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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, this study reveals a clear process of unconditional convergence for financial and business-related market services. Indeed this sector is more likely to be characterised by standardized technologies of production. 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.

Keywords: labour productivity, convergence, distribution dynamics, non parametric methods, structural change

JEL: C14, O11, O40, O47

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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 conditionally to economy-wide factors (Barro 1991, Barro and Sala-i-Martin 1992). Nevertheless, recent empirical studies, notably by Rodrik (2011, 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 strengthen 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 (1996a). 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 (1996c) in a sample of 14 OCED countries.

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 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.

[1]The equation to be empirically estimated commonly is a general version of the original Solow model, known as Barro's equation (see Caselli et al. 1996, Durlauf and Quah 1996, Durlauf et al. 2005).

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

Firstly, the present analysis is an empirical test of the Solow model using a sample for which one should suspect selection bias to apply. Indeed, despite the inclusion of the Eastern economies, the EU is reasonably homogeneous[3]. 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. However, results do not satisfy these expectations. Moreover, this paper uses the smallest territorial unity in the Eurostat classification (NUTS3). This 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.

Secondly, empirical evidence of (non) convergence has 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[4] (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.

Following Quah (1996; 1997) this study also analyses the distribution dynamics of aggregate labour productivity. This informs about how economies perform relative to each other, while convergence analysis only tells whether each country is converging to its own steady state (Quah 1996). Distribu-

[3]On the contrary, the inclusion of the Eastern regions should favour the emergence of the canonical negatively sloped curve.

[4]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, the 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).

tional analysis is performed also for manufacturing and market services to explain how the main sectoral dynamics sum up to the aggregate. Results are then interpreted together with the convergence regressions.

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[5], 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[6].

The paper proceeds as follows. Section II presents the data and the methodology. Section III reports the non parametric estimates for aggregate, manufacturing and market services productivity. In Section IV, distributional analysis tools are used to analyse aggregate productivity dynamics and its sectoral determinants. In Section V, aggregate productivity growth is decomposed in pure gains and structural change terms 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. 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, Spain, France, Ireland, Italy, Lithuania, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and the

[5]The authors define productivity gains as any increase in output keeping labour shares constant. The same definition is adopted in the last section of this paper.

[6]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; 2010) and McGuckin and van Ark (2005).

United Kingdom. Data refers to the period 1991-2007[7]. The CE database is consistent with NACE Rev 2 and adopts the sectoral definitions published by Eurostat under NACE Rev 1.1. 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 belong (F&O) to the second one[8]. Overall, six sectors are analysed.

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[9]. 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 (van Ark et al. 2008, O'Mahoney 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 reduces in every sector, indicating a process of *sigma* 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 *beta* regression. This allows to highlights non-linearity in the relationship between the growth rate and the initial level of productivity. Then, the distributional analysis originally proposed by Quah

[7]Since available data end in 2010, there is not enough information from which drawing relevant conclusion about distribution dynamics during the last crisis.

[8]Business-related services include computer and software activities, research and development, engineering and real estate, 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.

[9]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 for Spanish and Irish regions during 2008-2010 and it is defined as intensive model of growth (Marelli and Signorelli 2010, Marelli et al. 2012). Such a phenomenon is not observed in the sample used in this study.

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
NonMarket	10.067	10.198	0.008	0.777	0.568
Aggregate	10.190	10.537	0.022	0.768	0.594

(1996; 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 1987), conditional and ergodic distributions estimates are computed to investigate distributional dynamics[10] (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)[11].

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.

Differently from the standard linear regression, a semiparametric model is estimated to allow for non linearities in the relationship, 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

[10]The ergodic density represents the long term behaviour of the distribution, under the assumption that the underlying process is time invariant. It solves $f_\propto(z) = \int_0^\infty g_\tau(z|x) f_\propto(x) d_x$, 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 (2004), Fiaschi and Lavezzi (2007).

[11]Alternative decompositions can be used. See Bernand and Jones (1996a; 1996b), Paci and Pigliaru (1997), Fiaschi and Lavezzi (2007).

at the beginning of the period. Equation (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 1996a, 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 1996c). 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. Equation (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.

Table 2: Estimation of equation (1): Aggregate productivity

	Growth Path Estimate
Intercept	0.023^{***}
Non-param term	
$y_{i,1991}$	8.346^{***}
R.sq (adj)	0.566
GCV score ($x10^3$)	0.0002

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

The resulting growth path plotted in Figure 1 reveals the absence of a clear process of convergence. In particular, the curve intersects the average growth rate of the sample (the dotted horizontal line around 0.02) around

0.8 and 1.1, suggesting two potential agglomerations in the distribution[12].

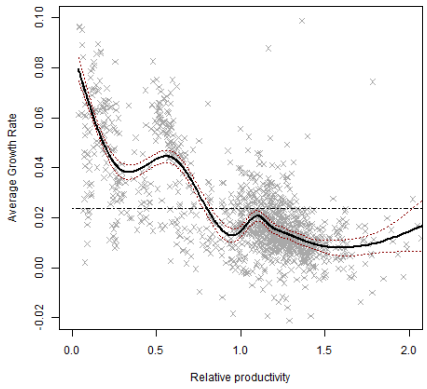
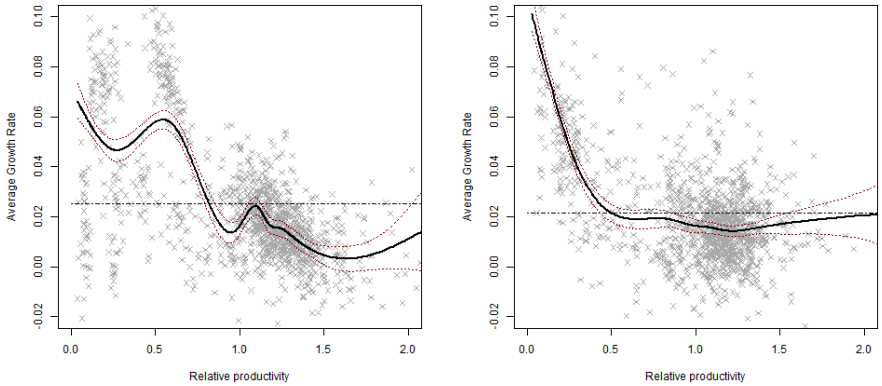


Figure 1: Semiparametric regression for aggregate labour productivity

However, there is reason to suspect that some changes in the growth path occurred in the Twenties. 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, Equation (1) is estimated separately for the Nineties and the Twenties to verify whether two different growth trajectories are in place. The plots of the non linear estimates in Figure 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, the Twenties are characterized by a different scenario. 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. A monotonic negative relationship is hardly identified for the main part of the distribution, the cloud of points being rather uninformative.

Overall, it can be inferred that a clear convergence process is in place only in the Twenties 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. Overall, the kind of linearities in the growth paths does not support the *neoclassical* hypothesis of unconditional convergence for aggregate productivity.

[12]The intersection around 1.1 is less clear. In this case, it is the upper dotted curve which intersects the average growth rate line. The dotted curves in Figure 1 indicate the 95% confidence bands of the estimate.



(a) Nineties (b) Twenties

Figure 2: Semiparametric regression for aggregate labour productivity in the two subperiods

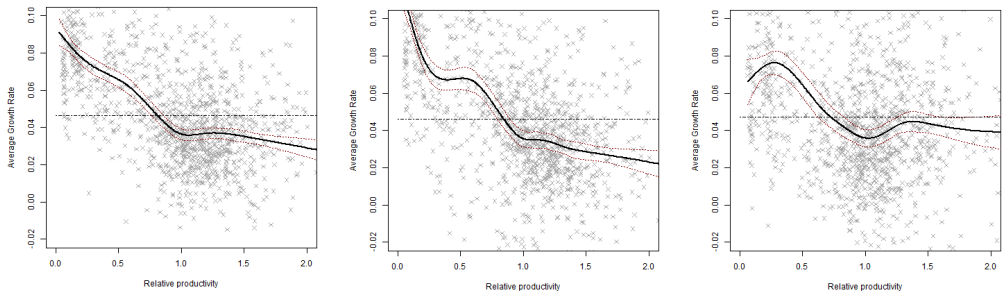
3.2 Manufacturing

The estimation of Equation (1) reveals a non linear growth path, as shown by the EDF reported in Table 3. The left panel of Figure 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 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 Twenties (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 economies, findings of the kind of Rodik (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 Twenties. 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.

Table 3: Estimation of equation (1): Manufacturing

	Growth Path Estimate
Intercept	0.046***
Non-param term	
$y_{i,1991}$	6.765***
R.sq (adj)	0.344
GCV score ($x10^3$)	0.0006

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



TCD Whole period TCD Nineties TCD Twenties

Figure 3: Semiparametric regression for manufacturing labour productivity

3.3 Market services

Figure 4 reports the estimation of Equation (1) for both TCD and F&O[13]. 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. A similar relationship holds for the whole period, with the exception of the range in [0.5, 0.75]. On the contrary, the Twenties reveal 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

[13]The estimates for TCD and F&O are not reported for the sake of space. However, the relationship is statistically significant and non linear, as indicated by the EDF equal to 8.564 and 8.463 respectively.

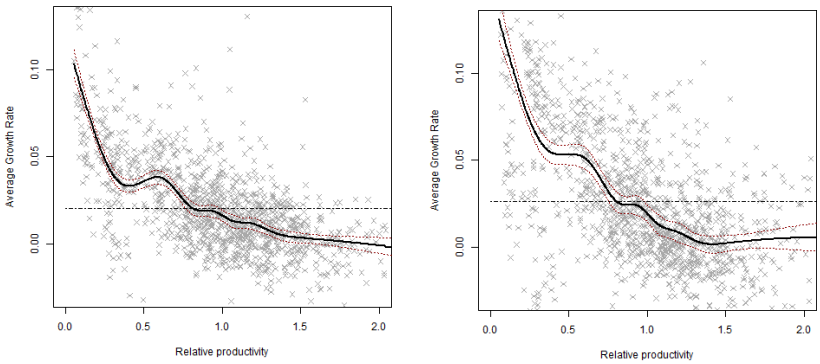
sloped in 1991-2007 than in the Nineties.

The findings for F&O are unexpectedly straightforward. Indeed, it is the only sector for which absolute convergence is found to hold clearly. This is true for the whole period, as well as for the two subperiods, as shown in Figure 4. Despite the growth path is non linear, the relationship is clearly negative. The estimate for the whole period and for the Nineties suggests one agglomeration point around 0.8, revealing a smooth convergence process. The non linearity for the Twenties is much more evident, and the curve is increasing in the range [0.5, 0.75]. However, the growth path still suggests convergence in two clubs, the first composed by Eastern regions. Indeed, the curve intercepts the average growth rate in two points, around 0.5 and 1[14].

Overall, the above analysis can be resumed as follows. EU regions are not converging unconditionally in aggregate labour productivity, consistently with the standard finding in the empirical literature. Absolute convergence in the manufacturing sector provides ambiguous results. 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 Twenties, in which the evidence is mixed and strongly non linear. Perhaps surprising, unconditional convergence is found to smoothly apply in the F&O subsector. These results are consistent with the findings of Bernard and Jones (1996c). 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. However, this is not necessarily the case of market services. 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[15]. Arguably, convergence in the F&O sector is also favoured by the progressive liberalization of the financial markets in the last

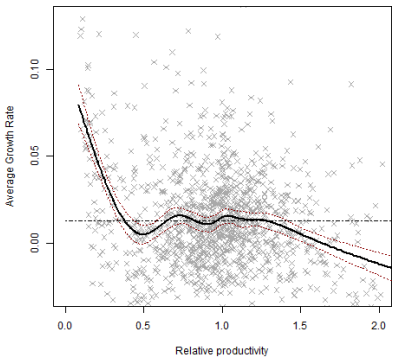
[14]The intersection around 0.5 is given by the confidence band of the estimate

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

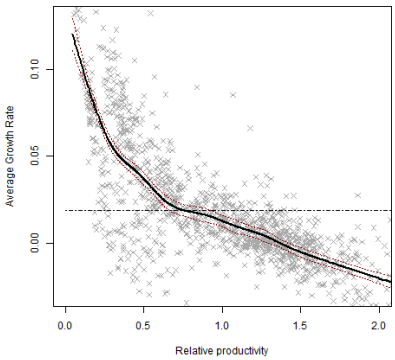


TCD Whole period

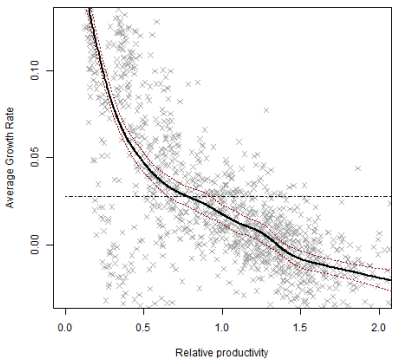
TCD Nineties



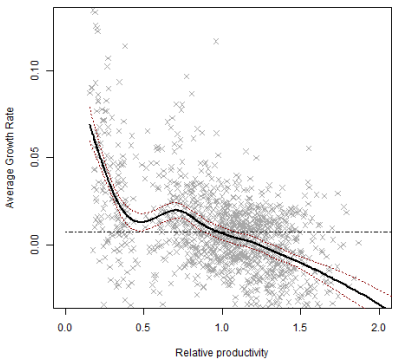
TCD Twenties



F&O Whole period



F&O Nineties



F&O Twenties

Figure 4: Semiparametric regressions for market services (TCD and F&O) labour productivity

decades. Such a process is particularly enhanced within the EU after 1992.

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). Moreover, results 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, Figure 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 part of the distribution, looking twin peaked in 1991, single peaked in 2000 and 2007.

Figure 5 provides a static picture of aggregate labour productivity, while it does not inform about the source of 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 or to some mobility in the close quantiles[16]. In other terms, a fundamental piece of information is provided by the intra-distribution dynamics, i.e. by regions moving forward or falling behind. Investigating such a process contributes explaining productivity dynamics. The transition matrix is a useful tool for the task. 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. Building a transition matrix requires the discretization of data, which could distort dynamics in an important way.

[16]See Bowman and Azzalini (1997) for further details about the smoothing of estimated densities and the choice of the bandwidth.

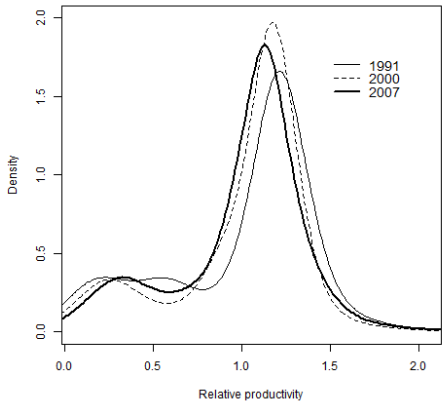


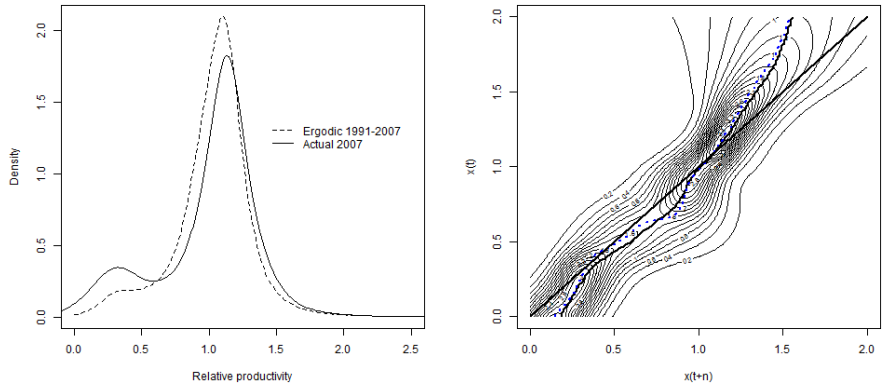
Figure 5: Estimated densities of aggregate labour productivity

Alternatively, it is possible to estimate conditional distributions[17], 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[18]. In what follows the ergodic distribution and the conditional densities are estimated, following Quah (1997) and Johnson (2004).

The left panel of Figure 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 than the density for 2007. Moreover, the bottom mode is much more smoothed than in the estimate with the actual data. 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. Firstly, observations at the bottom of the distribution tend to improve their relative performance. Secondly, observations around 1 tend to converge to the mean, as the intersection between the median curve

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

[18]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 (2004), Azomahou et al. (2005) and Fiaschi and Lavezzi (2007) for the continuous space approach.

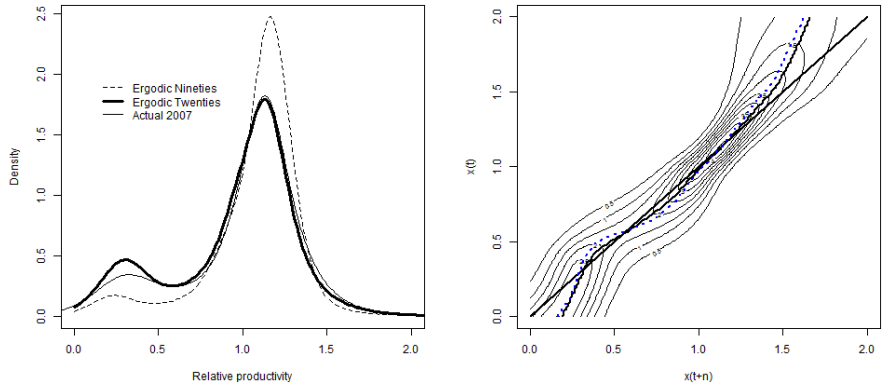


(a) Out of sample comparison (b) Conditional distribution 1991-2007

Figure 6: Distribution dynamics: ergodic estimates and conditional distribution

and the bisector suggests. This is consistent with the peak around 1 in the ergodic estimate. Hence, these findings suggest that the long run behaviour of the distribution is likely to be unimodal, predicting the disappearance of the bottom model. 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 Twenties. Hence, the left panel of Figure 7 compares the estimated density in 2007 and the ergodic estimates for the Nineties and the Twenties.

The ergodic estimate for the Twenties predicts 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 *if* the distribution dynamics of the Nineties had persisted. However, this is not the case, as a bimodal process is in place in the Twenties. Comparing Figure 7 with Figure 5 and the results of the semiparametric regressions in Figure 2 helps interpreting productivity dynamics. Figure 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 Twenties. This is also consistent with the semiparametric models in the previous section. 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 Twenties

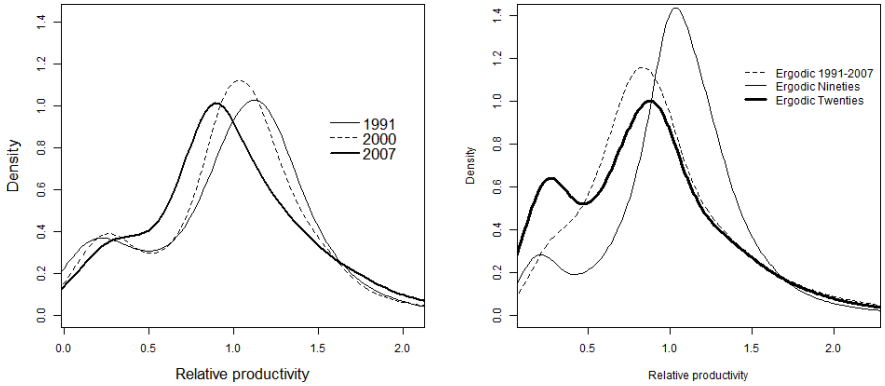


(a) Time variance of the process (b) Conditional distribution 2000-2007

Figure 7: Distribution dynamics for aggregate labour productivity

-

when the curve is almost flat.



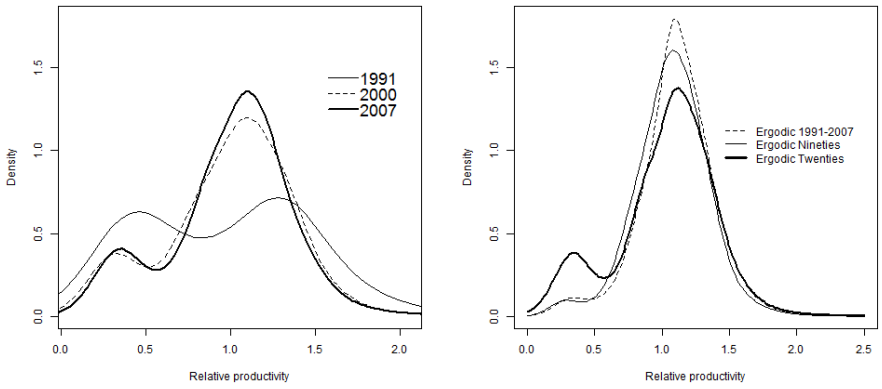
(a) Actual densities (b) Time variance of the process

Figure 8: Distribution dynamics for the Manufacturing sector

Figure 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[19]. The ergodic esti-

[19]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).

mate for the whole period in the right panel provides an ambiguous result. Even though there is some mass at the bottom of the distribution, it seems suggesting unimodal dynamics. This is due to the dynamics in the Twenties 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 Twenties suggests within distribution transitions towards the interval [0, 1], determining bimodality. This implies that the actual density in 2007 is somehow transitory and a twin peaked distribution is likely to prevail in the long run.[20]. 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, suggesting that convergence does not hold or, if any, it is in terms of clubs. Figure 8 is consistent with the semiparametric regressions in Figure 3. In particular, the unconditional convergence of the Nineties is transitory, while the divergence observed in the Twenties is consistent with the two modes of the ergodic estimate.



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

Figure 9: Distribution dynamics in the F&O sector

Distribution dynamics for the F&O sector are reported in Figure 9 and

[20]At a first glance, the ergodic estimate for the Twenties and the actual distribution in 2007 could seem incompatible. However, note that the shape of the density in 2007 is due to observations moving from the mean to the bottom, reverting the process in the Nineties. In other terms, the ergodic for the Twenties represents the long run behaviour which comes out if the process goes on. Therefore, the distribution dynamics generating the density in 2007 will eventually end up in the bimodal peak. The conditional densities confirm these findings and they are not reported for the sake of space.

are straightforward to interpret. The left panel suggests a unique evolution of the distribution. Being clearly bimodal in 1991, reduction in dispersion is observed both in 2000 and 2007, as the extreme observations move towards the mean. Bimodality is preserved only because of the Eastern economies at the bottom. The ergodic estimates in the right panel shows unimodal dynamics for the whole period and for the Nineties. Even though unimodality does not necessarily imply convergence, the ergodic estimates together with the semiparametric regressions in Figure 4 support this hypothesis. The ergodic estimate for the Twenties presents a second mode at the bottom of the distribution. Even in this case, findings are consistent with the nonlinear 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 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 1996a; 1996b, Paci and Pigliaru 1997, Cimoli et al. 2011, 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 Figure 5. Since the unit of observation is the NUTS3 territorial entity, grouping the economies by country would cause the loss of informations about within countries differentials. Therefore the *k-mean*[21] 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. Figure 10 summarizes the structural composition of the economies, 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[22], economies specialized too much in these sectors have a lower level of aggregate productivity. This can be defined as *wrong specialization* and it provides a first explanation of productivity differentials[23]. Overall, the top three clusters have a similar structural composition, while Cluster 1 is different from any other group[24].

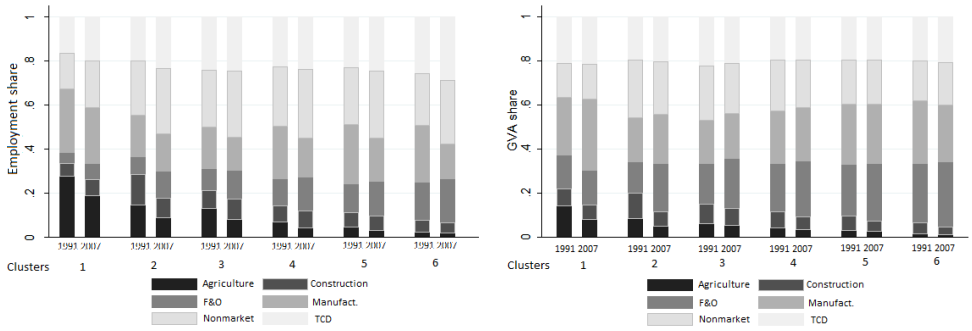
Different approaches for spotlighting the sources of productivity growth

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

[22]In Figure 10 it is possible to observe that GVA shares are lower than employment shares both in agriculture and non-market services

[23]Note 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. This suggests that the richest economies are the most productive in the sector.

[24]If clusters are created considering subsamples of the EU, interesting differences within the same national economy can also be observed, 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.



(a) Employment shares

(b) GVA shares

Figure 10: Structural composition in 1991 and 2007

can be used (Bernard and Jones (1996a; 1996b) and Rodrik (2013)). This section follows the decomposition by Cimoli et al. (2011). In particular, aggregate 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 4[25]. Overall, two main conclusions can be drawn.

[25]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.

Table 4: 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

Firstly, 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, it would be misleading to state that wrong structural change is taking place[26], because, although positive growth rates, productivity levels in agriculture are the lowest among the sectors, as reported in Table 1. In this case structural change is growth enhancing[27]. The negative total term for agriculture in Clusters 5 and 6 is due to insufficient PrG. 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 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.

[26]Wrong structural change indicates employment shift from more to less productive sectors.

[27]It must be stressed that DynEff is a dynamic 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.

Concluding remarks

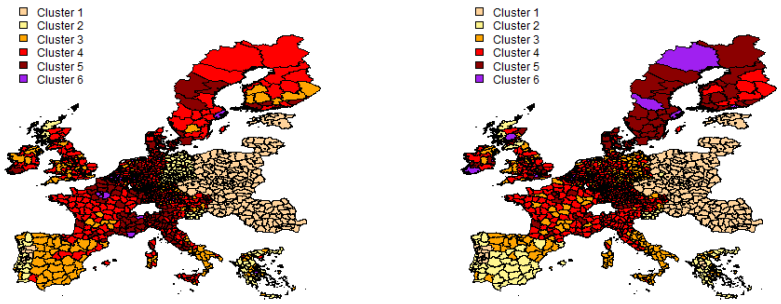
This paper analysed distribution dynamics in 1263 regions of the European Union, looking for absolute convergence and growth determinants for labour productivity. Findings reveal a clear process of convergence in F&O market services. Results are less straightforward for TCD and manufacturing. Indeed, 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 (1996c). 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 the only converging sector and it is mainly composed by financial activities: liberalization of capital markets may have affected the convergence process. However, this does not apply to the other sectors and to the economy as a whole. Since the overall behaviour of the economy is the result of sectoral aggregation, absolute convergence does not hold for aggregate labour productivity. Indeed, the growth paths are non linear and different patterns are observed along the distribution. Finally, 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.

These results has some policy implications. Indeed, despite this paper analyses absolute convergence, the above findings suggest that the EU policies addressing convergence and cohesion have been unsuccessful, as also shown by Figure 11 in Appendix A. Which policies have been the most ineffective in reducing regional inequalities (or contributed to their persistence) is the natural next step for future research, as well as the core of the political debate in the EU nowadays. Of particular interest are the so called structural reforms, first of all the deregulation of the job market and the Maastricht criteria, especially in comparison with the expansive policies adopted in the United States.

A Aggregate relative productivity: who is where

Figure 11 plots the maps of relative aggregate labour productivity in 1991 and 2007. Clusters have been obtained as described in the text, i.e. 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 th 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. Table 5 reports clusters' composition.



(a) 1991 (b) 2007

Figure 11: Distribution of labour productivity by Clusters in 1991 and 2007

Table 5: 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

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