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Essays on Economic Growth: Convergence, Labour Productivity and Energy

Supervisor:
Prof. Davide Fiaschi
Professor, University of Pisa

Co-Supervisor:
Phu Nguyen-Van
Chargé de recherche, BETA-CNRS

Author:
Roberto Martino

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Ai miei genitori. A Lucilla. Che hanno sempre avuto fiducia nonostante non abbiano mai capito bene dove stessi andando (e nemmeno io).

I would like to thank professor Fiaschi who introduced me to the topics and methods of this thesis; Phu Nguyen-Van who strongly contributed to this work during my stay in Strasbourg and beyond; all professors and colleagues in Strasbourg and Florence who supported me, gave me advice and provided constructive critics. Of course, all remaining errors are mine.

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Introduction

Understanding why some countries are prosperous while others fail in achieving high standards of welfare and wellbeing is one of the most interesting and investigated topics in economics. Several candidate exlplanations have been proposed, for instance cultural factors (Banfield, 1958; Putnam et al., 1993), geographical determinism (Diamond, 1997), institutional determinants (Acemoglu et al., 2000; Acemoglu and Robinson, 2012; North, 1990). Interestingly, a common feature of any theoretical argument is that each of them fits well with the recent European history. If it is the theory which has been adapted to Europe or if it is Europe which presents the characteristics suited to successful economic growth is debatable. According to Landes (1999), it is just a stylized fact that Europe took and kept the lead for at least the last one thousand years. Therefore, even though "some would say that Eurocentrism is bad [..], hence to be avoided", it can be understood as an aknowledgement of history. Of course, there is not full agreement on the topic and different perspectives on the matter have been proposed (Hobson, 2004). Whatever the story is, the European case is an interesting one, both in historical and in current terms. Indeed, since the Nineteenth century Europe (and the Western World) has been undertaking a continuous growth process, achieving unprecedented levels of wealth. Such a historical path allowed the Western countries to take the lead economically and politically. Using Landes (1999) words, "we live in a world of inequality and diversity, *in which there are* three kinds of nations: those that spend lots of money to keep their weight down; those whose people eat to live; and those whose people don't know where the next meal is coming from". Europe and the West have been constantly in the first kind.

However, richies have never been evenly distributed also within rich countries and this is true for Europe as well. In particular, European geography has been characterized by a growing dichotomy. On the one hand, some countries have been performing succesfully, maintaining levels of wealth which are top standards on a global scale. This is the case for continental countries, including Scandinavian economies and the United Kingdom. On the other hand, other countries have been falling behind and have not been able to keep in touch with the fast growing core. In this group we find the so called South of Europe, i.e. the Mediterranean countries, as well as the former sovietic Eastern economies. Of course, disparities have always been with us and this is not necessarily bad, since growth does not need to be a perfectly balanced process (Hirschman, 1958). However, such an issue becomes relevant as long as national and regional disparities either do not reduce or worsen overtime. This is even more important if the diverging economies belong to the same political entity. This is precisely the case of Europe, in particular of the European Union, a political and economic construct in which policy interventions have been implemented in the last decades to foster convergence and cohesion between economies.

This dissertation investigates some of the main topics in the empirical literature on economic growth. The scope is to assess empirically the validity of some theoreatical statements and policy provisions, focussing mostly on European economies because of their peculiar economic history. A broader cross-country analysis is also provided in the last section.

1.1 Economic growth in the European Union

As a first step we will test whether under some specific circumstances economies will tend to get closer and closer in terms of wealth. Theoretically, following Solow (1957), the standard neoclassical model predicts that one should find evidence of convergence, in the sense that poorer economies ar expected to grow faster than richer ones (Barro and Sala-i Martin, 1992; Mankiw et al., 1992). Of course, this holds as long as economies are similar in terms of structural characteristics (as the composition of output and the distribution of labour force across sectors) and technology. Empirically, these conditions are not likely to hold, hence the standard result provides support to the convergence hypothesis only if conditional variables are accounted for (Barro, 1991; Barro and Sala-i Martin, 1992). Differently, the unconditional (absolute) convergence hypothesis is satisfied only for homogenous samples of countries and for specific economic sectors (Baumol, 1986; Bernard and Jones, 1996c; Rodrik, 2011, 2013) . Indeed, disaggregating by sector allows to wipe out the role of sectoral composition in determining both the aggregate level and the aggregate growth rate of output. Moreover, it should also highlight the effect of technology and knowledge spillovers which are determining drivers of convergence.

Hence, the first part of this dissertation will address unconditional convergence in European regions from 1990 to 2007, a relatively homogeneous set of economies, emphasizing the role of sectoral dynamics in shaping aggregate outcome. Note that convergence regressions inform mainly on the average behaviour of the economies, while they do not inform about relative performance and distribution dynamics. Hence, we also make use of the tools originally proposed by Quah (1996, 1997) to investigate distribution dynamics overtime. Note that the main variable for the analysis is labour productivity, defined as the ratio between economic output (here measured as Gross Value Added) and employment. Indeed, a positive growth rate of output per capita is associated with a rise in wellbeing and living standards[1]. In particular, economic output per capita can be decomposed as $Y/P = Y/L * L/P$, where Y is output, P is population, L is employment. It is clear that the main component is given by Y/L, which is the amount of output produced by each worker, i.e. labour productivity, whose growth rate determines the growth rate of GDP per capita.

The first section concludes with a special focus on the Italian economy. Indeed Italy is a special case in the European scenario, characterized by regional inequalities which evolved in the last century following a clear regional pattern. In particu-

[1]Of course, economic growth alone is not a sufficient condition for guaranteeing diffused better living standards. Decreasing inequality is also needed to increase the wellbeing of the population and to reduce poverty. On the topic see Bourguignon (2004)

lar, Northern and Central regions became richer and richer, while Southern regions lagged behind. Even though there is no agreement in the literature on when exactly the divergence started, it has been continuing until today with the only exception of the two decades between 1950 and 1970 (Daniele and Malanima, 2011; Felice, 2005; Felice and Vecchi, 2012). The above tools are therefore applied to Italian provinces from 1991 to 2010. Results show that the Dualism strenghtened during the period considered: the observed trend shows increased polarization, North and South becoming more homogenous overtime.

1.2 Economic performance, labour market institutions and fiscal parameters

The analysis of the dynamics of economic output provides an insightful picture of trends in economic growth and inequality between regions, fully describing the evolution of the distribution. Even though some policy implications can be drawn, they are quite limited. Indeed, such an *unconditional* analysis does not allow to tell which factors are positively associated with economic performance and which are not. The second section of this dissertation explores this line of research by focusing on two domains which have become particularly relevant after the last crisis in 2008.

The first domain concerns deregulation and liberalization of the labour market, intended as a solution to remove frictions and increase productivity of the system. Overall, more flexible labour market institutions are part of a broader institutional framework in which liberalization, privatization and less State intervention are understood as a prerequisite for a better functioning of markets. Such a receipt has been adopted as one of the policy structural pillars defining the route to escape the last crisis. However, this perspsective is not a new comer. Indeed it was already part of mainstream policy packages since the Eighties, at the time known as Washington Consensus and used as conditioning requirement by Bretton Woods institutions in international aid programs (Stiglitz, 1998; Williamson, 1990).

The second domain concerns fiscal parameters. Balanced budget and low levels of public debt are usually seen as prerequisite for positive economic performance. However, there is no agreement in both theoretical and empirical literature on the topic (Barba, 2001; Blinder, 1997; Herndon et al., 2014; Reinhart and Rogoff, 2010). Despite this, policy interventions in the European Union in the aftermath of the last crisis have been targeting the reduction of public expenditure, balanced budget and the reduction of debt/GDP ratios. Similarly, the Maastricht criteria establish that the debt/GDP and the deficit/GDP shares must be lower than 60% and 3% respectively.

Therefore the relationship between labor market institutions, fiscal parameters and economic performance is investigated, using a sample of regional economies of the European Union. Instead of using a standard growth-regression approach, the adopted methodology is drawn from the empirical literature on the estimation of a production function, following the contributions by Olley and Pakes (1996), Levinsohn and Petrin (2003) and Ackerberg et al. (2006). A structural model is estimated, representing the long run relationship between economic performance and the variables considered.

1.3 A broader look: environment and growth

The last part of this work takes a broader perspective on economic growth and correlated phenomena, also enlarging the sample under analysis beyond the European Union. One of the emerging topic in the empirical literature concerns the investigation of the relationship between environment degradation and economic growth. If at a first glance a positive relationship may be the more obvious pattern, some theoretical arguments suggest that under specific conditions environmental degradation may start declining at higher levels of GDP. In particular, three factors may be fostering such a process: environmental friendly technological innovation, structural change towards less energy-intensive activities, change in individual preferences together with regulation. Given this set of hypothesis, starting from the Nineties a large amount of empirical studies has been investigating the relationship between various indicators of environmental degradation and GPD. The main scope is to test empirically the so called Environmental Kuznetz Curve hypothesis, which states that environmental degradation increases with income until a threshold level, after which the relationship turns negative (Grossman and Krueger, 1991; Panayotou, 1993; Shafik and Bandyopadhyay, 1992; Stern, 2004). The main idea is that at a sufficiently high level of income the three mechanisms above will trigger the switch in the relationship.

We will test this hypothesis for a large sample of countries, augmenting the standard model in order to account for convergence in environmental degradation. Indeed, as long as the EKC and convergence takes place simultaneously, economic growth will be associated with a reduction in the environmental impact of economic activity. Accounting for both phenomena together contributes to the existing literature providing a complementary analysis of the dynamics of environmental degradation and GDP.

Convergence and growth. Labour productivity dynamics in the European Union

2.1 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) 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 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 (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.

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 re-

[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.

gional 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. 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, 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 nonlinearities cannot be identified. Hence, in what follows the standard β regression is replaced by a semi-parametric model in which the growth rate of labour productivity is expressed as an unspecified function of its initial level. This allows to identify both nonlinearities and the existence of more than one potential *steady state* equilibrium in the growth path. Furthermore, 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

[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, 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).

(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 2.2 presents the data and the methodology. Section 2.3 reports the non parametric estimates for aggregate, manufacturing and market services productivity. In Section 2.4, distributional analysis tools are used to analyse aggregate productivity dynamics and its sectoral determinants. In Section 2.5, aggregate productivity growth is decomposed in pure gains and structural change terms and sectoral contributions are computed. Concluding remarks follow.

2.2 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, 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

[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

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 2.1 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 (LIGEP, 2013; O'Mahony et al., 2010; Timmer et al., 2010; Van Ark et al., 2008). 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 β regression. This allows to highlights nonlinearity 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] (Feyrer, 2008; Fiaschi et al.,

[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 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.

[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 for 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 $f_\propto(z) = \int_0^\propto g_\tau(z|x) f_\propto(x) d_x$, where the

Table 2.1: 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

2011; Fiaschi and Lavezzi, 2007; Quah, 1997). Finally, the growth rate of aggregate labour productivity is decomposed following the procedure in Cimoli et al. (2011).

2.3 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, i.e.

$$\bar{g}_i = a + \phi(y_{i,1991}) \tag{2.1}$$

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. 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 (Bernard and Jones, 1996c; Gerschenkron, 1962; 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.

2.3.1 Aggregate labour productivity

The estimates for aggregate labour productivity are reported in Table 2.2. In the linear estimator, observations are converging if the coefficient on $y_{i,1991}$ is negative

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).

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 2.2: 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	0.0002

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

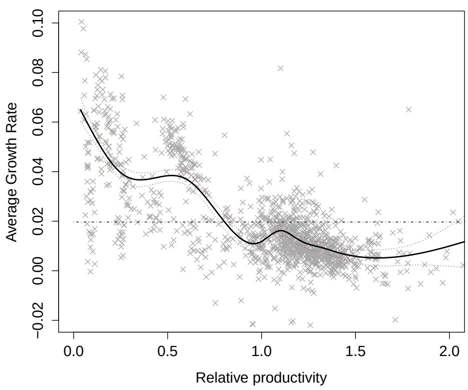
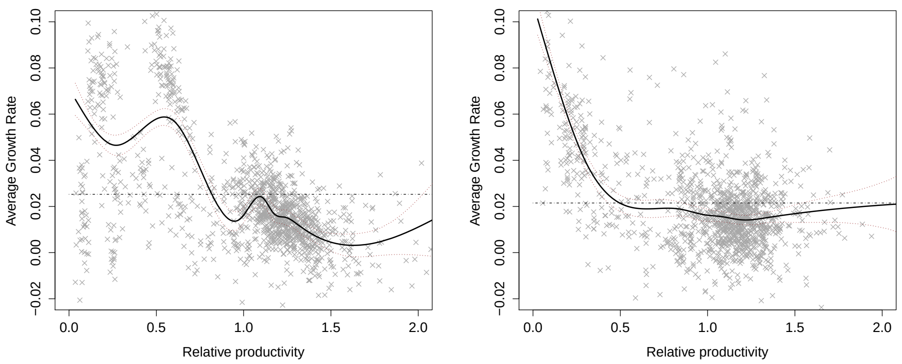


Figure 2.1: Semiparametric regression for Aggregate labour productivity

The resulting growth path plotted in Figure 2.1 clearly confirms the nonlinearity 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, 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

[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 Figure 2.1, in the steady state they will end up growing at the same rate, which will be equal to the average rate.

the next section will confirm that the non-linearities in Figure 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, Equation (1) is estimated separately for the Nineties and the Noughties to verify whether two different growth trajectories are in place.



(a) Nineties (b) Noughties

Figure 2.2: Semiparametric regression for Aggregate labour productivity in the two sub-periods

The plots of the non linear estimates in Figure 2.2 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. 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 linearities in the growth paths does not support the *neoclassical* hypothesis of unconditional convergence for aggregate productivity.

2.3.2 Manufacturing

The estimation of Equation (1) reveals a non linear growth path, as shown by the EDF reported in Table 2.3. The left panel of Figure 2.3 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 decreas-

[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.

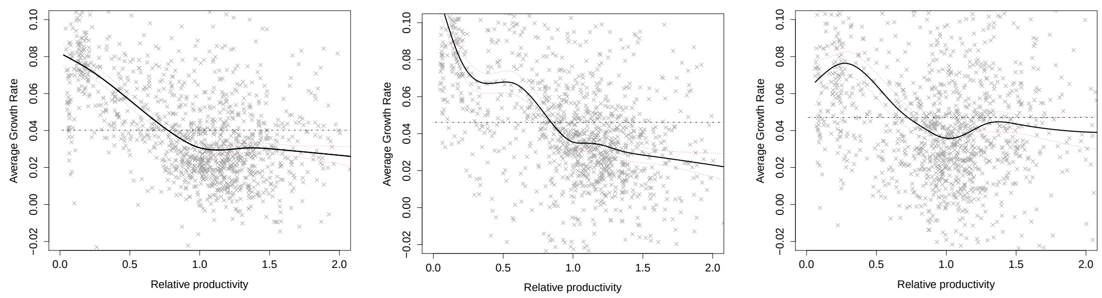
ing. Hence, unconditional convergence is found for the bottom of the distribution only, while findings are ambiguous for observations above the sample mean (1).

Table 2.3: 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	0.0006

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

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 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.



Whole period Nineties Noughties

Figure 2.3: Semiparametric regression for Manufacturing labour productivity

2.3.3 Market services

Figure 2.4 plots the growth path resulting from the estimation of Equation (1) for both TCD and F&O, while Table 2.4 reports the estimates, indicating a nonlinear 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 nonlinear. This is true for the whole period, as well as for the two subperiods, as shown in Figure 2.4. 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 agglomeration, the first around 0.5 because of the Eastern regions, the other around 1.

Table 2.4: Estimation of equation (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. $n = 1263$.

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. Abso-

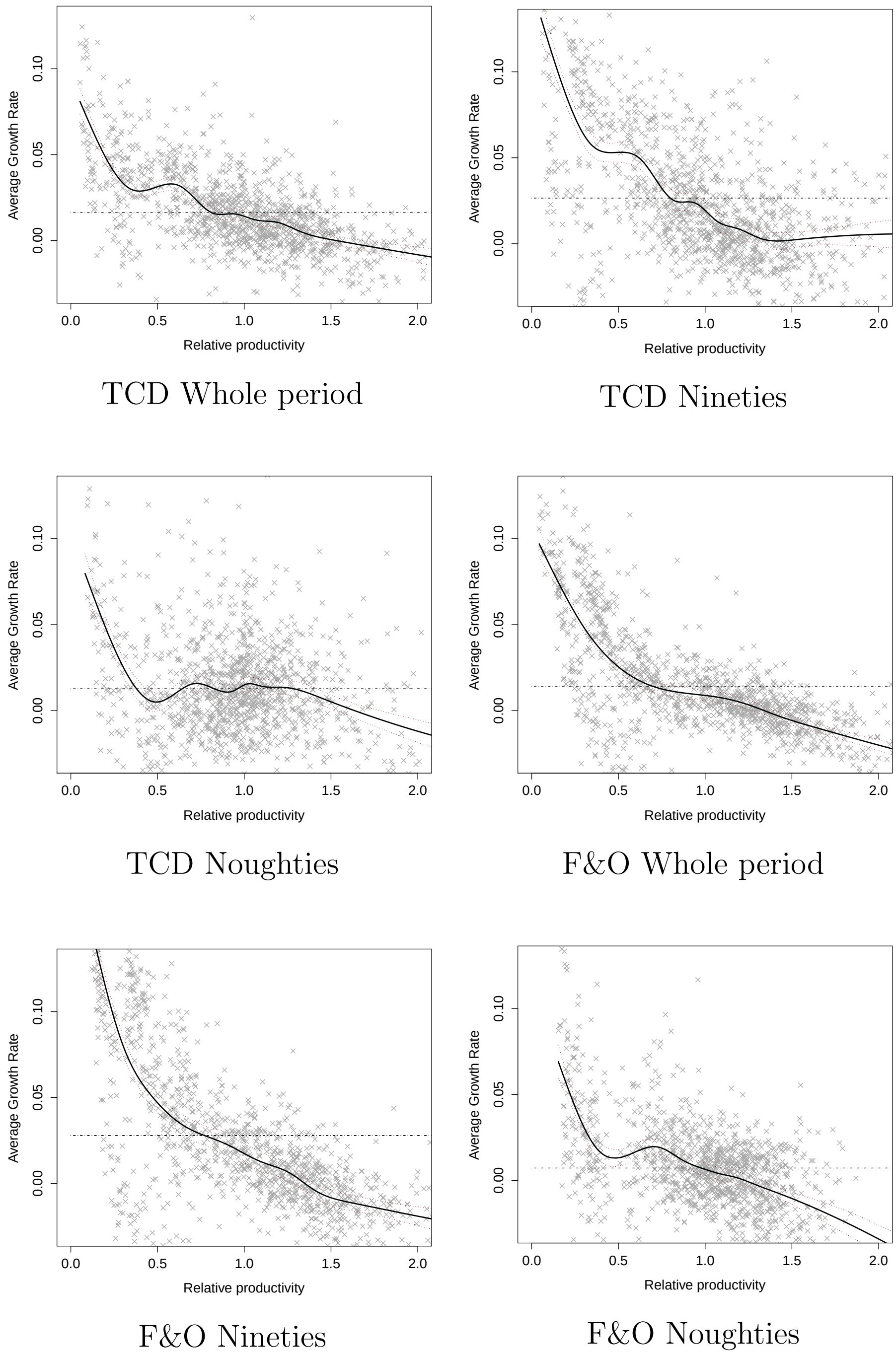


Figure 2.4: Semiparametric regressions for market services (TCD and F&O) labour productivity

lute 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 Figure 2.4. 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.

2.4 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, Figure 2.5 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.

Figure 2.5 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

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

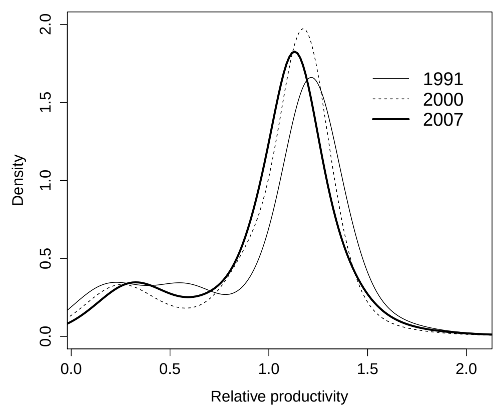


Figure 2.5: Estimated densities of aggregate labour productivity

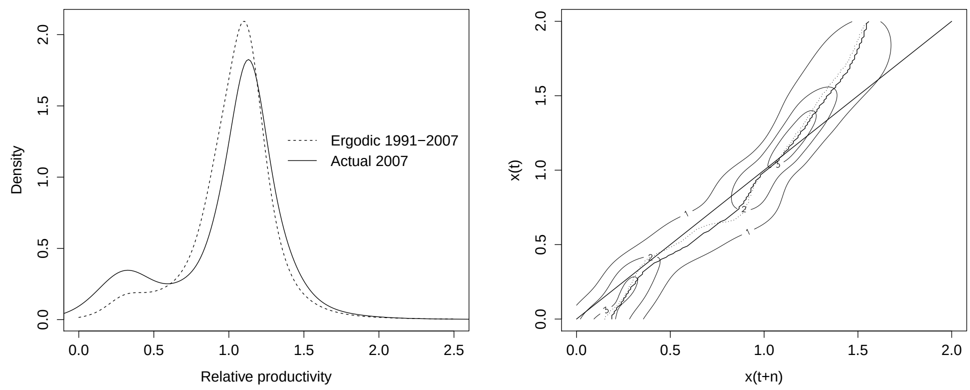
performance or to some mobility in the close quantiles[13]. In other terms, a fundamental piece of information is provided by the intra-distribution dynamics, i.e. by regions moving forward or falling behind. The transition matrix is a useful tool for investigating such a process. It gives the probability 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 Figure 2.6 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. 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 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

[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*.

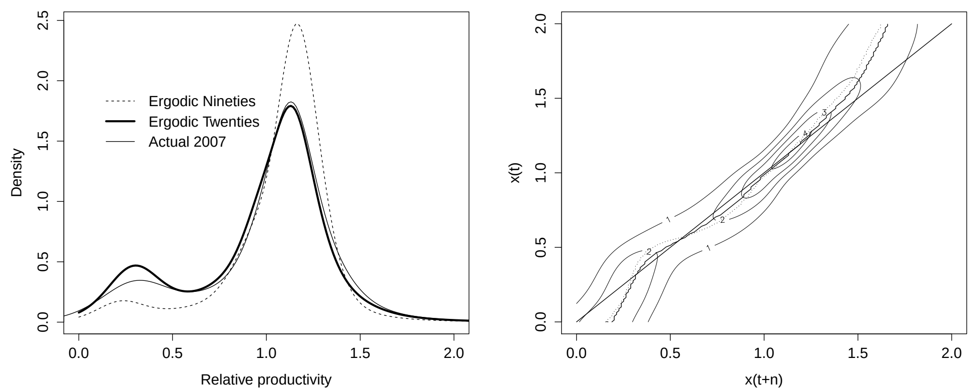
[15]Note that such a framework holds under the assumption that the underlying process is time-invariant. See Feyrer (2008) for the transition matrix and the ergodic distribution with the discrete Markov chain method. See Quah (1997), Johnson (2005), Azomahou et al. (2005) and Fiaschi and Lavezzi (2007)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



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

Figure 2.6: Distribution dynamics: ergodic estimates and conditional distribution

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 Figure 2.7 compares the estimated density in 2007 and the ergodic estimates for the Nineties and the Noughties.

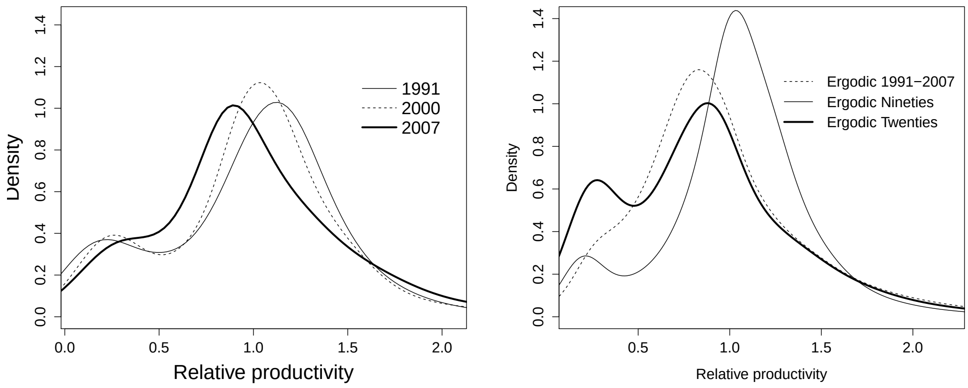


(a) Time variance of the process (b) Conditional distribution 2000-2007

Figure 2.7: Distribution dynamics for aggregate labour productivity

-

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 Figure 2.7 with Figure 2.5 helps interpreting productivity dynamics. Figure 2.5 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 Twentis in the right panel of Figure 2.7 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 Figure 2.2. 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.



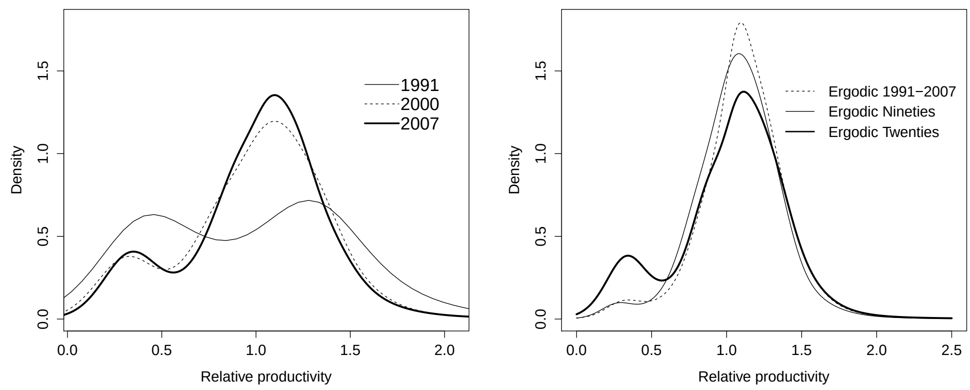
(a) Actual densities

(b) Time variance of the process

Figure 2.8: Distribution dynamics for the Manufacturing sector

Figure 2.8 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. Figure 2.8 is consistent with the semiparametric regressions in Figure 2.3. In particular, the unconditional convergence of the Nineties is transitory, while the divergence observed in the Noughties is consistent with the two modes of the ergodic estimate.

[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

Figure 2.9: Distribution dynamics in the F&O sector

Distribution dynamics for the F&O sector are reported in Figure 2.9. 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 Figure 2.4 support this hypothesis. Finally, the bottom mode for the Noughties is also consistent with the nonlinear growth path for the period.

2.5 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 (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.

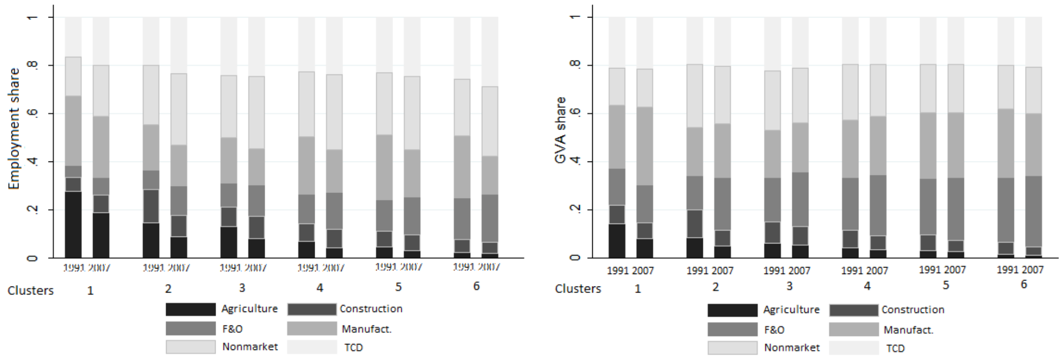
The decomposition exercise is usually done by set of countries. Here the departure point is the estimate of the distribution of relative aggregate labour productivity in Figure 2.5. Since the unit of observation is the NUTS3 territorial entity, grouping the economies by country would cause the loss of informations about within countries differentials. Therefore the *k-mean*[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. Figure 2.10 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 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, 1996b,c; Fiaschi and Lavezzi, 2007; McMillan and Rodrik, 2011; Paci and Pigliaru, 1997a). This section follows the decomposition by Cimoli et al. (2011). In particular, aggregate productivity growth is decomposed in three

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

[18] In Figure 2.10 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.



(a) Employment shares

(b) GVA shares

Figure 2.10: Structural composition in 1991 and 2007

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:

$$\Delta y/y_0 = \sum_i [\underbrace{(\Delta y_i L_0)/y_0}_{PrG} + \underbrace{(\Delta L_i y_0)/y_0}_{ShEff} + \underbrace{(\Delta y_i \Delta L_i)/y_0}_{DynEff}] \tag{2.2}$$

$\Delta y/y_0$ 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 2.5[20]. Overall, two main conclusions can be drawn.

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

[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.

Table 2.5: 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

$\Delta L < 0$ and $\Delta y > 0$. However, although positive growth rates, productivity levels in agriculture are the lowest among the sectors, as reported in Table 2.1. 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 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 2.1.

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 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. Firstly, despite this paper does not address the effectiveness of economic policy in the EU, the above findings on ag-

[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.

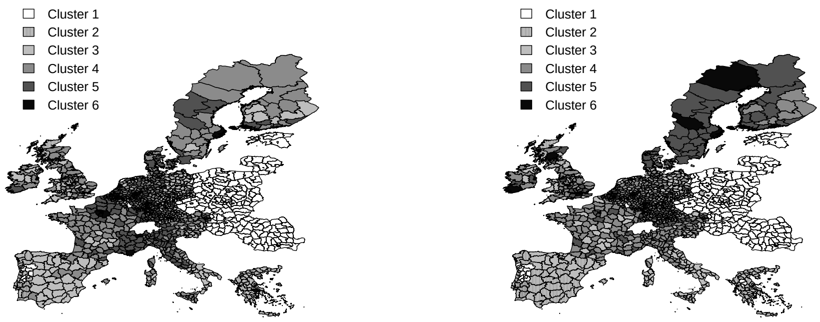
gregate labour productivity suggest that the efforts attempting to reduce regional inequalities have not been successful. On the opposite, the EU scenario in 2007 is characterized by a worsening of the centre-periphery gap than in 1990, as also shown in Figure A.11 in Appendix A[22]. Secondly, lack of 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.

[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).

Appendix

A.1 Aggregate relative productivity: who is where

Figure A.1 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.1 reports clusters' composition.



(a) 1991 (b) 2007

Figure A.1: Distribution of labour productivity by Clusters in 1991 and 2007

Table A.1: 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

A.2 Nonlinearities 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 Equation (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

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

Table A.2 reports the parametric estimates of Equation A.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, Figure A.2 plots the parametric estimates together with the semiparametric results of Section 2.3. 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[1], nonparametric results clearly show that this is not the case.

Table A.2: β-Convergence

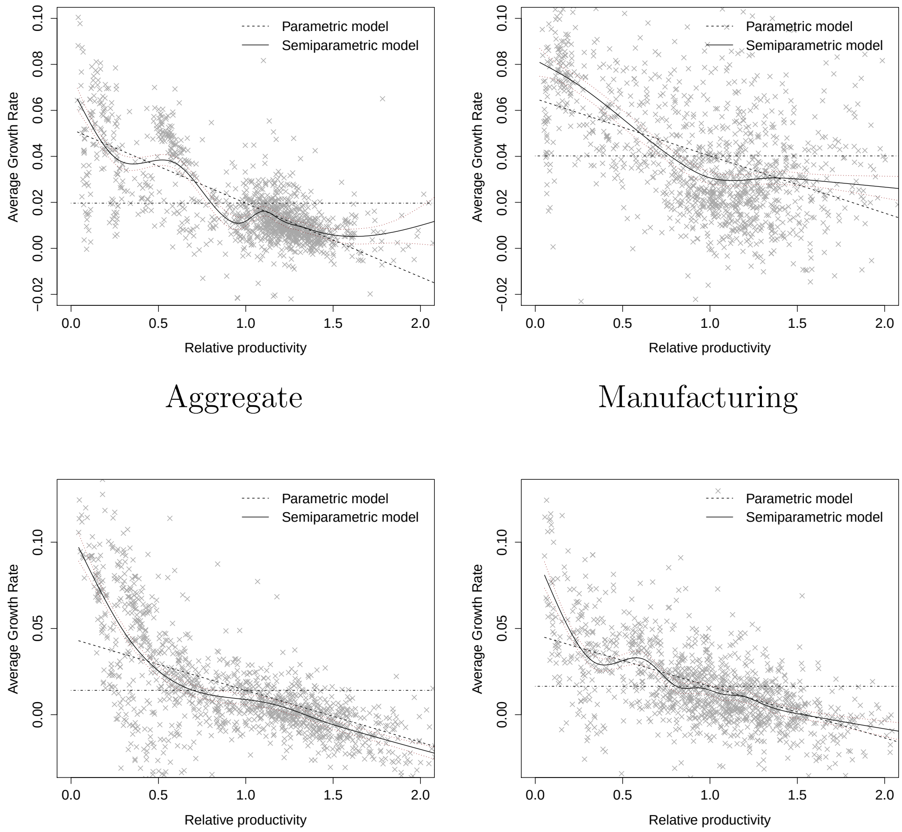
	Aggregate	Manufacturing	F&O	TCD
$\hat{\alpha}$	0.052***	0.065***	0.044***	0.046***
$\hat{\beta}$	-0.032***	-0.025***	-0.030***	-0.030***
R^2	0.457	0.233	0.400	0.322

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

A.3 A special case: the Italian Dualism

Economic development does not need to include all areas of a country at the same time and in the same way. It is rather that sequence leading persistently away from equilibrium, because "each move in the sequence is induced by a previous disequilibrium and in turns creates a new disequilibrium that requires a further

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



Aggregate | Manufacturing

F&O | TCD

Figure A.2: Comparison between parametric and semiparametric regressions for the whole period move" (Hirschman, 1958, pp. 66-67). Nonetheless, the Italian economy is a sort of special case in the European scenario. Indeed the evolution of its economic geography is characterized by regional inequalities which have been following a clear North-South divide since the birth of the State in 1861. In particular, the wealthiest and richest regions are mostly located in the North and in the Center. Among the scholars there is no full agreement on how far in the past are the roots of this territorial divide to be found[2]. However, dualism is a persistent feature of the Italian economic system, as well as the long lasting path of divergence between the South and the North of the country. In what follows, part of the analysis above is applied to the Italian provinces[3] for the period 1991-2010. The focus is on the evolution of disparities in a period characterized by policy interventions at both the national and the European level, whose main target was to fill the gap between the South and the rest of the Country, in line with the Convergence and Cohesion Objective of the European Union[4].

Data show that the standard deviation of (the log of) labour productivity among Italian provinces slightly decreased in the period considered. In other terms, a process of *sigma* convergence is in place, as shown in Figure A.3 in which a linear regression is superimposed[5]. However the process is really weak, since standard deviation falls just from 0.14 to 0.10. Moreover, no information can be drawn about the geographical pattern and we cannot say whether the reduction is due to reduced dispersion between the North and the South or it is only a phenomenon within the two macro-areas.

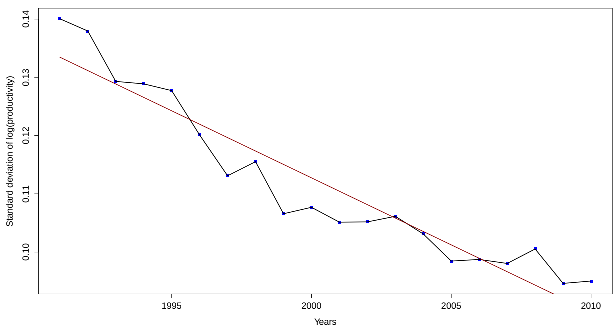


Figure A.3: Sgima convergence

Therefore, Figure A.4 plots the distribution of labour productivity for the Italian process at three points in time: 1990, 2000 and 2010. Two main conclusions can be

[2]Recent studies tend to reject the hypothesis that the territorial divide was already present before the creation of the Kingdom of Italy in 1861, highlighting rather the backwardness of the peninsula as a whole with respect to the European leaders of that time. However, even if present, the dualism was not yet as sharp as today, since more variation was to be found within than between the two macro-regions (Daniele and Malanima, 2011; Felice, 2005; Felice and Vecchi, 2012)

[3]This Appendix is a short extract of the paper "Trends in the Italian Dualism: labour productivity dynamics and structural change", published in *Quaderni di Ricerca Rassegna Economica*, 22, 11-38.

[4]Most of the Southern regions are part of the Objective 1 area, to which the Convergence and Cohesion policy is addressed. In particular, the regions are Basilicata, Calabria, Campania, Puglia, Sardegna and Sicilia.

[5]The standard OLS estimation $\sigma_t = a+\beta_t$ gives both coefficients significant at 1%. In particular, $\hat{a} = 4.717$ and $\hat{\beta} = -0.002$.

drawn from the picture. Firstly, the distribution is characterized by decreasing in dispersion, consistently with Figure A.3. Secondly, two main peaks emerge and the economy is polarized in 2010.

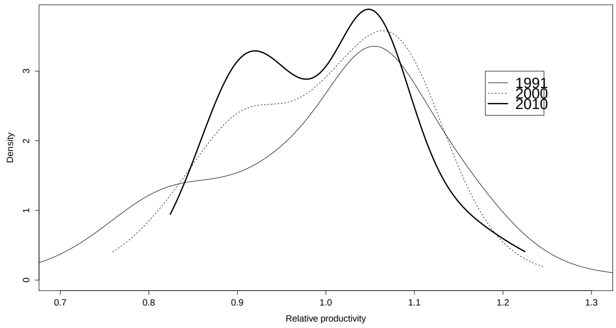


Figure A.4: Distribution of labour productivity in Italy

Ergodic and conditional densities (non reported for the sake of space) confirm that distribution dynamics have been determining a bimodal trend, especially from 2000 onwards. In particular, provinces with relative productivity between 0.8 and about 0.98 are converging towards 0.9, while observations whose productivity is larger than 0.98 are converging around 1.05. Therefore, we can identify two main agglomerations: a "LOW" productivity cluster in the range [0.85, 0.95], a HIGH productivity cluster in [1, 1.1]. The *attraction* role of the clusters can be summarized in Table A.3 and Table A.4. Table A.3 shows the composition of the two clusters in 1991, 2000 and 2010. The share of provinces belonging to them substantially increases overtime, going from 44% in 1991 to 69% in 2010. The main driver of this trend is the LOW cluster, which almost triples the number of provinces, from 12 in 1991 to 35 in 2010. Table A.4 summarizes transition probabilities between the clusters, i.e. the probability being in cluster y in 2010, belonging to cluster x in 1991. For provinces in cluster LOW in 1991, the probability of being in the same cluster in 2010 is 67%. For those in cluster HIGH, the probability is 60%. To add more support to the idea of the two poles as attractors, the bottom part of the Table shows the transition probabilities between cluster HIGH and the group of Leaders, defined as those provinces with aggregate relative probability larger than 1.1. For those who were leaders in 1991, the probability to switch to cluster HIGH – that is, worsening their relative performance – in 2010 is 48%. At the same time, the probability to become leaders in 2010 is just 9% . Similarly, provinces with relative productivity below 0.85 (Laggards) have 77% probability to move to cluster LOW.

Table A.3: Composition of the two clusters

Clusters	1991	2000	2010
LOW	12 (11%)	28 (26%)	35 (33%)
HIGH	35 (33%)	36 (34%)	39 (36%)
TOTAL	47 (44%)	64 (60%)	74 (69%)

The analysis above provides eveidence of a progressive polarization of the Italian economy. The only question left conerns how "well" the two clusters fit the

Table A.4: Transitions probabilities

		2010	
		LOW	HIGH
1991	LOW	0,67	0,17
	HIGH	0,11	0,60
		LAGGARDS	LOW
	LAGGARDS	0,091	0,773
	LOW	0	0,667
		LEADERS	HIGH
	LEADERS	0,44	0,48
	HIGH	0,09	0,60

North-South divide? In other terms, has this polarization evolved consistently with the historical Dualism or is the Italian economic geography changing? Figure A.5 provides the answer. The persistence of the Italian Dualism is clearly confirmed. Furthermore, its territorial dimension is also reinforced. Indeed, homogeneity within the two macro-areas increases overtime, as the map clearly shows for 2010: almost all Southern provinces belong to cluster LOW. Moreover, provinces in Sicily and Sardinia belonging to cluster HIGH in 1991 suffered a decline in relative productivity (they are Palermo, Catania, Siracusa and Olbia-Tempio). No Southern province belongs to cluster HIGH at the end of the period.

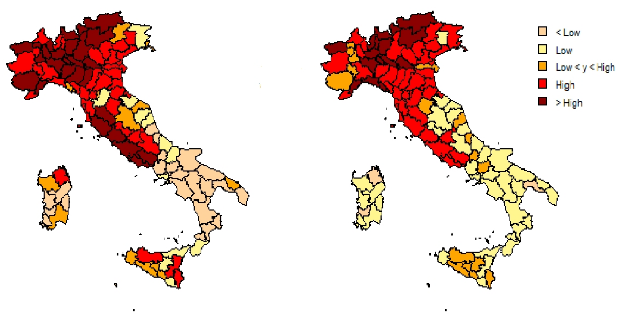


Figure A.5: The Italian Dualism in 1991 (left) and 2010 (right)

Labour market regulation and fiscal parameters: A structural model for European regions

3.1 Introduction

Starting[1] from the Eighties of the last century, economic receipts have been suggesting that a market oriented environment sets up the right conditions for successful economic activities. Liberalization, privatization and less State intervention have been invoked as a prerequisite for the appropriate functioning of markets. In particular, the State should just guarantee free competition and avoid any potentially distorting intervention. This implies more abstentions than active policies. Consequently, balanced budget has been proposed as the main policy target, to be achieved by reduced public spending rather than by increasing taxation. Deregulation is intended to remove frictions affecting markets' functioning in favour of free competition. Similarly, the rationale for privatization is the belief that private industry performs better than State enterprise because of the more direct incentives to managers (Williamson, 1990).

Originally catalysed by the experience of Latin America in the Eighties, this set of reforms has been adopted as main conditioning receipt by the Bretton Woods institutions for their Structural Adjustment programs, mainly in Africa and Latin America. It is known as the Washington Consensus after Williamson (1990). However, its main principles have been recently adopted in the European Union (EU), in particular during the last crisis. Indeed, despite no direct reference has been made to the Washington Consensus itself, the ingredients are the same, with more emphasis on fiscal consolidation and less on privatization.

Two main domains assume relevance in the current EU scenario. First, liberalization and deregulation have been advocated as the main means to make markets as close as possible to perfect competition. Indeed, regulation is traditionally seen as a source of both unemployment and unsatisfactory economic performance.[2] In particular, labour markets should be made more flexible, while employment protection should be reduced since it discourages firms to hire and invest because of firing restrictions.

Second, budget imbalances are usually invoked to explain the difficulties of some

[1]This chapter is a jointly work with Phu Nguyen-Van, Chargé de recherche, BETA-CNRS.

[2]For the relationship between labour market institutions and employment see for instance Blanchard and Wolfers (2000) and Bassanini and Duval (2007).

countries of the EU to get out of the crisis. Despite the crisis was not born as a debt crisis, it is argued that public debt must be addressed in order to help Europe to recover.[3] Moreover, the two Maastricht parameters concerning public finance state that the debt/GDP ratio should be lower than 60%, while the deficit/GDP ratio should not exceed 3%. On this basis, a conservative pro-cyclical response package has been adopted throughout Europe, mainly by cutting public expenditure.

As already happened for the original Consensus, the soundness of such polices has been heavily questioned. Theoretically, it can be argued that the relationship between public debt and economic performance is negative. For instance, high debt may cause uncertainty and generate expectations of future financial repressions, as well as it may increase sovereign risk (Cochrane, 2011; Codogno et al., 2003). Also, excessive debt burden may constrain the capacity of fiscal authority to engage in traditional countercyclical stabilization policies (Cecchetti et al., 2011). However, it is also true that as long as public debt is cumulated as a result of expansionary fiscal policies, it can be positively related to economic performance (Cecchetti et al., 2011; Panizza and Presbitero, 2014). The last point brings to the discussion on the role of contractionary fiscal policies and public deficit. Critics of the post-crisis policy package have pointed out how contractionary policies during a recession could worsen it, instead than favouring a recovery. Therefore, countercyclical interventions should be preferred.[4] Moreover, the Maastricht fiscal parameters have been criticized for being neither theoretically grounded nor supported by empirical evidence.[5] More generally, context conditions, such as the overall status of the economy, future prospects of growth, access to credit, etc. should be accounted for when considering budget deficit targets (Stiglitz, 1998). Empirical findings are not univocal as well. Some authors report evidence of a negative nonlinear relationship between public debt and growth, with turning point around a debt/GDP ratio above 80-90% (Cecchetti et al., 2011; Reinhart and Rogoff, 2010). Others find either weak or no association, also when the level of debt becomes high (Égert, 2015; Panizza and Presbitero, 2014; Pescatori et al., 2014). For what concerns deregulation and liberalization policies, Stiglitz (1998) already pointed out that they do not necessarily imply increased competition.[6] This can be true for the current deregulation of the labour market, if either the overall economic conditions do not allow for actual competitive markets or globalization opportunities (and threats) do exist. Moreover, deregulation could have perverse effects in terms of unemployment, especially for the youth (O'Higgins, 2012).

The present paper sets in this framework by analysing the relationship between labour market deregulation, fiscal parameters and Gross Value Added (GVA). We use several institutional indicators for the labour market, debt and deficit shares

[3]Reinhart and Rogoff (2010) is probably the most influential paper which gives support to the hypothesis that high debt hampers economic growth.

[4]See Blinder (1997) and Barba (2001) for an assessment of the depressive and the expansionary hypothesis of fiscal retrenchments.

[5]See Pasinetti (1998) for a critique of the 3% deficit/GDP criterion, Herndon et al. (2014) for a reassessment of the debt/GDP results of Reinhart and Rogoff (2010).

[6]With respect to the financial markets, the support for deregulation comes from the assumptions that free-market capitalism works better without the constraints imposed by State control. For a critical assessment on this regard, with a specific focus on the causes of the last crisis, see Soros (2009) and Varoufakis (2013). It is worth noting how such two different perspectives converge to the role of financial deregulation in favouring the crisis.

on GDP. We also consider the Maastricht thresholds to investigate their empirical relevance. The main scope of this study is to assess the existence of a long-run relationship between the variables considered, GVA being the main dependent variable. Hence, we estimate an augmented *structural equation*, drawing the methodology from the firm-level literature on production functions. In particular, we adapt the estimation procedure originally proposed by Olley and Pakes (1996) and reviewed by Levinsohn and Petrin (2003) and Ackerberg et al. (2006). This allows to approximate nonparametrically any unobserved factor influencing likely endogenous regressors. This in turn yields consistent estimates of the coefficients. Our structural model implies the estimation of am augmented production function in which capital, employment and the additional variables are included as regressors. Of course, our additional regressors are potentially correlated with the two "inputs", in particular with employment, since we consider labour market institutions. Therefore, their inclusion corresponds to the need to explain the residual term which accounts the most in explaining differences in productivity among economies (Easterly and Levine, 2001). In particular, we want to assess whether the fiscal parameters and labour market deregulation contribute to explain productivity and if their contribution is positive, as implied by the rationale of their application in the EU[7].

Our findings show no univocal evidence of a detrimental effect of labour markets regulation on GVA. Furthermore, deficit spending beyond the 3% criterion is associated with higher output, while public debt is found to be detrimental for economic performance only when its share on GDP becomes large.

The paper proceeds as follows. Section 2 introduces the methodological background on estimation of production functions. Section 3 describes the estimation procedure. The data are presented in Section 4. Results are discussed in Section 5. In Section 6 we present some specification tests to verify the appropriateness of our assumptions. Section 7 concludes.

3.2 Methodological background

We adopt the approach used in the *structural* literature, following Ackerberg et al. (2006), which focuses on the computation of total factor productivity (TFP) at the firm level by estimating a general production function, usually assumed as a Cobb-Douglas technology. The approach explained below works also with any different assumption about the form of the production function (Ackerberg et al., 2006; Levinsohn and Petrin, 2003; Olley and Pakes, 1996). The use of the Cobb-Douglas is just a convenient approximation which, in the case of the present study, helps also understanding the link between the adopted approach and the widely used growth regressions.[8] Olley and Pakes (1996) and Levinsohn and Petrin (2003) develop a method to estimate a production function providing more consistent results with respect to OLS and fixed effects estimators. The approach accounts for the simultaneity problem arising from the acknowledgement that any productivity shock known to the firm, but unknown to the analyst, could affect the choice of inputs. This in turn causes OLS estimates to be inconsistent. Similarly, fixed effect techniques

[7]Adapting the words of (Bresson et al., 2014, p. 1), we want to "ascertain the importance of these explanations of the residual" and their "contribution to productivity in different countries".

[8]See below for a discussion and Del Gatto et al. (2011) for a survey on production functions estimation.

make sense as long as the unobserved effect is assumed to be constant overtime. This is a strong assumption not likely to hold if we consider shocks (Ackerberg et al., 2006). Moreover, within estimators eliminate between-firm variation which is likely to contain relevant information for the estimates (Levinsohn and Petrin, 2003). Differently, the methodology we use builds on the use of a 'proxy' variable to solve the simultaneity problem, as well as any potential collinearity issue (Ackerberg et al., 2006). Therefore, such a solution should also be much more informative than traditional alternatives (Griliches and Mairesse, 1995).

The present paper differs in two ways from the previous literature on the topic. Firstly, the unit of observation is not the firm, but the regional economies of the European Union as defined by the Eurostat classification (NUTS2 level). This has some relevant implications in terms of the economic interpretation of the results. Indeed, the unobserved term cannot be merely referred to as a pure productivity shock, since at such a level of aggregation other factors affect economic activity and its output. After the pioneering study by Solow (1956), the literature has focused on the identification of the components of the TFP residual. For instance, Mankiw et al. (1992) augment the original model by adding human capital. In general, the approach proceeds by endogenizing those factors that originally were taken as exogenous. For what concerns practical applications, the empirical growth literature uses to adopt a generic representation of the implied equation of the Solow's model, by adding additional explanatory variables, depending on the specific focus of the study. The resulting equations are usually known as Barro regressions in growth econometrics (Barro, 1991; Caselli et al., 1996; Durlauf et al., 2005; Durlauf and Quah, 1999). In the present paper, the main interest concerns the long-run relationship between labour market deregulation, public finance constraints, and economic performance. Therefore, we *augment* the standard structural model by adding these explanatory variables and some additional controls to account for the structural composition of the economy.

Secondly, we are not directly interested in obtaining a measure of TFP, but in explaining which factors account for the heterogeneity in GVA and, therefore, labour productivity. However, it may still be that some other unobserved factors may affect economic choices, i.e. how much capital to use and how much employment to hire. Take for instance political factors, external economic shocks, non measurable innovations causing pure productivity increases. Hence, we think that the structural approach suits the goal of obtaining consistent estimates of the parameters. The TFP term can still be properly computed to understand how much variability in the dependent variable is left unexplained.

Our augmented specification is equivalent to the *canonical augmented* growth regression but with the dependent variable is in levels, instead of in growth rate, and steady-state implications are not considered. In other terms, the focus is on the *long-run* behaviour of the economy. In the following section, we can see that our approach appears to be theoretically grounded as well as suitable for a proper estimation of the parameters of a GVA equation. An equivalent application, with a different estimating procedure, is performed in Bresson et al. (2014). The use of the Olley and Pakes (1996) approach helps to obtain consistent estimates of the coefficients of interest, especially when there is reason to suspect simultaneity issues. As long as this is true, the point of such an estimation methodology applies fairly generally (Wooldridge, 2009).

3.3 Specification and estimation procedure

We begin by assuming a standard Cobb-Douglas production technology for the economy with two traditional inputs, capital stock and labour. We *augment* it by adding further explanatory variables leading to the following specification:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l}$$

with

$$A_{it} = A_0 e^{Z_{it}' \vartheta + \omega_{it}}$$

where K_{it} and L_{it} are capital stock and employment in the economy, respectively. Note that no specific restriction is imposed on the parameters. Additional factors affecting output are considered by specifying the composition of the technological level (or total factor productivity), A_{it}. A_0 is the initial technological level, whereas Z_{it} includes two sets of variables in which we are mainly interested, i.e. *fiscal parameters* and *labour market institutional indicators*. Unobserved factors (or shocks) likely to affect the choice of inputs, i.e. capital and employment, are included in ω_{it}. It follows that A_{it} is allowed to be varying over time and heterogeneous between observations. Taking the logs of the above production function we get

$$y_{it} = \beta_0 + z_{it}' \vartheta + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \epsilon_{it} \tag{3.1}$$

where lowercase letters indicate variables in log, $\beta_0 = \ln A_0$, ϵ_{it} is the standard i.i.d. disturbance. The presence of ω_{it} causes the the *simultaneity* issue. For a non-firm approach as in our case, we may think at any kind of macroeconomic perturbation, as well as pure technological drifts, political events or international factors which shape the economic environment. The intuition is still that such a perturbation is not observed (or measurable) by the analyst, still it may be known to the economic actors, therefore shaping their decisions.

In order to address the simultaneity issue, we follow the estimation procedure as proposed by Ackerberg et al. (2006), which draw on Olley and Pakes (1996) and Levinsohn and Petrin (2003). The approach requires a suitable proxy variable being *monotonically* related to ω_{it}. We use investment s_{it}, as originally proposed by Olley and Pakes (1996). This turns out to be an adequate proxy as long as we believe that investment reacts monotonically to ω_{it}. In other terms, we are just assuming that investment increases whenever the overall conditions become more favourable to economic activity.[9] The next step consists in specifying a function for s_{it}. Following Ackerberg et al. (2006), a resonable time schedule implies that k_{it} is chosen in $t-1$, l_{it} in $t-b$ with $0 < b < 1$, and finally investment decisions are taken in t. Therefore employment is treated as a flexible variable, while capital depends on investment decisions in $t-1$, while investment in t determines the level of capital

[9] Levinsohn and Petrin (2003) rise some doubts on the strict monotonicity assumption regarding investment. They argue that empirically investment is very lump, due to adjustment costs which reduce its responsiveness to the transmitted shocks. Therefore investment may not adequately capture the variation in inputs' usage due to productivity shocks. Although this sounds reasonable at the firm level, at the aggregate level, investment measures the overall increase in capital stock in response to depreciation *and* improved economic conditions. Moreover, considering macroeconomic data excludes cases in which investment is zero for some observations, as it may happen when using microdata.

stock in $t+1$ and depends on the information set available in t. The time schedule allows to express investment as function of capital stock, employment and overall unobserved economic factors (including any kind of shock)[10]. Therefore, we have

$$s_{it} = f(\omega_{it}, k_{it}, l_{it}). \tag{3.2}$$

where s_{it} is investment. We also assume that ω_{it} follows a first-order Markov process

$$\omega_{it} = E[\omega_{it}|\Omega_{it-1}] + \xi_{it} = E[\omega_{it}|\omega_{it-1}] + \xi_{it} \tag{3.3}$$

where ξ_{it} is a random disturbance. If monotonicity holds, it is possible to invert equation (3.2) as

$$\omega_{it} = f^{-1}(s_{it}, k_{it}, l_{it}). \tag{3.4}$$

Therefore, the equation to be estimated is the following

$$y_{it} = \beta_0 + z'_{it}\vartheta + \beta_l l_{it} + \beta_k k_{it} + f^{-1}(s_{it}, k_{it}, l_{it}) + \epsilon_{it}. \tag{3.5}$$

We also observe that β_0 is not separately identified from f^{-1} as the latter is a nonparametric function.

We use the two-stage estimation procedure given by Ackerberg et al. (2006) to obtain consistent estimates of the coefficients of the model. A step-by-step guide to the estimation is presented in their paper, and also in Olley and Pakes (1996), Levinsohn and Petrin (2003) and Yasar et al. (2008). Differences are due to the assumptions about the time schedule and the proxy, which lead to changes in the first step (see Van Beveren (2012) for a review). Alternatively, one may adopt the one step estimation as in Wooldridge (2009). Equation (3.5) can be rewritten as

$$y_{it} = z'_{it}\vartheta + \phi(s_{it}, k_{it}, l_{it}) + \epsilon_{it}. \tag{3.6}$$

where

$$\phi(s_{it}, k_{it}, l_{it}) = \beta_k k_{it} + \beta_l l_{it} + f^{-1}(s_{it}, k_{it}, l_{it}). \tag{3.7}$$

In the first stage, equation (3.6) is estimated by using an estimator which is linear in z_{it} and nonlinear in ϕ. One can use OLS and a polynomial expansion in s_{it}, k_{it} and l_{it}, to approximate $\phi(s_{it}, k_{it}, l_{it})$ as in Olley and Pakes (1996). Alternatively, a semi-parametric regression as in Robinson (1988) can serve the scope as well. This is the option we follow. Therefore f^{-1} is treated non parametrically and it is identified up to a constant, hence β_0 is not separately identified. More precisely, we use the Epanechnikov kernel and the Silverman (1986) rule-of-thumb for the bandwidth parameter. Results do not change when a normal kernel or different bandwidths are set (see also Racine (2008)). As a result, the first stage yields a consistent estimate of ϑ whereas β_k and β_l cannot be estimated at this step as capital stock and employment enter ϕ more than once. Therefore, their respective coefficients must be estimated at the second stage, solving any collinearity issue which could arise in the approach by Olley and Pakes (1996) and Levinsohn and Petrin (2003).

[10]The estimation procedure is also consistent with the assumption that l_{it} is set in $t-1$ ($b=1$). What is relevant here is the possibility to express investment as a function of both capital stock and employment, as it solves any collinearity issue which could arise in the procedure of Levinsohn and Petrin (2003). See (Ackerberg et al., 2006, p. 10)

Note that the additional variables z_{it} are not included in (3.2). The rationale for this assumption is twofold. Firstly, as k_{it} is a *state* variable that gathers all informations available in previous periods, i.e. investment decisions and other factors from time $t-1$ to time t, the inclusion of z_{it} in (3.2) would have a little additional value because z_{it} do not vary a lot between two successive years. Secondly, despite the previous argument, if we want to include z_{it} in equation (3.2) such as $s_{it} = f(\omega_{it}, z_{it}, k_{it}, l_{it})$, then the nonparametric estimation of $\phi(s_{it}, z_{it}, k_{it}, l_{it})$ will encounter the *curse of dimensionality* because of a high number of arguments in ϕ. A plausible way to include z_{it} is then to assume $s_{it} = f(\omega_{it} - z'_{it}\eta, k_{it}, l_{it})$ which gives $\omega_{it} = f^{-1}(s_{it}, k_{it}, l_{it}) + z'_{it}\eta$. However, in this case, the coefficient associated to z_{it} in equation (3.5) becomes $\vartheta + \eta$, the rest of the equation remaining unchanged, showing that η is not separately identified from ϑ. Thus, the model as described in (3.5) still applies here.

In the second stage, we firstly approximate non-parametrically $\phi(s_{it}, k_{it}, l_{it})$ from equation (3.6):

$$\hat{\phi}(s_{it}, k_{it}, l_{it}) = E[y_{it} - z'_{it}\hat{\vartheta}|s_{it}, k_{it}, l_{it}]. \tag{3.8}$$

Then, we can exploit equation (3.7) to compute an approximation for $\omega_{it} = f^{-1}(s_{it}, k_{it}, l_{it})$. For doing this we need a value for β_k and β_l to plug in the equation. We follow Levinsohn and Petrin (2003) and we estimate equation (1) by standard OLS for obtaining *candidates* β_k^0 and β_l^0. Hence, ω_{it} is approximated by

$$\tilde{\omega}_{it} = \hat{\phi}(s_{it}, k_{it}, l_{it}) - \beta_k^0 k_{it} - \beta_l^0 l_{it}. \tag{3.9}$$

Therefore, the Markov chain assumption leads to a nonparametric estimate of $\hat{\omega}_{it}$[11],

$$\hat{\omega}_{it} = E[\tilde{\omega}_{it}|\tilde{\omega}_{i,t-1}]. \tag{3.10}$$

Finally, we have all the elements needed to compute the residuals of equation (3.5). Using the coefficient $\hat{\vartheta}$ from the first stage, and the fact that the non-parametric estimate $\hat{\omega}_{it}$, under the Markov-Chain assumption, implies the innovation $\xi_{it} = \tilde{\omega}_{it} - E[\tilde{\omega}_{it}|\tilde{\omega}_{it-1}]$, equation (3.5) can be rewritten as (recall that β_0 is not separately identified from $\hat{\omega}_{it}$)

$$y_{it} = z'_{it}\hat{\vartheta} + \beta_l l_{it} + \beta_k k_{it} + \hat{\omega}_{it} + \xi_{it} + \epsilon_{it}. \tag{3.11}$$

Hence, the new residuals correspond to $\xi_{it} + \epsilon_{it}$. Since, by construction, the residuals are cleaned of the unobserved shock and therefore are uncorrelated with k_{it} and l_{it}, β_k and β_l can be estimated by GMM using the following moment conditions:

$$E[\widetilde{\xi_{it}}|k_{it}, l_{it-1}] = 0. \tag{3.12}$$

Finally, we use bootstrap to compute standard errors of our estimates in order to obtain consistent results.[12]

[11] The bandwidth for the non parametric estimation of $\hat{\omega}_{it}$ has been obtained by cross-validation. See Silverman (1986).

[12] Equation (3.12) can be replaced by the moment conditions in Levinsohn and Petrin (2003), i.e.

$$E[(\widetilde{\xi_{it} + \epsilon_{it}})|k_{it}, l_{it-1}] = 0$$

where $\widetilde{\xi_{it} + \epsilon_{it}} = y_{it} - z'_{it}\hat{\vartheta} - \beta_l l_{it} - \beta_k k_{it} - \hat{\omega}_{it}$. Furthermore, overidentification conditions can be

3.4 Data

The study uses data for the NUTS-2 sub-national territorial units, as classified by Eurostat. Overall, we have informations about regional economies for 20 European countries from 1995 to 2008. The countries are Austria (AT), Belgium (BE), Czech Republic (CZ), Germany (DE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Hungary (HU), Italy (IT), Netherlands (NL), Poland (PL), Portugal (PT), Sweden (SE), Slovakia (SK) and the United Kingdom (UK). In particular, we draw gross value added (GVA), employment, capital stock, investment from the Cambridge Econometrics database. We then compute the sector shares as the ratios on aggregate GVA. The focus is on manufacturing, financial services and other market services, since they are the sectors which contribute the most to productivity growth in Europe.[13]

Additional variables included in the augmented model are taken from different sources and they are indicators at the national level.[14] The *implicit tax on labour* is defined as the ratio of (direct and indirect) taxes and social security contributions on employed labour income to total compensation of employees. The *implicit tax on capital* is the ratio between revenue from all capital taxes, and all (in principle) potentially taxable capital and business income in the economy. Both of them are drawn from Eurostat.

The *public budgetary position* is taken from the World Bank and it is computed as the ratio of deficit/surplus over GDP. We will refer to it as *budget balance.* Note that positive values for the variable imply a surplus in public budget for the year. A negative sign for the coefficient implies a *positive* correlation between deficit spending (i.e. increased deficit) and GVA.

The remaining indicators are drawn from the OECD database. The *Employment Protection Legislation* (EPL) indicators refer to the regulation concerning hiring and firing workers and it is expressed in scale 0-6. It is decomposed in EPL for *individual* and *temporary* contracts. It is argued that excessive regulation (i.e., higher values of the indicator) may disincentive firms to employ workers, since firing costs increase. On the contrary, arguments in favour of employment protection concern macroeconomic stability against adverse shocks, as well as job security as a factor favouring human capital investment and productivity (see Cazes and Nesporova (2003) and OECD (2013)). The *unit labour cost* (ULC) measures the average cost of labour per unit of output and it is given by the labour compensation share on total GDP it refers to (i.e. the wage share). It should not be interpreted as a comprehensive measure of competitiveness, but as a reflection of cost competitiveness. Indeed it deals exclusively with the cost of labour and should be considered in relation to changes in the cost of capital, especially in advanced economies. *Trade union density* corre-

added, changing the equation in

$$E[\widetilde{\xi_{it} + \epsilon_{it}}|W_{it}] = 0$$

where W_{it} is the vector of instruments, for instance $W_{it} = \{k_{it}, k_{it-1}, l_{it-1}, ...\}$. However, in our case the above alternatives provide similar results. See also Petrin et al. (2004) and Wooldridge (2001) and Wooldridge (2010).

[13] See for instance Van Ark et al. (2008), O'Mahony et al. (2010) for a sectoral analysis on productivity in Europe. See Rodrik (2013) for an investigation of the role of manufacturing in cross-country convergence.

[14] A summary of variables definition is reported in Appendix B.1.

sponds to the ratio of wage and salary earners that are trade union members, divided by the total number of wage and salary earners. The *(youth) temporary employment* indicates the share of (15-24 aged) temporary workers for all dependent employees. The *debt/GDP ratio* and the *nominal interest rate* conclude the list.

Finally, we also consider the relationship between fiscal consolidations and GVA in the long run. We use the dataset developed by Devries et al. (2011), which focuses on discretionary changes in *taxes* and *government spending* motivated by budget deficit reduction. The main scope of the database is to provide data which are independent of the status of the economy. It is argued that fiscal retrenchments may have positive effects on the economy (Barba, 2001; Blinder, 1997). The fiscal policies in the EU following the last crisis, as well as the Maastricht criteria, respond to such an hypothesis. We use these data to verify if regions belonging to countries which adopted fiscal consolidation measures perform better in the long run.

Table 3.1: Descriptive statistics

	Mean	Std.Dev.	Min	Max
GVA*	10.10	0.97	6.43[a]	12.94[b]
Employment*	6.42	0.83	2.73[a]	8.63[b]
Capital stock*	11.39	0.93	7.51[c]	14.30[b]
Labour productivity*	1.58	0.12	1.29[d]	2.40[a]
Temporary empl. share	12.64	6.43	4.50 (SK)	34.04 (ES)
Temporary empl. youth share	35.75	16.13	10.98 (UK)	68.60 (ES)
EPL individual	2.53	0.76	1.03 (UK)	4.58 (PT)
EPL temporary	1.79	1.12	0.25 (UK)	4.75 (IT)
Trade Union Density	35.34	21.39	7.54 (FR)	80.63 (SE)
ULC*	-0.50	0.13	-1.06 (HU)	-0.31 (UK)
Tax on labour	37.05	6.47	21.60 (PT)	48.50 (SE)
Tax on capital	28.62	7.82	13.90 (SI)	49.90 (DK)
Debt/GDP	53.17	23.68	9.22 (CZ)	113.76 (BE)
Budget Balance	-1.57	2.80	-9.23 (NL)	6.79 (FI)

Note: * indicates that variables are in logs. [a] is the region of Aland (FI), [b] is Ile de France (FR), [c] is Ciudad de Melilla (ES), [d] is Lubelskie (PL)

Table 3.1 reports descriptive statistics for the main variables. Mean and standard deviation are in the second and third columns, while minimum and maximum values are in columns 4 and 5. The region with the highest levels of GVA, employment and capital is Ile de France, which includes Paris. The minimum value for capital stock is registered in the Spanish region of Melilla, while Aland (FI) has the lowest value of both employment and GVA. However, the latter is found to be the best performer in terms of labour productivity, defined as the share GVA/employment. Since the labour force is measured in terms of employees, this implies that Aland produces the highest level of GVA per worker. This can be due either to labour being more efficient or to specialization in more productive industries. To account for the latter, in the next Section we control for GVA shares in manufacturing, financial and business-related market services, since they are respectively the most growing and productive sectors in Europe. Specialization also contributes to explain why the lowest productive region is located in Eastern Europe. The Implicit taxes on labour and capital have the highest variation, as the standard deviation suggests.

Nordic countries have the maximum values for both, while the lowest are in Portugal and Slovenia for labour and capital respectively. EPL statistics are representative of the different labour market systems in Europe: Mediterranean countries (Italy and Portugal) have the highest levels of protection, while the United Kingdom has the lowest. The Continental regions are in between. Statistics on temporary employment reveal that the share of workers with temporary contracts is dramatically higher for people in age 16-24. In particular, the recent deregulation of labour markets had a significant impact on Spain, in which 3 young workers out of 4 have a temporary job, while the European mean is 1/3. The ratio of wage and salary earners that are trade union members varies considerably, ranging from 7.54 % (France) to 83.14% (Sweden). Public finance statistics are characterized by high standard deviation. Therefore, even though average Debt/GDP is 53%, some countries have a ratio larger than 1, such as Belgium and Italy, others have very low ratio, such as Czech Republic. Finally, governments are on average deficit spenders. Finland and Netherlands register respectively the highest surplus and deficit.

3.5 Estimation results

3.5.1 The base case

We proceed by estimating our model as described above. Standard errors are obtained by bootstrap procedure using resampling with replacement, as suggested by Levinsohn and Petrin (2003).[15] The focus is on two sets of variables. The first set describes the degree of regulation of the labour market. It includes the two indexes of employment protection and the measure of trade union density. The second set represents the budget status of the central government. It is composed by the ratio of debt and deficit on GDP. Additional variables are used as controls. Manufacturing and services sector shares account for the structural composition of the economy, which heavily affects the level of output. The increasing deregulation of the labour market during the last decades has changed the composition of employment, with a rise in the adoption of temporary contracts. This is especially true in the countries in which the level of employment protection was higher, as in Spain and in Southern Europe (O'Higgins, 2012). Therefore, we include the share of temporary employment for the whole labour force, as well for the youth. The implicit tax on capital and labour, and the unit labour cost (ULC) are used as indicators of competitiveness. However, both the ULC and the tax on labour include social contributions for employees. Therefore, in what follows we use them alternatively in two different sets of estimates. The nominal interest rate is also included.

Table 3.2 reports the results. All the variables are in logs, excluding the two indexes of employment protection, the budget balance and the implicit taxes on capital and labour, whose coefficients can be interpreted as semi-elasticities. In Model (1) ULC is included among the regressors. The coefficient on employment is 0.555, while the estimated elasticity of GVA with respect to capital is lower (0.240). Beginning with the labour market indicators, the coefficient on EPL is negative and

[15]For comparison purposes, estimations of the basic production function with just capital stock and employment as inputs are presented in Appendix B.2. Some results for robustness check are discussed in Appendix B.3.

Table 3.2: Estimation results: the base case

	Model 1	Model 2
Capital stock	0.240***	0.0.321***
	(0.049)	(0.096)
Employment	0.555***	0.473***
	(0.044)	(0.097)
Manufacturing share	0.079***	0.078***
	(0.026)	(0.022)
Financial share	0.254***	0.260***
	(0.031)	(0.029)
Trans. share	−0.122*	−0.165***
	(0.065)	(0.059)
ULC	0.032	–
	(0.098)	
Tax on labour	–	−0.007***
		(0.002)
Tax on capital	0.004***	0.004***
	(0.001)	(0.001)
EPL individual	−0.084***	−0.076***
	(0.016)	(0.015)
EPL temporary	0.005	0.016*
	(0.009)	(0.008)
Temp. empl. share	−0.138***	−0.221***
	(0.042)	(0.041)
Temp. empl. youth share	0.151***	0.239***
	(0.043)	(0.042)
Trade union density	0.031*	0.051***
	(0.017)	(0.018)
Debt/GDP	0.031	0.042**
	(0.021)	(0.019)
Budget balance	−0.005	−0.003
	(0.004)	(0.003)
Interest rate	0.006	0.007**
	(0.004)	(0.003)
Number of obs.	2885	2885

Notes. Bootstrap standard errors are in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

significant, while EPL for temporary workers has no significant effect. On the opposite, the density of trade unions is positively associated with higher levels of GVA. The coefficients for temporary employment shares indicate that the relationship between GVA and temporary contracts is different according to age. Indeed, the higher the share of non-permanent workers in the labour force the lower total GVA is. However, the relationship has a negative sign when the share of young temporary workers is considered. These findings suggest an incentive-disincentive mechanism depending on age: temporary employment is positively related to productivity for the youth joining the labour market, however insecure contracts all along the life cycle tend to hinder productivity[16]. For what concerns the competitiveness variables, ULC has no explanatory power, while the tax on capital has no economic relevance, even though it is statistically significant. Interesting results are obtained for the budgetary variables. Finally, both the debt/GDP and the deficit/GDP ratios are not significant[17]. In Model (2) we substitute ULC for the implicit tax on labour. The related coefficient is negative and significant, suggesting that implicit taxation on labour compensation hinders GVA, even though its magnitude is hardly economically significant. The shares of (total and young) temporary employment are still statistically significant, being their coefficients higher. The coefficient on EPL for temporary workers is now positive and significant, even though its magnitude is low, consistently with the above interpretation of the relationship between GVA and temporary contracts. The coefficient on temporary EPL is more than doubled with respect to Model (1), also being significant. Finally, the debt/GDP share is now positive and significantly related to GVA.

Overall, the results suggest that the deregulation of labour markets is not univocally associated with higher levels of GVA. For instance, even though employment protection has a negative effect on total output, regulation of temporary contracts has either no or positive effect on economic performance. Similarly, the diffusion of more *flexible* temporary employment is likely to produce a negative feedback if temporary contracts are widely (structurally) adopted. For what concerns budget policies, the estimates show no evidence of a detrimental effect of public debt on economic performance. If any, a positive association is in place, especially for debt/GDP.

3.5.2 Maastricht parameters

Maastricht parameters have been established as a prerequisite to join the Euro area. They are referred to as *convergence criteria* and presented as the conditions a country must respect to safely join the Euro area. In particular, soundness and sustainability of public finances are required, through limits on government borrowing and national debt. Soundness is defined through a threshold of 3% on public deficit relative to GDP. Sustainability requires the ratio Debt/GDP to be lower than 60%. The sustainability threshold finds its confirmation in Reinhart and Rogoff (2010) empirical study. However, the latter has been shown to be flawed by selective exclusion of available data, coding errors and inappropriate weighting of summary statistics (Herndon et al., 2014). The soundness criterion has not be criticized *per se*, but because of being imposed independently of context considerations. The sustainable deficit should be based on circumstances, including the cyclical state of the economy, prospects for future growth, the level of national savings and investment (Stiglitz, 1998, p. 16). In this section we proceed by testing the validity of the criteria using our structural model.

[16] Some caution must be used for what concerns the temporary share of youth workers. Indeed, countries differ in the kind of temporary contracts and in the rules for their application and renewal, as well as for the kind of activities which make use of them. The difference between the dual apprentice system in Germany and the temporary contracts in Italy and Spain is an example (see O'Higgins (2012) for an analysis on the topic).

[17] Recall that positive values of budget balance indicate budget surplus. Therefore, a negative value of the coefficient indicates a positive relationship between deficit spending and GVA. However, results in this and the following sections do not reveal a significant relationship.

Table 3.3: Estimation results: Maastricht parameters

	Model 3	Model 4	Model 1a	Model 2a
Capital stock	0.276***	0.265*	0.303***	0.285***
	(0.101)	(0.151)	(0.048)	(0.044)
Employment	0.507***	0.534***	0.475***	0.524***
	(0.069)	(0.192)	(0.049)	(0.046)
Manufacturing share	0.071***	0.072***	0.081***	0.083***
	(0.030)	(0.029)	(0.023)	(0.023)
Financial share	0.276***	0.269***	0.277***	0.276***
	(0.016)	(0.015)	(0.029)	(0.029)
Trans. share	−0.118*	−0.152**	−0.125**	−0.140**
	(0.064)	(0.063)	(0.060)	(0.060)
ULC	−0.010	–	−0.050	–
	(0.092)		(0.094)	
Tax on labour	–	−0.004*	–	−0.002
		(0.002)		(0.002)
Tax on capital	0.004***	0.006***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
EPL individual	−0.077***	−0.072***	−0.056***	−0.054***
	(0.016)	(0.016)	(0.016)	(0.015)
EPL temporary	0.016*	0.024***	0.027***	0.030***
	(0.003)	(0.009)	(0.009)	(0.009)
Temp. empl. share	−0.167***	−0.212***	−0.157**	−0.173***
	(0.041)	(0.044)	(0.040)	(0.045)
Temp. empl. youth share	0.164***	0.215***	0.127***	0.146***
	(0.043)	(0.045)	(0.040)	(0.048)
Trade union density	0.051***	0.066***	0.067***	0.070***
	(0.017)	(0.018)	(0.017)	(0.018)
Debt/GDP > 60%	−0.046**	−0.037*	–	–
	(0.021)	(0.021)		
Debt/GDP	–	–	1.098***	1.005***
			(0.204)	(0.226)
$(\text{Debt/GDP})^2$	–	–	−0.143***	−0.130***
			(0.027)	(0.030)
Def/GDP > 3%	0.041**	0.039**	–	–
	(0.016)	(0.017)		
Budget balance	–	–	−0.005	−0.004
			(0.003)	(0.003)
Interest rate	0.005	0.006*	0.007**	0.008**
	(0.004)	(0.003)	(0.003)	(0.003)
Number of obs.	2885	2885	2885	2885

Notes. Bootstrap standard errors are in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

In Table 3.3 we substitute the budgetary variables of Table 3.2 with the Maastricht parameters. In particular, $Def/GDP > 3\%$ is a binary variable which takes value 1 if deficit spending is larger than 3% of GDP, i.e. if the *Budget Balance* variable is lower than −3. Similarly, *Debt/GDP* > 60% is a binary variable which is equal to 1 if *Debt/GDP* is larger than 60%. The two thresholds are introduced in the first two columns of Table 3.3, in Model 3 and Model 4. Results are consistent with findings in Model 1 and Model 2. In particular ULC and Tax on Labour are not associated with GVA, while the not univocal conclusions on labour market regulation are confirmed. Findings support the sustainability criterion: economies with a Debt/GDP ratio higher than 60% have lower GVA. However, we find no evidence confirming the soundness criterion: on the opposite deficit spending beyond 3% is positively related to GVA. Similar conclusions can be drawn for Model 1a and Model 2a. Moreover, allowing for a quadratic term in debt/GDP reveals that higher ratios are associated with higher GVA until a turning point, after which debt/GDP and GVA are negatively associated. In particular, the turning point corresponds to 46.5% and 47.7% in Model 1a and Model 2a respectively, which is lower than the 60% critical level of the sustainability criterion.[18]

Summing up, findings in Table 3.3 suggests that what matters is a sustainable financial position, while deficit spending beyond 3% is beneficial for economic performance on the long run. Therefore, even though Stiglitz (1998)'s argument should be kept in mind when considering the case for deficit spending, the above results reject the soundness of the 3% threshold.

3.5.3 Fiscal consolidations

The analysis above shows that deficit spending and debt are not associated with lower levels of GVA. On the opposite, a reversed argument could be told. A further interesting piece of the story would be to understand if regions belonging to countries which undertake budget balancing policies are likely to have higher GVA levels on the long run. Note that this is a different exercise than analysing the short term effects of fiscal consolidations, i.e. the relationship between the growth rate of GDP and fiscal consolidations.[19] We use the dataset developed by Devries et al. (2011), which focuses on discretionary changes in taxes and government spending primarily motivated by a desire to reduce the budget deficit, independently of economic conditions. Contemporaneous policy documents are examined to identify the rationale of the fiscal policy. As a result, the latter are unlikely to be systematically correlated with other developments affecting output, and are thus valid for estimation purpose (Devries et al., 2011). The variable is given by the size of the deficit reduction over GDP. Note that the side effect of such a selection criterion is that the variable takes mostly values equal to zero, since countries adopt such a kind of polices only in few years in the period considered. Therefore, given the structural nature of our model, the following results must be interpreted with caution.

Results are reported in Table 3.4. In Model 5 and 6 fiscal consolidations are represented by the variable *Total contractionary*, given by the size of the sum tax increases and expenditure cuts over GDP in one year. We also allow for the interaction between contractionary policies and the debt/GDP ratio, in order to assess whether the relationship with GVA changes at higher levels of debt. There is no evidence of neither a beneficial nor a detrimental effect on economic performance, since the coefficient is not statistically significant. The coefficients on the other variables confirm the findings of the previous sections, both in terms of significance and magnitude. In Model 7 and Model 8 we disaggregate contractionary policies in tax increases and expenditure cuts, to allow for two different measures of fiscal con-

[18]Note that the standard result in the literature reveals nonlinearity with the growth rate of GDP as dependent variable, while here we are using GVA in levels. See for instance Reinhart and Rogoff (2010) and Cecchetti et al. (2011).

[19]The positive effect of fiscal consolidations on economic growth is usually referred to as the non-Keynesian effect, or expansionary austerity. For some empirical reviews on the topic, see, for instance, Giudice et al. (2007),Guajardo et al. (2014), and Medvedev and Seth (2014).

Table 3.4: Estimation results: Fiscal consolidations

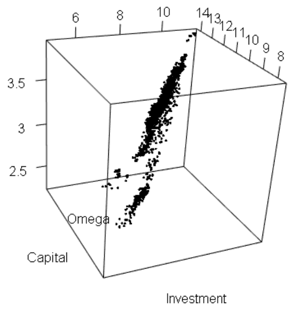
	Model 5	Model 6	Model 7	Model 8
Capital stock	0.238**	0.302***	0.359***	0.368***
	(0.114)	(0.035)	(0.029)	(0.031)
Employment	0.557***	0.512***	0.510***	0.579***
	(0.152)	(0.046)	(0.006)	0.006)
Manufacturing share	0.078***	0.078***	0.129***	0.127***
	(0.016)	(0.022)	(0.016)	(0.015)
Financial share	0.257***	0.262***	0.338***	0.340***
	(0.030)	(0.028)	(0.024)	(0.024)
Trans. share	−0.124**	−0.166***	0.047	0.040
	(0.062)	(0.037)	(0.039)	(0.038)
ULC	0.030	–	−0.135	–
	(0.095)		(0.098)	
Tax on labour	–	−0.006***	–	−0.002
		(0.002)		(0.001)
Tax on capital	0.004***	0.005***	0.007***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
EPL individual	−0.082***	−0.073***	−0.165***	−0.173***
	(0.016)	(0.014)	(0.012)	(0.011)
EPL temporary	0.006	0.017**	0.006	0.011*
	(0.009)	(0.009)	(0.004)	(0.004)
Temp. empl. share	−0.131***	−0.215***	0.099**	0.068
	(0.043)	(0.041)	(0.037)	(0.036)
Temp. empl. youth share	0.145***	0.232***	0.057	0.084*
	(0.043)	(0.041)	(0.036)	(0.034)
Trade union density	0.030*	0.052***	0.043***	0.042***
	(0.017)	(0.017)	(0.013)	(0.011)
Debt/GDP	0.039*	0.051***	0.033	0.053***
	(0.023)	(0.020)	(0.018)	(0.015)
Budget balance	−0.004	−0.003	−0.011***	−0.011***
	(0.003)	(0.003)	(0.002)	(0.002)
Total contractionary	0.098	0.100	–	–
	(0.096)	(0.092)		
Total contr.×Debt/GDP	−0.022	−0.023	–	–
	(0.022)	(0.021)		
Tax increase	–	–	0.275***	0.291***
			(0.047)	(0.047)
Tax increase×Debt/GDP	–	–	−0.063***	−0.067***
			(0.011)	(0.011)
Exp. cuts	–	–	0.052	0.003
			(0.067)	(0.063)
Exp. cuts×Debt/GDP	–	–	0.005	0.018
			(0.017)	(0.016)
Interest rate	0.006	0.007**	−0.010	−0.006
	(0.004)	(0.003)	(0.014)	(0.014)
Number of obs.	2885	2885	2885	2885

Notes. Bootstrap standard errors are in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

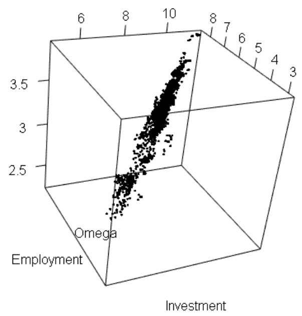
solidations. Results suggest that tax increases are positively associated with GVA, even though the relationship becomes negative at high levels of debt/GDP. ratios.

3.6 Specification test

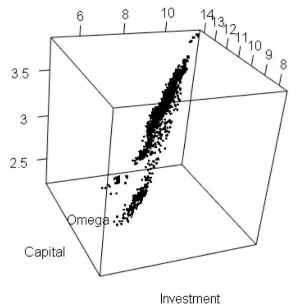
The model we estimate rests on the assumptions about the proxy for the unobserved term. In particular, our estimates are consistent only if the investment proxy can be expressed as a monotonically increasing function of ω_{it}, capital stock and employment. As long as this is true, then $s_{it} = (\omega_{it}, k_{it}, l_{it})$ can be inverted with respect to ω_{it} and the procedure is valid. However, if this is not the case, then the approach is inappropriate. Therefore, in this section we perform the test proposed by Levinsohn and Petrin (2003). What we do is to visually examine $\omega_{it} = f^{-1}(s_{it}, k_{it}, l_{it})$ by plotting the smoothed function firstly against investment and capital, secondly against investment and employment. Our monotonicity assumption is satisfied if ω_{it} is increasing in both cases. The two top panels of Figure 3.1 show the plots of ω estimated using Model 1. In the left panel, the estimate of ω_{it} is on the vertical axis, while capital and investment are on the horizontal ones. In the right panel the same plot is shown, with employment in place of capital. In both cases the smoothed function is increasing in investment. The middle and the bottom panels plot the same relationship for for Model 2 and Model 0, the latter being the basic production function, i.e. considering only the inputs capital and employment (estimation results are in Table B1 in Appendix B.2). Also in this case, ω_{it} is increasing in investment. Therefore, we can conclude that monotonicity holds and that our theoretical assumptions are verified empirically.



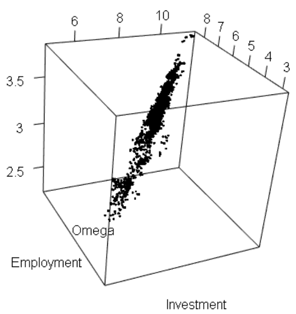
(s, k), Model 1



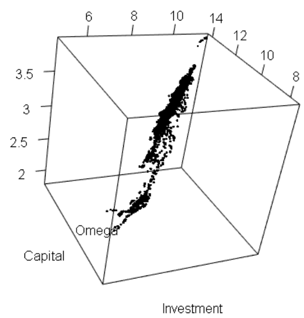
(s, l), Model 1



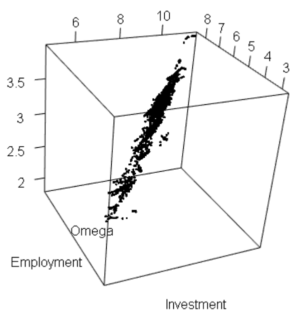
(s, k), Model 2



(s, l), Model 2



(s, k), Model 0



(s, l), Model 0

Figure 3.1: Monotonicity test for ω_{it}.

3.7 Conclusions

This study analysed the long-term relationship between indicators of labour market regulation, public finance parameters and GVA. We used the estimation procedure as proposed by the *structural literature*, augmenting the model with the additional variables of our interest (labour market protection and fiscal parameters). Therefore, we obtained consistent estimates of the parameters by approximating nonparametrically any unobserved factor influencing likely endogenous regressors. Moreover, less stringent assumptions were needed about endogeneity, differently from the GMM approach.

Some interesting implications for policy can be drawn. Indeed, we do not find univocal evidence of a detrimental effect of labour protection on the long term performance of regional economies. Even though a negative relationship is found for EPL (individual contracts), regulating hiring and firing for temporary workers is associated with higher GVA. Consistently, even though the share of temporary workers among the youth is positively related to economic performance, the share on the whole labour force negatively affects output. These results suggest that on the job security over the life of workers is associated with a higher long-run GVA, while *tout-court* deregulation is not a prerequisite for a better performance. For what concerns the fiscal indicators, the estimates show that larger debt/GDP and deficit/GDP ratios are associated with a higher output. This is especially true for deficit spending over the 3% threshold established by the convergence criteria. Such an evidence can be interpreted as a support for crowding in and expansionary effects of public expenditure, while debt is found to be detrimental for economic performance only when its share on GDP is really large.

As for future research, the relationship between the structure of the labour market and economic performance can be further investigated by considering additional features. Apprenticeship systems and active policies can facilitate the inclusion in the labour market of the unemployed and avoid the depletion of skills, increasing GVA per worker in the long run. Moreover, as the estimation procedure allows to specify several production functions, it would be interesting to investigate the results obtained with different specifications of the model.

Appendix

B.1 Summary of variables definition

Variable	Definition
GVA	Gross Value Added at 2000 constant prices.
Employment	Number of workers.
Manufacturing share	Share of GVA in manufacturing on total GVA.
Financial serv. share	Share of GVA in financial market services on total GVA.
Business related serv. share	Share of GVA in business-related and other market services on total GVA.
ULC	Unit Labour Costs measure the average cost of labour per unit of output and are calculated as the ratio of total labour costs to real output. ULC should not be interpreted as a comprehensive measure of competitiveness, but as a reflection of cost competitiveness.
Implicit tax on labour	Sum of direct taxes, indirect taxes and compulsory actual social contributions paid by employees and employers on labour employed, divided by compensation of employees increased by wage bill and payroll taxes.
Implicit tax on capital	Ratio between revenue from all capital taxes, and all (in principle) potentially taxable capital and business income in the economy, such as net operating surplus of corporations and non-profit institutions, imputed rents of private households, net mixed income by self-employed, net interest, rents and dividends, insurance property income.
EPL	Indexes of employment protection concerning the legal procedures to fire workers, both individually and collectively. Each index is built using several item which aggregate to the indicator. An index for temporary contracts is also used. All indicators are expressed in scale 0-6.
Temporary employment share	Ratio of temporary employment for dependent employees of all ages.
Temporary employment share for the youth	Ratio of temporary employment for dependent employees in the age 15-24
Trade Union Density	Ratio of wage and salary earners that are trade union members, divided by the total number of wage and salary earners.
Debt/GDP	Central government debt, divided by Gross Domestic Product.
Budget Balance	Central government deficit (<0) or surplus (>0), divided by Gross Domestic Product.

Fiscal consolidations	Fiscal actions primarily motivated by the desire to reduce the budget deficit and not by a response to prospective economic conditions. Policy makers' intentions and actions are taken from contemporaneous policy documents (Devries et al., 2011).
Interest rate	This is the nominal interest rate set by the monetary authority. Therefore we have 1 value for the Euro area plus several values for non Euro countries

Note: Definitions are taken from the respective data source of each variable.

B.2 Estimation of the basic production function

We consider the basic production function with just capital stock and employment as inputs without additional explanatory variables (i.e. $Y_{it} = A_{it}K_{it}^{\beta_k}L_{it}^{\beta_l}$). Data availability allows us to include four countries which were excluded in the estimation of the augmented equation, i.e. Greece (GR), Ireland (IE), Romania (RO) and Slovenia (SI). Results are shown in Table B1 under Model 0. Differently from the augmented specifications, the elasticity of output with respect to capital is higher than with respect to employment, being the coefficients 0.639 and 0.371 respectively. The magnitude of the estimated coefficients is in line with Olley and Pakes (1996) results, while opposite findings are in Levinsohn and Petrin (2003) and Ackerberg et al. (2006). It is interesting to compare the results of this paper with those in Bresson et al. (2014) since they use macro data as we do, differently from the original strand of literature. Even though Bresson et al. (2014) do not follow the structural approach estimation, their non-Bayesian results are comparable to ours. In particular, they obtain higher elasticity of output with respect to capital when estimating the basic production function, while the coefficient for employment is higher when they augment their equation.

Table B1 also compares Model 0 with four different specifications, respectively OLS, Fixed Effect within estimator (FE) and two alternative GMM models. The first GMM model treats employment as endogenous, while the second one treat both capital and employment as endogenous. Excluding OLS, elasticity estimates for capital are slightly lower than in Model 0 and they are rather constants across specifications. Differently, estimated coefficients for employment are lower than in Model 0, ranging from 0.257 in the FE case to 0.090 for OLS. It is worth noting that the coefficient for capital is higher than the coefficient on employment in every model of Table B1.

Recall that estimates in Table B1 are obtained using a larger sample than for the augmented specifications. This can affect estimation results as long as economies composing the two samples are different in terms of structure of the economy, level of development and so on. To investigate such an issue we firstly report samples composition in Table B2. In the augmented specification regional economies from some *peripheral* countries are dropped. In particular, Spanish (ES) and Polish (PL) regions are almost halved, while Greek (GR), Irish (IE), Romanian (RO) and Slovenian (SI) regions are completely wiped out. Hence, the smallest sample is somehow more representative of the richest regions of the EU and this may affect the estimation of the basic production function. Therefore, as a further check, we estimate

Table B1: The basic production function

	Model 0	OLS	FE	GMM (1)	GMM (2)
Capital stock	0.639***	0.940***	0.585***	0.601***	0.616***
	(0.090)	(0.006)	(0.008)	(0.012)	(0.013)
Employment	0.371***	0.090***	0.257***	0.191***	0.176***
	(0.084)	(0.008)	(0.019)	(0.029)	(0.032)
Adjusted R^2	—	0.944	0.689	0.721	0.739
Number of obs.	3542	3542	3542	3542	3289

Notes. Bootstrap standard errors are in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Model 0, the FE, the OLS and the GMM models using the smallest subsample. Results are reported in Table B3. Excluding the OLS case, the elasticity of GVA with respect to employment increases for every estimator, while the coefficient on capital decreases. However, excluding the FE within estimator, the magnitude of the coefficient is still higher for capital. We may interpet this finding as the effect of including economies whose output structure is specialized in labour intensive activities. Therefore, the elasticity of GVA with respect to capital is still higher, while the coefficient on employment increases being GVA measured as the value of output net of intermediate consumption.

Table B2: Samples composition

	AT	BE	CZ	DE	DK	ES	FI	FR	GR	HU
BASIC	126	154	112	546	70	266	70	308	182	98
AUGM.	126	154	112	546	70	171	60	308	0	56
	IE	IT	NL	PL	PT	RO	SE	SI	SK	UK
BASIC	28	294	168	224	70	112	112	28	56	518
AUGM	0	294	168	128	70	0	80	0	24	518

Table B3: The basic model with the smallest subset

	Model 0	OLS	FE	GMM (1)	GMM (2)
Capital stock	0.521***	0.975***	0.463***	0.524***	0.514***
	(0.023)	(0.010)	(0.010)	(0.015)	(0.015)
Employment	0.494***	0.048**	0.483***	0.327***	0.349***
	(0.023)	(0.011)	(0.025)	(0.041)	(0.041)
Adjusted R^2	0.946	0.721	0.753	0.754	
Number of obs.	2919	2919	2691	2691	2919

Notes. Bootstrap standard errors are in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

B.3 Robustness check

The model allows to control for any unobserved factor (or shock) that may cause simultaneity or endogeneity issues. The scope of the procedure is to approximate ω_{it} in order to get consistent estimates of the coefficients. Here, we compare our results of Model 1 and Model 2 with the Fixed Effect within estimator. Results for the OLS estimator are included as a reference. Moreover two alternative GMM models, where endogeneity for employment and capital is taken into account, have been also estimated. However, results are not reported here as they are not conclusive.

Table C1: Robustness check for the augmented model

	Model 1	Model 2	OLS 1	OLS 2	FE 1	FE 2
Capital stock	0.240***	0.321***	0.651***	0.705***	0.273***	0.298***
	(0.050)	(0.095)	(0.011)	(0.010)	(0.011)	(0.010)
Employment	0.555***	0.473***	0.320***	0.256***	0.496***	0.504***
	(0.044)	(0.097)	(0.011)	(0.009)	(0.020)	(0.020)
Manufacturing share	0.079***	0.078***	0.007	0.019**	−0.094***	−0.101***
	(0.026)	(0.022)	(0.010)	(0.008)	(0.011)	(0.011)
Financial share	0.254***	0.260***	0.331***	0.327***	0.117***	0.106***
	(0.031)	(0.028)	(0.013)	(0.011)	(0.010)	(0.010)
Trans. share	−0.122*	−0.165*	−0.036	−0.209***	−0.110***	−0.121***
	(0.065)	(0.059)	(0.025)	(0.022)	(0.021)	(0.021)
ULC	0.032	—	0.409***	—	0.093***	—
	(0.098)	—	(0.041)	—	(0.018)	—
Tax on labour	—	−0.007***	—	−0.025***	—	−0.001*
	—	(0.002)	—	(0.001)	—	(0.001)
Tax on capital	0.004***	0.004***	0.012***	0.010***	−0.003***	−0.002***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
EPL individual	−0.084***	−0.076***	−0.052***	−0.048***	0.035***	0.027***
	(0.017)	(0.015)	(0.006)	(0.005)	(0.010)	(0.010)
EPL temporary	0.005	0.016*	0.045***	0.078***	0.040***	0.042***
	(0.009)	(0.008)	(0.004)	(0.003)	(0.002)	(0.002)
Temp. empl. share	−0.138***	−0.221***	−0.012	−0.372***	0.087***	0.065***
	(0.042)	(0.041)	(0.018)	(0.017)	(0.011)	(0.010)
Temp. empl. youth share	0.151***	0.239***	0.088***	0.428***	−0.027**	−0.004
	(0.043)	(0.042)	(0.018)	(0.015)	(0.011)	(0.011)
Trade Union density	0.031*	0.051***	0.107***	0.156***	−0.199***	−0.231***
	(0.017)	(0.018)	(0.007)	(0.006)	(0.011)	(0.009)
Debt/GDP	0.031	0.042***	0.042***	0.048***	−0.028***	−0.038***
	(0.021)	(0.019)	(0.009)	(0.007)	(0.005)	(0.005)
Budget Balance	−0.005	−0.003	−0.008***	−0.001	0.003***	0.003***
	(0.004)	(0.003)	(0.002)	(0.001)	(0.000)	(0.000)
Interest rate	0.006	0.007**	−0.002	0.003*	−0.001**	−0.002***
	(0.004)	(0.003)	(0.002)	(0.002)	(0.000)	(0.000)
(Intercept)	—	—	0.385***	0.116	—	—
	—	—	(0.110)	(0.087)	—	—
R^2	—	—	0.974	0.981	0.884	0.883
Adj. R^2	—	—	0.973	0.980	0.810	0.809
Num. obs.	2885	2885	2885	2885	2885	2885

Notes. Bootstrap standard errors are in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table C1 reports the results for the two augmented models. The OLS results report coefficients on capital which are more than twice the magnitude in our models and the FE specifications. Even though the elasticities with respect to capital and employment are similar, comparing the FE models and our structural equations reveal different findings for the additional regressors than in Model 1 and Model 2. In particular, the FE estimations suggest that temporary employment is associated with higher GVA, while the opposite holds for the share of temporary contracts among the youth. Also, employment protection is found to be positively related to GVA, while Trade Unions membership has a negatively coefficient. For what concerns the fiscal parameters, the FE models show a negative relationship between Debt ratios and GVA, while having a positive budget balance (i.e. a surplus) is associated with higher economic output, even though the magnitude is not economically signifiant. A similar reasoning applies to the tax on capital and the interest rate. As remarked by Levinsohn and Petrin (2003), a within estimator eliminates *between* variation which can be relevant for obtaining consistent estimates of the coefficients. This is likely to affect the results.

Environmental Kuznets curve and environmental convergence: A unified empirical framework for CO_2 emissions

4.1 Introduction

This chapter aims to provide a unified framework bridging two lines of empirical literature in environmental economics: the environmental Kuznets curve (EKC) hypothesis and environmental convergence[1]. The EKC argument states that environmental degradation increases with income until a turning point after which it decreases for higher levels of income. If this is the case, an inverted U-shaped relationship should be observed. Environmental convergence occurs if countries with low emissions of pollutants per capita increase their level of emissions, while the opposite applies to high emissions countries. The two lines of research are closely related. Indeed, the EKC hypothesis holds if the richest (and most polluting) countries reduce their emissions. As long as this is true, the process of economic growth undertaken by poorer and developing countries will get their level of emissions per capita closer to that of developed economies. This is exactly what a process of convergence implies (Nguyen-Van, 2005; Strazicich and List, 2003).[2] From a policy perspective, evidence of convergence of emissions per capita in developed economies attained at a specified target together with a confirmation of the EKC relationship has two consequences. Firstly, it may ensure sustainability of the growth process. Secondly, it would make global agreements targeting reduction in pollutant emissions politically feasible, since developing countries would be encouraged to accept a cap on their own emissions (Romero-Ávila, 2008).

Investigations of the EKC hypothesis date back to the beginning of the Nineties, following the studies of Grossman and Krueger (1993), Shafik and Bandyopadhyay (1992), Panayotou (1993), Grossman and Krueger (1995) and World Bank (1992)among others. Theoretically, the EKC can be triggered by three mechanisms, two of them relating to the structure of the economy, the third considering agents

[1] This chapter is a jointly work with Phu Nguyen-Van, Chargé de recherche, BETA-CNRS.

[2] However, convergence can take place even if high polluting economies do not reduce their emissions. For instance, low emissions countries could increase their pollutant impact and fill the gap with the most polluting economies. In such a case, countries would be converging to a high level of emissions.

behaviour. Firstly, the composition of output affects the environmental impact of countries' economic activity. Indeed, economies mostly specialized in agricultural production or tertiary activities pollute less than economies relying mostly on manufacturing production. It follows that the EKC hypothesis is strictly linked to economic transition from less to more advanced activities, in particular from manufacturing to a services-based economy. Indeed, the tertiarization of the economy is likely to favour changes in the output (input) mix which are less environmentally damaging (Panayotou, 1993; Stern, 2004). Secondly, technological advance may favour the adoption of the above mentioned change in the output (input) mix, as well as it may foster the diffusion of less polluting techniques of production (Stern, 2004). Finally, changes in individual preferences together with regulation and enforcement contribute to increase demand for environmentally friendly goods and services.[3] However, the theoretical argument for the EKC hypothesis has been criticized, for instance by Arrow et al. (1995) and Stern et al. (1996) which note that the process actually in place is mainly driven by the reallocation of polluting economic activities from developed to developing countries and therefore it is not valid on a global scale. Moreover, Dasgupta et al. (2002) remark that the argument does not apply to every pollutant and that regulation plays a determining role in shaping the relationship.

Empirical analysis of the EKC hypothesis abound in the literature. Various environmental degradation indicators have been examined: emissions or concentrations of pollutants (CO, CO_2, SO_2, NO_x,...), deforestation rate, water quality, etc. The standard approach adopts a parametric specification in which the environmental indicator is regressed on income as a linear, quadratic and also cubic function. Results vary according to the environmental indicator and the data sample under analysis. For instance, Suri and Chapman (1998) use parametric panel models finding that the relationship between energy consumption and income displays an increasing pattern with turning point outside the data sample. Richmond and Kaufmann (2006a,b), by using parametric specifications for panel data, find little evidence of an EKC for energy consumption, which is found to increase with income at a decreasing rate. Similar results are obtained by Hettige et al. (2000), Heil and Selden (2001), Bertinelli and Strobl (2005) for different indicators, while evidence of an inverted U-shaped relationship is found by Shafik (1994) and Schmalensee et al. (1998) among others. More recently, semi and nonparametric techniques have been implemented to investigate the validity of the EKC hypothesis. The advantage of such an approach is that non semi and nonparametric estimations do not require the specification of an ad hoc functional form. However, even in such a case, empirical results are still not univocal and vary with the sample and the indicator used.[4]

Environmental convergence has been a prolific subject of empirical studies following methodologies used in the economic growth literature. Hence, the topic has been investigated in terms of β convergence using cross-sectional analysis (as in Strazicich and List (2003) and Brock and Taylor (2010), among others), panel data models (see, e.g., Nguyen-Van (2005), Miketa and Mulder (2005), Mulder and de Groot (2007), Criado et al. (2011)), distribution dynamics techniques (for in-

[3]See Pearson (1994) and Stern (2004) for a review of the theoretical groundings of the EKC hypothesis.

[4]See Stern (2004), Azomahou et al. (2006), Kijima et al. (2010) and Bo (2011) for a more detailed review on the empirical literature on the topic.

stance, in Nguyen-Van (2005), Criado and Grether (2011), Criado et al. (2011), Bassetti et al. (2013)), or time series approach (e.g., Strazicich and List (2003).[5]

However, less attention has been devoted to the link between the EKC hypothesis and environmental convergence, in particular accounting for the implications described above. Even though in some cases the standard EKC equation has been transformed in a dynamic setting by adding lagged emissions among the regressors there is no explicit argument relative to convergence. This has been done mainly for statistical needs. This is the case, for instance, of Agras and Chapman (1999); Bernard et al. (2015); Lee et al. (2009), in which no reference to the environmental convergence is made.[6] Theoretically, a specific framework for environmental convergence in an EKC framework is given by Bulte et al. (2007) and Brock and Taylor (2010), which builds on the Solow model assuming that pollution occurs as a by-product of economic activity and it can be reduced through abatement efforts. In a slightly different vein, Criado et al. (2011) adopt a Ramsey-Cass-Koopmans model, but do not refer to the EKC hypothesis, to provide theoretical support and empirical evidence for environmental convergence. Such a theoretical background and the lack of an empirical strategy clearly addressing together convergence and the EKC motivate the present study.

In what follows we propose a unique framework in order to investigate the occurrence of both the EKC hypothesis and environmental convergence, using CO_2 emissions as indicator, since it is a major greenhouse gas and closely linked to energy consumption. The estimation uses the panel data model proposed by Li and Stengos (1996), Baltagi and Li (2002) and Li and Racine (2007). This way of modelling has two interesting aspects. Firstly, it allows for a dynamic structure capturing some habits or persistence behaviour in energy consumption, since energy cuts might take time. Indeed, the literature has shown that adoption of energy-saving technologies is costly and that diffusion of these technologies is a lengthy process (Jaffe and Stavins, 1994; Mulder et al., 2003). Moreover, and most important for our purposes, such a dynamic setting can be used to test for convergence, following the panel solution provided by Islam (1995) in the spirit of a theoretical framework in line with Bulte et al. (2007) and Brock and Taylor (2010). Secondly, our model includes a nonparametric function of income which allows us to avoid possible misspecified functional forms that might affect parametric EKC studies (Azomahou et al., 2006).

The chapter proceeds as follows. Section 2 presents the data and investigates distribution dynamics of CO_2 emissions per capita, following the approach originally proposed by Quah (1996). Section 3 describes the econometric specification. In Section 4 we present the results for the semiparametric specification, as well as for several parametric estimators. In Section 5 we distinguish between OECD and non OECD economies, and we also perform some robustness checks within the parametric estimators and between them and the semiparametric specifications. Section 6 concludes.

[5]See Pettersson et al. (2014) for a survey on environmental convergence studies.

[6]For example, Lee et al. (2009) estimate the convergence equation in levels rather than in logs which would be required to keep consistency with a standard convergence model (see Islam (2003)).

Table 4.1: Descriptive statistics

	GDP per capita[a]	CO_2 per capita (kt)
Minimum	132.82	0.004
Maximum	113204.29	49.30
Mean	8553.96	4.10
Std. Dev.	10207.05	5.61

Notes. [a] Real GDP per capita (PPP, 2005 US dollars). The whole sample includes $n = 954$ observations ($N = 106$ countries and $T = 9$ five-year periods).

4.2 Data and distribution dynamics

4.2.1 Data

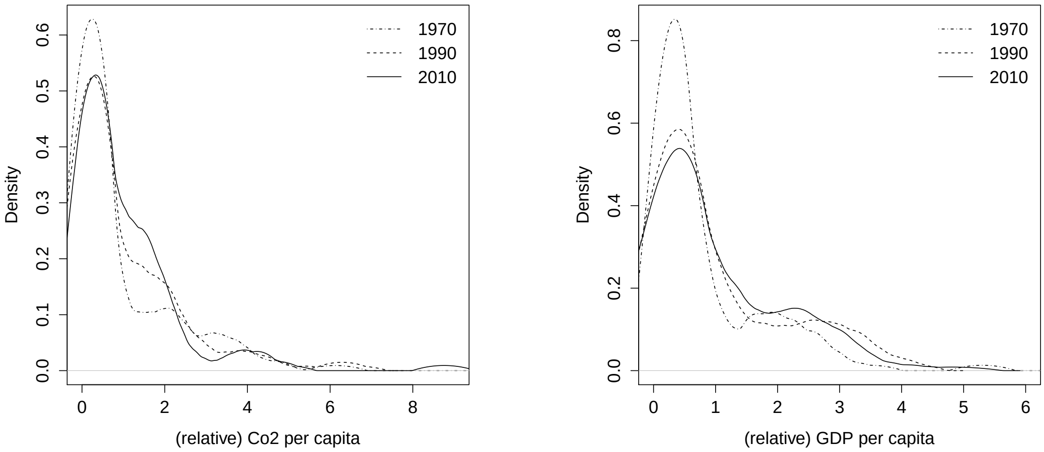
We use CO_2 emissions per capita, drawn from the World Bank Development Indicators database. They correspond to carbon dioxide emissions stemming from the burning of fossil fuels and the manufacture of cement, including carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. CO_2 are then strictly linked to production and economic activity in general. GDP per capita is instead drawn from the World Penn Tables 8.0 and it is expressed at PPPs in 2005 US dollars. The whole sample includes 107 countries which differ greatly in GDP per capita levels, over the period 1970-2010. We also focus the analysis on two separate subsamples consisting of 21 OECD and 85 non OECD economies in order to reduce heterogeneity of the data.

Table 4.1 reports the descriptive statistics. The high value of the standard deviation for both GDP and CO_2 emissions per capita is indicative of the heterogeneity of the sample. The very high maximum value for GDP per capita corresponds to Saudi Arabia in 1973. Similar high values are also observed for Bahrain, especially in the Seventies. The highest value of CO_2 emissions per capita corresponds to Bahamas, in which consumption of liquid fuels more than doubled in the Seventies for then reverting to the previous trend in the Eighties. Overall, higher levels of CO_2 per capita are observed in the oil countries included in the sample (Bahrain and Saudi Arabia) and also in Luxembourg and the United States.

Complementary to Table 4.1 are the kernel density estimates in Figure 4.1. Values are standardized with respect to the mean. The distribution of CO_2 and GDP per capita is reported for 1970, 1990 and 2010 and the pattern is similar in both cases. The number of countries in the bottom of the distribution is decreasing over time, while the mass increases in the interval [1,3] favouring a bimodal distribution in the case of GDP per capita. This implies that the average levels of GDP and CO_2 per capita are increasing overtime.

4.2.2 Distribution dynamics

Convergence analysis in growth econometrics is usually done by either estimating a convergence equation using cross-sectional data, panel data, or time series. However, the estimation results provide information regarding the average behaviour in the sample and no relevant insights are given with respect to relative performances.



(a) CO_2 (b) GDP

Figure 4.1: Distribution of CO_2 and GDP per capita.

Hence, the analysis of distribution dynamics is a complementary tool providing a complete picture of CO_2 emissions (Quah, 1996, 1997). In particular, we study the evolution of the distribution of CO_2 emissions assuming that the process determining its dynamics is time-invariant and first-order (Johnson, 2000, 2005), such as that the distribution prevailing at time $t + \tau$ is given by

$$\phi_{t+\tau}(y) = \int_0^{+\propto} f_\tau(y|x)\phi_t(x)dx \tag{4.1}$$

where y is relative CO_2 emissions per capita at time $t + \tau$, $\phi_t(x)$ is the distribution of emissions at time t and $f_t(y|x)$ is the conditional density τ periods later. The latter informs about transition dynamics within the distribution during the period considered, mapping the position of each country at time t and $t + \tau$.[7]

Figure 4.2 plots $f_\tau(y|x)$, for which $\tau = 5$, hence considering data for 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, and 2010.[8] Observations which did not change their position from t to $t + \tau$ lie on the 45 degrees line. Observations below the bisector improved their relative position along the period (i.e. relative emissions increase in $t + \tau$ conditionally to information in t), while observations above fell behind (i.e. relative emissions decrease in $t + \tau$)). The density contours represented in the plot show that observations in the bottom of the distribution are stable overtime, while countries above 1.5 reduced their emissions relatively to the sample mean. The dotted line is the median curve, which suggests that countries around the mean (equal to 1) improved their relative position, i.e. increased their relative per capita emissions. This is also true for countries with relative emissions close to 0. However, contours show that overall the distribution is very sparse, with most of the mass lying close to the bisector. Therefore Figure 4.2 suggests that convergence is not in place, since most of the countries maintain their position in the bottom of the distribution, while a small peak consolidates around 2.

[7] The conditional density represents the continuous analogue of the transition matrix. See Johnson (2000, 2005) and Nguyen-Van (2005) for estimation details.

[8] Results obtained with $\tau = 10$ are very similar.

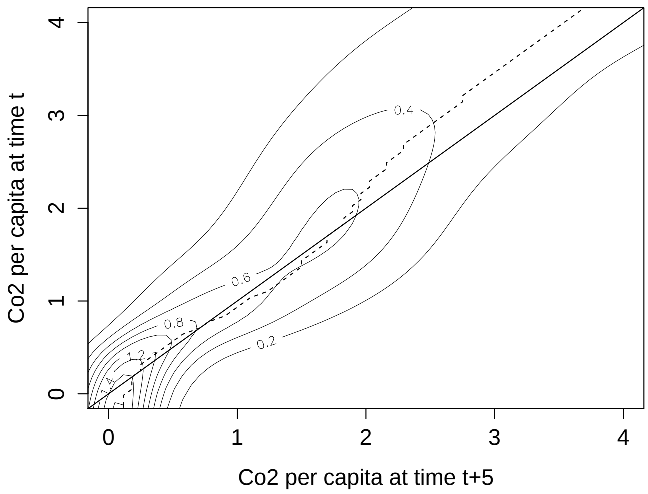


Figure 4.2: Conditional distribution of relative CO_2 emissions per capita.

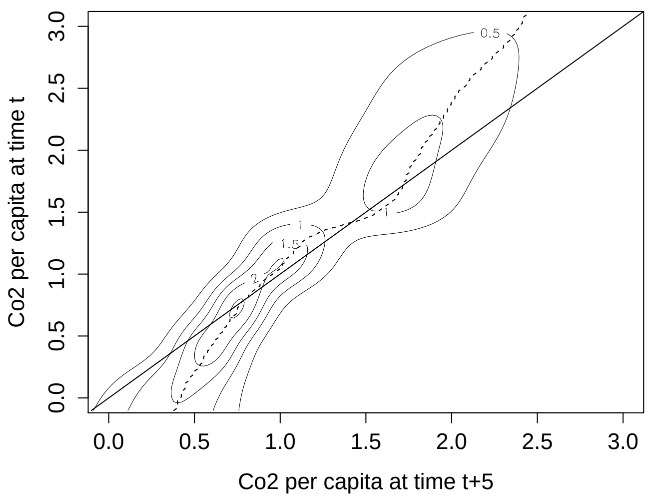


Figure 4.3: Conditional distribution of relative CO_2 emissions per capita in OECD countries.

Richer countries are responsible for higher CO_2 emissions because of their output structure. Moreover, more advanced countries are the most engaged in policies oriented to reduce the environmental impact of economic activity and to exploit alternative energy sources. We perform the above analysis for the subsample of 21 OECD countries. Figure 4.3 plots the resulting conditional density. The contours indicate that, differently from the full sample, distribution dynamics are characterized by a higher mobility. Two main peaks can be detected between 0.5 and 1, one of them above the 45 degrees line, suggesting a reduction in emissions. Another peak in the upper tail of the distribution is mostly located above the bisector. Hence, Figure 4.3 suggests a bipolarization process between OECD countries. Some economies are converging toward a level of CO_2 emissions below the sample mean, while countries in the upper tail of the distribution are converging toward a level higher than the OECD average. Such an evidence is consistent with findings for industrial countries reported by Nguyen-Van (2005) and Strazicich and List (2003).

4.3 The econometric model

To complete the previous distribution analysis, in this section we propose a framework to study the average behaviour of the data. Following the definition of an income convergence equation in the panel data framework proposed by Islam (1995), we can model convergence for environmental indicator y (CO_2 emissions in our analysis) as follows

$$y_{it} = \alpha y_{i,t-1} + \zeta_{it} \tag{4.2}$$

where y_{it} is the log of CO_2 emissions per capita of country i ($i = 1, ..., N$) at period t ($t = 1, ..., T$). The equation allows to capture the local dynamics toward the steady state. More generally, it accounts for adjustment dynamics of emissions overtime: if α is less than 1, pollutants in time $t + 1$ are a smaller proportion of the level in t. It should be note that, in equation (4.2), $\alpha = \exp^{-\lambda\tau}$, where λ and τ indicate the rate of convergence and the time span, respectively. The former measures how fast emissions are converging to their steady state or, more generally, how fast the gap between countries is being closed.[9] The smaller α, the larger the rate of convergence λ. When an estimation of α is available, we can use the delta method to recover λ (Islam, 2003). The time span between t and $t + 1$ may be fixed to a period of several years. Following Islam (1995) we opt for 5 years time intervals in order to avoid short-term disturbances or business cycle fluctuations which are likely present in shorter intervals. Hence, as in the previous analysis about distribution dynamics, the data used in the regressions below correspond to 1970, 1975,..., 2010.

The literature regarding the EKC hypothesis usually assumes the following parametric specification for environmental indicator y and income z (in logs):

$$y_{it} = Z'_{it}\beta + \eta_{it} \tag{4.3}$$

where a quadratic form in income is often specified such that

$$Z'_{it}\beta = \beta_0 + \beta_1 z_{it} + \beta_2 z_{it}^2. \tag{4.4}$$

[9] Islam (2003) remarks the tension between the neoclassical and the general interpretation of the convergence parameters α and λ. This tension arises whenever additional regressors other than the lagged dependent variable are considered. In such a case, if the neoclassical derivation of equation (4.2) is considered, convergence towards each economy's steady state and the reduction of cross-countries gaps do not longer coincide.

Our intuition is to gather these two equations into a single-equation specification which can allow for investigating both the EKC and the environmental convergence hypotheses

$$y_{it} = \alpha y_{i,t-1} + Z'_{it}\beta + \varepsilon_{it}. \tag{4.5}$$

We assume that the data is independent across the i index. Moreover, our analysis is based on the case of large N and fixed T. It should be noted that this model can be estimated by using divers approaches: random effects (RE, GLS estimator), fixed effects (FE, within estimator), instrumental variables (IV). However, the presence of the lagged dependent variable $y_{i,t-1}$ implies a correlation between it and the regression residuals, which makes the RE-GLS and the FE-within estimators inconsistent and then justifies the use of the IV estimator.[10]

Recent studies underline the possible misspecification regarding the parametric form of the EKC (see Azomahou et al. (2006), Bertinelli and Strobl (2005)). Hence, taking this issue into account, we can replace the parametric functional form $Z'_{it}\beta$ by a nonparametric form $g(z_{it})$. The resulting specification is a semiparametric dynamic panel data model:

$$y_{it} = \alpha y_{i,t-1} + g(z_{it}) + \varepsilon_{it}. \tag{4.6}$$

It is assumed that the residuals in model (4.6) are given by $\varepsilon_{it} = \mu_i + u_{it}$ where μ_i represents the country-specific effect and u_{it} the standard error term.[11] The estimation of this model can be performed following the methods developed by Li and Stengos (1996), Baltagi and Li (2002) and Li and Racine (2007). These authors proposed two instrumental variable solutions for estimating α, which also allow for the assumption that the residuals ε_{it} are serially correlated. The procedure requires firstly to eliminate $g(z_{it})$ as in Robinson (1988), by taking the expectation of (4.6) conditional on z_{it} and then by subtracting it from (4.6). This yields

$$y_{it} - E(y_{it}|z_{it}) = \alpha\left[y_{i,t-1} - E(y_{i,t-1}|z_{it})\right] + \left[\varepsilon_{it} - E(\varepsilon_{it}|z_{it})\right] \equiv \alpha v_{it} + \xi_{it} \tag{4.7}$$

where $v_{it} \equiv y_{i,t-1} - E(y_{i,t-1}|z_{it})$ and $\xi_{it} \equiv \varepsilon_{it} - E(\varepsilon_{it}|z_{it})$. If we use $E(\varepsilon_{it}|z_{it}) = 0$, then $\xi_{it} = \varepsilon_{it}$.

Following Li and Stengos (1996) and Baltagi and Li (2002), assuming there exist $q \geq 1$ instrumental variables w_{it} correlated with $y_{i,t-1}$ and uncorrelated with ξ_{it}, the instrumental variable estimators are given by

$$\hat{\alpha}_{IVO} = (v'ww'v)^{-1}v'ww'(y-\psi) \tag{4.8}$$

$$\hat{\alpha}_{IVG} = (v'\Sigma^{-1}w(w'\Sigma^{-1}w)^{-1}w'\Sigma^{-1}v)^{-1}v'\Sigma^{-1}w(w'\Sigma^{-1}w)^{-1}w'\Sigma^{-1}(y-E(y_{it}|z_{it})) \tag{4.9}$$

where $\psi_{it} \equiv E(y_{it}|z_{it})$. Note that estimator (4.8) is computed using OLS while estimator (4.9) relies on GLS using w_{it} as an instrument. Moreover, the IVO estimator

[10] The parametric model can be also estimated using the GMM estimators developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998), which work under the assumption that $y_{i,t-1}$ and z_{it} are weakly exogenous (or predetermined), i.e. $E(\varepsilon_{it} \mid y_{i,t-1-s}) = E(\varepsilon_{it} \mid z_{is}) = 0, \forall s < t$. GMM estimates are reported in Appendix B. They however provide mixed results.

[11] This specification includes the situation where μ_i are considered as random effects. The case of fixed effects μ_i is interesting but much more complex to handle. Moreover, the literature that considers not only $y_{i,t-1}$ but also z_{it} as endogenous regressors is still under development. These issues would deserve to be studied in our further work.

requires w_{it} to be weakly exogenous, while the IVG requires strong exogeneity of the instrument and conditional homoskedasticity of the residuals.

Li and Stengos (1996) used $w_{it} = z_{i,t-1}$ as an IV for $v_{it} = y_{i,t-1} - E(y_{i,t-1}|z_{it})$ because $z_{i,t-1}$ is uncorrelated with ξ_{it} and it is possibly correlated with v_{it}. However, Baltagi and Li (2002) showed that in some cases $E(v_{it}z_{i,t-1}) = 0$ so that $w_{it} = z_{i,t-1}$ is uncorrelated with v_{it}.[12] To avoid this possibility, they proposed to use $w_{it} = E(y_{i,t-1}|z_{i,t-1})$, instead of $z_{i,t-1}$, as an instrument for v_{it}. This is the approach we follow.

A further piece of information concerns the appropriateness of the functional form. Indeed, it may be interesting to test whether the parametric functional form is a good approximation. Therefore, we apply the procedure developed by Henderson et al. (2008) to test the parametric dynamic panel data model in (4.5) against the semiparametric dynamic panel data model in (4.6). The test statistic is given by

$$I_N = \frac{1}{NT}\sum_{i}^{N}\sum_{t}^{T}\left[\tilde{\alpha}y_{i,t-1} + Z_{it}'\tilde{\beta} - \hat{\alpha}y_{i,t-1} - \hat{g}(z_{it})\right]^2 \tag{4.10}$$

where $\tilde{\alpha}$ and $\tilde{\beta}$ denote the consistent estimators based on model (4.5) and $\hat{\alpha}$ and $\hat{g}$ are consistent estimators based on model (4.6). The null hypothesis H_0 is the parametric model in (4.5), while the alternative H_1 is the semiparametric specification in (4.6). Note that I_N converges to zero in probability under the null and it converges to a positive constant under the alternative. However, the asymptotic distribution of I_N is unknown. Therefore, Henderson et al. (2008) employ a bootstrap procedure to generate an empirical distribution for I_N which approximates its finite sample null distribution. Hence, inference is done by making use of such an empirical distribution.[13]

4.4 Estimation results

We start by implementing the two semiparametric IV estimators for model (4.6), using $w_{it} = E(y_{i,t-1} \mid z_{i,t-1})$ as instrument for v_{it}. Results are reported in Table 4.2, with both the dependent and independent variables being expressed in logs. Findings suggest that countries are converging in terms of CO_2 emissions per capita, given estimates for α lower than 1 and statistically significant for both the IVO and the IVG models. In particular, the IVO estimator provides an estimated value for α equal to 0.713, while the IVG estimator yields α equal to 0.870. This implies the convergence rate λ is 6.8% and 2.8%, respectively. For what concerns the relationship between emissions and GDP per capita, Figure 4.4 plots the function $g(z_{it})$ resulting from the two IV estimators. The relationship is slightly increasing along the whole distribution of income, despite a short decreasing path at the lower tail. It can be observed that CO_2 emissions per capita keep rising even at higher levels of GDP per capita, i.e. in the very upper tail of the distribution. This contrasts with the theoretical argument supporting the EKC hypothesis. The shape of $g(.)$ is similar for both the IVO and the IVG estimators, the former having a steeper

[12] See Baltagi and Li (2002) for more details.

[13] The bootstrap procedure generates n new samples of y_{it}^*, according to the parametric model. Then, both models (4.5) and (4.6) are estimated n times and the respective coefficients are obtained. For further details see Henderson et al. (2008).

Table 4.2: Semiparametric estimations

	IVO		IVG	
Coefficient	Estimate	(Std. Err.)	Estimate	(Std. Err.)
α	0.713***	(0.039)	0.870***	(0.034)
Implied λ	0.068***	(0.003)	0.028***	(0.003)

Note. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Bootstrapped standard errors in parenthesis. The implied λ is calculated by the delta method. The sample includes $n = 954$ observations ($N = 106$ countries and $T = 9$ five-year periods).

slope. It can be also noted that the slope of both curves becomes steeper for levels of log of income higher than 10, which is exactly the opposite feature of an EKC. Grey lines indicate the confidence bands of the estimation and have been obtained by bootstrap.

Therefore, the semiparametric models support environmental convergence but they provide no confirmation of the EKC hypothesis. Recall that the benefit of a nonparametric approach for $g(z)$ is that no ad-hoc specification of the emissions-income relationship is needed. It is of interest to compare the above results with estimations obtained in a parametric setting. This will provide a more extensive overview of the topic, as well it will allow to determine which model is preferred. Hence, as a further step, we calculate three parametric estimators corresponding to the parametric specification in equation (4.5). In particular, we firstly compute the RE and the FE estimators. Because of the potential endogeneity of the lagged dependent variable $y_{i,t-1}$, both the RE and the FE estimators would be inconsistent. Hence, we also perform an IV estimation for model (4.5) using w_{it} as instrumental variable. Results of these estimators are reported in Table 4.3.[14]

The first two columns report the results of the RE and the FE estimators, respectively. In both cases the estimated coefficient for $y_{i,t-1}$ is less than 1 and significant, implying a convergence rate of 8.1% and 3% respectively. For what concerns the relationship between emissions and income, both the RE and the FE estimators support a quadratic form even though the turning point is around $z = 12$, which is outside the sample. Therefore no confirmation of the EKC argument is provided. The third column reports results for the IV estimator. In this case the coefficient on $y_{i,t-1}$ is more than halved with respect to both the parametric (RE and FE) and semiparametric (IVO and GVO) estimators, being equal to 0.313, with a corresponding rate of convergence of 23%. For what concerns the EKC hypothesis, the results support a quadratic relationship, however also in this case the turning point is well outside the sample. The relationship between CO_2 emissions per capita and GDP per capita for the RE, FE and IV estimators is presented in the left panel of Figure 4.5, confirming the absence of the EKC effect.

Overall, no empirical confirmation for the EKC hypothesis is confirmed, neither in the semiparametric setting nor in the parametric specifications. A significant convergence process is supported by the semiparametric estimates and by the para-

[14] All the parametric models are estimated allowing for individual effects. Including time effects does not change the results for the RE GLS, FE within, and IV estimators. Furthermore, they are not statistically significant.

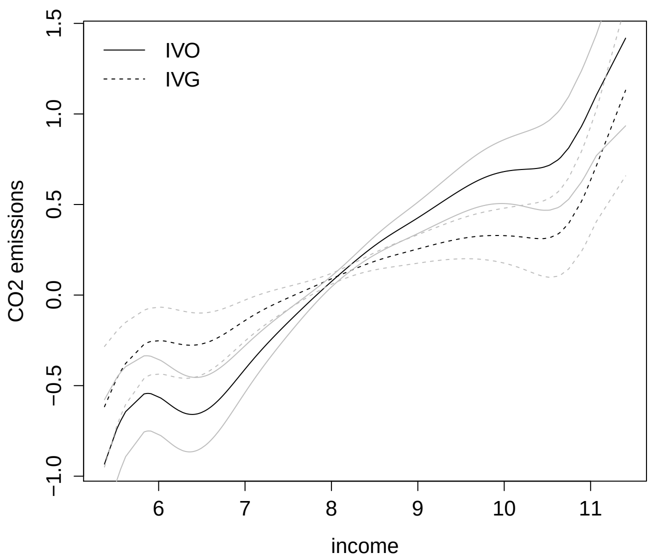


Figure 4.4: Semiparametric estimation of the relationship between CO_2 emissions and income. The black curves represent the IVO and IVG estimates. The grey curves correspond to the bootstrap 95% confidence intervals.

Table 4.3: Parametric estimations

	RE	FE	IV
Intercept	-3.178^{***}	–	–
	(0.496)		
α	0.858^{***}	0.665^{***}	0.313^{***}
	(0.013)	(0.022)	(0.095)
β_1	0.620^{***}	0.833^{***}	1.454^{***}
	(0.116)	(0.189)	(0.273)
β_2	-0.026^{***}	-0.034^{***}	-0.060^{***}
	(0.007)	(0.011)	(0.014)
Implied λ	0.081^{***}	0.030^{***}	0.232^{***}
	(0.006)	(0.003)	(0.060)
Adjusted R^2	0.961	0.596	0.521

Notes. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Robust standard errors in parenthesis. The implied λ is calculated by the delta method. The sample includes $n = 954$ observations ($N = 106$ countries and $T = 9$ five-year periods).

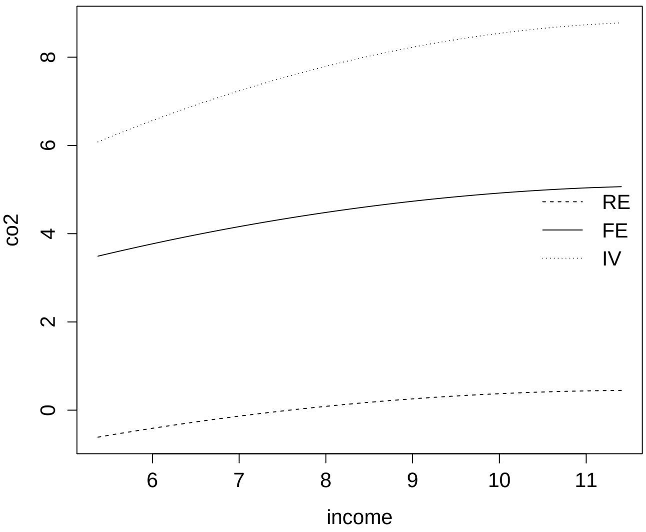


Figure 4.5: Parametric estimation of the relationship between CO_2 emissions and income.

metric RE, FE, IV estimators. It must be stressed that such a result must be interpreted in terms of steady-state convergence within the conditional convergence framework of equation (4.6), as emphasized by Islam (2003). Distribution dynamics presented in Section 2 provide complementary information.

4.5 Subsample analysis and tests

4.5.1 OECD and non-OECD subsamples

As outlined in the Introduction, the theoretical EKC argument implies that we should observe a weakening of the positive relationship between pollutant emissions and income in high income economies. Therefore, replicating the above estimates for a subsample of developed countries should provide evidence of either a decreasing relationship or, at least, of the EKC itself. In addition, we should find simultaneous evidence of a convergence process as long as we consider a group of high income countries with similar structure of output, capable to implement environmentally-friendly technologies and in which interventions targeting environmental degradation are in the policy agenda. Some empirical results support this view, as for instance Galeotti et al. (2006) (among others), which report evidence of an inverted U-shaped relationship for OECD countries, while an increasing curve is found for non-OECD economies. Indeed, countries belonging to the OECD group are more likely to present the three mechanisms triggering the EKC discussed above. Therefore, in the present Section we firstly estimate the semiparametric and parametric models for the subsample of the OECD economies. Then we compare the results with findings for non-OECD countries.

Results for the 21 countries in the OECD group are reported in Table 4.4. Semi-parametric estimates for α in the first two columns indicate that OECD countries are converging in terms of emissions per capita. The rate of convergence is particularly

Table 4.4: Semiparametric and parametric estimations for OECD countries

	IVO	IVG	RE	FE	IV
Intercept	–	–	2.670	–	–
			(2.188)		
α	0.571***	0.821***	0.857***	0.734***	0.756***
	(0.039)	(0.034)	(0.025)	(0.040)	(0.125)
β_1	–	–	−0.426	0.766	3.988***
			(0.451)	(0.532)	(1.102)
β_2	–	–	0.019	−0.041	−0.198***
			(0.023)	(0.027)	(0.055)
Implied λ	0.112*	0.039*	0.031***	0.062***	0.056***
	(0.064)	(0.022)	(0.006)	(0.011)	(0.064)
Adjusted R^2	–	–	0.890	0.705	0.595

Notes. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Bootstrap (semiparametric) and robust (parametric) standard errors in parenthesis. The implied λ is calculated by the delta method. The sample includes $n = 189$ observations ($N = 21$ countries and $T = 9$ five-year periods).

higher in the IVO estimator (11%), while it is lower in the IVG case (3.9%) and it is statistically significant in both cases. The $g(z)$ curves plotted in Figure 4.6 show a slightly increasing relationship between emissions per capita and GDP per capita in the IVO case, while no relationship emerges following the IVG estimator. Also, confidence bands for the IVO estimate are quite large. In both case, the curve is neither decreasing nor inverted U-shaped, hence no empirical support for the EKC argument is provided.

Parametric estimations are reported from columns 3 to 7. Results support environmental convergence, being the estimated coefficient for $y_{i,t-1}$ between 0.734 (FE) and 0.857 (RE), for a corresponding rate of convergence λ between 6.2% and 3.1%. It must be noted that, similarly to the full sample case, the IV estimator yields a lower estimate with respect to any other specification, equal to 0.296. For what concerns the relationship between CO_2 emissions and income, results are consistent with the semiparametric estimates. Indeed, no significant relationship arises, being the estimated coefficients for z and z^2 no statistically significant in every model but the IV estimator. Note that in the RE model, the coefficients on z and z^2 are negative and positive respectively, even though the resulting curve is almost flat and the relationship not significant. Concerning the IV estimator, the relationship is significant and the quadratic form is first increasing and then decreasing. However, even in this case the curve is almost flat. The resulting curves are plotted in Figure 4.7.

Overall, our results for OECD countries do not provide support for the EKC argument, even though the estimates and distribution dynamics in Figure 4.3 indicate that environmental convergence is in place in terms of both steady states and relative emission. Said differently, evidence of convergence does not imply neither an EKC relationship nor a reduction in emissions overtime.

As a further step we compare the above OECD evidence with findings for the non-OECD subsample. Semiparametric results in the first two columns of Table 4.5 support environmental convergence, being the estimated coefficient for α lower than

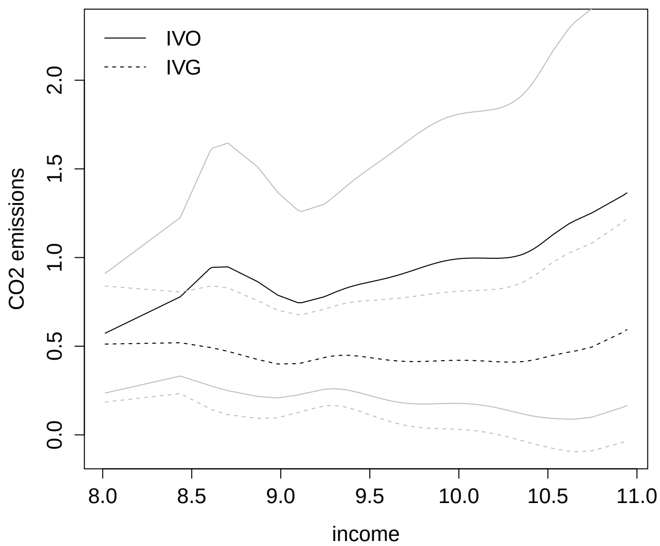


Figure 4.6: Semiparametric estimation of the relationship between CO_2 emissions and income for the OECD subsample. The black curves represent the IVO and IVG estimates. The grey curves correspond to the bootstrap 95% confidence intervals.

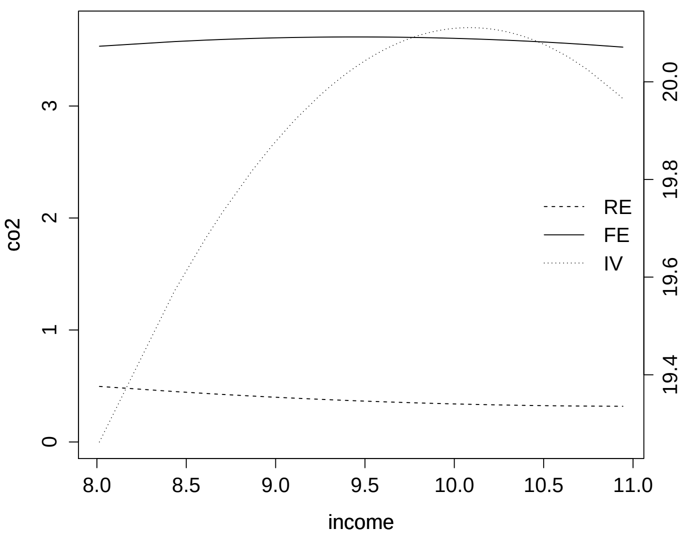


Figure 4.7: Parametric estimation of the relationship between CO_2 emissions and income for the OECD subsample. The scale for the RE and the FE models is on the left axis, the scale for the IV model is on the right axis.

Table 4.5: Semiparametric and parametric estimations for non-OECD countries

	IVO	IVG	RE	FE	IV
Intercept	–	–	-2.141^{***}	–	–
			(0.621)		
α	0.644^{***}	0.825^{***}	0.855^{***}	0.663^{***}	0.321^{***}
	(0.049)	(0.041)	(0.014)	(0.024)	(0.110)
β_1	–	–	0.339^{**}	0.445^{*}	1.021^{***}
			(0.151)	(0.237)	(0.328)
β_2	–	–	-0.008	-0.008	-0.032^{*}
			(0.009)	(0.014)	(0.018)
Implied λ	0.088^{*}	0.038^{*}	0.031^{***}	0.082^{***}	0.227^{***}
	(0.005)	(0.004)	(0.003)	(0.007)	(0.064)
Adj. R^2	–	–	0.95	0.59	0.53

Notes. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Bootstrap (semiparametric) and robust (parametric) standard errors in parenthesis. The implied λ is calculated by the delta method. The sample includes $n = 765$ observations ($N = 85$ countries and $T = 9$ five-year periods).

1, for a corresponding statistically significant rate of convergence equal to 8.8% and 3.8% for the IVO and the IVG model respectively. Similar conclusions can be drawn from the parametric specifications, with convergence rates λ between 3.1% and 8.2%. Once more, the IV model stands on its own, since the estimated coefficient for $y_{i,t-1}$ is equal to 0.321. Similarly to the full sample case, we do not find empirical support for the EKC hypothesis. Both the semiparametric curves $g(z)$ are increasing along the whole distribution and present an N-shaped pattern in the upper part, with a pattern close to the estimation for the whole sample. They are plotted in Figure 4.8. The parametric estimators yield a similar result. The relationship between emissions and income is positive and significant in the RE, FE and IV model. However, the quadratic term z^2 is slightly significant only in the IV estimator. The parametric estimates are plotted in Figure 4.9. Overall, results for the non-OECD countries are very similar to the results for the full sample.

Overall, findings can be summarized as follows. Firstly, even though we consider a sample large (and heterogeneous) enough to satisfy the structural conditions likely to trigger the EKC effect, we find no evidence of an inverted U-shaped relationship between CO_2 emissions and income. Estimations reveal an increasing pattern for the whole distribution and no reversion occurs in the upper tail. This implies that the EKC argument fails because of richer economies not reducing the energy intensity of economic activity. Such a pattern is confirmed by the evidence for the OECD subsample. Indeed, if we consider the semiparametric models, the relationship is either flat or slightly increasing with large confidence bands. Similarly, no support for the EKC argument can be drawn according to the parametric estimations. Secondly, results on convergence can be interpreted together with the failure of the EKC argument. Indeed, even though estimates of α are between 0 and 1, the relationship between CO_2 emissions and income together with the conditional densities in Section 2 clearly show that economies are not converging towards low levels of emissions. On the opposite, OECD countries are not reducing their emissions, while the growth path of poorer and developing economies is associated with higher levels

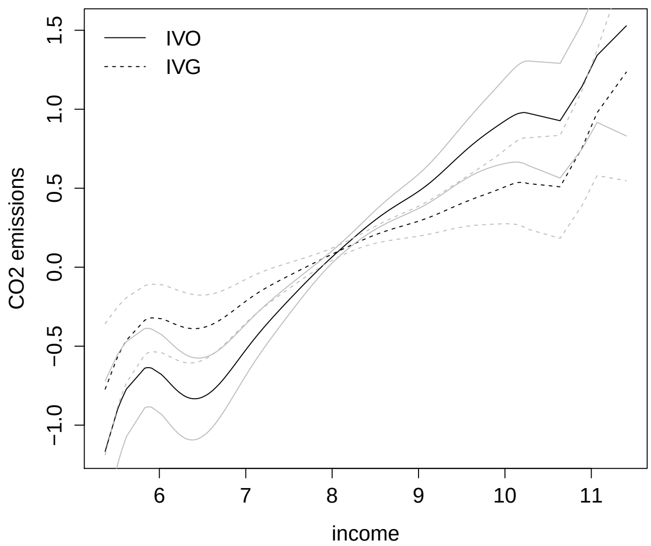


Figure 4.8: Semiparametric estimation of the relationship between CO_2 emissions and income for the non-OECD subsample. The black curves represent the IVO and IVG estimates. The grey curves correspond to the bootstrap 95% confidence intervals.

of CO_2 per capita.[15] In other words, the observed convergence process does not appear as the result of an environmentally friendly change in economic activity, and this is true also for richer economies.

4.5.2 Specification tests

This chapter makes use of parametric and semiparametric models. Even though the latter have the advantage of not imposing an ad hoc functional form, results are quite comparable. In what follows some specification tests will be performed. Firstly, we compare the parametric estimators among them in order to understand which of them is more reliable. Then, we test the parametric against the semiparametric models to see whether the parametric functional form is a reasonable approximation of the true data generating process. We apply the test developed by Henderson et al. (2008). The null hypothesis H_0 is the parametric model, while the alternative H_1 is the semiparametric specification. Rejecting H_0 implies that the semiparametric model should be preferred to the parametric one. The test is based on the test statistics in Equation 4.10. Note that the null is rejected if I_N lies in the top 5% of the empirical distribution and that the statistics is always greater than 0 by construction.[16] While results are reported for the full sample case, findings for the two subsamples are similar.

As a first step we apply the Hausman test to couples of parametric models.

[15] Recalling again Islam (2003) argument on the interpretation of a conditional convergence equation, we may say that countries are converging towards their own steady states which do not need to coincide. Results in Section 2 are consistent with this interpretation

[16] See also Li and Racine (2007).

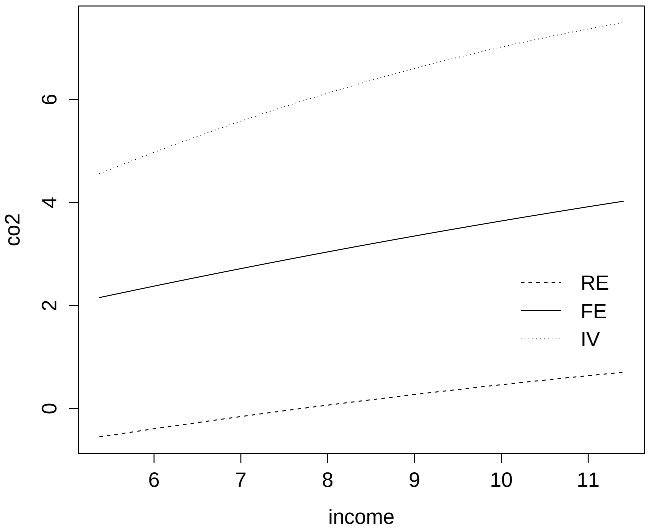


Figure 4.9: Parametric estimation of the relationship between CO_2 emissions and income for the non-OECD subsample.

Table 4.6: Results of the Hausman test

Estimators	Result of the Hausman test	Restriction
RE vs FE	RE is inconsistent compared to FE	$E(\mu_i \mid y_{i,t-1}, z_{it}) = 0$
FE vs IV	FE is inconsistent compared to IV	$E(u_{it} \mid y_{i,t-1}) = 0$

Results are reported in Table 4.6. The first column indicates which pair of estimators are under testing (the first estimator is under the null hypothesis, the second one is under the alternative). The second column reports the result of the test. The last column describes the restriction under the null. Overall, the random effect hypothesis is rejected, hence the RE model is rejected in favour of a FE specification. Similarly, the IV estimator performs better than the FE within estimator which suffers from the potential endogeneity of $y_{i,t-1}$.

The second specification test follows Henderson et al. (2008), comparing the parametric to the semiparametric models. If H_0 is rejected, than the parametric functional form is not a good approximation of the data generating process and the $g(z)$ nonparametric function should be preferred. In Table 4.7 we summarize results comparing the IV, FE and RE to both the IVG and IVO models in the full sample case. Also in this case results are not univocal. However, we can conclude that

Table 4.7: Results of the Henderson et al. (2008) test

Parametric specification (under H_0)	Semiparametric IVO	Semiparametric IVG
RE	H_0 rejected	H_0 not rejected
FE	H_0 not rejected	H_0 not rejected
IV	H_0 not rejected	H_0 rejected

the semiparametric specifications are not systematically better than the parametric alternatives.

Replicating the test for the OECD and non-OECD subsamples does not provide different results. Therefore, we can state that the quadratic parametric specification yields evidence which is comparable with a more ‘agnostic’ semiparametric model. Similar conclusions are obtained by Bertinelli and Strobl (2005) when comparing a semiparametric and a linear model. Nevertheless, the merit of the semiparametric model resides in its generality that encompasses the parametric model.

4.6 Concluding remarks

This chapter contributes to the empirical environmental literature by testing environmental convergence together with the EKC hypothesis in a unified empirical framework. We use parametric and semiparametric methods, drawing from a sample of 106 countries from 1970 to 2010. Results do not provide support for an inverted U-shaped relationship between CO_2 emissions and GDP per capita. On the opposite, an increasing path is obtained and we fail to find a turning point within the sample. Differently from some recent empirical evidence, our result is robust across specifications and holds also for the OECD subsample, for which an inverted U-shaped relationship should be theoretically more likely to be in place. Evidence of convergence can be reconciled with the lack of an EKC relationship by using both the Islam (2003) argument of steady-state convergence and the distributional analysis presented in this chapter.

Therefore, international efforts and agreements aimed to reduce the environmental impact of economic activity have not been strict enough to invert the ‘natural’ positive relationship between economic growth and environmental degradation. Results are relevant especially because this is true also for OECD countries. Indeed, the relationship is positive at high levels of income despite international agreements, the tertiarization of output structure, technological advance, economic incentives for environmental-friendly technologies of production and the delocalization of heavily pollutant activities in poor and developing countries. From a policy point of view, such an evidence weakens the capability of rich economies and international institutions to impose environmental-friendly policies to developing countries. Moreover, this raises serious concerns about the environmental sustainability of the current development process.

The present study can be extended and improved in various ways, for instance by repeating the analysis using different environmental indicators. Most importantly, a further step would be to modify the semiparametric models to allow for fixed effects, which are not encompassed in the present chapter. Finally, it may be of interest to further augment the equation under analysis to investigate the role of determinants of CO_2 emissions. In particular, two kinds of factors could deserve special attention: technological advance and policy indicators. All of this is left to further research.

Appendix

C.1 Countries included in the study

Table A1: List of countries

Countries included				
Angola	Albania	Argentina	Australia*	Austria*
Burundi	Belgium*	Benin	Burkina Faso	Bulgaria
Bahrain	Bahamas	Belize	Bolivia	Brazil
Barbados	Bhutan	Canada*	China	Cote d'Ivoire
Congo, Dem. Rep.	Congo, Rep.of	Colombia	Comoros	Cape Verde
Costa Rica	Cyprus	Djibouti	Dominica	Denmark*
Dominican Republic	Egypt	Spain*	Ethiopia	Fiji
France*	Gabon	United Kingdom*	Ghana	Guinea
Gambia	Guinea-Bissau	Equatorial Guinea	Greece*	Grenada
Guatemala	Honduras	Hungary	Indonesia	Iran
Iraq	Iceland*	Israel*	Italy*	Jamaica
Jordan	Japan*	Kenya	Cambodia	St. Kitts & Nevis
Korea, Rep.*	Lebanon	Liberia	St. Lucia	Luxembourg*
Madagascar	Mali	Malta	Mongolia	Mauritania
Mauritius	Malawi	Malaysia	Niger	Nigeria
Netherlands*	Nepal	New Zealand*	Panama	Peru
Philippines	Poland*	Portugal*	Paraguay	Romania
Rwanda	Saudi Arabia	Senegal	Singapore	Sierra Leone
El Salvador	Suriname	Sweden*	Swaziland	Syria
Togo	Thailand	Trinidad & Tobago	Tunisia	Turkey
Uganda	United States*	Venezuela	South Africa	Zambia
Zimbabwe				

Note: OECD countries are starred.

C.2 Parametric GMM estimations

The presence of the lagged dependent variable $y_{i,t-1}$ implies a correlation between it and the regression residuals, which makes the RE-GLS and the FE-within estimators inconsistent and calls for the implementation of the IV estimator. Another parametric alternative used to deal with dynamic models as equation (4.5) is the General Method of Moments (GMM) estimator developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). The GMM estimator is particularly suited for dynamic panels with small T and large N, and it is designed for cases in which the only available instruments are the lags of the endogenous variable. In this section, we present the estimates of the parametric model of equation (4.5) using the Arellano-Bond Difference GMM (AB) and the Blundell-Bond System GMM (BB).[1] Results are presented in Table B1, allowing for individual fixed effects. Two main conclusions can be drawn.

Firstly, while the coefficient for α and the relative rate of convergence λ are significant in every specification, evidence does not support the existence of the EKC with the exception of the OECD subsample. In particular, the relationship is either not significant – as indicated by the AB estimator in both the full sample and the non-OECD subsample – or increasing in z (despite β_1 is negative and β_2 is positive for the BB estimator, the turning point is around $z = 4$ in both the full and non-OECD samples). For what concerns the OECD case, an inverted U-shaped curve arises for the AB case, while a slightly decreasing pattern is in place for the BB estimator (being the turning point out of the sample, i.e. around $z = 7.4$).

Secondly, reported tests indicate that the GMM estimators are not adequate. Indeed, the rejection of the null hypothesis for the Sargan test is against the overidentifying restriction related to these estimators. Moreover, the autocorrelation test indicates that a second-order serial correlation can exist, contrary to the assumption of absence of an AR(2) process for the GMM specification. The only exception is the AB estimator for the OECD subsample.

Overall, the reported evidence does not support the GMM models, hence we prefer the parametric IV and the semiparametric IVO and IVG estimators.

[1] The GMM estimators developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) work under the assumption that $y_{i,t-1}$ and z_{it} are weakly exogenous (or predetermined), i.e. $E(y_{i,t-1-s}\varepsilon_{it}) = E(z_{is}\varepsilon_{it}) = 0$ for $s < t$.

Table B1: GMM estimations

	Full Sample		OECD		non-OECD	
	AB	BB	AB	BB	AB	BB
α	0.702***	0.827***	0.615***	0.858***	0.656***	0.769***
	(0.080)	(0.047)	(0.073)	(0.054)	(0.079)	(0.052)
β_1	0.521	-0.183***	2.652***	0.118***	-0.130	-0.314***
	(0.429)	(0.063)	(0.935)	(0.028)	(0.504)	(0.069)
β_2	-0.017	0.023***	-0.135***	-0.008***	0.026	0.039***
	(0.026)	(0.007)	(0.0046)	(0.002)	(0.030)	(0.008)
Implied λ	0.071***	0.038***	0.097***	0.030***	0.084***	0.053***
	(0.010)	(0.005)	(0.007)	(0.005)	(0.011)	(0.005)
Sargan Test	0.006	0.003	0.803	0.989	0.045	0.017
AR (1) Test	0.022	0.014	0.157	0.061	0.027	0.012
AR (2) Test	0.026	0.018	0.183	0.084	0.031	0.018

Notes: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Robust standard errors in parenthesis. The implied λ is calculated by the delta method. The $p-$values are reported for the Sargan, AR(1) and AR(2) tests. The data include $N = 106$ countries (whole sample), $N = 21$ countries (OECD subsample), and $N = 85$ countries (non-OECD subsample), for $T = 9$ five-year periods.

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