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Convergence and growth. Labour productivity dynamics in the European Union

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ABSTRACT

This paper investigates labour productivity dynamics for 1263 regional economies of the European Union during 1991–2007. Despite convergence is usually found to occur conditionally to economy-wide factors, results reveal a clear process of unconditional convergence for financial and business-related market services. Such an evidence is not found for manufacturing and aggregate productivity, for which long run distribution dynamics are characterized by bimodality. The decomposition of the growth rate of aggregate labour productivity reveals that pure productivity gains drive growth. Structural change plays a minor role in the process, however it halves the contribution of the manufacturing sector for the richest regions, while it enhances the weight of financial market services.

1. Introduction

The neoclassical model implies that one should find evidence of *absolute* convergence, in the sense that poor economies are expected to grow unconditionally faster than richer ones (Barro and Sala-i Martin, 1992; Mankiw et al., 1992). The theoretical groundings of such an hypothesis are in the original model by Solow (1956), from whose steady state condition the empirical equation is derived[1]. Such a line of research dates back to Gerschenkron (1962) and has been the main core of growth theory and empirical work, also in historical perspective (Baumol, 1986). However, the standard empirical result tends to provide little support to the *absolute* hypothesis, usually reporting convergence only conditionally to economy-wide factors (Barro, 1991; Barro and Sala-i Martin, 1992). Nevertheless, recent empirical studies, notably by Rodrik (2011) and Rodrik (2013), find evidence of unconditional convergence whenever the focus is displaced from the aggregate level to the manufacturing sector. These results are consistent with the idea that convergence does not need to apply to the economy as a whole, but it can still take place in some specific modern sectors particularly suited for the flow and adoption of innovative activities[2]. The relevance of these findings is strengthened by the heterogeneity of countries included in Rodrik's analysis, compared to previous studies in which absolute convergence was found for homogeneous samples, such as the OECD countries in Baumol (1986) or the US states in Bernard and Jones (1996c). Less attention has been devoted to the services sector. Nevertheless, there is reason to suspect that absolute convergence could apply because of the standardized technologies of production. Empirical evidence consistent with such an argument is reported by Bernard and Jones (1996a) in a sample of 14 OCED countries.

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[1] The equation to be empirically estimated commonly is a general version of the original Solow model, known as Barro's equation (Caselli et al., 1996; Durlauf and Quah, 1999).

[2] For instance, this argument is proposed by Bernard and Jones (1996b), which however find no empirical support for absolute convergence in manufacturing.

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This paper sets in this framework by providing empirical evidence for the European Union (EU). Adopting both a non parametric approach and distributional analysis tools, convergence and growth are investigated for a large sample of EU regional economies, focusing on aggregate, manufacturing and market services labour productivity. Is unconditional convergence observed at the aggregate level? Does it take place for sectors? How do sectoral dynamics explain differences in aggregate growth rates? These questions are of interest for at least a couple of reasons. First, the present analysis is an empirical test of the Solow model using a sample for which one should suspect selection bias to apply. Indeed, the EU is reasonably homogeneous and the inclusion of the Eastern regions should favour the emergence of the canonical negatively sloped curve. Moreover, it is a common market in which commodities, capital and people are free to circulate (Single European Act 1992). Finally, policies addressing internal inequalities have been implemented over the years, under the label of Convergence and Cohesion Objective. Despite this, results do not satisfy these expectations. Secondly, empirical evidence of (non) convergence may have some relevant policy implications in the EU scenario. Indeed, social and economic cohesion is the issue which European policies have been addressing the most. However, the EU does not seem to be on track in reducing regional disparities and the last economic crisis has exacerbated such an issue[3] (European Commission, 2013). The present analysis does not address directly the role of policy factors. However it is informative about the dynamics of labour productivity for almost two decades in which European, national and regional programs have been implemented. Therefore, finding no evidence of unconditional convergence for aggregate labour productivity signals that policies were not able to reduce disparities within the EU, despite this has been the primary target of regional programs. A similar result at the sectoral level - especially for manufacturing - would also suggest that EU integration policies aimed at promoting innovation and technological transfers have been unsuccessful in favouring increased efficiency and market integration of less productive regions.

In the literature there are two main approaches for investigating convergence: growth (β) regressions and distributional analysis (Durlauf and Quah, 1999). The methodology used in this paper implements both of them in a complementary way, also modifying the former in order to provide more accurate information on the growth process. Indeed, a standard growth regression usually estimates a cross-sectional model with the growth rate of labour productivity (income) expressed as a linear function of its initial level. Evidence of a negative relationship would suggest that a convergence process is in place, as in Rodrik (2013). However, results are heavily affected by the imposed linear relationship and non-linearities cannot be identified. Hence, in what follows the standard β regression is replaced by a semiparametric model in which the growth rate of labour productivity is expressed as an unspecified function of its initial level. This allows to identify both non-linearities and the existence of more than one potential *steady state* equilibrium in the growth path. However, regressions inform only on the average behaviour of the sample and on convergence towards the steady state, while no information concerning relative performance, mobility and persistence within the distribution can be drawn (Quah, 1996). Therefore, the second main approach is used by performing distributional analysis following Quah (1996) and Quah (1997). Results will (i) inform on relative performance of economies, (ii) allow to trace the evolution of the overall distribution overtime and (iii) provide complementary information for interpreting results of semiparametric regressions. A comparison between the methodology of this paper and alternative approaches is in Appendix B.

Finally, the structural composition of economies heavily affects their capacity to produce output. Some sectors are intrinsically less productive, while others are characterized by high innovation opportunities, which in turn imply higher growth rates. Aggregate growth is driven by both increases in output per worker and structural change, i.e. switches from less to more productive sectors. For instance, Bernard and Jones (1996b) find that productivity gains are the main source of aggregate catching up, while structural change is found to be marginal. Thereafter, empirical studies focused on the sectoral determinants of productivity growth and on differences among countries. An analysis of this kind is done in the last Section, following the decomposition of productivity growth as in Cimoli et al. (2011). This informs about the sectoral sources of aggregate growth[4].

The paper proceeds as follows. Section 2 presents the data and the methodology. Section 3 reports the non parametric estimates for aggregate, manufacturing and market services productivity. In Section 4, distributional analysis tools are used to analyse aggregate productivity dynamics and its sectoral determinants. In Section 5, aggregate productivity growth is decomposed in pure gains and structural change components and sectoral contributions are computed. Concluding remarks follow.

2. Data and methodology

The analysis draws upon territorial units at the NUTS3 level according to the classification adopted by Eurostat[5]. Data on Gross Value Added (GVA) and employment are taken from the Cambridge Econometrics (CE) database. The sample includes 1263 regional economies of the European Union, belonging to Belgium, Czech Republic, Denmark, Germany, Estonia, Greece,

[3] In particular, it has been argued that German policies and the European conservative response package have been damaging the poorest economies, while favouring the richest. See for instance Davanzati et al. (2009). The discussion on this point was already ongoing before the surge of the crisis. Indeed, economic theory does not provide unique results about the effects of austerity policies on economic activity and output growth. The same holds for the consequences of fiscal retrenchment on neighbours' economies. See Blinder (1997) and Barba (2001).

[4] Further insights about the determinants of productivity growth can be obtained by decomposing the growth rate in output per hour worked and hours per employees. This is not the scope of this paper, also data on hours per employee were not available. For an approach of this kind, see Gordon (2003), Gordon (2010) and Van Ark et al. (2005).

[5] The NUTS classification (Nomenclature of Territorial Units for Statistics) is a hierarchical system for dividing up the economic territory of the EU. In particular, NUTS0 corresponds to the country level, while NUTS1 to NUTS3 correspond to smaller territorial units, listing 98 regions at NUTS1, 276 regions at NUTS2 and 1342 regions at NUTS3 level.

Table 1
Descriptive statistics: labour productivity.

Sector	1991	2007	Annual growth rate	Std. Dev. 1991	Std. Dev. 2007
Agriculture	9.561	10.120	0.050	1.047	0.990
Construction	10.207	10.285	0.005	0.775	0.537
Manufacturing	10.200	10.836	0.040	0.842	0.705
TCD	10.120	10.366	0.015	0.668	0.531
F&O	10.915	11.125	0.013	0.733	0.488
Non-Market	10.067	10.198	0.008	0.777	0.568
Aggregate	10.190	10.537	0.022	0.768	0.594

Spain, France, Ireland, Italy, Lithuania, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and the United Kingdom. Using the smallest territorial unity in the Eurostat classification (NUTS3) distinguishes the present analysis from the standard approach which usually considers the country as the reference unit. It can be argued that the smaller the geographical scale, the more fragmented is the available statistical information (Corrado et al., 2005). However, adopting a deeper regional focus helps identifying local specificities which would be lost at a higher regional level. This is particularly important the wider the sub-national differences and the higher the policy role attributed to local public administrations. Since this is exactly the case of the EU, what follows uses the NUTS3 subregional economies as the statistical unit. The CE database is consistent with NACE Rev. 2 and adopts the sectoral definitions published by Eurostat under NACE Rev. 1.1[6]. This allows to decompose both GVA and employment at the sectoral level, i.e. agriculture, construction, non market services, manufacturing and market services. The latter are divided in two subsectors. Transportation, communication and distribution services (TCD) constitute the first. Financial, real estate and business-related activities (F&O) belong to the second one[7]. Overall, six sectors are analysed. Data refers to the period 1991–2007.

Labour productivity is the main variable of interest, defined as GVA over the number of employees, standardized with respect to the mean of each year[8]. Table 1 reports descriptive statistics. Data are in logarithms. F&O is the most productive sector in 2007, followed by manufacturing, TCD and construction. However, market services are characterized by an annual growth rate around three times smaller (1.5% for TCD, 1.3% for F&O) than manufacturing (4%). The disappointing performance of market services started in 1996 and it is often identified as the main determinant of low aggregate growth in Europe (Van Ark et al., 2008; OMahony et al., 2010; Timmer et al., 2010; LIGEP, 2013). Manufacturing is the sector growing the most together with agriculture, even though the latter has the lowest level of labour productivity. Both sectors have the highest standard deviation, while market services have the lowest. Overall, the standard deviation sharply decreases overtime in every sector, indicating a process of σ convergence. Given the sectoral differences, aggregate labour productivity is determined by the structural composition of output and employment. This is the topic of the last Section. A mapping of relative levels of aggregate productivity is presented in the Appendix.

Concerning the methodology used, a semiparametric model is estimated rather than the standard linear β regression. This allows to highlight non-linearities in the relationship between the growth rate and the initial level of productivity. Then, the distributional analysis originally proposed by Quah (1996) and Quah (1997) is performed, using the statistical instruments as in Silverman (1986), Bowman and Azzalini (1991) and Quah (1997). In particular, densities are estimated by adaptive kernel (Silverman, 1986), conditional and ergodic distributions estimates are computed to investigate distributional dynamics[9] (Quah, 1997; Feyrer, 2008; Fiaschi and Lavezzi, 2007; Fiaschi et al., 2011). Finally, the growth rate of aggregate labour productivity is decomposed following the procedure in Cimoli et al. (2011).

3. Absolute convergence

To assess if regions are converging in absolute terms, the average growth rate of labour productivity is regressed on the initial level. Absolute convergence is observed if the poorer grow systematically at a faster pace than the richer, unconditionally to any other factor.

[6] The Statistical classification of economic activities in the European Community (NACE) is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity. NACE Rev. 2 is the last revision implemented in 2007.

[7] Business-related services include computer and software activities, research and development, engineering, renting of machinery. Financial services are financial intermediation and related activities, insurance and pension funding. All the other market services are in the TCD group.

[8] Increasing labour productivity is a fundamental source of economic growth. However, it may be that sharp reductions in employment artificially either maintain high or increase productivity levels, even though no actual gain in GVA occurs. This is the case of Spanish and Irish regions during 2008–2010 and it is defined as *intensive* model of growth (Marelli et al., 2010; 2012). Such a phenomenon is not observed in the sample used in this study.

[9] The ergodic density represents the long term behaviour of the distribution, under the assumption that the underlying process is time invariant. It solves $f_\infty(z) = \int_0^\infty g_\tau(z|x) f_\infty(x) d_x$, where the x and z are the two levels of the variable, $g_\tau(z|x)$ is the density of z conditional on x, τ periods ahead. In what follows, $\tau = 10$ for the whole period estimation, $\tau = 3$ for the subperiods. The adaptive kernel estimator is used, following the approach as in Johnson (2005), Fiaschi and Lavezzi (2007).

Table 2
Estimation of Eq. (1): Aggregate productivity.

	Growth path estimate
Intercept	0.023***
Non-param term	
$y_{i,1991}$	8.346***
R.sq (adj)	0.566
GCV score	0.0002

Note: *** indicates significance at 1%. For the smooth term, estimated degrees of freedom (EDF) are reported. $n = 1263$.

Differently from the standard linear regression, a semiparametric model is estimated, i.e.

$$\bar{g}_i = a + \phi(y_{i,1991}) \tag{1}$$

where $\bar{g}_i$ is the average growth rate of each region along the time period, ϕ is the smooth term and $y_{i,1991}$ is relative labour productivity of region i at the beginning of the period. Eq. (1) is firstly estimated for aggregate labour productivity, then for manufacturing and market services. Theoretically, spillovers, diffusion and implementation of technology enhanced by trade and internationalization of production constitute the *advantage of backwardness* supporting convergence in manufacturing (Gerschenkron, 1962; Bernard and Jones, 1996c; Rodrik, 2013). Standardization of production technologies may promote the same process in market services, especially since the international movement of services and financial capitals is progressively freer (Bernard and Jones, 1996a). Furthermore, investigating convergence is also informative about the overall decline of the sector in Europe. Within the European slowdown in productivity growth, are some regions catching-up the others? Finally, the EU common market since the Single European Act in 1992 and the liberalization of financial markets should be favouring convergence in both sectors.

3.1. Aggregate labour productivity

The estimates for aggregate labour productivity are reported in Table 2. In the linear estimator, observations are converging if the coefficient on $y_{i,1991}$ is negative and significant. Eq. (1) allows to identify non-linearities. Indeed, the relationship between $\bar{g}_i$ and the initial level of productivity is statistically significant and strongly non-linear, as shown by the estimated degrees of freedom (EDF) of the smooth term being higher than 1.

The resulting growth path plotted in Fig. 1 clearly confirms the non-linearity of the relationship. In particular, the curve intersects the average growth rate of the sample (the dotted horizontal line around 0.02) around 0.8, suggesting a potential agglomeration in the distribution. This occurs because economies below the intersection point will grow at a faster rate than economies above it, being the curve decreasing. Therefore the former will improve their relative position along the distribution,

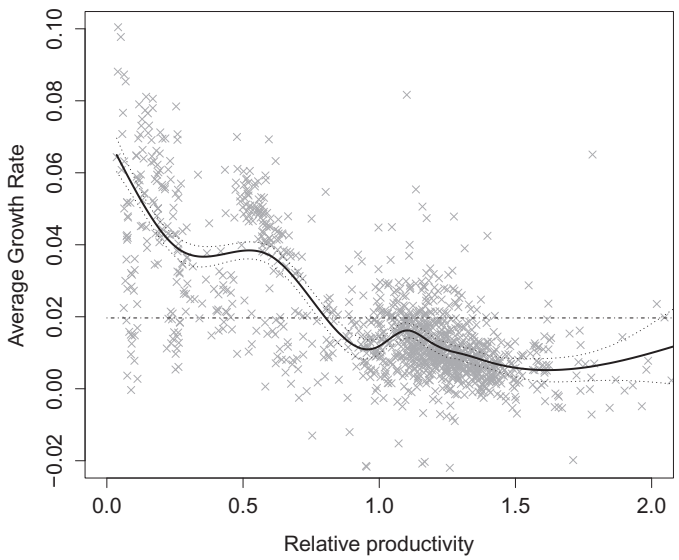
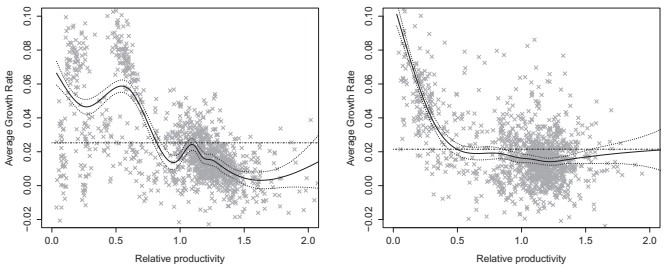


Fig. 1. Semiparametric regression for Aggregate labour productivity.



(a) Nineties (b) Noughties

Fig. 2. Semiparametric regression for Aggregate labour productivity in the two subperiods.

Table 3
Estimation of Eq. (1): Manufacturing.

	Growth path estimate
Intercept	0.046***
Non-param term	
$y_{i,1991}$	6.765***
R.sq (adj)	0.344
GCV score	0.0006

Note: *** indicates significance at 1%. For the smooth term, estimated degrees of freedom (EDF) are reported. $n = 1263$.

while the latter will be "caught up" and will decrease their relative position[10]. Differently, around 1.2 the curve is slightly below the average growth rate, then in principle one could not speak about an agglomeration point here. Consequently, this could imply absolute convergence towards a single point in the distribution, i.e. 0.8. However, the evidence on distribution dynamics reported in the next section will confirm that the non-linearities in Fig. 1 are indeed relevant and will support the existence of the (main) potential agglomeration around 1.2[11]. There is also reason to suspect that some changes in the growth path occurred in the first decade of the 2000s (Noughties henceforth). For instance, the Eastern countries joined the European Union after 2004 and this may be a political event affecting economic performance. Moreover, the Euro was introduced in 2002. Therefore, Eq. (1) is estimated separately for the Nineties and the Noughties to verify whether two different growth trajectories are in place.

The plots of the non-linear estimates in Fig. 2 confirm such an hypothesis. The left panel shows the estimated curve for the Nineties. The relationship is quite similar to what observed for the whole period and two agglomerations can be predicted about roughly the same points in the distribution. Differently, in the Noughties an almost linear negative relationship is observed in [0, 0.5]. However, in the rest of the distribution the path is roughly horizontal, slightly declining and increasing around 1.2. Hence, a monotonic negative relationship is hardly identified for the main part of the distribution. Overall, it can be inferred that a clear convergence process is in place only in the Noughties and just for the lower part of the distribution. This is due mainly to the Eastern Europe transitional economies whose growth rates are significantly above the sample mean. The kind of non-linearities in the growth paths does not support the *neoclassical* hypothesis of unconditional convergence for aggregate productivity.

3.2. Manufacturing

The estimation of Eq. (1) reveals a non-linear growth path, as shown by the EDF reported in Table 3. The left panel of Fig. 3 reveals that the relationship is negative for the observations in between 0 and 1. However, in the interval [1, 1.4], where most of the observations lie, the curve first increases for then slightly decreasing. Hence, unconditional convergence is found for the bottom of the distribution only, while findings are ambiguous for observations above the sample mean (1).

Concerning the two subperiods, results are quite different. For the Nineties (middle panel), absolute convergence holds for roughly the whole distribution, even though the relationship is still non-linear with a minor slope for the observations above 1. The estimation for the Noughties (right panel) is different and there is no room left for convergence. On the contrary, both at the bottom and at the top of the distribution the growth path is increasing, meaning that divergence is in place. More precisely, the growth path suggests two agglomerations around 0.5 and about 1.4. Overall, despite the favourable characteristics of the EU

[10] The reasoning is the same as in the basic Solow model, to which absolute convergence regressions are usually linked to (Durlauf and Quah, 1999). The difference is that in the Solow case the steady state corresponds to a growth rate equal to zero, while here it corresponds to the average growth rate: if economies keep growing according to the relationship in Fig. 1, in the steady state they will end up growing at the same rate, which will be equal to the average rate.

[11] This shows that using non-linear regressions and distribution dynamics is more informative on unconditional convergence than using just a single tool, and that it is much more informative than the standard linear regression approach. See Appendix B for further details.

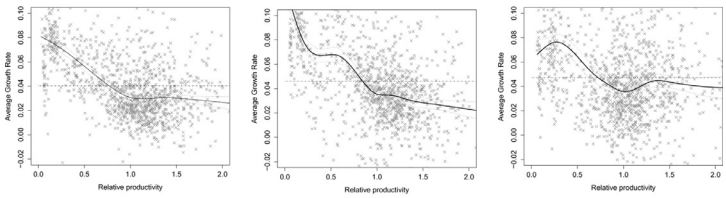


Fig. 3. Semiparametric regression for Manufacturing labour productivity.

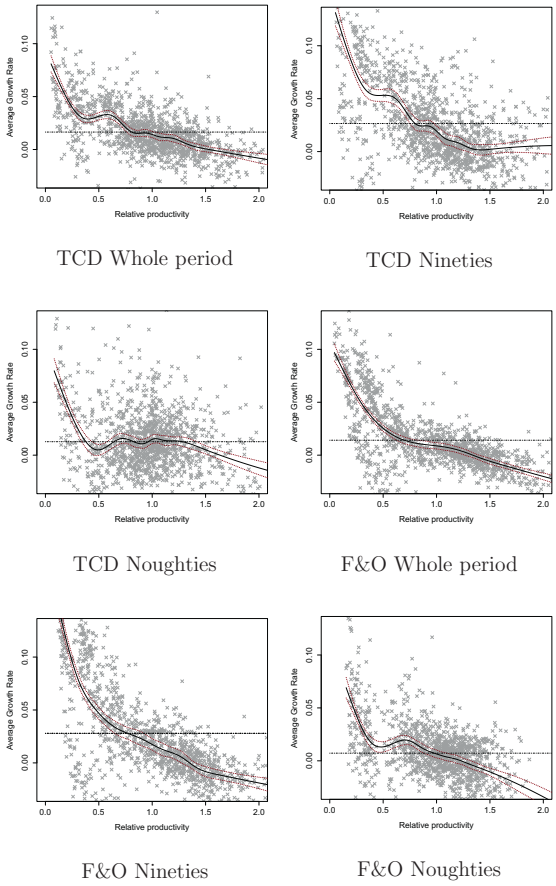


Fig. 4. Semiparametric regressions for market services (TCD and F&O) labour productivity.

economies, findings of the kind of Rodrik (2013) do not clearly apply to the sample. Indeed, unconditional convergence holds only for the bottom of the distribution, and this is mainly due to the non-linear negative relationship observed in the Nineties. Divergence holds for the Noughties. These results are closer to those of Bernard and Jones (1996b) which do not find evidence of unconditional convergence in the manufacturing sector in a sample of 14 OECD countries.

3.3. Market services

Fig. 4 plots the growth path resulting from the estimation of Eq. (1) for both TCD and F&O, while Table 4 reports the estimates, indicating a non-linear relationship, being the EDF equal to 8.564 and 8.463 respectively. Findings for TCD are ambiguous. The growth path for the whole period suggests a converging process in the range of the distribution in between 0 and 0.5. Then the curve increases until 0.75, for afterwards declining non-linearly. A similar relationship holds in the Nineties, but in this case divergence is observed for observations above 1.4. However, the estimate for the Noughties reveals clearly that regions are converging no more. If any - excluding the Eastern less productive regions - a divergence process is in place. This explains why the estimated curve is less negatively sloped in 1991–2007 than in the Nineties. The findings for F&O are unexpectedly straightforward. Indeed, it is the only sector for which absolute convergence is found to hold clearly, despite being non-linear.

Table 4
Estimation of Eq. (1): F&O and TCD market services.

Growth path estimate	F&O	TCD
Intercept	0.014***	0.016***
Non-param term		
$y_{i,1991}$	6.723***	8.516***
R.sq (adj)	0.575	0.382
GCV score	0.0005	0.0004

Note: *** indicates significance at 1%. For the smooth term, estimated degrees of freedom (EDF) are reported. $n = 1263$.

This is true for the whole period, as well as for the two subperiods, as shown in Fig. 4. The estimates for the whole period and for the Nineties suggest one agglomeration point around 0.8, revealing a smooth convergence process. The non-linearity for the Noughties is much more evident, and the curve is increasing in the range [0.5, 0.75], implying two agglomerations, the first around 0.5 because of the Eastern regions, the other around 1.

The above findings can be summarized as follows. EU regions are not converging unconditionally in aggregate labour productivity, consistently with the standard finding in the empirical literature. Results for the manufacturing sector are ambiguous. Indeed, considering the whole period, convergence holds only in the first part of the distribution, while the relationship is weak for most of the observations. A negative non-linear relationship can be observed for the Nineties, while it does not hold for the Noughties, in which the evidence is mixed and strongly non-linear. Perhaps surprising, unconditional convergence is found to apply smoothly in the F&O subsector. These results are consistent with the findings of Bernard and Jones (1996a). Their explanation relies on the difference between tradables and nontradables. In sectors characterized by tradables, such as manufacturing, comparative advantages lead to specialisation. Since this implies different economic activities across economies, there is no reason to expect convergence in production technologies, hence in labour productivity. On the other hand, nontradable work as an *aggregate growth model* as technologies tend to be similar. Such an interpretation is consistent with the findings of this paper. Indeed, manufacturing is characterized by tradables, while this is not necessarily the case of market services. Hence, the disaggregation of the latter in TCD and F&O allows to spot differences. Absolute convergence is found in F&O, which includes mostly financial activities with technologies of production more likely to be common among regions and countries. This is also true for services related to software, hardware, research and real estate. Differently, the same reasoning does not necessarily apply to the kind of activities included in TCD[12]. In the case of this paper's sample, the above reasoning must be read within the progressive process of liberalization of financial markets and capital movements in the last decades, which has been particularly promoted in the EU after 1992. As a result, differentials in terms of returns to financial activities progressively decreased across regions causing the negatively-sloped curve for the average growth rate, as shown in the F&O panels of Fig. 4. If this is true, distribution dynamics must reveal a trend towards unimodality together with reducing dispersion. Results in the next Section confirm such an interpretation. Finally, lack of convergence in manufacturing and TCD suggests instead that the EU integration process has not fully triggered those mechanisms capable to foster convergence - i.e. competitive pressures increasing efficiency, technology transfers and more integration in international production networks (Rodrik, 2013) - especially in the peripheral regions of Southern Europe.

4. Distribution dynamics

The above analysis mainly informs about the average behaviour of the data. No straightforward conclusion can be drawn, since even small differences in growth rates would cause large disparities in relative levels (Breinlich et al., 2013). A similar argument points out as convergence analysis does not inform about the relative performance of economies, but it just reveals whether countries converge to their own steady states (Quah, 1996). Henceforth, this Section analyses the distribution dynamics of labour productivity to assess how economies are performing relative to each other (Quah, 1996; 1997). Results also provide complementary information to the above analysis. The exercise is done for aggregate productivity, as well as for manufacturing and the F&O services.

To start with, Fig. 5 presents the estimated densities of relative aggregate labour productivity at three points in time: 1991, 2000 and 2007. The densities have been obtained by using the adaptive kernel estimator, following Silverman (1986). Two observations follow. First, the distribution is far from being unimodal. Second, the degree of dispersion is indicative of the gap between the Eastern regions and the rest of the EU. Indeed the distribution ranges from values close to zero to two times the sample mean, it is skewed with a persistent main peak moving towards the mean over time. A second smaller mass is in the lower tail of the distribution and it changes shape overtime, having two peaks in 1991 and a single peak in 2000 and 2007. Therefore, the overall distribution is trimodal in 1991, bimodal in 2000 and 2007.

Fig. 5 provides a static picture of aggregate labour productivity, while it does not inform about its long run behaviour. For instance, the change in the shape of the bottom mode may be due to either poor regions improving their relative performance

[12] See the Eurostat website for the full classification of activities in each sector.

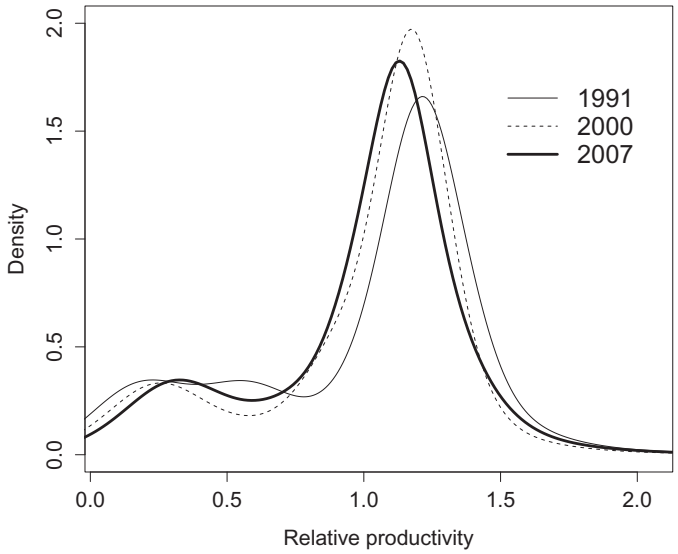
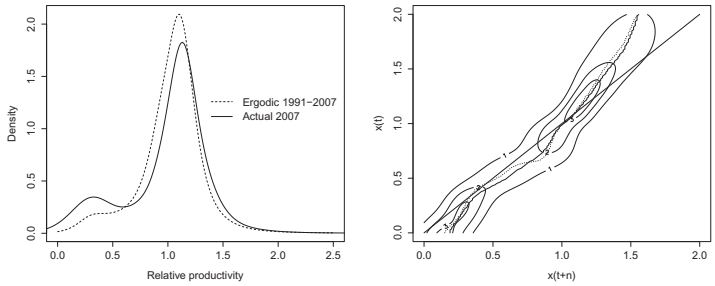


Fig. 5. Estimated densities of aggregate labour productivity.



(a) Out of sample comparison (b) Conditional distribution 1991-2007

Fig. 6. Distribution dynamics: ergodic estimates and conditional distribution.

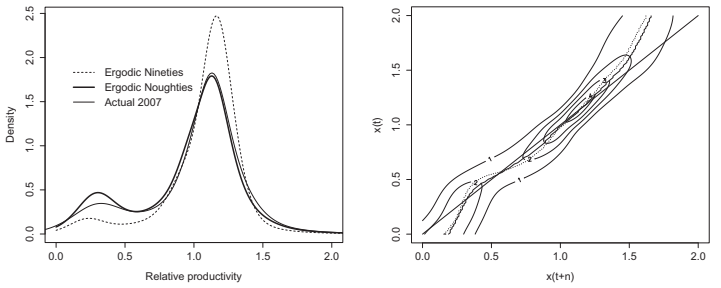
or to some mobility in the close quantiles[13]. In other terms, a fundamental piece of information is provided by intra-distribution dynamics, i.e. by regions moving forward or falling behind. The transition matrix is a useful tool for investigating such a process. It gives the probability of moving from one state to another within the distribution. The lower the transition probabilities, the higher the persistence of the system and the less likely a distributional change. However, building a transition matrix requires the discretization of data, which could distort dynamics in an important way. Alternatively, it is possible to estimate conditional distributions[14], i.e. the continuous analogue of the transition matrix fully describing transitions from any state to another (Quah, 1997). Similar information is provided by the ergodic density, which is the nonparametric estimate of the distribution to which the current one tends as time goes to infinite[15]. In what follows the ergodic distribution and the conditional densities are estimated, following Quah (1997) and Johnson (2005).

The left panel of Fig. 6 plots the estimates of the ergodic distribution for 1991–2007 and the density for the actual data in 2007. It is possible to observe that the ergodic distribution forecasts more mass around the mean and less in the bottom mode than the estimated density in 2007. The conditional distribution is plotted in the right panel. The 45^o line is the locus of points in which the relative productivity in t (on the y axis) is unchanged in $t + 10$. Observations lying above (below) the bisector indicate a decline (increase) in relative productivity, the continuous curve is the median line and contours indicate probability mass. Observing the median curve helps understanding the nature of the process. First, observations at the bottom of the distribution tend to improve their relative performance. Second, observations around 1 tend to converge to the mean, as the intersection between the median curve and the bisector suggests. This is consistent with the peak around 1 in the ergodic estimate. Hence,

[13] See Bowman and Azzalini (1991) for further details about the smoothing of estimated densities and the choice of the bandwidth.

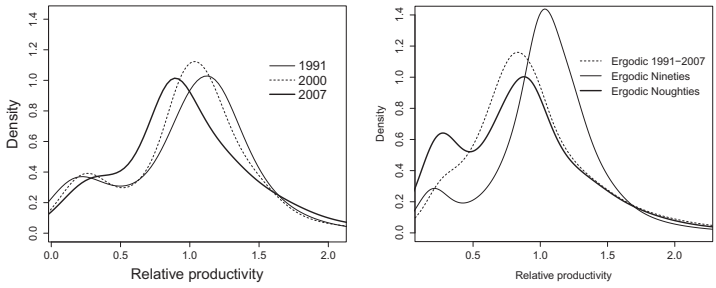
[14] Quah (1997) refers to conditional densities as *stochastic kernels*.

[15] Note that such a framework holds under the assumption that the underlying process is time-invariant. See Feyrer (2008) for the transition matrix and the ergodic distribution with the discrete Markov chain method. See Quah (1997), Johnson (2005), Azomahou et al. (2005) and Fiaschi and Lavezzi (2007) for the continuous space approach.



(a) Time variance of the process (b) Conditional distribution 2000-2007

Fig. 7. Distribution dynamics for aggregate labour productivity.



(a) Actual densities (b) Time variance of the process

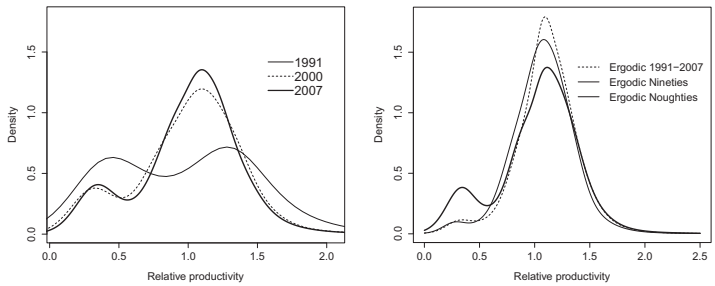
Fig. 8. Distribution dynamics for the Manufacturing sector.

these findings suggest that the long run behaviour of the distribution is likely to be unimodal, predicting the disappearance of the bottom mode in the long run. However, this is true as long as the evolution of the process is time invariant. If this is not the case, the above results are misleading. To investigate this possibility, the time span is divided in the two subperiods 1991–2000 and 2001–2007. If the process is time invariant, then the ergodic estimate for the Nineties does not differ from the estimated density in 2007. If it does, the process changed in the Noughties. Hence, the left panel of Fig. 7 compares the estimated density in 2007 and the ergodic estimates for the Nineties and the Noughties.

The ergodic estimate for the Noughties is bimodal, predicting more mass in the range [0, 0.5] than the estimate for the Nineties. The latter in turn is closer to the ergodic for the whole period. Therefore, unimodality would have emerged only *if* the distribution dynamics of the Nineties had persisted in the Noughties. Comparing Fig. 7 with Fig. 5 helps interpreting productivity dynamics. Fig. 5 shows that the bottom mode is emptying in 2000, preserving the mass close to 0. However, in 2007 there is again more mass in the range [0, 0.5]. This is the process revealed by the ergodic estimates for the two subperiods: the bottom of the distribution is moving towards the mean in the Nineties, but the dynamics revert in the Noughties. Moreover, the median curve of the conditional density for the Noughties in the right panel of Fig. 7 is closer to the bisector than in the full sample case, and it lies above it around 0.5. These results are also consistent with the semiparametric estimates in Fig. 2. Indeed, in the Nineties, the regions in the range [0.5, 0.75] have the highest growth rates, while this is no more true in the Noughties when the curve is almost flat.

Fig. 8 shows the main results for the manufacturing sector. The left panel plots the estimated densities in 1991, 2000 and 2007. Bimodality is evident in 1991 and 2000, while it is less clear in 2007[16]. The ergodic estimate for the whole period in the right panel provide an ambiguous result. Even though there is some mass at the bottom of the distribution, the long run behaviour seems suggesting unimodality. This is due to the dynamics in the Noughties reverting the process of the Nineties. The latter was moving the mass from the extremes of the distribution towards the mean, with the only exception of the Eastern regions at the very bottom. The estimate for the Noughties shows a shift of the distribution towards the interval [0, 1], determining bimodality. Conditional densities are not reported for the sake of space, but they confirm the described process. This implies that the actual density in 2007 is somehow transitory and a twin peaked distribution is likely to prevail in the long run if the process in the Noughties persists. It is worth noting that a unimodal distribution does not necessarily imply convergence, since observations can be very sparse. On the contrary, bimodality implies two agglomerations, therefore absolute convergence does not hold or, if any, it is in terms of clubs. Fig. 8 is consistent with the semiparametric regressions in Fig. 3. In particular, the unconditional

[16] Still, the Hartigan test for the distribution in 2007 gives 0.013 (dip statistics), rejecting the null hypothesis of unimodality (see Hartigan and Hartigan (1985)).



(a) Actual densities (b) Time variance of the process

Fig. 9. Distribution dynamics in the F&O sector.

convergence of the Nineties is transitory, while the divergence observed in the Noughties is consistent with the two modes of the ergodic estimate.

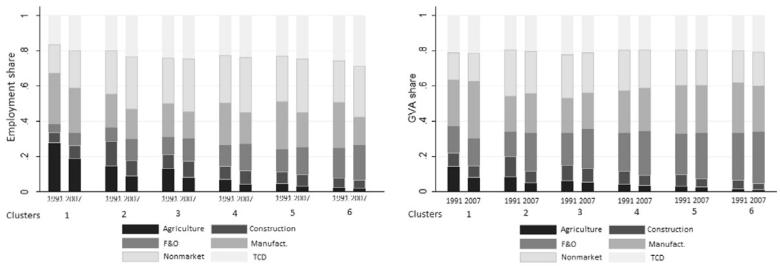
Distribution dynamics for the F&O sector are reported in Fig. 9. The left panel suggests a straightforward trend for the distribution. Being clearly bimodal in 1991, a reduction in dispersion is observed both in 2000 and 2007, as the extreme observations move towards the mean with the exception of the Eastern economies at the bottom. Moreover, the ergodic estimates in the right panel shows unimodal dynamics for the whole period and for the Nineties. This is fully consistent with the explanation provided for the convergence estimates in the previous section, which is based on decreasing dispersion and an unimodal process of the distribution. Note that even though unimodality does not necessarily imply convergence, the ergodic estimates together with the semiparametric regressions in Fig. 4 support this hypothesis. Finally, the bottom mode for the Noughties is also consistent with the non-linear growth path for the period.

5. Structural change and productivity growth

Differences in the composition of output are fundamental sources of growth rates differentials. Some sectors, such as market services, are more productive than others, while some industries have higher growth rates, as manufacturing. In addition, some regions perform better than others, having higher aggregate productivity growth despite a similar structure of output. Overall, three sources of aggregate growth can be identified: either an increase in output per worker, or the change in the structure of output due to the reallocation of employment across sectors, or both. The last two mechanisms are labelled *structural change*. It is growth enhancing (i.e. determining positive growth rates) if the reallocation of labour favours those sectors whose productivity is either higher or growing (see Bernard and Jones (1996c), Bernard and Jones (1996b), Paci and Pigliaru (1997a), Cimoli et al. (2011) and Rodrik (2013)). In this last Section, productivity growth is decomposed by sector and by source to provide a sectoral foundation to the observed heterogeneity in economic performance. From a theoretical perspective, acknowledging the role of structural change for productivity growth allows for an alternative explanation of the convergence process. In the standard Solowian neoclassical framework, absolute convergence takes place because economies sharing the same initial conditions and technology tend to convergence to their steady state. Differently, episodes of *"aggregate convergence in which structural change plays the major role, in the presence of a negligible contribution yielded by within-sector convergence, would, for instance, signal the existence of underlying mechanisms hardly compatible with [..] the β convergence hypothesis, and more compatible with models in which technologies can vary across areas and factor prices are not continually equalized at the margin"* (Paci and Pigliaru, 1997b, p. 303). Therefore, it is possible to explain convergence as the consequence of "*the laggards moving towards increasing return activities* in some sectors of the economy, *not from decreasing returns in the leader countries*" (Cimoli et al., 2011, p. 28). Since the above analysis finds (non-linear) β convergence only in the F&O sector, investigating structural change provides a complementary piece of information to explain productivity differentials.

The decomposition exercise is usually done by set of countries. Here the departure point is the estimate of the distribution of relative aggregate labour productivity in Fig. 5. Since the unit of observation is the NUTS3 territorial entity, grouping the economies by country would cause the loss of information about within countries differentials. Therefore the *k-mean*[17] criterion for clustering has been implemented according to the levels of relative aggregate productivity in 1991. Six clusters are identified. The first contains the less productive regions (mainly Eastern and Portuguese economies), while the sixth includes the most productive. Fig. 10 summarizes the structural composition by cluster, presenting the sectoral shares for both employment and GVA in 1991 and 2007. The poorest economies are characterized by higher shares of agriculture and non-market services. This is true for both years, even though in 2007 shares are smaller. The contrary holds for market services which contribute very little to the composition of output for the regions in Cluster 1. Since output per worker is the lowest in agriculture and non-market services, while it is the highest in F&O, economies specialized too much in these sectors will have a lower level of aggregate

[17] The k-mean procedure has been done by imposing 6 centroids. Similar results are obtained if the k-median criterion is used.



(a) Employment shares (b) GVA shares

Fig. 10. Structural composition in 1991 and 2007.

productivity[18]. Overall, the top three clusters have a similar structural composition, while Cluster 1 is different from any other group[19].

Different approaches for spotlighting the sources of productivity growth can be used (Bernard and Jones, 1996c; 1996b; Paci and Pigliaru, 1997a; Fiaschi and Lavezzi, 2007; McMillan and Rodrik, 2011). This section follows the decomposition by Cimoli et al. (2011). In particular, aggregate labour productivity growth is decomposed in three components: (i) pure productivity gains (*PrG*) in each sector from t_0 to t_1, given the share of employment in t_0; (ii) the variation in employment shares in each sector (*ShEff*) from t_0 to t_1, given the level of productivity in t_0; (iii) an *interaction* term between *PrG* and *ShEff*, labelled *DynEff*. The last term indicates whether structural change is favouring growing sectors. Indeed, if its sign is positive, then, on average, there is either an outflow *from* sectors suffering productivity loss, or an inflow *towards* sectors whose productivity is growing (see Cimoli et al. (2011)). The following relation holds:

$$\Delta y/y_0 = \sum_i [(\underbrace{\Delta y_i L_0)/y_0}_{PrG} + (\underbrace{\Delta L_i y_0)/y_0}_{ShEff} + (\underbrace{\Delta y_i \Delta L_i)/y_0}_{DynEff}] \tag{2}$$

$\Delta y/y_0$ is the growth rate of aggregate productivity, where y_0 is aggregate productivity in t_0, Δy_i is productivity increase in sector i in the period, that is $y_T - y_0$, ΔL_i is the variation in the employment shares, $L_T - L_0$. The results of the decomposition for the whole period (1991–2007) are summarized in Table 5[20]. Overall, two main conclusions can be drawn.

First, the main driver of aggregate productivity growth is the PrG term, which explains the most part of the increase over the period. The contribution of structural change, given by the sum of ShEff and DynEff, is negative for each cluster, excluding the transitional economies of Cluster 1 and, on a lesser extent, regions in Cluster 2. However, even in this case, PrG contributes the most. Some caution must be taken in interpreting the sign of DynEff. Take for instance the case of manufacturing, whose DynEff term is negative for the whole distribution. This is due to the increasing outflow of employment $\Delta L < 0$, while the growth rate of GVA is positive $\Delta y > 0$. As suggested by Rodrik (2013), an adequate policy suggestion for fostering productivity should *encourage* the *inflow* of employment to manufacturing. Consider now agriculture, for which DynEff is also negative. Again, this is due to $\Delta L < 0$ and $\Delta y > 0$. However, although positive growth rates, productivity levels in agriculture are the lowest among the sectors, as reported in Table 1. Therefore, in this case structural change is growth enhancing[21]. Overall, the role of structural change is slightly positive for the first two clusters, negative for the last three, in particular for Cluster 6.

Secondly, manufacturing is the leading sector for what concerns pure productivity gains. Indeed, it has the highest PrG term in every cluster, ranging from 0.18 (Cluster 5) to 0.596 (Cluster 1). Interestingly, economies in Cluster 6 have the highest values, after the first two groups. However, it is worth noting that manufacturing is not the sector with the highest contribution to total aggregate productivity growth. Indeed, excluding Cluster 1, it falls behind F&O and, in the case of Cluster 6, also behind TCD and NonMarket services. This is due to the ShEff term, being negative in every cluster, in particular for the sixth group. Hence, despite

[18] In Fig. 10 it is possible to observe that GVA shares are lower than employment shares both in agriculture and non-market services. Note also that economies in Cluster 1 have the highest employment shares in manufacturing, which is the sector growing the most. This is not surprising, since most of the regions in the group are economies in transition. However, it should also be noted that Cluster 6 has the highest GVA/Employment shares ratio for manufacturing: the richest economies are the most productive in the sector.

[19] Clustering subsamples of the EU may highlight interesting differences within the same national economy, as in the case of the striking and persistent North-South Italian dualism. See Paci and Pigliaru (1997b) for an analysis of the role of structural change in affecting convergence in the case of the Italian regions; Fiaschi et al. (2011) for an investigation on polarization and convergence in the case of Italian provinces, and Martino (2013) for a similar analysis addressing also structural composition and change.

[20] Values are group averages for the whole period. Note that grouping is made according to an *a priori* criterion: regions in group *i* are those belonging to that group in 1991. This is consistent with the convergence analysis above. However, the same exercise could have been done according to groups in 2007, no matter the relative position in 1991. Different results would be obtained: economies in Cluster 6 would have the highest growth rate *by construction*, after the regions in Cluster 1. This would be informative about the path followed by each economy in order to reach their final relative position, but it would have a minor link with the convergence issue.

[21] It must be stressed that DynEff is an interaction term. Therefore, if employment is moving to, say, the sector with the highest productivity level *but* with negative growth rates over the period, then DynEff is going to be negative.

Table 5
Sources of productivity growth.

Sector	PrG	ShEff	DynEff	SectTot	%
Cluster 1					
Agriculture	0.152	−0.033	−0.092	0.027	2.06
Construction	0.064	0.021	0.014	0.099	7.55
F&O	0.089	0.09	0.027	0.205	15.54
Manufacturing	0.596	−0.021	−0.089	0.486	36.89
Non market	0.114	0.056	0.034	0.203	15.43
TCD	0.194	0.065	0.038	0.297	22.53
Total	1.208	0.178	−0.068	1.318	100
Cluster 2					
Agriculture	0.075	−0.03	−0.04	0.004	0.42
Construction	0.076	−0.031	−0.039	0.006	0.62
F&O	0.151	0.099	0.036	0.286	30.25
Manufacturing	0.318	−0.019	−0.034	0.265	28.01
Non market	0.139	0.057	0.018	0.214	22.64
TCD	0.117	0.046	0.007	0.171	18.07
Total	0.876	0.122	−0.052	0.946	100
Cluster 3					
Agriculture	0.047	−0.019	−0.026	0.002	0.57
Construction	0.008	0.019	−0.01	0.017	5.08
F&O	0.045	0.074	−0.005	0.115	34.48
Manufacturing	0.169	−0.03	−0.049	0.09	26.96
Non market	0.008	0.086	−0.041	0.053	15.87
TCD	0.06	0.004	−0.007	0.057	17.04
Total	0.337	0.134	−0.137	0.334	100
Cluster 4					
Agriculture	0.028	−0.014	−0.014	0.001	0.21
Construction	0	0.004	−0.003	0.001	0.38
F&O	0.043	0.082	−0.016	0.109	36.6
Manufacturing	0.2	−0.064	−0.058	0.079	26.66
Non market	0.01	0.053	−0.012	0.051	17.06
TCD	0.049	0.012	−0.005	0.057	19.09
Total	0.33	0.074	−0.107	0.297	100
Cluster 5					
Agriculture	0.014	−0.009	−0.007	−0.001	−0.58
Construction	−0.007	0.002	−0.002	−0.007	−3.65
F&O	0.017	0.068	−0.011	0.074	38.12
Manufacturing	0.18	−0.076	−0.053	0.051	26.5
Non market	0.003	0.041	−0.005	0.04	20.6
TCD	0.027	0.011	−0.001	0.037	19
Total	0.235	0.039	−0.079	0.194	100
Cluster 6					
Agriculture	0.004	−0.003	−0.003	−0.002	−1.2
Construction	−0.011	−0.001	−0.002	−0.014	−7.75
F&O	0.041	0.058	−0.012	0.087	47.88
Manufacturing	0.211	−0.106	−0.091	0.014	7.48
Non market	0.004	0.05	−0.008	0.046	25.69
TCD	0.032	0.021	−0.002	0.05	27.91
Total	0.281	0.018	−0.118	0.181	100

structural change has a minor impact on aggregate productivity growth, it deeply affects the contribution of the manufacturing sector. On the contrary, it positively affects the growth rate of TCD and F&O, which in turn have very low PrG, consistently with the findings of Van Ark et al. (2008) and the statistics in Table 1.

Concluding remarks

This paper analysed distribution dynamics in 1263 regions of the European Union, looking for absolute convergence and growth determinants for labour productivity. Findings reveal a clear process of convergence in F&O market services. Results are less straightforward for TCD and manufacturing. Indeed, in both cases the growth path is not clearly negatively sloped and divergence is observed in some parts of the distribution. The relationship is non-linear in every sector. The interpretation follows Bernard and Jones (1996a). Convergence is found in that subsector of market services characterized by non-tradables, more suited to behave as an aggregate growth model with similar technologies. Also F&O is mainly composed by financial activities: liberalization of capital markets in the EU is likely to have affected the convergence process. However, this does not apply to the other sectors and to the economy as a whole. In particular, the mechanisms triggering convergence did not succeed in reducing productivity gaps among regions in the manufacturing sector and, to a lesser extent, in TCD. On the opposite, the specialization effect discussed by Bernard and Jones (1996a) seems to have prevailed over the advantages of market integration and

(a) 1991 (b) 2007

Fig. A.11. Distribution of labour productivity by Clusters in 1991 and 2007.

technology transfers, which are the main drivers of Rodrik (2013) results. Since the overall behaviour of the economy is the result of sectoral aggregation, absolute convergence does not hold for aggregate labour productivity, being it limited to F&O market services. Finally, the decomposition of labour productivity growth shows that productivity gains are the main driver of aggregate growth. However, structural change plays a role by enhancing the weight of F&O services, and halving the contribution of the manufacturing sector for the richest economies.

Some policy implications can be drawn. First, despite this paper does not address the effectiveness of economic policy in the EU, the above findings on aggregate labour productivity suggest that the efforts attempting to reduce regional inequalities have not been successful. On the opposite, the EU scenario in 2007 is characterized by a worsening of the centre-periphery gap than in 1990, as also shown in Fig. A.11 in Appendix A[22]. Second, lack of convergence in the manufacturing sector suggests that those mechanisms capable to reduce the gap between less and most productive economies - i.e. competitive pressures increasing efficiency, technology diffusion and adoption and more integration in production networks - did not work properly for peripheral economies. This is particularly true for economies of Southern Europe which cannot build economic growth on low-cost activities and low productive sectors, differently from Eastern economies which are still in a transition phase. This calls for a reconsideration of EU policies promoting regional integration, technology transfers and innovation. A similar reasoning applies, to a lesser extent, to TCD, since they include communication services.

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Appendix A. Aggregate relative productivity: who is where

Fig. A.11 plots the maps of relative aggregate labour productivity in 1991 and 2007. Clusters have been obtained according to the levels of productivity in 1991 and 2007. Note that clustering in 2007 has been done by imposing 7 centroids. However the last two groups have been merged in Cluster 6, the seventh including just three observations. Eastern, Portuguese and Greek economies occupy the bottom of the distribution along the whole period, while Spanish regions fall behind in 2007. Eastern Germany shows a relevant increase in relative labour productivity along the period, while Scandinavian regions move from Cluster 3 and 4 to 5 and 6. German, French and Northern Italian regions worsen their relative position during the period. Overall, the centre-periphery gap increased along the period. Table A.6 reports clusters' composition.

Table A.6
Composition of the clusters.

Cluster	1	2	3	4	5	6
1991	173	170	175	393	290	62
2007	177	117	271	433	220	45

[22] However, the analysis of this paper does not allow to assess neither the extent of policy failure, nor the contribution of adopted policies at different levels of government (regional, national or European). For instance, suppose that no policy targeting convergence had been implemented: it could be that in such a case regional differences in 2007 would have been wider. If this was true, even though policies did not achieve the convergence and cohesion objective, they contributed to keep regions closer than in the case of no policy intervention. Put differently, it may be the case that gaps between economies' own steady states are smaller than in a scenario without policy. To investigate such a possibility, conditional convergence should be investigated. I would like to thank Miguel Lebre de Freitas for pointing this argument out. An empirical investigation of this kind is in de Freitas et al. (2003).

Table B.7
β-Convergence.

	Aggregate	Manufacturing	F&O	TCD
$\hat{\alpha}$	0.052***	0.065***	0.044***	0.046***
$\hat{\beta}$	−0.032***	−0.025***	−0.030***	−0.030***
R^2	0.457	0.233	0.400	0.322

Note: *** indicates significance at 5%. $n = 1263$.

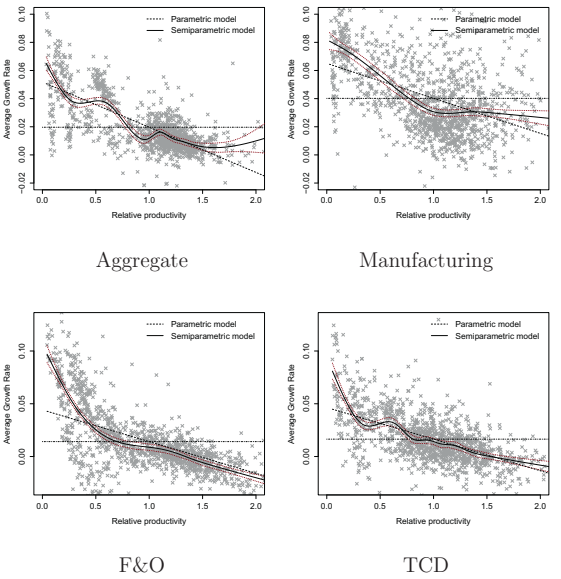

Fig. B.12. Comparison between parametric and semiparametric regressions for the whole period.

Appendix B. Non-linearities and absolute convergence

The informational gain of analysing distributional dynamics in addition to static density estimations has been shown in Section 4. A similar advantage holds if we consider as alternative a σ-convergence exercise, i.e. the linear regression of the standard deviation of the distribution on time t: $\sigma_t = \alpha + \gamma t$. Indeed, even in this case one can just say whether the dispersion of the distribution has been decreasing overtime (estimated $\gamma < 0$), while no insight is provided concerning the long run behaviour. As a further piece of information, this Appendix highlights the advantage of using the semiparametric model of Eq. (1) whenever the growth process is characterized by relevant non-linearities. In particular, the methodology of this paper is compared with the main alternative approach in the literature, i.e. the standard parametric β-regression, given by

$$\bar{g}_i = a + \beta(y_{i,1991}) \tag{B.1}$$

Table B.7 reports the parametric estimates of Eq. B.1 for aggregate labour productivity and for each of the subsectors, using the full sample. Being the estimated coefficient for β significant and less than zero in all four columns, results suggest that absolute convergence is in place. This is due to the imposed linear relationship in the parametric specification, which does not allow for non-linearities in the growth path. This is an issue as long as the underlying relationship is non-linear. To see this, Fig. B.12 plots the parametric estimates together with the semiparametric results of Section 3. The inadequacy of the standard β-regression is evident in the case of aggregate and manufacturing labour productivity, for which the relationship is indeed strongly non-linear, as shown by the plot of the curves. Moreover, non-linearities arise also in the TCD sector and, to a lesser extent, in the case of F&O. Hence, while parametric estimates suggest the existence of a unique global equilibrium[23], nonparametric results clearly show that this is not the case.

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[23] Note that the equilibrium in the parametric case is located exactly at 1 because labour productivity is expressed as relative to the sample mean.

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