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A hierarchical analysis of structural change and labour productivity convergence across regions, countries and industries within the EU

Abstract: This study explores the effect of structural change on the process of labour productivity convergence at different levels of data aggregations (regions, industries, countries), which is also known as hierarchical convergence analysis in the recent literature. Different forms of structural changes have occurred in the European Union (EU), for instance, variations in the share of employment in different industries, variations in the demand pattern, variations in trade patterns and advancement in technology, which may have an influence on the nature of convergence. Earlier studies on convergence have neglected the effect of the structural change, which may have resulted in different conclusion about the convergence. Based on the results, the study found that the nature of convergence changes after considering the effect of the structural change.

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

Keywords: Labour productivity; convergence; structural changes; panel data; panel unit root

1. Introduction

Productivity convergence has been a core area of research in regional economics over the past two decades. Usually, in the literature, GDP per capita is used to test the convergence hypothesis for measuring disparities at regional or country levels.¹ However, there are some other indicators that can be

¹ See for example (Abramovitz, 1986; Baumol, 1986; Dollar and Wolff, 1988; Dollar et al., 1993; Barro and Sala-i-Martin, 1992; Quah, 1993; O'Leary, 1997)

used to test the differences across economies or regions. Testing labour productivity convergence has been widely used by several studies for comparing performance among regions and industries. For instance, Bernard and Jones (1996) stated that productivity levels significantly vary across sectors and across states, as do sectoral output and employment shares. Moreover, Abramovitz (1986) also specified that labour productivity growth and productivity levels are inversely related to different industries and regions. Therefore, it is important to test labour productivity convergence rather than just output or income convergence. According to Melachroinos and Spence (1999) and Filippetti and Peyrache (2013), labour productivity not only affects living standards but also reduces disparities across regions and countries, especially in the long run. Another important determining factor that affects the labour productivity over-time is structural change, which is defined in the literature as a change in sectoral employment share (for details, see Van Ark (1996)). Particularly, in the European Union (EU) context, there have been many structural changes that occurred over time which could be a reason for differences in levels of labour productivity. These differences not only exist across countries but also across regions and industries.² Therefore, the main focus of this paper is to analyse the effect of structural change on the process of labour productivity convergence at different levels of aggregations (regions, industries, countries), which is also known as hierarchical convergence in the recent literature (Fazio and Piacentino, 2018). Furthermore, the analysis at different levels of aggregation is important since there is a possibility of heterogeneity across regions, countries, and industries.³

Besides testing labour productivity convergence, an additional contribution of this paper is the analysis of structural change that gained less importance in the empirical literature (Chenery et al., 1986). These

² For detail see, (Webber and Horswell, 2009; Byrne et al., 2009; Enflo and Hjertstrand, 2009).

³ Some studies discussed and find the evidence of heterogeneity across industries and countries. For detail see (Bernard and Durlauf, 1995; Artige and Nicolini, 2006).

structural changes may affect the process of convergence, but few studies have investigated the impact of structural changes on productivity convergence.⁴ For instance, Van Ark (1996) finds that structural changes may affect productivity and growth, especially when labour moves from low productivity sectors to high productivity sectors. For example, when labour moves from agriculture (low-productive) to manufacturing (high-productive) sector, the result will be an increase the productivity in agriculture sector while a decrease in the productivity in the manufacturing sector, which leads to convergence in labour productivity. Similarly, structural change may foster the productivity convergence at the regional (or country) level when people move from a low productive region to another highly productive region (Niebuhr and Schlitte, 2004).

In the empirical literature, usually, panel data is employed to test the beta (β) or sigma (σ) convergence. Where σ -convergence refers to a reduction in the dispersion of levels of income across economies, the concept of β -convergence explains that poor economies grow faster than rich ones. However, these approaches did not consider the stochastic properties of time- and a cross-sectional dimension and therefore criticised in the literature (for detail see, Quah, 1993; Durlauf and Quah, 1999; Le Gallo and Dall'Erba, 2008). A panel data approach allows macroeconomic variables to be observed over a long period of time, therefore, non-stationarity should be considered in the economic analysis (Baltagi et al., 2005; Carrion-i-Silvestre and German-Soto, 2009). In a more recent study, Naveed and Ahmad (2016) employ panel data techniques to test the convergence of labour productivity aggregate and disaggregate levels. However, they do not consider the stochastic properties of time- and cross-sectional dimension (panel unit root test) and suggest this for future research. Therefore, this study fills the gap by employing a panel unit-root analysis to test stochastic convergence, which takes cares of both times- and cross-

⁴ For detail see, (Kuznets and Murphy, 1966; Gemmell, 1982; Dowrick and Nguyen, 1989; Dollar et al., 1993; Van Ark, 1996; Doyle and O'Leary, 1999).

sectional dependence of the data.

Additionally, available research about convergence hypothesis have focused separately for countries, regions, and industries and arrived at different conclusions (for details, see Abramovitz, 1986; Baumol, 1986; Dollar and Wolff, 1988; Dollar et al., 1993; Barro and Sala-i-Martin, 1992; Quah, 1993; O’Leary, 1997; Doyle and O’Leary, 1999). For example, a few studies found convergence at the country level but not at regional and industry levels for the same list of countries.⁵ Rodrik (2012) find strong evidence of convergence within the manufacturing industry at an industrial level, but not at country levels. Therefore, this paper simultaneously considers the convergence hypothesis at three different hierarchical orders i.e. is country, regions, and industry.

The results of this paper show that there is not sufficient evidence of convergence for countries, but there is for regions after integrating structural change. The industry-specific results indicate that agriculture, construction and market services sectors have strong evidence of stochastic convergence while manufacturing, financial services, and non-market services sectors have no evidence of convergence. Moreover, the results in agriculture, financial services, and non-market services sectors have been changed after integrating structural change which indicates that structural change has an important implication for industry-specific convergence among EU countries. Based on these results, evidence of heterogeneity exists across the industries and regions of EU economies. Moreover, further analysis also reveals that only agriculture and construction sectors at regional levels have strong evidence of convergence whereas all other sectors have no convergence across EU regions. These results show that productivity in agriculture and construction sectors are converging to their steady state at the regional level.

⁵ For detail see, (Dollar and Wolff, 1988; Dowrick and Nguyen, 1989; Dollar et al., 1993; Bernard and Jones, 1996; O’Leary, 1997; Curran and Sensier, 2012; Sondermann, 2014).

The rest of the paper is ordered as follows: Section 2 reviews literature related to the convergence hypothesis. Section 3 discusses the theoretical background and methodology. Section 4 sheds light on data and descriptive statistics. Section 5 reveals the results. Section 6 concludes the discussion.

2. Literature Review

A number of studies related to convergence have been discussed in the literature. The following paragraphs review some selected papers from three different groups of literature. The first group is based on cross-country analysis. The second group consists of regional analysis and the third group of literature focusses on industry and/or industry-specific discussion in their analysis.

To begin with cross-country analysis, the pioneering work has been done by Barro and Sala-i-Martin (1992). Their study was based on country (98 countries from 1960 to 1985) and regional (48 US states from 1840 to 1988) analysis with results showing that poor states tend to catch up with rich states at the speed of 2% per annum. With regards to the country analysis, convergence exists in a conditional sense, meaning that countries are converging to their own steady state. Another study Islam (1995) used the panel data approach to analyse the Total Factor Productivity (TFP) convergence for 96 non-oil, 74 international and 22 OECD countries. They also compared the panel results with cross-section results of other studies. Their findings confirm that conditional convergence exists for most of the countries in the groups but the results from the panel data approach are significantly different from the cross-section regression. A similar study by Evans and Karras (1996) also examines the convergence for two groups of countries. First, for 48 US states during the period of 1929-1991, and the second world sample of 54 countries over the period of 1950-1990. Their results indicate that conditional convergence exists for both groups of countries. Based on Evans and Karras (1996) approach, Gaulier et al. (1999) likewise

examine the convergence for a larger sample based on 86 countries belonging to a world sample, 15 belongs to EU sample and 27 belongs to OECD group during the period of 1960-1990. Their results indicate that there is convergence in the EU and the OECD group of countries but does not exist for the world sample. Furthermore, the common speed of convergence hypothesis is rejected their study. By using a panel unit root test for convergence, Beyaert (2008) finds that absolute convergence exists for the wealthiest countries while conditional convergence holds only for underdeveloped countries.

With regards to regional level analysis, Gardiner et al. (2004) employ the regional level data (211 NUTS 2 regions) for 15 EU countries and find that the regional convergence process is relatively low but regions with lower productivity are continuously improving their relative position within EU. In general, the speed of convergence at the regional level is slow as less than 1% per annum. Similarly, Le Gallo and Dall'Erba (2008) also confirm the presence of labour productivity convergence among EU economies by using a regional data set. However, in their extended sectoral analyses, there was no evidence of convergence except for the services sectors. It is also important to note that they only discussed the importance of sectoral employment share in the process of convergence, but did not use in their empirical method. Curran and Sensier (2012) compare the regional productivity convergence between NUTS 2 and NUTS 3 regions and also compare the convergence for different periods for the same group of regions. According to their results, convergence exists between the period of 1982 and 1992 but does not exist for the period of 1992 and 2006 for NUTS 2 regions. In contrast, labour productivity convergence exists for NUTS 3 regions. They determine that further analysis is needed to uncover the convergence across different aggregation levels.

A number of studies also investigate the productivity convergence at industry/industry-specific levels. For instance, Dollar and Wolff (1988) employ the data for manufacturing industries for the period of 1963-82. Their results confirmed the convergence in all industries, especially those using high

technology in their production techniques. Van Ark (1996) considered the sectoral employment share as an indicator of structural change in the analysis of productivity convergence. Van Ark's findings confirm that structural change plays an important role and gives a proper explanation of productivity convergence in different industries. However, it is necessary to compare the importance of structural change in convergence processes at different levels of aggregation. Another sectoral level study by Bernard and Jones (1996) employs both cross-section and panel unit root approaches for TFP convergence for 14 OECD countries. According to their results, convergence exists at the aggregate level but does not exist at the sectoral level. Similar results are also found by Sondermann (2014) for 12 EU countries as slow convergence exists at the aggregate level while strong evidence of convergence is found at the sectoral level. Despite this, they do not consider the role of structural change in their studies.

The literature cited above has independently tested the convergence hypothesis at either country, industrial, or regional levels. The main issue in these studies is that results are not comparable with different levels since they used different data sets and method to test the convergence. Contrary to the previous studies, this study empirically tests the convergence hypothesis at all levels using the same data and methodology. Furthermore, this study also incorporates structural changes for testing convergence at the aggregate and disaggregates levels.

3. Theory and Methodology: A brief overview

The theoretical debate about convergence begins with neoclassical growth models, as presented by Ramsey (1928); Solow (1956); and Cass (1965). According to these models, if economies are similar in terms of savings, preferences, and technology, then poor economies grow faster than rich ones. As a result, all economies should eventually converge to the same steady-state level. Diminishing marginal

returns to capital is a fundamental assumption of these models. Since developing economies have a lower level of capital, they, therefore, have the potential to grow faster compared to rich economics, or capital-rich countries, as a result of diminishing returns to capital. Additionally, poorer economies may have the ability to replicate the production methods, technologies, and institutions already adopted by richer economies. Usually, convergence is defined as absolute convergence or conditional convergence. Where absolute convergence refers a situation where poorer economies will grow faster than richer ones until they will reach to a common steady-state level (same per capita income level), regardless of their initial endowments (such as saving rate, population growth rates, and capital). On the other hand, conditional convergence is the idea that economies will converge to their own steady-state levels under certain given conditions, and therefore will have individual steady-states levels.⁶ The debate is then extended by the empirical work done by Barro (1991) where the different economies have different rates of human capital and therefore have different steady-states level.

In order to test the convergence hypothesis, growth literature used two main terms of the convergence: Sigma (σ) convergence and Beta (β) convergence (for detail, see, Barro and Sala-i-Martin (1992)). On the other hand, there is an alternative approach called stochastic convergence. According to this approach, convergence can be assumed only if idiosyncratic individual-specific shocks have temporary effects on productivity in country A relative to country B. These relative productivity levels will follow a stationary process. If there is a non-stationary process then relative productivity shocks will lead to permanent deviations from steady-state (Evans and Karras, 1996; Sondermann, 2014). As the data used in this study is based on large time and cross-sectional units (country, industry, and regions), which requires that non-stationarity should be considered when carrying out meaningful economic analyses. Recent

⁶ For detail see, (Solow, 1956; Barro and Sala-i-Martin, 1992)

developments in the econometric literature allowed us to use the stochastic concept of convergence based on generalizing unit root tests under panel data framework (for detail, see (Banerjee, 1999; Baltagi et al., 2005; Breitung and Pesaran, 2008)). Furthermore, it also allows for the test of group-wise convergence. The traditional methods of testing the convergence hypotheses, such as beta or sigma-convergence, do not specifically incorporate time-series properties in panel data. Therefore, a stochastic approach is used instead of beta or sigma convergence approaches as used by other researchers (Pesaran, 2004; Banerjee et al., 2004; Carrion-i-Silvestre and German-Soto, 2009; Solarin et al., 2018)

3.1 Stochastic Convergence Approach

The concept of stochastic convergence is based on unit root and co-integration analysis in time series (Bernard and Durlauf (1995)). According to this approach, the panel unit root test can be used to test the convergence for any series. Usual unit root tests are applied when the convergence between two-time series is under consideration. Whereas, if we have more than two series (for countries, regions or industries), panel unit root tests allow for a group-wise test of convergence. Furthermore, panel unit root tests have more advantages by providing a higher power (via pooling information) across panel units compared to the univariate variant (Levin et al., 2002; Im et al., 2003)

Following Bernard and Durlauf (1995) and Carrion-i-Silvestre and German-Soto (2009), let $y_{i,t}$ is the per capita output of the i -th time series for $i=1, \dots, N$ and these economies are said to converge if a common trend μ_i and finite parameters $\omega_1, \dots, \omega_N$ exist so that

$$\lim_{t \rightarrow \infty} (y_{i,t} - \mu_t) = \omega_i, \quad (1)$$

In order to account for the unobservable common trend, the average of the N economies can be defined as,

$$\lim_{t \rightarrow \infty} (\bar{y}_t - \mu_t) = \bar{\omega}_t \quad (2)$$

Where $\bar{y}_t = N^{-1} \sum_{i=1}^N y_{i,t}$ and $\bar{\omega}_t = N^{-1} \sum_{i=1}^N \omega_i$ are average of the log of per capita income and average of the final parameter respectively. If there is a common trend so that $\lim_{t \rightarrow \infty} (\bar{y}_t - \mu_t) = 0$, and subtracting (2) from (1), stochastic convergence exists if and only if

$$\lim_{t \rightarrow \infty} (y_{i,t} - \bar{y}_t) = \omega_i, \quad (3)$$

In equation (3), convergence is said to be absolute if, and only if, the unconditional mean $\omega_i = 0$, while convergence is said to be conditional when $\omega_i \neq 0$. Stochastic convergence occurs when per capita income of region (country or industry) i relative to the benchmark region (country or industry) is stationary. It also shows that region i is close to the steady-state level. Furthermore, stochastic convergence also implies that differences across countries are not persistent and long-run movements in regional GDP are driven by common technology shocks. In this case, the presence of stochastic convergence can be tested assessing the stochastic properties of $(y_{i,t} - \bar{y}_t)$ using unit root and stationary test statistics (Bernard and Durlauf, 1995; Evans, 1998; Carrion-i-Silvestre and German-Soto, 2009). The procedure to test the panel unit root is analogous to the test of convergence in panel data sets.

The panel unit root test is the extension of a time series based unit root tests. Consider a simple panel data model with the first-order autoregressive component.

$$y_{i,t} = \rho_i y_{i,t-1} + \gamma_i z_{i,t} + \epsilon_{i,t} \quad (4)$$

Where $i = 1, \dots, N$ indexes panel; $t = 1, \dots, T_i$ indexes time; $y_{i,t}$ is the variable being tested and $\epsilon_{i,t}$ is a stationary error term. The $z_{i,t}$ is panel specific mean or time trend, depending on the assumptions of the model (which could be fixed effect). Equation (4) may be written as dynamic panel data model as

follows,

$$\Delta y_{i,t} = \varphi_i y_{i,t-1} + \gamma_i z_{i,t} + \epsilon_{i,t} \quad (5)$$

Where $\varphi_i = \rho_i - 1$, so that the null hypothesis is $H_0 : \varphi_i = 0$ or non-stationary (unit root / no convergence) for all i versus the alternative $H_1 : \varphi_i < 0$ means stationary or presence of convergence. There are various panel unit root tests available which differ in terms of assumptions. The most usable tests in the empirical literature are Levin-Lin-Chu (LLC) Test (Levin et al., 2002), Im-Pesaran-Shin (IPS) test (Im et al., 2003) and the Fisher-type test (Maddala and Wu, 1999).⁷ All these tests assume unit roots in the null hypothesis against the alternative hypothesis of stationary (convergence). However, the procedure of implementation is different. These entire tests are based on a parametric approach except the Fisher-type test, which is non-parametric. Short presentation of these tests is presented here, however, the detail about the individual test can be found in the appendix Section A1.

Levin-Lin-Chu (LLC) Test:

LLC test by Levin et al. (2002) is based on equation (5) and the augmented model with additional lags of the dependent variable can be written as follows,

$$\Delta y_{i,t} = \varphi y_{i,t-1} + \gamma_i z_{i,t} + \sum_{j=1}^p \theta_{ij} \Delta y_{i,t-j} + \mu_{i,t} \quad (6)$$

Where the autoregressive parameter φ is common for all panels. After including sufficient lags of $\Delta y_{i,t}$ the error term $\mu_{i,t}$ will be a white noise. Under the null hypothesis of a unit root, $y_{i,t}$ is non-stationary

⁷ The test is suggested by Fisher (1922) and defined by Maddala and Wu (1999).

Im-Pesaran-Shin (IPS) test:

The IPS test (Im et al., 2003) relaxes the assumption of the common autoregressive parameter for all panels φ_i and does not require balanced datasets as required by LLC. Augmented form of IPS test is shown as following.

$$\Delta y_{i,t} = \varphi_i y_{i,t-1} + \sum_{j=1}^p \theta_{ij} \Delta y_{i,t-j} + \epsilon_{i,t} \quad (7)$$

Under the null hypothesis, all panels contain a unit root, $\varphi_i = 0$ for all i . The alternative is that the fraction of panels that follows the stationary process or has nonzero φ_i that is, as N tends to infinity, the fraction N_1/N converges to a non-zero value.

Fisher-type test

The Fisher-type test is basically a non-parametric test which is explained by Maddala and Wu (1999). This test is simple and straightforward to use and is a better test compared LLC and IPS tests since it based on combining the p -value obtained by test-statistics from the results of individual unit root test for each panel.⁸ The Fisher-type test can be defined as follows.

$$\lambda = -2 \sum_{i=1}^T \ln(\Pi_i) \quad (8)$$

Where λ is the test statistic and Π_i is the p -value from the individual unit root test which has a χ^2 distribution with $2N$ degree of freedom. In Stata, this test combines p -value from the panel-specific unit root tests using the four different methods proposed by Choi (2001). The detail descriptions of these tests is given in the appendix A1.

⁸ Furthermore, they also proved that IPS test is better than LLC, because LLC test is based on the homogeneity of the autoregressive parameter while IPS test based on heterogeneity of the autoregressive parameter.

3.2 Structural Change

In order to measure the structural change, we used the methodology mainly developed by van Ark (1995) and used by several other studies (see, (Doyle and O’Leary, 1999; van der Linden and Dietzenbacher, 2000; Chenery et al., 1986; Naveed and Ahmad, 2016). According to this definition, structural change not only contains the shift in sectoral employment share but also adds the changing patterns of technology, factors of production, trade, and demand of goods and services. Consequently, it must affect the whole economy at aggregate and disaggregate levels. However, the effect of labour productivity convergence could be different across different aggregation levels (country, region, industry). Another reason for using this method, it directly measures the sectoral share of labour which is more appropriate for testing labour productivity convergence in the presence of structural change.

For the estimation purpose, we construct the labour productivity weighted by structural change measure (same as used by earlier studies). The labour productivity is calculated as gross value added (GVA) per working hours and then weighted by structural change measure. The datasets are prepared at three levels from equations 9-11: country (c), region (r), and industry (i).

$$\text{Structural change at industry level: } W.LP_i^r = \left[\frac{L_i}{L_r} \right] . LP_i^r \quad (9)$$

Where LP_i^r is industrial labour productivity in region r and L_i/L_r represents industrial employment share in region r represents the effect of structural change (as weight). The effect of structural change will be higher if there is either more number of labour moves into industry (i) or moves out from the region (r).

$$\text{Structural change at the regional level: } W.LP_r^c = \left[\frac{L_r}{L_c} \right] . LP_r^c \quad (10)$$

Where LP_r^c is regional labour productivity in country c and L_r/L_c represents regional employment share

in country c represents the effect of the structural change.

$$\text{Structural change at country level: } W.LP_c^T = \left[\frac{L_c}{L_T} \right] . LP_c^T \quad (11)$$

Where LP_T^c is labour productivity in country c and L_c/L_T represents labour share in country c , as labour is mobile across EU countries and captures the overall effect of the structural change at the country level.⁹

4. Data and Variables

This paper employs three types of data set for empirical analysis: 1) country level, 19 countries from the EU, 2) regional level, 259 regions at NUTS 2 level, 3) industry level, consisting of 6 industries, including agriculture, energy & manufacturing, construction, market services, financial services, and non-market services. All datasets are available during the period of 1991-2009. Tables 1 and 2 list the name of countries, regions, and industries. The main reason for using the benchmark sample (regions, country, and industries) is that we were interested to test the convergence in hierarchical order (country, regions and industries), therefore, we used a common sample where the data set is more consistently available for all three levels (country, regions, and industries). The primary source of data is Cambridge econometrics and the main variable is labour productivity measured as gross value added (GVA) per working hours. Following the early literature, we used sectoral employment share as a measure of structural change.¹⁰ The data set at the aggregate (country) and disaggregate level (region and industry) is similar to the study by Naveed and Ahmad (2016).

Table 1: Countries and Regions

Nr.	CODE	Countries	Nr.of.Regions
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⁹ Naveed and Ahmad (2016) have used this methodology for measuring structural change.

¹⁰ Structural changes usually measured as sectoral shares of employment. For detail see, (Kuznets and Murphy, 1966; Gemmell, 1982; Chenery et al., 1986; Dowrick and Nguyen, 1989; Dollar et al., 1993; Van Ark, 1996; Doyle and O'Leary, 1999).

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 2: 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, Storage and Communications(I)	G+H+I
5	Financial Services Financial intermediation (J) Real estate, renting and business activities (K)	J+K
6	Non-Market Services	L+M+N+O+P

5. Empirical Results

The empirical results for stochastic convergence for labour productivity are presented in this section. For that purpose, we employed two parametric (LLC and IPS) and one non-parametric (Fisher-type) panel unit root tests for convergence.

Table 3 reports the results from Fisher-type panel unit root test for country and region levels. The Fisher-type test uses the p-values obtained from individual panel unit root test for each cross-sectional unit, therefore, this test is considered better than the other two tests as mentioned by Maddala and Wu (1999).¹¹ The results in Table 3 are based on equation (6) and test statistics are based on equation (8). There are 6 columns in Table 3 where column 1 to 3 reports the results without structural change (WO-SC), whereas columns 4 to 6 report the results with structural change (W-SC). Furthermore, we also applied three different options while testing the stochastic convergence. The first option is without using drift and trend as '*no-drift*'.¹² The second option is '*demean*' that subtract the cross-sectional averages from the series in order to diminish the effect of cross-sectional dependence. The third option includes both drift and demean together as '*demean + drift*', for more details on different options see Maddala and Wu (1999) and Choi (2001). We have reported the results with three different options here. However, the most relevant one for this study is demean option because it reduces the effect of cross-section dependence. The values reported in the table test statistic and their p-values are from the 'Modified inverse chi-squared' method.¹³ Moreover, the rows of Table 3 report the results at country and regional levels.

The results reported in the first row are based on 19 EU countries. Based on the results in the first three columns without structural change, we reject the null hypothesis of no convergence (unit roots in the

¹¹ The results for other two panel unit root tests (LLC and IPS) are available on request from the authors.

¹² Where drift mean a constant is included in the specifications while no-drift does not include constant. This is a standard procedure followed by empirical literature for robustness check.

¹³ Fisher test reports 4 different values of test-statistic (provide same decision) but for the convenience, we only report modified inverse chi-squared and others are available on request.

panel). The results are significant at 1% level, meaning that over time, some countries are converging to a steady-state level. The results with incorporating structural change are reported in column 4 to 6. The test statistics are significant only at 10% level and if we assume 1% or 5% level of significance then we may not reject the null hypothesis of no convergence (or unit root) at the country level. These findings also indicate that after controlling for structural change the results have been changed which has important implication in explaining the convergence across EU countries.

The results at the regional level are reported in the second row of which consists of 259 regions at NUTS 2 level during the period 1991-2009. According to the results, stochastic convergence exists in both cases with and without incorporating structural change. These results imply that regional productivity is converging to their regional steady-state level. Furthermore, the results at the regional level are different than country level with respect to conditional convergence which implies that regions are more specialized, united and integrated than the countries. The results confirm the earlier findings by (Naveed and Ahmad, 2016), however, the results from stochastic convergence are more reliable in the sense that it takes care of time-series and cross-sectional dependence properties of the panel data.

Table 3: Stochastic Convergence (Fisher test) Results

	WO-SC			W-SC		
Models	1	2	3	4	5	6
	No-drift	Demean	demean+drift	No-drift	demean	demean+drift
Country	5.17 (0.000)	10.14 (0.000)	18.326 (0.000)	4.01 (0.056)	2.77 (0.050)	2.87 (0.066)
Region	47.42 (0.000)	68.11 (0.000)	9.35 (0.000)	10.14 (0.000)	52.32 (0.000)	9.46 (0.000)

Note: test statistics are 'Modified inverse chi-squared Pm' and p-values are in parenthesis. Three other test statistics, 'inverse chi-squared, inverse normal and inverse logit t' are available on request but the p-values are close to each other.

Four option use for test statistics; 1-no constant and no trend, 2- cross-sectional demean and 3- demean and drift together.

Panel dimension is 19 for countries, 259 for regions and time period 1991-2009

In summary, after controlling for structural change, we found no convergence for the countries, but regions did show convergence. These results provide two important implications. The first is that after incorporating structural change, the stochastic model predicts the convergence after taking care of time- and cross-sectional dimension of panel data, which we believe more reliable. The second implication is that regions in EU countries are similar in terms of size and function, and more united and integrated than countries and industries. Having different results at country and regional levels make it interesting to investigate stochastic convergence for different industries. Therefore, we extended our analysis by testing the stochastic convergence at industry-specific levels and results are reported in Table 4.

The industry wise results for 19 countries are reported in Table 4. According to these results for the agriculture sector, the null hypothesis of no convergence is accepted when we do not incorporate the structural change, while the null is rejected when we incorporated structural change. This result indicates that structural change plays an important role in identifying the convergence in the agriculture sector. In the case of manufacturing sectors, there is evidence of convergence when we do not control for a structural change. This result is in line with Rodrik (2012) who also finds strong evidence of convergence in manufacturing industries. Contrary to the agriculture sector, the manufacturing sector has no convergence after incorporating structural change, which indicates that manufacturing sectors across EU countries are not converging to the common steady-state. If we look at the construction and market sectors, stochastic convergence exists before and after incorporating structural change. It indicates that there is no significant effect of a structural change in construction

and market services. Similar to the manufacturing sector, non-market services and financial services sectors have convergence before incorporating structural change but no convergence after incorporating structural change. This means that specialization plays an important role in converging processes at industry levels as well.

Table 4: Stochastic Convergence (Fisher test) industry-specific within a country

	With-SC		W-SC	
Models	1	2	4	5
	No-drift	Demean	No-drift	Demean
Agriculture	1.34	3.09	3.95	4.21
	0.11	0.06	0.00	0.00
Manufacturing	1.51	1.81	0.76	0.03
	0.080	0.04	0.21	0.43
Construction	4.23	3.98	2.71	2.95
	0.00	0.00	0.03	0.015
Market Services	3.98	4.10	1.34	5.64
	0.00	0.00	0.012	0.00
Finan-Services	5.95	6.23	0.566	2.81
	0.00	0.00	0.69	0.17
Non-Market-Services	3.35	4.22	0.15	1.71
	0.02	0.00	0.39	0.049

Note: test statistics are 'Inverse normal Z test' and p-values are in parenthesis. Three other test statistics are computed in the Fisher test but for a finite N sample, Z test is relevant.

No-drift: option in the test which does not include constant and drift.

Demean: option in the test which subtracts the cross-sectional mean from the series.

Panel dimension: 19 countries for each industry and time period 1991-2009

In summary, the industry-specific results at country level indicate that after incorporating structural change only agriculture, construction and market services sector have strong evidence of stochastic

convergence while manufacturing, financial services, and non-market services sectors have no evidence of convergence. Moreover, the results in agriculture, financial services, and non-market services sectors have been changed after incorporating structural change which indicates the importance of structural change in explaining the industry-specific convergence of labour productivity among EU countries. These results also imply that there is heterogeneity across industries in EU countries (also confirmed by Bernard and Jones (1996)). Having different results across different industries at country levels, it would also be interesting to investigate the stochastic convergence across different industries at the regional level.

Table 5: Stochastic Convergence (Fisher test) industry-specific within a region

	WO-SC		W-SC	
Models	1	2	4	5
	No-drift	Demean	No-drift	Demean
Agriculture	33.45	43.33	62.83	67.887
	0.01	0.42	0.031	0.042
Manufacturing	33.81	44.13	33.47	46.743
	0.041	0.000	0.04	0.090
Construction	44.21	32.23	56.09	72.002
	0.051	0.000	0.041	0.011
Market Services	35.21	8.55	49.53	12.775
	0.02	0.22	0.05	0.131
Finan-Services	68.22	75.83	33.44	88.247
	0.031	0.21	0.32	0.063
Non-Market-Services	39.77	9.27	31.22	15.455
	0.101	0.21	0.053	0.631

Note: test statistics are ‘Modified inverse chi-squared Pm test’ and p-values are in parenthesis. Three other test statistics are computed in the Fisher test and available on request.

No-drift: option in the test which does not include constant and drift.

Demean: option in the test which subtracts the cross-sectional mean from the series.

Panel dimension: 259 regions for each industry and time period 1991-2009

The industry-wide results for 259 regions are reported in Table 5. According to these results for the agriculture sector, no convergence exists when structural change is not incorporated, while the null is rejected at 5% level with structural change incorporated. If we look at the results of the manufacturing sector, there is strong evidence of convergence before incorporating structural change but no convergence has been found after incorporating structural change.

Similar to the agriculture sectors, there is significant evidence of convergence for the construction sector with structural change. In summary, only agriculture and construction sectors have strong evidence of convergence after incorporating structural change, but all other sectors have no convergence across EU regions. These results show that productivity in the agriculture and construction sectors is converging to their steady-state at the regional level.

6. Conclusion

In this paper, we try to investigate the impact of structural change on labour productivity convergence at aggregate and disaggregate (country, regional, industrial) levels. For the empirical purpose, we use the country (19 EU countries), regional (259 NUTS 2 regions) and industrial (6 industries) data during the period of 1991-2009. A panel unit root test is employed to test the convergence hypothesis. In particular,

this paper considers convergence analysis at different hierarchical orders (country, regions, and industry). Furthermore, this paper properly measures and integrates the impact of structural change in labour productivity and then tests the labour productivity convergence weighted by the structural change at three hierarchical levels.

The results of this study show that, after incorporating structural change, convergence exists at the regional level, but not at the country level. This implies that after integrating structural change, the stochastic model predicts the true nature of convergence at regional levels. The reason for regional convergence could be that the regions in EU countries are similar, in relations to their size and function, and more united and integrated than countries and industries. Moreover, we investigate stochastic convergence for different industries separately. The industry-specific results indicate that only agriculture, construction and market services sector have strong evidence of stochastic convergence while manufacturing, financial services, and non-market services sectors have no evidence of convergence. Specifically, the results for agriculture, financial services, and non-market services sectors changed after incorporating structural change which indicates the significance of structural change and specialization at industry levels in explaining labour productivity convergence among EU countries. The explanation about specialization is consistent with Rodrik (2012). These results also confirm the heterogeneity across different aggregation levels. In addition, we analyse stochastic convergence at the regional level for different industries. According to this analysis, only the agriculture and construction sectors have strong evidence of convergence after incorporating structural change but all other sectors have no convergence across EU regions. These results imply that structural change plays an important role in the convergence process of the agriculture and construction sectors. The reason for this could be the different rate of specialization in different industries, as also highlighted by Rodrik (2012).

In summary, an important inference from this study is that convergence varies across a different unit of analysis. Therefore, one should be careful in interpreting the general results at different aggregation (country, region, and industry) levels. Additionally, there is an ongoing process of structural change that is taking place in the whole economy, which should be considered for convergence analysis. It is obvious that any structural change that supports the relatively less developed area or regions will have a greater effect on the process of convergence.

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Appendix

A1: Panel unit-root tests for convergence

Levin-Lin-Chu Test (2002)

Levin-Lin-Chu (LLC) test (Levin et al. (2002)) is based on equation (5) where $\epsilon_{i,t}$ may create the problem of serial correlation, so to overcome this problem, the augmented model with additional lags

of the dependent variable can be written as follows,

$$\Delta y_{i,t} = \varphi y_{i,t-1} + \gamma_i z_{i,t} + \sum_{j=1}^p \theta_{ij} \Delta y_{i,t-j} + \mu_{i,t} \quad (a1)$$

In equation (6) the autoregressive parameter φ is common for all panels. After including sufficient lags of $\Delta y_{i,t}$ the error term $\mu_{i,t}$ will be a white noise. Under the null hypothesis of a unit root, $y_{i,t}$ is non-stationary. The OLS estimate of equation (6) to be biased toward zero because of the inclusion of a fixed effect term but LLC test produces a bias-adjusted t statistic which has an asymptotically normal distribution (Maddala and Wu, 1999).

Im-Pesaran-Shin test (2003)

The Im-Pesaran-Shin (IPS) test (Im et al., 2003) relaxes the assumption of the common autoregressive parameter for all panels φ_i and does not require balanced datasets as required by LLC. The starting point for the IPS test is a set of Dickey-Fuller regressions, the same as in equation (5) which is based on the mean of the individual Dickey-Fuller statistics for each part of the panels. The fundamental difference between IPS and LLC tests is that in the IPS equation (5) φ_i is panel specific, indexed by i , whereas, in equation (6) of LLC, the φ term is constant. Furthermore, the IPS test assumes $\epsilon_{i,t}$ is independently normally distributed for all i and t that allows $\epsilon_{i,t}$ to have heterogeneous variance σ_i^2 across panels. In order to avoid the serial correlation, one can augment the regression equation (5) with further lags of the dependent variable as shown in the following equation.

$$\Delta y_{i,t} = \varphi_i y_{i,t-1} + \sum_{j=1}^p \theta_{ij} \Delta y_{i,t-j} + \epsilon_{i,t} \quad (a2)$$

Under the null hypothesis, all panels contain a unit root, $\varphi_i = 0$ for all i . The alternative is that the fraction of panels that follows the stationary process or has nonzero φ_i that is, as N tends to infinity,

the fraction N_1/N converges to a non-zero value. Where N_1 is the number of panels that are stationary. The IPS test uses separate unit root tests for the N cross-section units (Maddala and Wu (1999)).

Fisher-type test

The Fisher-type test is basically a non-parametric test which is explained by Maddala and Wu (1999). They compare the two well-known panel data unit root tests, LLC and IPS, with the Fisher-type test. According to Maddala and Wu (1999), this test is simple and straightforward to use and is a better test compared LLC and IPS tests since it based on combining the p -value obtained by test-statistics from the results of individual unit root test for each panel.¹⁴ The Fisher-type test has only one drawback that p -value has to be derived by Monte Carlo simulation. The IPS test, on the contrary, has available tables for p -value. The Fisher-type test can be defined as follows.

$$\lambda = -2 \sum_{i=1}^T \ln(\Pi_i) \quad (a3)$$

Where λ is the test statistic and Π_i is the p -value from the individual unit root test which has a χ^2 distribution with $2N$ degree of freedom. In Stata, this test combines p -value from the panel-specific unit root tests using the four different methods proposed by Choi (2001).

¹⁴ Furthermore, they also proved that IPS test is better than LLC, because LLC test is based on the homogeneity of the autoregressive parameter while IPS test based on heterogeneity of the autoregressive parameter.