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Labour productivity convergence and structural changes: simultaneous analysis at country, regional and industry levels

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Abstract

Many structural changes have occurred in the European Union countries, for example, there have been changes in sectoral employment share, in the demand of goods due to technology, in trade patterns and in technology. These structural changes may affect the process of convergence. Most of the existing studies on convergence have ignored the role of structural change, which may have resulted in different conclusion. This study considers the role of structural change in testing labour productivity convergence and its speed at the country, region and industry levels simultaneously. The results show that conditional convergence exists at country, regional and industry levels. However, speed of convergence is different across different aggregation levels. Convergence speed at the regional levels is faster than at the country and industry levels. Furthermore, if we do not incorporate structural change, convergence speed may be over- or underestimated.

Keywords: Labour productivity, Convergence, Structural changes, Country, Regional and industry

JEL Classification: C31, D24, O49, O52, R10

1 Background

Over the past two decades, The EU commission's (2011) main focus has been on reducing regional disparities across EU economies. Usually, the GDP per capita convergence concept has been used in the literature for testing regional disparities or catching-up hypothesis.[1] A reduction in regional disparities can also be attributed to the enhancement of innovation and technology, narrowing technological gap, improvement in living standards and particularly labour productivity convergence. An increase in labour productivity over the long run not only affects the living standards but also reduces the disparities across regions and countries (Melachroinos and Spence 1999; Filippetti and Peyrache 2013). Furthermore, labour productivity is also affected by the structural change which is defined by a shift of employment from the low sector to the high sector (Van Ark 1995). Moreover, the differences in the levels of labour productivity are still considerable in EU economies; these differences can be attributed to the structural changes that occur over time. These differences in labour productivity exist for most

[1] See for example Abramovitz (1986), Baumol (1986), Dollar and Wolff (1988), Dollar (1993), Barro and Sala i Martin (1992), Quah (1993, 1996) and O'Leary (1997).

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countries at regional and industry levels.[2] Therefore, the main contribution of the current study is to consider the role of structural change on the process of labour productivity convergence and speed of convergence at country, regional and industry levels. The reason for doing analysis at various levels is that there exists heterogeneity in labour productivity across regions and industries.[3]

The convergence debate was started by Abramovitz (1986), Baumol (1986), Dollar and Wolff (1988), Dollar (1993), Barro and Sala i Martin (1992), Quah (1993, 1996), O'Leary (1997) and Doyle and O'Leary (1999), and has continued ever since. Most of the studies on this issue have tested the convergence separately between countries, regions and industries and have reached different conclusions. For example, some studies found a greater degree of convergence at the aggregate (country) level than at the disaggregate (regions and industry) level, while others have found the opposite. For instance, Sondermann (2014) found no convergence at the aggregate level but did find strong evidence of convergence at the disaggregate level for some sectors. Conversely, Bernard and Jones (1996) found convergence at the aggregate level but not at the disaggregate. Furthermore, the results of productivity convergence at different disaggregation levels of sectors and NUTS (Nomenclature of Units for Territorial Statistics) also differ from one study to another.[4] The speed of convergence could also be different because of heterogeneity in labour productivity at different levels of aggregation. For example, in the case of EU economies, regions are more integrated than countries and industries. Therefore, one can expect to find a different speed of convergence across countries, regions and industries. Since there are a much larger number of regional borders than a number of national borders in EU economies, this might be the reason for having different speeds of convergence across different levels. Therefore, the current study will extend the analysis of productivity convergence at all three levels: countries, regions and industry simultaneously.

In addition to analysing the productivity convergence, another important idea that gained less attention in the empirical literature is the role of structural changes. Many structural changes have occurred in the EU during the last two decades, for example, there have been changes in employment share in different sectors, in the demand for goods due to technology, in trade patterns and in technology (Chenery et al. 1986). These structural changes may affect the process of convergence. There are very few studies which have discussed and argued that structural changes play an important role in the process of convergence and its speed.[5] As discussed by Van Ark (1995), structural changes may affect productivity and growth, especially when labour moves from a low-productivity industry to a high-productivity industry, which may increase the overall productivity level. Therefore, another important contribution of this study is to integrate the structural change in testing convergence and its speed.

[2] For detail see, Webber and Horswell (2009), Byrne et al. (2009), Enflo and Hjertstrand (2009) and Basile (2008).

[3] Some studies discussed and find the evidence of heterogeneity across industries and countries. For detail see, Bernard and Jones (1996) and Artige and Nicolini (2006).

[4] For detail see, Dollar and Wolff (1988), Dowrick (1989), Dollar (1993), Bernard and Jones (1996), Doyle and O'Leary (1999) and Curran and Sensier (2012).

[5] For detail see, Kuznets and Murphy (1966), Gemmell (1982), Dowrick (1989), Dollar (1993), Van Ark (1995) and Doyle and O'Leary (1999).

More specifically, the aim of this study is to test the effects of structural changes on labour productivity convergence at aggregate and disaggregate levels. Aggregate level analysis means a panel set-up of 19 EU countries during the period of 1991–2009. The disaggregate level analysis includes the regional-level and industry-level analysis which includes 259 regions and 6 industries for the same 19 EU countries during the period of 1991–2009. The specific objectives of the study are threefold: *First*, it will investigate whether there is sufficient evidence of convergence after integrating structural change at the country, regional and industry levels. *Second*, if so, it will investigate whether the speed of convergence changed with (and without) incorporating structural change. *Third*, it will seek to determine whether the process of convergence found at the aggregate level is also valid at the disaggregate level. Table 1 provides the basic structure of the aggregation levels used in the study.

In terms of estimation, usually cross-sectional or time-series methodology has been applied for testing the beta-convergence hypothesis. However, these approaches were heavily criticised in the literature for producing biased results (Quah 1993; Durlauf and Quah 1999; Le Gallo and Dallerba 2008).[6] Therefore, this study employs most advanced methodological concepts. For estimation purposes, this study used the concept of β convergence as defined by Barro and Sala i Martin (1992) and applied GMM procedure suggested by Anderson and Hsiao (1981) and Arellano and Bond (1991).[7] Furthermore, the study also used and compared the results with the Least Square Dummy Variable (LSDV) method for the panel data model.

The results of the study show that conditional convergence exists at country, regional and industry levels, but the speed of convergence is different across different aggregation levels. More precisely, after incorporating structural change, the speed of convergence at regional levels is faster than at the country and industry levels, which shows that structural change plays a very important role in explaining the regional convergence process. The reason for the high convergence rate at a regional level compared to country and industry levels could be that regions are more specialized, united and integrated than the countries. Furthermore, these findings also suggest that without incorporating structural changes into the analysis of productivity convergence, the speed of convergence could be over- or underestimated at the aggregate and disaggregate levels.

The remainder of the paper is organised as follows: Section 2 discusses the theoretical background and methodology. Section 3 sheds light on data and descriptive statistics. Section 4 reveals the results. Section 5 concludes the discussion.

2 Theory and methodology

The theoretical background is inspired by neoclassical Solow (1956) model, which assumes exogenous saving rates and a production function based on a decreasing productivity of capital and constant returns to scale. Under these assumptions, the model predicts that an economy's income converges towards its steady-state level of income in the long run, where all variables grow at a constant rate equal to the rate of technological progress.

[6] The detail discussion on method is given in Sect. 2.

[7] For stata command, we follow the procedure explained by Roodman (2009) and Mileva (2007).

Table 1 Aggregation level of data

Aggregation level		Panel dimension	Time
Country level	19 countries	19	1991–2009
Regional level	259 regions	259	1991–2009
Industry level	6 industries in 259 regions	$6 \times 259 = 1554$	1991–2009

Data Source: Cambridge Econometrics dataset 2011

Usually, two types of convergence concepts are used in the literature. First, *absolute convergence* is based on the idea that poorer economies will grow faster than richer ones until they have reached a same per capita income level (common steady-state level) irrespective of their initial endowments such as capital, saving, population growth rates, infrastructure, etc. Second, *conditional convergence* is the concept that happens when every economy moves towards its own steady state under certain given conditions, and hence different steady states are captured.[8]

2.1 Empirical specification

Following Solow (1956) and Islam (1995), the cross-sectional ($T = 1$) convergence equation with takes the following form:

$$\log[y_{i,t}] - \log[y_{i,t-1}] = a - b \cdot \log[y_{i,t-1}] + \varepsilon_{it} \quad (1)$$

The above Eq. (1) illustrates that the annual growth rate of per capita output of economy/region i between time t and time $t-1$ is inversely related to the per capita output at time $t-1$, where a and b are constants, and ε_{it} is a disturbance term. The parameter b captures the relationship to be tested and should take a value between 0 and 1 (for detail, see, Barro and Sala i Martin 1992, 1995; Tondl 1999). Barro and Sala i Martin (1992) proposed the following convergence equation in order to get a direct measure of the speed of convergence β,

$$1/T\,[\log(y_{iT}/y_{i0})] = a - (1 - e^{-\beta T})/T \cdot \log\,[y_{i0}] + \varepsilon_{i0T}, \quad (2)$$

The above Eq. (2) is in the form of an average growth rate of output per capita during the period T. Furthermore, the Eq. (2) assumes a common steady state for all economies/regions (absolute convergence). In the estimation of conditional convergence, the following equation can be estimated where different steady states are captured,

$$1/T\,[\log(y_{iT}/y_{i0})] = a - (1 - e^{-\beta T})/T \cdot \log\,[y_{i0}] + \gamma X_{i0} + \varepsilon_{i0T}, \quad (3)$$

where the left-hand side states the average annual growth rate of per capita output during the period T, the right-hand side includes a_i constant term, β rate of convergence, $\log[y_{i0}]$ initial per capita output, γX_{i0} a vector of variables that conditions the steady-state and ε_{i0T} the disturbance term.

For a panel data model, the regression equation takes the following form:

$$\log\,(y_{i,t}/y_{i,t-1}) = a_i - \lambda \cdot \log\,[y_{i,t-1}] + \gamma X_{i,t} + \varepsilon_{it}, \quad (4)$$

[8] For detail see, Solow (1956) and Barro and Sala i Martin (1992).

where the error term is $\varepsilon_{it} = \eta_i + \tau_t + \mu_{it}$ and Eq. (4) can be written as the following:

$$\log\left(y_{i,t}/y_{i,t-1}\right) = a_i - \lambda \cdot \log\left[y_{i,t-1}\right] + \gamma X_{i,t} + \eta_i + \tau_t + \mu_{it}, \tag{5}$$

where η_i is an unobserved individual effect that is constant over time but varies across economy/region, τ_t is a time-specific factor that equally affects all individuals and represents the global shocks, e.g. a decline in economic activity or a technology shock, and μ_{it} is a random error term.[9] In econometric terms, the above panel regression model is also called a two-way fixed-effect model. λ is the coefficient of lagged value of output per capita $\log[y_{i,t-1}]$, which captures the relationship between growth rate of output per capita $\log(y_{i,t}/y_{i,t-1})$ and its lagged value in the level form. The coefficient of interest β can be obtained from λ $(\beta = -\ln(1-\lambda))$, which measures the annual speed of convergence.

In order to determine whether convergence across regions has taken place, researchers usually apply either a cross-sectional or panel framework. A cross-sectional approach has been criticised in the literature because it suffers an omitted variable bias and cannot model countries'- or regions'-specific unobservable factors (fixed effect).[10] In contrast, panel data model can incorporate these unobservable region-/country-specific components and is considered to be better than a cross-sectional analysis. Islam (1995) show that the Least Squares Dummy Variables (LSDV) estimator, based on the fixed effect, is still permissible if asymptotic properties of panel data are considered in the direction N (large N).

Islam (1995):

> *the presence of a lagged dependent variable on the right-hand side makes LSDV an inconsistent estimator, when asymptotic are considered in the direction of N tends to infinity. However, the asymptotic properties of panel data estimators can be considered in the direction of T, and Amemiya (1967) has shown that when considered in that direction, LSDV proves to be consistent and asymptotically equivalent to the Maximum Likelihood Estimator (MLE).*

The growth equation in (5) can be presented as dynamic panel data model with per capita output as a dependent variable and its one period lag as independent variable as follows:

$$\log\left[y_{i,t}\right] = \theta \log\left[y_{i,t-1}\right] + \gamma x_{i,t} + \eta_i + \tau_t + \mu_{it}, \tag{6}$$

where $\theta = (1-\lambda)$; therefore, the convergence equation in the growth form of Eq. (5) or level form of Eq. (6) can be estimated, but Hsiao (1986), Baltagi (1995), Islam (1995) and Tondl (1999) discussed two problems with that model. First, the lag of the dependent variable on the right-hand side gives rise to autocorrelation in error terms. Second, the control variables might be endogenous and can create the causal relationship in both directions. Then GMM, or instrument variable estimation, is necessary in this case. Regarding the first problem, LSDV estimation is affected by applying OLS on a

[9] Cross-sectional approach neglects the individual unobservable component ϕ_i and suffers from an omitted variable bias. By the inclusion of this term the regression equation explain the concept of conditional convergence without having *X* variables. For detail see, Islam (1995), Tondl (1999) and Islam (2003).

[10] For detail see, Islam (1995, 1999) and Tondl (1999).

transformed series, where individual time mean is subtracted from each observation to sweep out the individual effect but is not suitable for the regional growth model (Islam 1995; Tondl 1999). For the second problem, Anderson and Hsiao (1981) suggested IV estimation which was criticised by Arellano and Bond (1991) and they suggested that all available lags of instrument variables can be used for getting the consistent estimation results. Therefore, for estimation purposes, the GMM procedure can be applied to Eq. (6), as suggested by Anderson and Hsiao (1981) and Arellano and Bond (1991).[11]

Another criticism on the cross-sectional regression approach has been raised by Quah (1993, 1996), Bernard and Jones (1996), Evans and Karras (1996), Le Gallo and Dallerba (2008), and Sondermann (2012) for producing biased results. They claimed that the basic assumption of identical first-order properties among regions and countries relies on the prior assumption that $X_{i,t}$ is enough to control for all cross-region differences. However, it is highly unlikely; the error term tends to be correlated with the initial level of income dynamic properties of the data. On the other hand, alternative approach has been employed in the literature, i.e. the panel unit root approach (stochastic convergence). The idea is that convergence can be assumed only if idiosyncratic country-specific shocks have temporary effects on productivity in country A relative to country B. These relative productivity levels would hence follow a stationary process. Without stationarity, however, relative productivity shocks would lead to permanent deviations (Evans and Karras 1996; Sondermann 2012). According to this definition, convergence can be tested in a unit root test framework.

2.2 Structural change

As defined earlier that structural change is not only the shift of labour from one industry to another industry over time, but also includes changes in patterns of demand, trade, technology and the use of production factors (Chenery et al. 1986). However, whenever there is any structural change that takes place in a country, that not only affects the regions but also the sectors or industries in that country. The effects of these structural changes could be different on macro-, regional and industry levels because of the existence of heterogeneity. Many structural changes have occurred in the EU over the past two decades. Some studies have discussed the role of structural change in productivity growth analysis. As Kuznets and Murphy (1966) explains, that structural change is a major stylized fact of growth. Van Ark (1995) used the sectoral share of employment as structural change and calculated the productivity growth weighted by the sectoral shares of employment. Therefore, it is important to analyses whether these structural changes affect the convergence and its speed differently at the aggregate and disaggregate levels.

2.2.1 Measurement of structural change

Following Van Ark (1995), we used sectoral employment share as a measure of structural change. The structural change is incorporated by weighting labour productivity with employment share. Furthermore, labour productivity is measured as gross value added (GVA) per working hours. This measure is more relevant for this study because it not only captures the shift of employment from one sector/industry to another (employment

[11] For stata command, we follow the procedure explained by Roodman (2009) and Mileva (2007).

share), but also captures the effects of change in demand, trade and innovation pattern. More explicitly, this study computed the structural change at industry, regional and country levels as follows.

There are data sets at three levels: country (c), region (r) and industry (i). Suppose that labour productivity is denoted by P, calculated as $Y/L.hrs$, where Y represents GVA and $L.hrsS$ is employment working hours.

First, consider the productivity of each industry i, in region r, weighted by structural changes (for convenience, drop time subscript t).

$$(PW)_i^r = \frac{Y_i^r}{L.hrs_i^r} \cdot \left[\frac{L_i}{L_r}\right] = P_i^r.[w_i] \tag{7}$$

where L_i is employment in industry i, L_r is total employment in region r and $w_i = L_i/L^r$ denotes employment share in industry i. Similarly, the productivity of each region r in country c, weighted by structural changes can be written as the following:

$$(PW)_r^c = \left[\sum_{i=1}^{n} (P_i^r.w_i)\right] \cdot \left[\frac{L_r}{L_c}\right] = P_r^c \cdot [w_r] \tag{8}$$

where L_r is employment in region r, L_c is total employment in country c and weight w_r denotes the employment share in region r which incorporates the sectoral shift of employment across regions. The productivity at country level weighted by structural changes can be written as the following:

$$\begin{aligned}(PW)_c &= \left[\sum_{r=1}^{R}\left[\sum_{i=1}^{n}(P_i^r w_i)\right]\cdot w_r\right]\left[\frac{L_c}{L_T}\right] \quad \text{or,} \\ &= \left[\sum_{r=1}^{R}\left[\sum_{i=1}^{n}(P_i^r w_i)\right]\cdot w_r\right]\cdot\left[\frac{L_c}{L_T}\right] \quad \text{or} \\ &= \left[\sum_{r=1}^{R} P_i^c w_i\right]\cdot\left[\frac{L_c}{L_T}\right] = P_c \cdot [w_c]\end{aligned} \tag{9}$$

where L_c is employment in country c, L_T is total employment in a sample of countries and weight w_c denotes the employment share in country c. The measure of weighted productivity at the country level controls the sectoral shifts of employment not only at the industry and regional levels but also at the country level.

3 Data and variables

Labour productivity convergence is analysed by using three different data sets. First, at the aggregate (country) level, the data set consists of 19 EU countries during the period of 1991–2009. The choice of countries is based on data availability from a single data source. Second, at the disaggregate (regional) level, the data set includes 259 NUTS 2-level regions that belong to the same 19 EU countries during the same period of 1991–2009.[12] Third, the regional-level data are further disaggregated into 6 industries: agricul-

[12] The map of 19 EU countries and 259 regions is presented in Fig. 1.

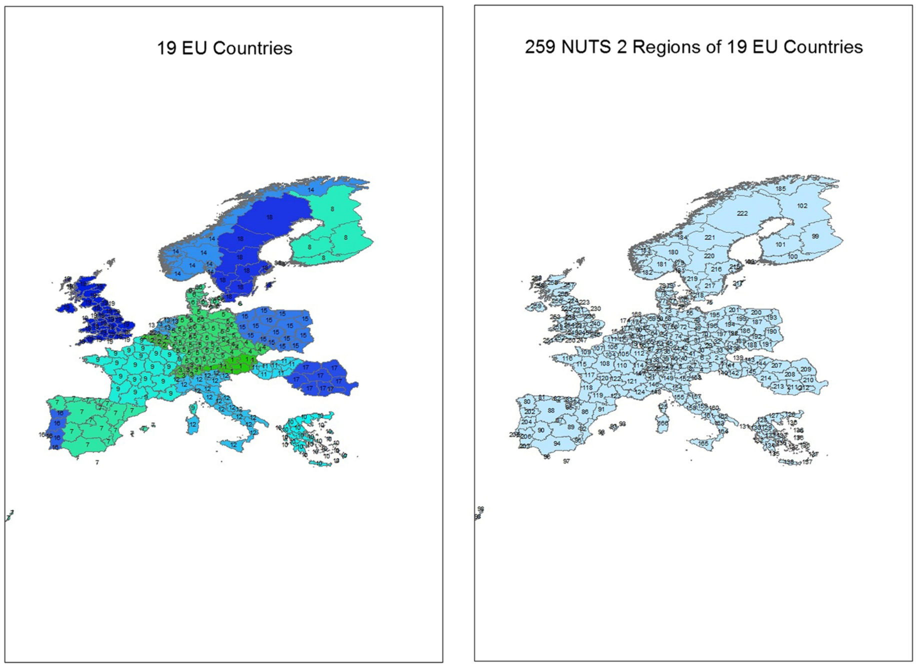

Fig. 1 Nineteen EU countries and 259 regions

ture, energy and manufacturing, construction, market services, financial services and non-market services.

The main variable is labour productivity which corresponds to the gross value added (GVA) per capita in 2000 million Euro, adjusted for the number of working hours across countries. Neglecting differences in average annual hours worked would lead to over- or underestimation of the productivity level. The main source of data is Cambridge Econometrics (2012), which is based on the Eurostat Regio database. The Cambridge dataset also uses a large amount of input from national statistical sources to fill the missing values. In contrast, the Eurostat Regio database contains the missing values for some regions, but new versions include some input. For the structural change, this study used sectoral employment share as used by the other studies.[13] Details about data, variables and their sources with descriptive statistics are given in Appendix Tables 4, 5, 6, 7 and 8.

3.1 Graphical analysis

This study attempted to do some graphical analysis with the data sets at the country, regional and industry levels. The analysis begins by analysing graphically the β-convergence test by plotting the growth rates (average growth of productivity from 1991 to 2009) against the initial values (log of productivity in 1992). Figure 2 and 3 represent the scatter plot of growth rates of productivity against the initial level of productivity for 259 regions and 6 industries in 259 regions, respectively. The right-hand panel incorporates the structural change, while the left-hand panel is without structural

[13] Structural changes usually measured as sectoral shares of employment. For detail see, Kuznets and Murphy (1966), Gemmell (1982), Chenery et al. (1986), Dowrick (1989), Dollar (1993), Van Ark (1995) and Doyle and O'Leary (1999).

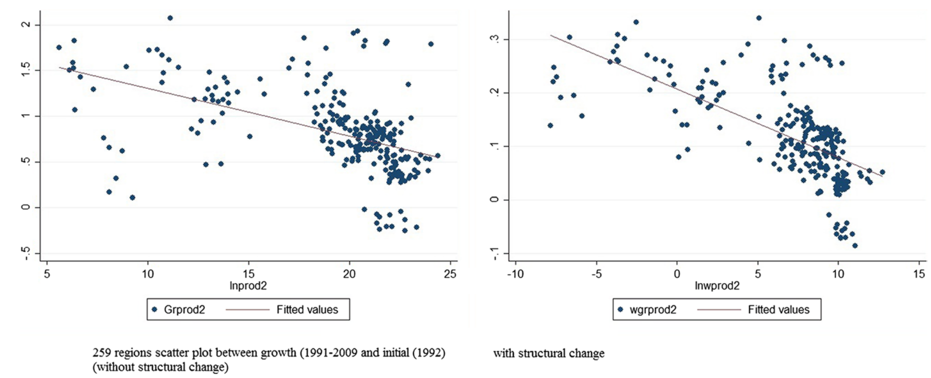

Fig. 2 Two hundred fifty-nine EU regions scatter plot growth and initial (1991–2009)

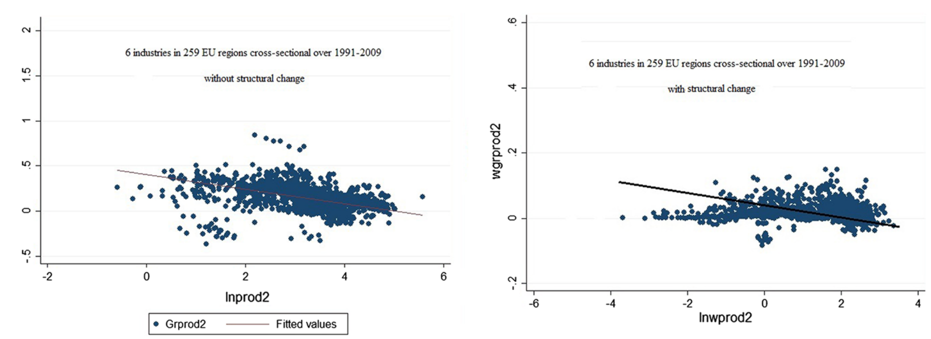

Fig. 3 Six industries in 259 EU regions scatter plot between growth and initial (1991–2009)

change.[14] Visual inspection of both figures shows the negative relation between growth rate and initial per capita productivity which confirms the presence of convergence at both regional and industry levels.

In addition, the slope of the relationship between growth and initial value at the regional level (Fig. 2) is steeper than the slope at the industry level, which gives an indication that the speed of convergence at the industry level is slower than the speed of convergence at regional and country level. The graphical analysis reveals a strong indication of heterogeneous convergence rates across industries, regions and countries. Therefore, it is important to analyse the convergence with proper econometric methodologies at country, regional and industry levels, simultaneously.

4 Empirical results

The results related to the country-, region- and industry-level analyses are reported in this section where convergence coefficient (β) is estimated for all three models. Table 2 reports the results of the specifications presented in (6) as the dynamic panel data model. This study estimates the model by employing the GMM procedure as explained by Arellano and Bond (1991). The system GMM procedure uses the level equations to obtain a

[14] The productivity weighted by employment share is called with structural change and without structural change means unweighted productivity.

system of two equations.[15] Column 1 and 2 report the results at country level with structural change (W-SC) and without structural change (WO-SC). These results confirm that β-convergence exists for the sample of 19 EU countries, meaning that over time, countries are converging to their own steady-state level.[16] The only difference between the models with and without structural change is the size of the estimated coefficient for the annual speed of convergence. The one with structural change has a lower convergence coefficient (β) than the one without structural change, i.e. 0.034 and 0.015, respectively. Therefore, if we do not control for the effect of structural change then the speed of convergence is overestimated.

The results reported in columns 3 and 4 are based on regional-level data, which consists of 259 regions at NUTS 2-level during the period 1991–2009. The results show that the convergence coefficient (β) is 0.086 and 0.122 for with and without structural change, respectively. These results show that regional productivity is converging to their regional steady-state level. The speed of convergence at the regional level is faster than the speed of convergence at the country level for both without and with structural change, i.e. 8.6 and 12.2 % compared to 3.4 and 1.5 %, respectively.[17] Furthermore, the speed of convergence at the regional level has increased after incorporating structural changes, contrary to the country-level results. At the current speed, it would take approximately 6–8 years until a region may have eliminated half of its productivity gap, which shows that structural change plays a very important role in explaining the regional convergence process. The reason for a higher convergence rate at the regional level could be that regions are more specialized, united and integrated than the countries.

The results at the industry level are reported in columns 5 and 6 and are based on 6 industries in 259 regions during 1991–2009. In this disaggregated level, a separate panel ID was used for each industry and region, which means industry 1 in region 1 is different from industry 1 in region 2, and so on.[18] The coefficient estimates of the lagged dependent variable (θ) are 0.975 and 0.983 without and with structural change, respectively. These results also show that regional productivity at the industry level is converging to their own steady-state level. The speed of convergence is very close to the country level, i.e. 2 % without incorporating structural change and 1 % with structural change. These results also show that β coefficient will be overestimated if one does not take into account the effects of structural change, which is similar to the country-level results.

In order to test the robustness of the results, we also estimated the model by using LSDV fixed effect for conditional convergence, and the results of LSDV are reported in Appendix Table 9.[19] According to the results of LSDV, there is evidence of convergence with and without incorporating structural change. In general, the results are similar in both LSDV and GMM methods. However, Islam (1995) and Tondl (1999) discussed that

[15] One differenced and one in levels. The variables in second equation in level form instrumented with their own first differences which usually increases the efficiency. For detail see Roodman (2009) and Mileva (2007).

[16] It means conditional convergence exists. We have also tested the absolute convergence, but results are not reported here, available on request.

[17] The results are in line with Tondl (1999).

[18] The specification in this form not only includes the unobservable country-specific effect but also models the regional- and industry-specific unobservable effects, and ignoring these unobservable effects may lead to under- or overestimation of convergence coefficients.

[19] OLS results are available on request.

LSDV method is not suitable for the regional growth model because of the transformed series. Therefore, we prefer to rely on GMM results in this section.

The results of the specification tests are reported at the bottom of each column in Table 2. The results of AR test are shown in row 1, which tests the null hypothesis of no autocorrelation and is not rejected for each model. The second row reports the Sargan test, which has a null hypothesis of "the instruments as a group are exogenous". The results of Sargan statistic show that we can not reject the null hypothesis.

Table 3 reports the results of convergence speed and required time to cover halfway between initial and steady-state levels. Based on the results of WO-SC, the speed of convergence at the country level is 3.4 % per annum which reduced to 1.5 % (more than half) after incorporating structural change. It implies that with structural change these countries require 46 years to cover the halfway between the initial and steady-state level, whereas it requires only 20 years to cover the same distance without controlling the effect of structural change. At the regional level, the speed of convergence has increased from 8.6 to 12.2 % per annum which implies that only 5.6 years are required to cover the

Table 2 GMM results: at country, regional and industry levels

Variables	Dependent variable: labour productivity					
	Country level		Regional level		Industry level	
	WO-SC	W-SC	WO-SC	W-SC	WO-SC	W-SC
	(1)	(2)	(3)	(4)	(5)	(6)
θ	0.965	0.985	0.910	0.870	0.975	0.983
t value	(1.90)	(2.39)	(11.30)	(76.19)	(71.16)	(202.42)
λ	−0.035	−0.015	−0.090	−0.130	−0.025	−0.017
β	−0.034	−0.015	−0.086	−0.122	−0.025	−0.017
AR (1 2)	0.180	0.220	−1.070	0.970	−1.510	−0.980
p value	(0.86)	(0.83)	(0.29)	(0.99)	(0.13)	(0.33)
Sargan chi^2	182.330	59.850	76.590	83.140	84.430	0.490
p value	(0.56)	(0.93)	(0.96)	(0.17)	(0.99)	(0.99)

Estimation method, GMM (ArellanoBond) two-step robust

Sample: 19 countries, 259 regions, 6 industries and time is 1991–2009

WO-SC and W-SC are without and with structural change, respectively

In col 5 and 6 used separate id for industry and region

Table 3 GMM Results: speed of convergence and time duration

Aggregation levels	Dependent variable: labour productivity			
	Annual %		Half-distance[a] (years)	
	WO-SC	W-SC	WO-SC	W-SC
Country level	3.4	1.5	20.0	46.3
Regional level	8.6	12.2	8.0	5.6
Industry level	2.5	1.7	29.9	41.2

Sample: 19 countries, 205 regions over the time 1991–2009

W/WO-SC represents with/without structural change

Annual % measured as ($\beta = -\ln(1-\lambda)/T$) and HL = ($\ln(2)/\beta$)

HL shows time required for y to be halfway between

[a] Half-distance means time required to cover the half distance between initial and steady-state level of income

halfway between the initial and steady-state level after incorporating the effect of structural change which was 8 years without it. For industries, the speed of convergence has reduced from 2.5 to 1.7 % after incorporating structural change. It implies that for these industries 30 years are required to cover the half distance while same distance is covered in 41 years when we do not control structural change. These results clearly show that controlling structural change is very important to get the correct speed of convergence.

The above results are in line with many other studies with respect to the conditional convergence for EU countries, regions and industries. That is, poor countries are growing faster than richer ones (Islam 1995; Gaulier et al. 1999; Beyaert 2008). Barro and Sala i Martin 1992; Gardiner et al. 2004; and Curran and Sensier 2012 found convergence at the regional level, whereas Dollar and Wolff 1988; Dowrick and Nguyen 1989; and Bernard and Jones 1996 found the convergence at the industry level.

In summary, these results suggest that convergence follows a smooth process, but it is also influenced by continuing structural change. Therefore, it is important to identify the structural change when assessing the smooth process of convergence. Figure 4 summarizes the points of βs' coefficients from the GMM estimation for all models. The βs' for the regional-level data are higher than the country- and industry-level βs' in both cases of with (W-SC) and without (WO-SC) structural change, but the βs' for the country and industry levels are lower after incorporating structural change. These results suggest that structural change plays a very important role in assessing the process of convergence and its speed at the aggregate and disaggregate levels.

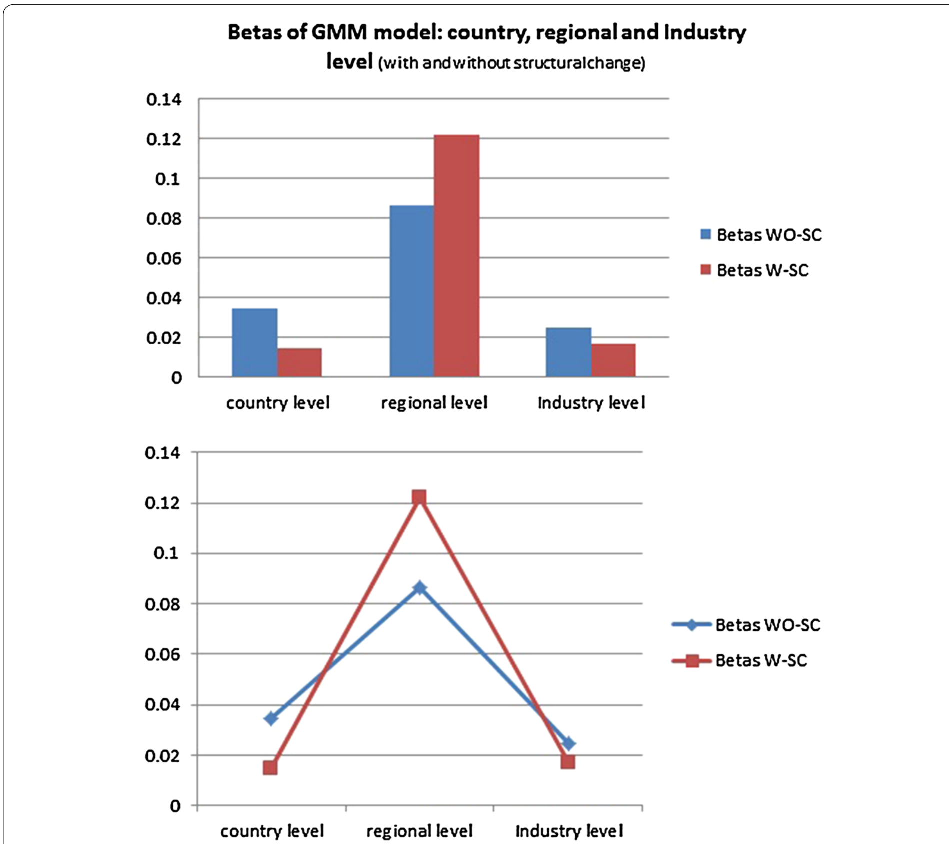

Fig. 4 βs from GMM estimation with and without SC (country, regional industry)

5 Conclusion and discussion

This paper has explored the role of structural change on labour productivity convergence at the country, regional and industry levels. For that purpose, this study used the data from Cambridge Econometrics, which consist of 19 EU countries, 256 regions at NUTS 2 level and 6 industries during the period of 1991–2009. For estimation purposes, this study systematically applied recently established techniques for the panel data models, such as LSDV and GMM (Arellano and Bond). The results of this study have shown some interesting findings with respect to convergence. More specifically, this study tried to provide answers to the questions raised at the start of this study. The first question was: is there sufficient evidence of convergence after incorporating structural change at different levels of data? The second question was: if so, has the speed of convergence changed with (and without) incorporating structural change? The third question was: is the process of convergence found at the country level is also valid at the region and industry levels?

The answer to the first two questions is yes; convergence takes place at all levels (country, regional, industry and industry-specific) even after incorporating structural change. The speed of convergence appears to be different before and after incorporating structural change. More precisely, at the country level, the speed of convergence before incorporating structural change was 3.4 % per annum, but after that, it was reduced to 1.5 % per annum. Similarly, at the industry level, the speed of convergence after incorporating structural change was reduced from 2.5 to 1.5 % per annum. However, contrary to the country and industry levels, the speed of convergence at the regional level has increased from 8 to 12 % per annum after incorporating structural change. These results show that regions are converging faster than countries and industries. The reason for the high convergence rate could be that regions are more specialized, united and integrated than countries. The results also show that the speed of convergence will be over- or underestimated if one does not take into account the effects of structural change. This may be due to the fact that some of the dynamics in labour productivity are not captured by without incorporating structural change.

This study has policy implication for EU countries, region and industries, for instance, the regions (or countries or industries) with low growth rate can reallocate labour towards relatively high-productivity regions (or countries or industries) to speed up the convergence process. Our findings are also consistent with the EU policy of free mobility of labour. Furthermore, this reallocation of labour (structural change) has to be incorporated while studying the convergence process. Moreover, the disparities may reduce if the process of reallocation is considered intensely in relatively less-developed regions or industries. For the better outcome of the structural change, the improvement in technology, research and development activities and better education could support the less-developed areas. Hence, the findings of this study are not only relevant for making the policy at the national level but also applicable at regional and local industry levels.

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Competing interests

The authors declare that they have no competing interests.

Appendix

See Tables 4, 5, 6, 7, 8 and 9.

Table 4 List of countries and regions

Nr.	Code	Countries	Nr. of. regions
1	AT	Austria	9
2	BE	Belgium	11
3	CH	Switzerland	7
4	CZ	Czech Republic	8
5	DE	Germany	39
6	DK	Denmark	5
7	ES	Spain	19
8	FI	Finland	5
9	FR	France	22
10	GR	Greece	13
11	HU	Hungary	7
12	IT	Italy	21
13	NL	Netherlands	12
14	NO	Norway	7
15	PL	Poland	16
16	PT	Portugal	5
17	RO	Romania	8
18	SE	Sweden	8
19	UK	United Kingdom	37
		Total=	259

Table 5 List of industries

Nr.	Industry names	Codes-in EuroStat
1	Agriculture	A + B
2	Energy and manufacturing (mining, quarrying and energy supply)	C + D + E
3	Construction	F
4	Market services [distribution (G), hotel and restaurants (H), transport, and storage and communications (I)]	G + H + I
5	Financial services [financial intermediation (J), and real estate, renting and business activities (K)]	J + K
6	Non-market services	L + M + N + O + P

Table 6 Variables: definition and values

Variables	Description	Time period	Value
TGVA	Gross value added	1991–2009	2000 million Euro
THRS	Hours worked per week	1991–2009	Per week
TEMP	Employment	1991–2009	1000
Shareemp	share of employment in industry	1991–2009	Emp-in-industry/emp-in-region
Prod	Labour productivity per- worked hour	1991–2009	GVA per working hour

Data Source: Cambridge Econometrics

Shareemp is share of employment in industry (author calculation)

Table 7 Descriptive statistics, 19 countries over 1991–2009

Variables	$N = 19 \times 9$	Mean	SD	Min	Max
TGVA	361	449,248.2	553,263	19,418	2,223,222
THRS	361	3197.634	2240.517	1068	9012
Shareemp	361	13.63158	9.828813	5	39
Prod	361	3143.127	2833.682	200.1131	11,534.59
Wxprod	361	507.5039	485.6837	18.83783	2024.146
Gr-prod	361	11.23503	9.080614	−8.28935	38.08341
WxGrprod	361	1.597945	1.41367	−1.80947	8.198125
ln-prod	361	275.3426	223.3409	50.83778	883.0272
Wxln-prod	361	106.6606	103.4678	−56.7406	381.8042

TGVA is gross value added, THRS is number of hours worked

TEMP is employment, Prod is productivity measured as per capita GVA

Adjusted with working hours, *W* is weight measured as share of employment

Gr represents growth rate and ln shows natural log

Table 8 Descriptive statistics, 259 regions over 1991–2009

Variables	$N = 259 \times 19$	Mean	SD	Min	max
TGVA	4921	32,956.43	42,023.99	342	506,466
THRS	4921	234.5755	17.03141	175	293
TEMP	4921	787.2095	659.9652	15	5595
Shareemp	4921	1	1.38E − 08	1	1
Prod	4921	230.5769	95.3298	18.22813	663.2707
Wxprod	4921	37.23001	18.23892	1.961702	17.3469
Gr-prod	4921	0.824191	0.678805	−6.45402	6.075842
WxGrprod	4921	0.117224	0.11741	−0.23443	1.30445
ln-prod	4921	20.19888	3.860795	5.573728	26.29345
Wxln-prod	4921	7.824521	3.831163	−7.87449	13.85119

TGVA is gross value added, THRS is number of hours worked

TEMP is employment, Prod is productivity measured as per capita GVA

Adjusted with working hours, *W* is weight measured as share of employment

Gr represents growth rate and ln shows natural log

Table 9 LSDV results: at country, regional and industry levels

Variables	Dependent variable: labour productivity growth					
	Country level		Regional level		Industry level	
	WO-SC	W-SC	WO-SC	W-SC	WO-SC	W-SC
	(1)	(2)	(3)	(4)	(5)	(6)
Cons	86.51***	1.696	86.51***	0.314***	0.882***	0.0543***
	(32.38)	(0.90)	(32.38)	(38.09)	(45.04)	(35.50)
λ	−0.103	−0.029	−0.045***	−.056***	−0.220***	−0.0326***
	(−1.98)	(−2.08)	(−10.33)	(−6.13)	(−39.08)	(−24.68)
β	0.036	0.009	−0.015	−0.019	−0.0828	−0.011
N	95	95	1295	1295	7747	7747

Sample: 19 countries, 259 regions, 6 industries and time is 1991–2009

WO-SC and W-SC are without and with structural change, respectively

t values are in parentheses and * 5, ** 1, and *** 0.1 % significance level

In col 5 and 6 used separate id for industry and region

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