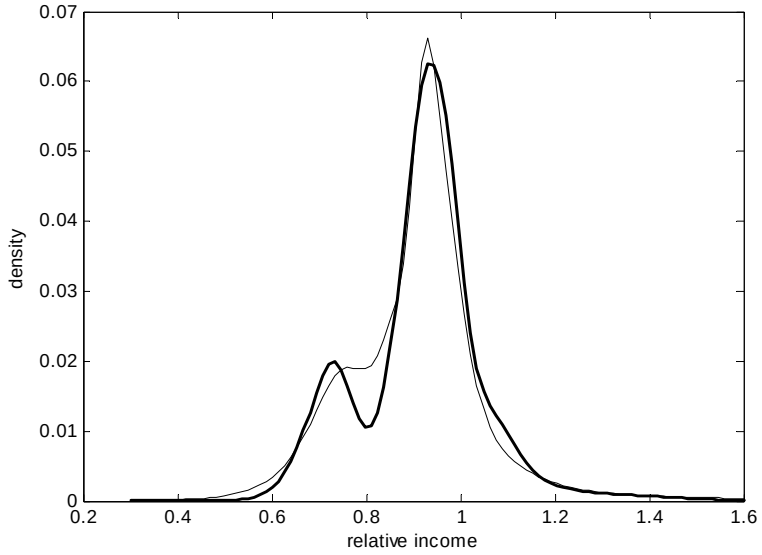

Figure 7: Bold line: Ergodic density of relative incomes, calculated on the basis of $g_1(z|x)$ (yearly transitions between 1995-2002). Thin line: Actual density of relative incomes in 2002.

tively few observations (271). To increase the efficiency of the estimation, we now vary the assumed frequency of transitions from multiple years to annual and then pool the observed transitions. This procedure is strongly recommended by Quah (2001, 308) because taking transition steps with long time intervals instead of annual frequencies is likely to be "correspondingly noisy, with even fewer observations informing the estimate".

In order to get a more realistic estimate for the long-run distribution of relative incomes, we estimate the law of motion for $g_1(z|x)$ based on one-year transitions during 1995 to 2002, which means we pool the transitions 1995-1996, 1997-1998, and so on. The sample now consists of 2168 observations (271 labor market regions times 8 observed transitions).

The thick line in Figure 7 displays this ergodic density evaluated at the same values as the ergodic density based on $g_{10}(z|x)$.

The important finding is that *not* all regions become eventually equal to one another in the long-run. We find a tendency of the cross-regional income distribu-

tion to converge to a long-run distribution having two clusters, an outcome which can be called polarization (Quah, 1997). The left mode in the distribution is at a relative labor productivity of only 0.73 times the national average. The peak with the highest density corresponds to 93% of the German average.

One can examine the long-run distribution only visually because the continuous approach provides no formal statistical tests (Quah, 2001). This means, there is "as yet" no theory of inference for testing hypotheses on the distributions (Quah, 2001). It could be that the data are also consistent with other limiting descriptions, but the important insight of our study is that we do *not* find evidence for long-run equalization of relative incomes, which is the major aim of regional policy in Germany. Even if we smooth the data by using a logarithmic transformation of the relative income per worker variable, the ergodic density still exhibits twin-peaked polarization and the results are very similar.[13]

We also tried to assess how long the cross-section income distribution could take to converge to the invariant limit. To do so, we computed the distance between the density and the density associated with the next multiplication for any repeated multiplication (with the supremum norm) when computing the ergodic density. If the absolute difference between these two densities is smaller than a certain threshold, the density is considered to have converged to the limit. Although the choice of the threshold is ad hoc, this procedure gives us a rough feel for whether the invariant limit is reached rather fast or slowly. For a threshold of 0.01, we find that it will take about 120 years until the limit is reached. This long time span again illustrates that short-run equalization of regional incomes in Germany is unlikely to be achieved.

The thin line in figure 7 shows the actual density of relative incomes in 2002 evaluated at the same grid points. Comparing the ergodic density with the actual one gives us interesting insights: for relative incomes greater than 0.93 times the German average (the right peak) the two densities look very similar. The most striking difference to the actual distribution in 2002 is that the long-run distribution shows a more pronounced clustering of regions with below average relative income, which means that multimodality is less pronounced in the actual

[13]This figure is available from the author on request. The left peak corresponds to 0.73 and the right peak to 0.95 times the average.

point-in-time distribution of the year 2002.

Income per capita We also performed the whole analysis for relative income per capita instead of income per worker. In this paper all figures are omitted due to space limitations. The important finding is that our general result is confirmed: Equalization across German regions is unlikely to be achieved in the future. The estimated ergodic density of relative income per capita shows a three-peaked pattern and again looks similar to the actual observed distribution in 2002. The left mode in the distribution is at a relative income of only 0.60 times the national average. The peak with the highest density is at 0.79 and the right peak corresponds to 93 percent of the German average.

5 Conclusion

Our analysis provides evidence for convergence across German labor market regions during 1992 to 2002. Extremely poor regions in 1992 tend to have increasing incomes while extremely rich regions tend to have decreasing incomes. The convergence process is driven mostly by the catching-up of East German regions in relative terms.

However, we do not predict a tendency towards *equality* in the long-run, so it is unlikely that all regions will eventually become equal to one another. Rather, our long-run estimates predict a persistent inequality among German regions for the future.

Taking the most benevolent view of German regional policy, one can interpret the evidence for convergence during 1992 to 2002 as a success. Yet, our study suggests that the aim of long-run equalization will not be achieved given that the observed law of motion of the regional income distribution remains unchanged. Under the assumption that policy has an influence on the the law of motion, one can either conclude that a continuation of past and current efforts is not sufficient or that policy expenditures are ineffective. In both cases, the substantial regional policy expenditures made by the German government and the EU need to be reviewed critically.

The theoretical literature on economic growth offers various economic justifications or rationales as to why convergence may or may not occur. As summarized

by Durlauf, Johnson, and Temple (2005, 41), two important scenarios can be distinguished: "Steady state effects of initial conditions imply the existence of convergence clubs whereas steady-state effects of structural characteristics do not". In other words, the expectation that the effects of initial conditions eventually disappear, is the heuristic basis for the convergence hypothesis. The results of the present paper suggest that initial conditions matter a lot in reunified Germany.

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