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LABOUR PRODUCTIVITY AND TECHNOLOGY GAP IN EUROPEAN REGIONS: A NON-PARAMETRIC APPROACH

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Abstract

The endogenous approach to regional development policy has become central over the last decade. By employing the conditional frontier approach, this paper investigates the relative contribution to labour productivity growth of: (1) capital accumulation, (2) exogenous technical change and efficiency, and (3) endogenous technological capabilities – i.e. innovation capability and human capital. We find overall convergence in labour productivity growth driven by capital accumulation and exogenous technical change, in 211 European regions in 18 countries over the period 1995-2007. Differences in terms of relative contribution arise concerning advanced regions vis-à-vis backward regions. As for the latter, productivity growth is mainly driven by capital accumulation, while the lack of convergence in terms of endogenous technological capabilities cast some doubts on the sustainability of the convergence process and suggest some implications for the European Cohesion policy.

Key words: labour productivity growth; technology gap; data envelopment analysis; EU Cohesion policy.
Jel code: O3; R11; C14.

INTRODUCTION

Labour productivity convergence is a fundamental pillar of European Union (EU) cohesion. Since technological innovation plays a major role in enhancing productivity growth, closing the technology gap in Europe has become a prominent concern of policy makers. To this regard, increasing attention has been devoted to the role of (sub-national) regions. This follows a major shift of development theory and development policy from redistributive policies across regions to an endogenous approach, or 'place-based policies' (Barca 2009). Accordingly, Structural Funds have provided regions substantial resources for innovation and technology policy. This paper explores the sources of labour productivity growth (output per worker) in 211 European regions in 18 countries over the period 1995-2007. By employing a non-parametric frontier approach, we decompose labour productivity growth into four components: (i) capital deepening; (ii) exogenous technical change; (iii) technology gap change; (iv) catching-up.

The endogenous approach to local and regional development policy has become central over the last decade. It contends that regional development and economic growth should be driven by endogenous forces in terms of 'a highly educated workforce and to knowledge and technologies developed in the region' (Toedtling 2010:28). Innovation has also become a central concern of regional development policies due to the growing importance of knowledge economy and regional level for innovation support policy. The regional level is increasingly regarded as the key level to foster growth thanks to the presence of local knowledge spill-overs, intra-regional labour mobility, and networks (Oecd 2011). This process rests on the increasing awareness of the very mechanisms underlying the process of generation of knowledge and innovation. It has been showed the prominence of interaction within localized context for learning (Lundvall and Johnson 1994). Thus co-location and proximity have been recognized central for innovation generation and diffusion (Iammarino 2005, 2005; Iammarino and McCann 2006). The presence of increasing returns to scale which work at the local level emphasized by growth-related literature also points to the role of endogenous capabilities to enhance growth and productivity (Martin and Sunley 1998; Krugman 1991).

European regions are characterized by an extreme polarization in terms of innovation and technology (European Commission 2010). This situation has been exacerbated as a result of the recent process of enlargement in which less advanced countries joined the EU. As explained in Barca (2009) 'the innovation gap between the EU, the US and Japan is reflected in *productivity growth* […] Major disparities in innovation capacity persist *within* the EU, both at Member State and regional level' (p. 153, our emphasis). Given the local and reinforcing nature of the process of economic growth discussed above, two opposite scenarios might occur. In the first, the presence of different technological capabilities coupled with localized increasing returns and spillover might broaden the economic differences across EU regions. In the second, lagging behind regions would manage to close their gap in terms of productivity growth, technology and innovation. The central claim of the endogenous approach to development regional policy is that the latter scenario is contingent upon the endogenous creation of innovation capability, technological knowledge, and qualified labour force. In other words, the 'convergence' scenario would prevail insofar as lagging regions will manage to close their technology gap.

Since the seminal paper by Fare et al. (1994), studies employing Data Envelopment Analysis (DEA) have aimed to attribute the change in labor productivity growth to different components: technological change, technical efficiency, capital accumulation and human capital (Kumar and Russell 2002; Los and Timmer 2005; Henderson and Russell 2005). This approach has been recently employed in a study covering 69 Western European regions in France, Germany, Italy, Spain, and Ireland, in which labour productivity growth is decomposed into capital accumulation, technical change, and efficiency (Enflo and Hjertstrand n.d.). The authors employ the bootstrapping method to account for the inherent bias and the stochastic elements in the efficiency estimation and find that the relative ranking of the efficient scores estimated with the DEA remain stable. In these studies technological change is essentially exogenous and is regarded 'as an indication of technological opportunities, given that technology is publicly available, at every region's respective capital per worker level' (Enflo and Hjertstrand n.d.).

A weakness of the aforementioned approach rests on the fact that it does not allow estimating the role played by the *endogenous* effort of the region in building its technological capabilities. In these studies, technical change results as an upward shift of the production frontier obtained as an external envelop of the fully efficient regions. A region which lies below the frontier is classified as 'inefficient' because it did not manage to take advantage of the expansion of the technological opportunities driven by exogenous technical change. In fact, in order to take advantage of exogenous technical change by means of adoption and imitation processes a region has to develop technological capabilities itself. Therefore, a region can lies below the frontier for two distinctive reasons: (i) an insufficient development of technological capabilities, or absorptive capacity (technology gap); (ii) a lack of efficiency in the use of its inputs.

This argument has been put forward by several scholars from different perspectives. Economic historians have argued that developing countries may exploit their backwardness position by imitating and adopting new technologies produced in advanced economies. However, they have also shown that the process of imitation is costly, and that it requires the existence of technological capabilities (Gerschenkron 1962; Landes 1969; Abramovitz 1986). Technology-gap models argue that two main dimensions determine the ability of a country to catch up. The first is its absorptive capacity, i.e. its ability to imitate foreign advanced technologies (Cohen and Levinthal 1990). The second is its innovative capability, namely the extent to which the country is able to produce new advanced knowledge. This research contends that imitation and catching up process is expected to be more rapid when the potential provided by a large technology-gap can be exploited by means of a well-developed absorptive capacity (Castellacci 2008, 2011; Benhabib and Spiegel 2005). A third related stream of research points to the development of technological capabilities as a pre-condition for countries to generate and manage technical change, both in terms of the introduction of new technology, as well as the incremental improvements of existing productive capacity (Bell and Pavitt 1993; Lall 1992; Archibugi and Coco 2004). Our work seeks to bring these arguments together and give them a quantitative assessment using a non-parametric approach to decompose labour productivity growth. In order to do that, we include a measure of technology gap (proxied by the endogenous development of technological capabilities) among the sources of labour productivity change. This would bring more analytical insight about the patterns of growth of labour productivity. By being more consistent with the endogenous approach of development policy in Europe, our results would also offer relevant insights for policy recommendations.

We find overall convergence in labour productivity growth driven by capital accumulation and exogenous technical change. Important differences in terms of relative contribution arise concerning advanced regions vis-à-vis backward regions. As for the latter, productivity growth in mainly driven by capital accumulation, while the lack of convergence in terms of endogenous technological capabilities cast some doubts on the sustainability of the convergence process and suggest some implication for EU Cohesion policy.

The remainder of the paper is organized as follows. The next section presents our empirical strategy in a descriptive fashion while more technical details can be found in the methodological appendix. Section 2 presents the data, while empirical results are discussed in Section 3. A summary of the key findings and policy implications are discussed in the last section.

THE EMPIRICAL STRATEGY

This section describes the empirical strategy, while the technical details about the computational model are given in the methodological appendix. We employ Data Envelopment Analysis (DEA) to build a nonparametric production frontier for European regions. This approach was pioneered by Fare et al. (1994) and has been extended by Kumar and Russell (2002). They provide a decomposition of labour productivity growth into capital deepening and total factor productivity. We bring this method a step further by developing an extended decomposition which includes a technology gap component. A production frontier is built as the locus of the most efficient regions: regions lying on the frontier are those which use inputs – capital and labour – in a fully efficient way to produce output – gross domestic product (GDP). According to the standard frontier approach, the distance of a region from the frontier represents a form of technical inefficiency. Since we assume constant returns to scale, the production frontier can be represented in its intensive form, i.e. capital per worker ratio as the only input (x-axis) and GDP per worker ratio as the output (y-axis). This implies that for any given capital per worker ratio there is an efficient level of GDP per worker.

The static model (Development accounting)

In the Kumar and Russell (2002) approach (Figure 1, left chart) the difference in GDP per worker between region *a* and region *b* can be accounted for by two main components: (i) the distance of region *a* from the efficient frontier; (ii) the different level of capital per worker between the two regions. Although very useful, within this framework it is not possible to take into account the role of endogenous technological capabilities, for they treat technological change as an exogenous component à la Solow. We make a further step by incorporating explicitly a number of variables which account for the technology gap (we call these variables Z's).

In order to account for the role of the technology gap to explain labour productivity disparities, we introduce a conditional frontier. In Figure 1 (right chart) two different frontiers are now drawn: a single *unconditional* frontier which coincides with the left chart frontier in figure 1; a *conditional* frontier *for each region* which depends on the level of technological capabilities of the region. The higher the level of technological capabilities of a region, the higher the level of the conditional frontier (next section on data will explain the selection of technology variables). The area comprised between the two frontiers represents a technological constraint, a technological opportunity space which is not available to region *a*. The intuition here is simple: it is very hard for lagging behind region to implement technologies developed in more advanced regions, unless they have appropriate levels of human capital and technology. The gap between the region specific conditional frontier and the overall unconditional frontier is what we define as *the technology gap*. [1] Here the unconditional (or overall) frontier represents the upper boundary for the conditional one.

[1] Technology gap and the level of technological capabilities are two faces of the same coin. The former is the distance between the overall frontier and each country's conditional frontier. In turn, the conditional frontier depends on the country's level of technological capabilities.

Our decomposition allows attributing the overall distance of the region to the unconditional frontier – the technical inefficiency in the Kumar and Russell (2002) model – to two components: (i) a measure of the technology gap; and (ii) a refined measure of inefficiency, which we call *conditional inefficiency*. With reference to Figure 1 (right chart), region *a* is inefficient with respect to its own conditional frontier and this represents the conditional inefficiency. Here a region can be efficient in using its inputs in producing outputs - it lies on the conditional frontier - but can still be below the unconditional frontier represented by the technological leading regions: this distance is what we define as the technology gap. Hence, a region is fully efficient – it lies on the overall frontier – when it lies on its conditional frontier and the technology gap is absent - its conditional frontier lies on the unconditional frontier. Finally, once the distance from the unconditional frontier has been taken into account, one can attribute the last part of GDP per worker gap to a difference in the capital per worker endowment of the two regions as in the Kumar and Russell (2002) model.

[FIGURE 1]

To recap the previous argument: for region *a* the conditional frontier represents the highest level of labour productivity which can be reached *given* its technology gap – or its level of technological capabilities. In order to get closer to the unconditional frontier, in addition to gain in efficiency, lagging behind regions need to close their technology gap. This rests on the idea that when lagging behind regions close their technology gap, they are increasingly able to adopt more productive – close to the frontier - technologies. In terms of notation, we call *technical efficiency* (TE) the distance between a region and the unconditional frontier; TE is then further decomposed into a *technology gap* (ZE) component and a *conditional technical efficiency* (CTE) component:

$$TE = ZE \cdot CTE \qquad (1)$$

The dynamic model (Growth Accounting)

So far, we have assumed a static point of view by comparing two regions in a given point of time. In order to investigate labour productivity growth we now turn to a dynamic perspective. In Figure 2 we compare region *a* in period t with region *a* in period t+1. For simplicity only the unconditional frontier is shown in the figure. The difference in GDP per worker between the two time periods is due to three effects: first, the displacement of the unconditional production frontier between the two time periods due to technical change (TC); second, the variation in the technical efficiency of the region, which is the ratio of TE in the two time periods; third, the increase in capital per worker due to a deepening of capital (KD). Therefore, in formulas, the change in output per worker can be written as:

$$\frac{Y^{t+1}/L^{t+1}}{Y^t/L^t} = TC \cdot TEC \cdot KD \qquad (2)$$

where $TEC = \frac{TE^{t+1}}{TE^t}$. Now, since technical efficiency can be decomposed into a conditional technical efficiency component (CTE) and a component representing the technology gap (ZE), the previous decomposition becomes:

$$\frac{Y^{t+1}/L^{t+1}}{Y^t/L^t} = TC \cdot (CTEC \cdot ZEC) \cdot KD \qquad (3)$$

where $CTEC = \frac{CTE^{t+1}}{CTE^t}$ and $ZEC = \frac{ZE^{t+1}}{ZE^t}$. This is our growth accounting formula. Labour productivity growth is therefore ascribed to four different sources: (i) an exogenous technical change component (TC) which captures the upward displacement of the production frontier over time; (ii) a capital deepening effect (KD) which represents the effect of an increase in the capital intensity of the economy; (iii) a catching up component (CTEC) which signals how much a specific region is moving toward, or mowing away, from its conditional frontier; (iv) a technology gap component (ZEC) incorporating the effect of technological capabilities accumulation onto the production of output.

[FIGURE 2]

To summarize, our model accommodates two important phenomena: *first*, the possibility that a region is lagging behind with respect to the production frontier (inefficiency); *second*, it incorporates explicitly the role of technological capabilities in the production model through the introduction of the technology gap. Two countries with the same level of capital and labour can produce very different output levels according to their level of conditional technical efficiency, and their level of technological capabilities. It should also be stressed that our nonparametric model accommodates biased technical change, i.e. we do not assume Hicks neutrality (or any other type of neutrality) in technical change (which is indeed assumed in many growth accounting exercises). Moreover, technical change is region specific, meaning that at different points of the production technology there could be different magnitudes and biases of technical change. The production frontier and its associated efficiency parameter can be estimated using Data Envelopment Analysis (DEA, see the appendix for the mathematical specification). One advantage of using DEA is that the omission of the Z variables from the associated linear program returns an unconditional production frontier, i.e. the quantity of output which a region is expected to produce taking into account only the quantity of labour and capital and ignoring its level of technological capabilities.

DATA

The technology gap literature rests on a key lesson (stemming from studies dating back to Gerschenkron (1962) and lately Abramovitz, (1986) which emphasizes the importance of technology transfer and the role of absorptive capacity in fostering growth and catch up. In technology gap models, two main dimensions determine the ability of a country to catch up. The first is its absorptive capacity, i.e. the ability to adopt foreign advanced technologies. The second is its innovative capability, namely the extent to which the country is able to produce new advanced knowledge (Castellacci 2011). This is closely related to the concept of technological capabilities (Lall 1992), which have been conceptualized as a pre-condition for countries to generate and manage technical change, both in terms of the introduction of new technology, as well as the incremental improvements of existing productive capacity (Bell and Pavitt 1993). We therefore employ variables accounting for the level of absorptive capacity and innovation capability of a regions to capture its change in the level of technological capabilities and reflect the change in the technology gap.

The innovative capability is measured using patents, while absorptive capacity is measured by means of Human Resources in Science and Technology sectors. Patent is a standard measure of innovation output and has been broadly used in order to measure innovation performance of countries (Griliches 1990; Archibugi 1992; Trajtenberg 1990). As such, they can be considered a "tolerable assumption" of the innovative activities of firms (Schmookler 1962). The variable "Human Resources in Science and Technology" represents the quality of human capital, which has been recognized as a key factor of absorbing capacity (Nelson and Phelps 1966; Castellacci 2011). We decided to smooth the variables in order to avoid volatility in the data by using the exponential moving average procedure. These variables are customary in this setting (Lall, 1992; Archibugi and Coco, 2004; Castellacci, 2008, 2011). Table 1 summarizes the data collected for the empirical analysis. GDP is at constant prices and deflated by PPP's. GDP per worker (active population) is our dependent variable, and represents a standard measure for labour productivity (see Kumar and Russell, 2002 among others). The stock of capital has been built using the permanent inventory method. Labour is proxied as the number of active people in a region.

[TABLE 1 about here]

RESULTS

Figure 3 plots the yearly average labour productivity change in the considered period and the level of labour productivity at the beginning of the period. It shows that a process of convergence took place. A simple OLS regression of labour productivity growth against the log of labour productivity in 1995 gives a negative coefficient significant at 1% level, thus confirming the presence of beta-convergence among the European regions. In what follows we explore the determinants of labour productivity growth firstly in terms of the dynamic model (see eq. 2 and 3 above) and then in terms of the static model (see eq. 1 above).

[FIGURE 3 about here]

The sources of labour productivity growth (Growth Accounting)

Table 3 illustrates the results of the labour productivity growth decomposition for the 211 regions. We have grouped the regions into two sub-samples. The first includes the more advanced regions, while the second includes the backward regions.[2] The rationale for this sub-grouping is twofold. First, it allows to pointing out important differences among the two groups characterized by different degree of economic development. Second, it allows making some considerations about the EU Cohesion Policy which operates a considerable distinction between these two groups of regions. Following the models explained in the second Section (see eq. 2), we have first employed the standard decomposition - i.e. the one used in Kumar and Russell (2002) - to decompose labour productivity growth into the following three components: (i) capital deepening; (ii) change in exogenous technical change; and (iii) change in efficiency (see columns 2-4). Columns 5 and 6 of the table display our decomposition (see eq. 3) in which we further decompose change in efficiency (TEC) into two components: (i) change in conditional efficiency (CTEC) and change in technology gap (ZEC).

The last row shows the average results relative to the entire sample. Labour productivity grew by a yearly average of 1.8%. The relative contribution of capital deepening (0.9%) and change in exogenous technical change (1.1%) is similar, while change in efficiency is close to zero. By looking at the TEC decomposition, a positive contribution of change in conditional technical efficiency arises, thus suggesting a catching-up effect, while the average contribution of change in technology gap is moderately negative.

[TABLE 2 about here]

[2] The grouping of the regions have been done by distinguishing in terms of the level of GDP per capita between the objective 1 regions (backward regions) as defined in the Structural Funds in the programming period 2000-2006, and the other regions (advanced regions).

Turning the attention to the two groups of regions, the results of the decompositions are summarized in Figure 4. The figures about GDP growth confirm that the backward regions have been growing at a relatively larger pace (a yearly average equal to 2.8%) compared to advanced regions (1%). Different patterns arise in terms of the relative contribution in the standard composition. Backward region benefited remarkably from capital deepening and to a lesser extent from exogenous technical change, while on average they show a negative contribution for technical efficiency (below 1). By contrast, in advanced regions exogenous technical change and a moderate increase in efficiency contributed most to labour productivity growth, while the contribution of capital deepening is negligible. As for the further TEC decomposition into catching-up effect (ZEC) and change in technology gap (CTEC), we observe that technology gap is moderately positive for advanced regions and close to one – that is no change - for backward regions.

[FIGURE 4 about here]

Technology gap and the levels of labour productivity (Development accounting)

So far we have illustrated the drivers of labour productivity growth for the considered regions. This Section presents the results of the development accounting, as in eq. 1 and Figure 1 above. This allows us to investigate (i) to what extent the technology gap is reducing within European regions, and (ii) what is the importance of the technology gap in explaining the differences in the *levels* of labour productivity?

By employing the static model described above, the three charts in Figure 5 show the static values of technical efficiency (TE), technology gap (ZC), and conditional technical efficiency (CTE) for the thirteen considered years (see equation no. 1 and Figure 1 - right chart). The first graph showing the TE values for the two groups of regions is quite revealing. Advanced regions and backward regions have followed a divergence trend with the former displaying an increase in their levels of technical efficiency while the opposite holds for the latter. This explains the different results arisen in Figure 4 in relation to the contribution of TEC to labour productivity growth. When looking at the dynamic of CTE and technology gap it emerges that the divergent pattern of TEC is the results of a marked divergence in terms of CTE and a stable gap as for the technology gap. This points out to a pattern of growth for backward countries heavily based on investment in physical capital. At this stage backward regions are still unable to build-up a good level of technological capabilities, which would allow for a stronger pattern of growth. Thus, the technology gap can be viewed as a source of unutilized growth potential.

[FIGURE 5 about here]

DISCUSSION

In this last section we discuss our results with the help of some maps also vis-à-vis previous results, and then we conclude by pointing out some implications for policy arising from the present analysis. In a recent paper, Enflo and Hjertstrand (N.d.) carry out an empirical analysis covering the Western European regions for the period 1980-2002 using the DEA approach. In the first place, they prove DEA to be robust in identifying efficiency scores even after controlling for spatially correlated measurement errors. In terms of results, they find that capital deepening and technological change have been the main drivers of productivity growth, while the role of technical efficiency resulted negligible. Our results are in line with them, as we also find that capital accumulation and exogenous technical change make a similar contribution to labour productivity growth, while change in technical efficiency is close to zero.

Our aim was to contribute to this research in two ways. First, by updating and expanding the numbers of regions in order to take into account the EU enlargement process. Second, by further decomposing technical efficiency in order to include the role played by the development of endogenous technological capabilities. In fact, since the reform of the Structural Funds in 1988, the European Cohesion policy has been inspired by a theory of economic development which stresses the role of endogenous creation of innovation capability and human capital to foster local self-sustained growth paths. We therefore divided our sample into two regions: the advanced regions, and the backward regions.

Figure 6a shows the yearly average of labour productivity growth for the considered period. It clearly arises that backward regions, especially those belonging to the Eastern countries, have been catching up. By looking at Figure 6b, it is also clear that capital deepening has been the central driver of labour productivity growth for Eastern countries regions: the correlation coefficient between capital deepening and the level of labour productivity in 1995 is equal to -0.74. The good performance of some regions in Portugal and Greece confirm the importance of capital deepening for labour productivity growth in backward regions. The pictures changes by looking at the Figure 6c where we plot efficiency change. It shows that the results for technical efficiency are more scattered, and on average show a better performance in Western regions. As for Eastern regions, the only regions showing a high performance are those of the capitals, such as Bratislava, Bucharest, and Prague.

[FIGURE 6 about here]

A central concern of this paper, as well as of the EU Cohesion policy, was to investigate to what extent the technology gap was reducing across the European regions. It has been often argued (see Barca 2009 among others) that the existence of a technology gap is a central obstacle for economic convergence and cohesion. To this regard, this paper's evidence does not point to a reduction in the technology gap across regions. True, the best performers in terms of change in technology gap are regions in Poland, Hungary, Slovak Republic, and Czech Republic. However, a part from these few cases, Western regions perform relatively better: the correlation coefficient between technology gap change and the level of labour productivity in 1995 being positive and equal to 0.11.

What can we conclude from our evidence? At the core of the integration first, and the enlargement process later, there is the idea that lagging behind regions can benefit from technological change occurring in the common market by being able to adopt technology developed in advanced regions. A necessary condition is that backward regions developed their innovation capabilities and human capital. A substantial portion of the EU Cohesion policy has been therefore devoted to support the development of endogenous technological capabilities. Our results show that backward regions had little support from endogenous technological capabilities accumulation, while they predominantly benefited from capital accumulation. This brought about convergence in labour productivity over the period 1995-2007. Yet, our results cast some doubts on the sustainability of this pattern of growth. As long as regions move towards the frontier, technology and human capital become increasingly necessary to absorb technology and spur innovation (Los and Timmer 2005). In fact, in the considered period backward regions did not manage to even narrow their technology gap vis-à-vis the more advanced regions, a part from a few isolated cases, as also reflected in the poor performance of technical efficiency. It is likely that this pattern of capital accumulation is the result of a process of structural change in which backward regions have shifted from low-productivity and labour intensive sectors (i.e. agriculture), to more productive sectors as well as more mechanized processes in the agriculture. It will be difficult to keep the same pace of capital accumulation for the coming years. Investment in technology, innovation capabilities, and human capital will be therefore become increasingly necessary.

To conclude, this paper suggests that we should not be entirely satisfied with the observed process of convergence. Our results indirectly point to the ineffectiveness of policy directed to encourage the endogenous creation of technological capabilities. Whether this is a matter of quantity or quality is hard to tell. Future research could investigate in a more direct way the relationship between innovation-related policy and innovation performance of regions.

Tables and Figures

Fig. 1. *The static models: The Kumar and Russell model (left) vs. our proposed model (right)*

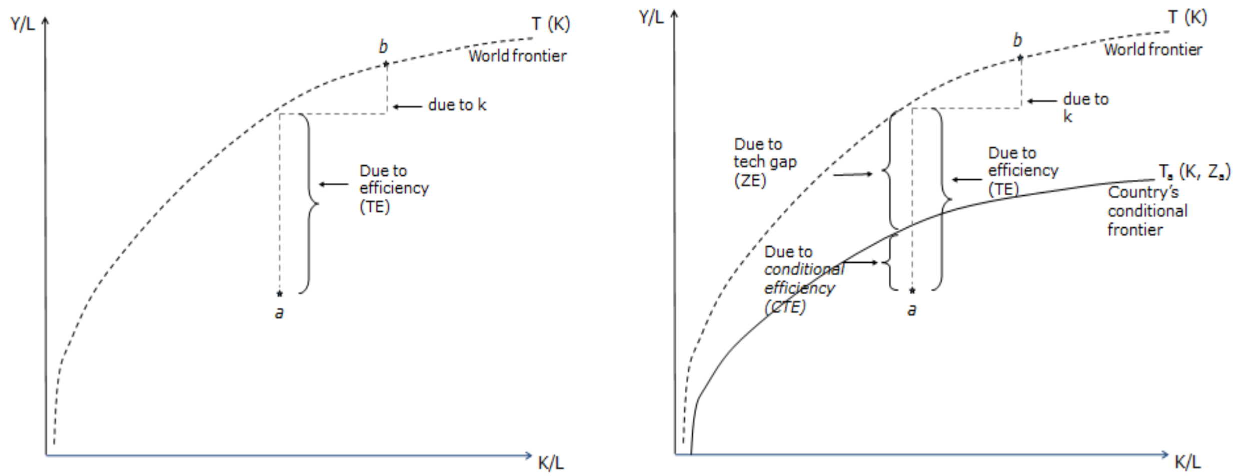


Fig. 2. The Dynamic model: the decomposition over time

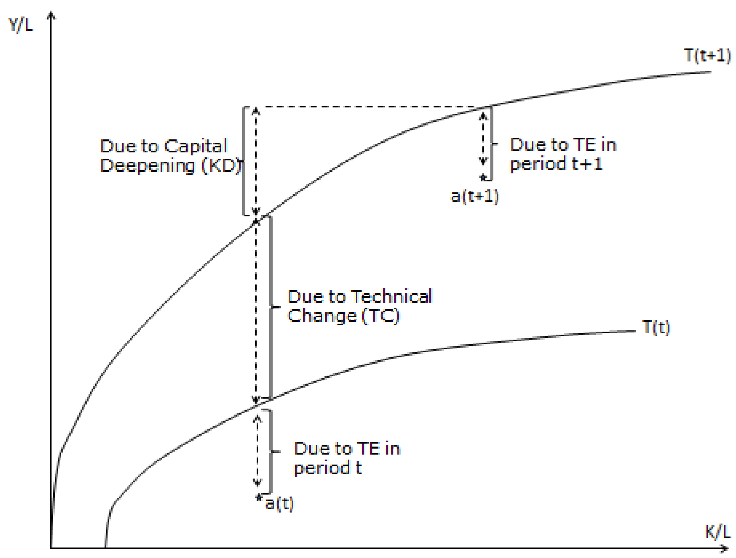


Table 1. Variables and sources

	Variable	Sources
GDP per worker: productivity	GDP (PPP, constant prices)	Eurostat
	Active population	Eurostat
Capital deepening	Fixed capital (build with the permanent inventory method)	Crenos* database and our calculations on Eurostat
Innovation capabilities	Patents application in the EPO	Eurostat
Absorptive capacity	Human Resources in Science and Technology (Core**)	WDI (World Bank)

Note: data on capital for several countries were taken from the Crenos Databas (Dettori, Marrocu, and Paci 2011).

Fig. 3. Convergence in labour productivity growth across the European regions

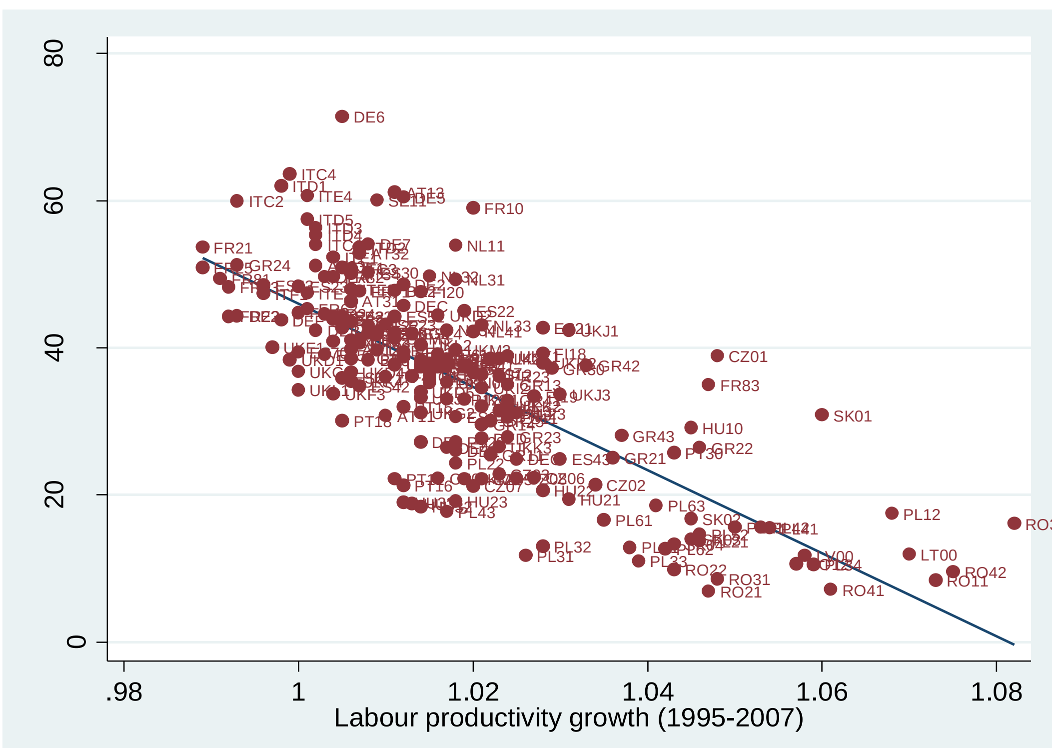


Table 2. The results of the decomposition

				Contribution to change in labour productivity				
				standard decomposition			TEC decomposition	
region	id	advanced/ backward *	productivity growth	capital deepening	change in exogenous technical change (TC)	change in efficiency (TEC)	change in conditional efficiency - catching-up (CTEC)	change in technology gap (ZEC)
			(1)	(2)	(3)	(4)	(5)	(6)
Burgenland	AT11	1	1.010	1.001	1.006	1.003	1.027	0.976
Niederösterreich	AT12	0	1.006	0.999	1.005	1.002	1.015	0.987
Wien	AT13	0	1.011	1.001	1.003	1.006	1.003	1.003
Kärnten	AT21	0	1.006	1.001	1.004	1.002	1.010	0.992
Steiermark	AT22	0	1.008	0.999	1.004	1.004	1.013	0.991
Oberösterreich	AT31	0	1.006	0.998	1.004	1.004	1.014	0.991
Salzburg	AT32	0	1.007	1.001	1.003	1.003	1.008	0.995
Tirol	AT33	0	1.002	0.999	1.005	0.998	1.005	0.993
Vorarlberg	AT34	0	1.006	0.998	1.003	1.004	1.010	0.994
BE_Flemish Region	BE2	0	1.011	1.004	1.005	1.001	1.003	0.998
BE_Walloon Region	BE3	0	1.008	1.006	1.012	0.991	0.998	0.993
Praha	CZ01	1	1.048	1.030	1.006	1.011	1.016	0.995
Stredni Cechy	CZ02	1	1.034	1.027	1.017	0.990	0.979	1.011
Jihozápad	CZ03	1	1.023	1.027	1.017	0.980	0.967	1.014
Severozápad	CZ04	1	1.016	1.021	1.017	0.978	0.977	1.000
Severovýchod	CZ05	1	1.021	1.020	1.017	0.984	0.989	0.995
Jihovýchod	CZ06	1	1.027	1.025	1.016	0.986	0.991	0.995
Stredni Morava	CZ07	1	1.020	1.021	1.017	0.982	0.983	0.998
Moravskoslezsko	CZ08	1	1.025	1.025	1.015	0.985	0.984	1.001
Baden-Württemberg	DE1	0	1.005	0.999	1.005	1.001	1.003	0.998
Bayern	DE2	0	1.012	1.000	1.003	1.009	1.011	0.998
Berlin	DE3	0	0.993	1.006	1.010	0.976	0.980	0.996
Brandenburg	DE4	1	1.017	1.030	1.012	0.976	0.984	0.992
Bremen	DE5	0	1.012	1.002	1.004	1.007	1.004	1.003
Hamburg	DE6	0	1.005	1.003	1.002	1.000	1.000	1.000
Hessen	DE7	0	1.008	1.000	1.005	1.002	1.004	0.998
Mecklenburg-Vorpommern	DE8	1	1.014	1.030	1.011	0.974	0.985	0.989
Niedersachsen	DE9	0	1.005	1.000	1.005	1.000	1.006	0.994
Nordrhein-Westfalen	DEA	0	1.003	0.999	1.005	0.998	1.003	0.995
Rheinland-Pfalz	DEB	0	1.002	0.998	1.005	0.999	1.004	0.996
Saarland	DEC	0	1.012	1.001	1.004	1.007	1.013	0.995
Sachsen	DED	1	1.021	1.029	1.011	0.981	0.988	0.992
Sachsen-Anhalt	DEE	1	1.018	1.025	1.012	0.982	0.994	0.988
Schleswig-Holstein	DEF	0	0.998	0.998	1.006	0.995	1.000	0.994
Thüringen	DEG	1	1.025	1.029	1.013	0.982	0.990	0.992
Galicia	ES11	1	1.024	0.999	1.013	1.012	1.026	0.986
Principado de Asturias	ES12	1	1.021	1.001	1.010	1.010	1.017	0.993
Cantabria	ES13	0	1.009	0.997	1.007	1.005	1.010	0.995
País Vasco	ES21	0	1.028	1.001	1.008	1.018	1.022	0.996
Comunidad Foral de Navarra	ES22	0	1.019	1.000	1.005	1.013	1.019	0.995
La Rioja	ES23	0	1.000	0.995	1.007	0.997	0.995	1.003
Aragón	ES24	0	1.013	1.001	1.009	1.004	1.012	0.992
Comunidad de Madrid	ES30	0	1.008	1.000	1.009	1.000	1.010	0.990
Castilla y León	ES41	1	1.019	1.002	1.011	1.006	1.015	0.991
Castilla-la Mancha	ES42	1	1.007	0.994	1.009	1.003	1.016	0.987
Extremadura	ES43	1	1.030	1.000	1.014	1.016	1.037	0.980
Cataluña	ES51	0	1.011	0.999	1.010	1.002	1.013	0.989
Comunidad Valenciana	ES52	1	1.003	0.992	1.013	0.999	1.011	0.988
Illes Balears	ES53	0	0.996	0.995	1.007	0.994	1.003	0.991
Andalucía	ES61	1	1.018	0.999	1.014	1.004	1.027	0.978
Región de Murcia	ES62	1	1.005	0.990	1.013	1.002	1.024	0.979
Canarias (ES)	ES70	1	1.000	0.996	1.013	0.992	1.008	0.984
Itä-Suomi	FI13	1	1.024	1.000	1.005	1.019	1.015	1.004
Etelä-Suomi	FI18	0	1.028	1.008	1.016	1.003	1.003	1.000
Länsi-Suomi	FI19	0	1.027	1.010	1.016	1.001	1.004	0.997
Åland	FI20	0	1.014	1.000	1.005	1.009	1.005	1.004
Île de France	FR10	0	1.020	1.005	1.000	1.015	1.015	1.000
Champagne-Ardenne	FR21	0	0.989	0.991	1.007	0.991	0.996	0.995
Picardie	FR22	0	0.992	0.996	1.007	0.990	1.002	0.988
Haute-Normandie	FR23	0	1.023	1.002	1.006	1.015	1.023	0.992
Centre (FR)	FR24	0	1.003	0.998	1.007	0.999	1.007	0.992
Basse-Normandie	FR25	0	0.989	0.992	1.006	0.990	0.992	0.998
Bourgogne	FR26	0	1.009	0.999	1.007	1.003	1.012	0.991
Nord - Pas-de-Calais	FR30	0	1.012	0.998	1.007	1.006	1.019	0.987
Lorraine	FR41	0	1.004	0.997	1.006	1.000	1.010	0.991
Alsace	FR42	0	1.004	0.995	1.007	1.002	1.008	0.994
Franche-Comté	FR43	0	1.000	0.997	1.007	0.997	1.005	0.992
Pays de la Loire	FR51	0	1.017	1.000	1.008	1.008	1.019	0.990
Bretagne	FR52	0	1.017	0.999	1.007	1.011	1.018	0.993
Poitou-Charentes	FR53	0	1.007	0.998	1.007	1.002	1.014	0.988
Aquitaine	FR61	0	1.016	1.001	1.008	1.007	1.018	0.989
Midi-Pyrénées	FR62	0	1.001	0.996	1.007	0.998	1.007	0.992
Limousin	FR63	0	0.992	0.997	1.006	0.989	0.994	0.995
Rhône-Alpes	FR71	0	1.007	0.997	1.006	1.004	1.009	0.995
Auvergne	FR72	0	1.007	0.999	1.007	1.002	1.010	0.992
Languedoc-Roussillon	FR81	0	0.991	0.994	1.007	0.990	1.000	0.990
Prov.-Alpes-Côte d'Azur	FR82	0	1.004	0.997	1.006	1.000	1.006	0.994
Corse	FR83	0	1.047	1.008	1.006	1.033	1.035	0.998
Anatoliki Makedonia, Thraki	GR11	1	1.022	1.016	1.016	0.989	1.007	0.982
Kentriki Makedonia	GR12	1	1.017	1.011	1.015	0.990	1.003	0.987
Dytiki Makedonia	GR13	1	1.024	1.004	1.008	1.012	1.019	0.993
Thessalia	GR14	1	1.021	1.016	1.016	0.989	0.997	0.991
Ipeiros	GR21	1	1.036	1.012	1.015	1.009	1.026	0.983
Ionia Nisia	GR22	1	1.046	1.015	1.015	1.016	1.021	0.995
Dytiki Ellada	GR23	1	1.024	1.011	1.015	0.998	1.008	0.990
Sterea Ellada	GR24	1	0.993	1.009	1.012	0.973	1.000	0.973
Peloponnisos	GR25	1	1.022	0.998	1.014	1.010	1.029	0.981
Attiki	GR30	1	1.029	1.007	1.015	1.007	1.017	0.991
Voreio Aigaio	GR41	1	1.024	1.012	1.015	0.996	1.008	0.988
Notio Aigaio	GR42	1	1.033	1.002	1.013	1.018	1.020	0.998
Kriti	GR43	1	1.037	1.021	1.018	0.999	1.003	0.995
Közép-Magyarország	HU10	1	1.045	1.020	1.016	1.007	1.020	0.987
Közép-Dunántúl	HU21	1	1.031	1.022	1.019	0.990	0.995	0.994
Nyugat-Dunántúl	HU22	1	1.028	1.020	1.018	0.989	0.973	1.016
Dél-Dunántúl	HU23	1	1.018	1.021	1.017	0.980	0.990	0.990
Észak-Magyarország	HU31	1	1.013	1.019	1.018	0.976	0.989	0.988
Észak-Alföld	HU32	1	1.014	1.020	1.018	0.977	0.987	0.989
Dél-Alföld	HU33	1	1.012	1.015	1.019	0.978	0.993	0.985
Piemonte	ITC1	0	1.002	1.000	1.004	0.997	1.006	0.991
Valle d'Aosta	ITC2	0	0.993	1.003	1.002	0.988	0.992	0.995
Liguria	ITC3	0	1.006	1.002	1.007	0.998	1.008	0.990
Lombardia	ITC4	0	0.999	1.001	1.005	0.993	1.003	0.990
Prov. Aut. Bolzano	ITD1	0	0.998	1.016	1.001	0.982	1.000	0.982
Prov. Aut. Trento	ITD2	0	1.007	1.000	1.005	1.002	1.008	0.994
Veneto	ITD3	0	1.002	1.001	1.005	0.996	1.010	0.986
Friuli-Venezia Giulia	ITD4	0	1.002	1.003	1.005	0.994	1.006	0.988

Table 2. The results of the decomposition (continued)

				Contribution to change in labour productivity				
				standard decomposition			TEC decomposition	
region	id	advanced/ backward*	productivity growth	capital deepening	change in exogenous technical change (TC)	change in efficiency (TEC)	change in conditional efficiency - catching-up (CTEC)	change in technology gap (ZEC)
			(1)	(2)	(3)	(4)	(5)	(6)
Emilia-Romagna	ITD5	0	1.001	1.001	1.005	0.995	1.005	0.991
Toscana	ITE1	0	1.004	1.003	1.006	0.995	1.007	0.988
Umbria	ITE2	0	1.001	1.003	1.006	0.992	1.002	0.990
Marche	ITE3	0	1.006	1.006	1.010	0.990	1.003	0.987
Lazio	ITE4	0	1.001	0.999	1.006	0.996	1.002	0.994
Abruzzo	ITF1	0	0.996	0.998	1.006	0.992	0.997	0.995
Molise	ITF2	0	1.014	0.999	1.005	1.010	1.009	1.002
Campania	ITF3	1	1.015	1.000	1.007	1.007	1.008	0.999
Puglia	ITF4	1	1.010	1.001	1.010	1.000	1.009	0.991
Basilicata	ITF5	1	1.014	0.999	1.005	1.009	1.010	0.999
Calabria	ITF6	1	1.015	1.003	1.006	1.006	1.005	1.001
Sicilia	ITG1	1	1.013	1.001	1.007	1.004	1.009	0.995
Sardegna	ITG2	1	1.006	1.003	1.006	0.996	1.006	0.991
Lietuva	LT00	1	1.070	1.055	1.017	0.997	0.994	1.004
Latvija	LV00	1	1.058	1.055	1.017	0.985	0.989	0.996
Groningen	NL11	0	1.018	1.001	1.005	1.012	1.017	0.995
Friesland (NL)	NL12	0	1.015	1.003	1.007	1.005	1.014	0.991
Drenthe	NL13	0	1.006	1.000	1.006	1.000	1.007	0.994
Overijssel	NL21	0	1.016	1.002	1.008	1.006	1.013	0.993
Gelderland	NL22	0	1.016	1.003	1.008	1.005	1.011	0.994
Flevoland	NL23	1	1.025	1.010	1.002	1.012	1.020	0.992
Utrecht	NL31	0	1.018	1.006	1.005	1.007	1.009	0.998
Noord-Holland	NL32	0	1.015	1.002	1.005	1.008	1.012	0.996
Zuid-Holland	NL33	0	1.021	1.004	1.005	1.013	1.015	0.997
Zeeland	NL34	0	1.017	1.002	1.004	1.011	1.013	0.999
Noord-Brabant	NL41	0	1.020	1.004	1.006	1.010	1.012	0.998
Limburg (NL)	NL42	0	1.022	1.002	1.007	1.013	1.018	0.995
Lódzkie	PL11	1	1.038	1.038	1.019	0.982	1.000	0.982
Mazowieckie	PL12	1	1.068	1.038	1.017	1.012	0.996	1.016
Malopolskie	PL21	1	1.046	1.040	1.017	0.989	0.968	1.021
Slaskie	PL22	1	1.018	1.011	1.016	0.991	0.988	1.003
Lubelskie	PL31	1	1.026	1.036	1.023	0.968	0.990	0.978
Podkarpackie	PL32	1	1.028	1.037	1.019	0.973	0.984	0.989
Swietokrzyskie	PL33	1	1.039	1.048	1.019	0.973	1.003	0.970
Podlaskie	PL34	1	1.059	1.058	1.018	0.982	0.996	0.986
Wielkopolskie	PL41	1	1.054	1.036	1.016	1.001	0.987	1.014
Zachodniopomorskie	PL42	1	1.053	1.035	1.016	1.001	0.982	1.020
Lubuskie	PL43	1	1.017	1.015	1.019	0.983	0.983	1.000
Dolnoslaskie	PL51	1	1.050	1.035	1.016	0.999	0.983	1.017
Opolskie	PL52	1	1.046	1.035	1.016	0.994	1.004	0.990
Kujawsko-Pomorskie	PL61	1	1.035	1.021	1.018	0.996	0.999	0.997
Warminsko-Mazurskie	PL62	1	1.042	1.041	1.019	0.982	0.997	0.985
Pomorskie	PL63	1	1.041	1.021	1.018	1.002	0.987	1.016
Norte	PT11	1	1.011	1.010	1.017	0.984	0.996	0.988
Algarve	PT15	1	1.012	1.010	1.016	0.987	1.021	0.966
Centro (PT)	PT16	1	1.012	1.008	1.017	0.987	0.994	0.993
Lisboa	PT17	0	1.020	1.002	1.011	1.007	1.014	0.992
Alentejo	PT18	1	1.005	1.011	1.015	0.979	1.001	0.978
Região Aut. dos Açores	PT20	1	1.018	1.028	1.014	0.976	1.011	0.966
Região Aut. da Madeira	PT30	1	1.043	1.000	1.005	1.038	1.046	0.992
Nord-Vest	RO11	1	1.073	1.062	1.026	0.984	1.009	0.975
Centru	RO12	1	1.057	1.048	1.024	0.986	1.004	0.982
Nord-Est	RO21	1	1.047	1.035	1.029	0.983	1.021	0.962
Sud-Est	RO22	1	1.043	1.052	1.025	0.967	0.993	0.974
Sud - Muntenia	RO31	1	1.048	1.047	1.029	0.973	1.005	0.968
Bucuresti - Ilfov	RO32	1	1.082	1.044	1.018	1.018	1.010	1.007
Sud-Vest Oltenia	RO41	1	1.061	1.058	1.029	0.974	1.007	0.968
Vest	RO42	1	1.075	1.059	1.022	0.993	1.013	0.981
Stockholm	SE11	0	1.009	0.998	1.011	1.000	1.000	1.000
Östra Mellansverige	SE12	0	1.016	1.005	1.011	1.000	1.003	0.997
Småland med öarna	SE21	0	1.012	1.000	1.005	1.007	1.009	0.998
Sydsverige	SE22	0	1.008	0.999	1.013	0.997	0.999	0.998
Västsverige	SE23	0	1.010	1.005	1.015	0.990	0.992	0.998
Norra Mellansverige	SE31	1	1.015	1.008	1.015	0.992	0.996	0.996
Mellersta Norrland	SE32	1	1.004	1.001	1.003	0.999	1.004	0.996
Övre Norrland	SE33	1	1.005	0.999	1.005	1.001	1.000	1.001
Bratislavský kraj	SK01	1	1.060	1.028	1.011	1.019	1.028	0.992
Západné Slovensko	SK02	1	1.045	1.032	1.017	0.995	0.980	1.016
Stredné Slovensko	SK03	1	1.045	1.046	1.016	0.983	0.996	0.988
Východné Slovensko	SK04	1	1.043	1.050	1.015	0.978	0.997	0.981
Tees Valley and Durham	UKC1	0	1.000	0.999	1.005	0.995	0.987	1.008
Northumberland - Tyne and Wear	UKC2	0	1.011	0.999	1.020	0.992	1.000	0.992
Cumbria	UKD1	0	0.999	1.000	1.005	0.995	0.985	1.009
Cheshire	UKD2	0	1.016	1.000	1.005	1.011	1.001	1.009
Greater Manchester	UKD3	0	1.014	1.002	1.017	0.995	1.002	0.993
Lancashire	UKD4	0	1.006	0.998	1.013	0.996	1.004	0.992
Merseyside	UKD5	1	1.014	1.001	1.014	0.998	1.004	0.995
Lincolnshire	UKE1	0	0.997	1.000	1.014	0.983	0.996	0.988
North Yorkshire	UKE2	0	1.015	0.999	1.005	1.011	1.004	1.008
South Yorkshire	UKE3	1	1.023	1.003	1.003	1.017	1.005	1.012
West Yorkshire	UKE4	0	1.009	0.994	1.008	1.007	1.009	0.998
Derbyshire and Nottinghamshire	UKF1	0	1.011	0.995	1.013	1.003	1.009	0.994
Northamptons.	UKF2	0	1.017	0.991	1.027	1.000	1.000	1.000
Lincolnshire	UKF3	0	1.004	1.002	1.003	0.999	0.988	1.011
Warwicksh.	UKG1	0	1.019	1.004	1.011	1.005	1.012	0.993
Shropshire and Staffordshire	UKG2	0	1.014	1.002	1.002	1.010	0.999	1.012
West Midlands	UKG3	0	1.011	1.000	1.011	1.000	1.007	0.993
East Anglia	UKH1	0	1.017	0.999	1.013	1.005	1.012	0.993
Bedfordshire and Hertfordshire	UKH2	0	1.028	1.002	1.013	1.013	1.019	0.994
Essex	UKH3	0	1.021	1.000	1.005	1.016	1.012	1.004
Outer London	UKI2	0	1.021	1.003	1.015	1.003	1.000	1.003
Oxfordshire	UKJ1	0	1.031	1.003	1.008	1.019	1.022	0.998
Surrey, East and West Sussex	UKJ2	0	1.023	1.001	1.013	1.009	1.015	0.994
Hampshire and Isle of Wight	UKJ3	0	1.030	1.001	1.010	1.019	1.021	0.997
Kent	UKJ4	0	1.014	1.004	1.002	1.009	1.004	1.004
Gloucestershire, Wiltshire, Bristol	UKK1	0	1.024	1.002	1.018	1.004	1.004	1.000
Dorset and Somerset	UKK2	0	1.024	1.012	1.020	0.992	0.997	0.995
Cornwall and Isles of Scilly	UKK3	1	1.023	1.000	1.005	1.018	1.008	1.009
Devon	UKK4	0	1.006	0.997	1.007	1.002	1.000	1.002
West Wales and The Valleys	UKL1	1	1.000	1.001	1.011	0.988	0.997	0.991
East Wales	UKL2	0	1.014	1.003	1.015	0.995	1.003	0.992
Eastern Scotland	UKM2	0	1.018	1.002	1.008	1.008	1.008	0.999
South Western Scotland	UKM3	0	1.011	1.002	1.006	1.004	1.001	1.003
Highlands and Islands	UKM6	0	1.019	1.000	1.005	1.014	1.002	1.012
Northern Ireland (UK)	UKN0	0	1.017	1.005	1.004	1.008	1.002	1.006
average all sample			*1.018*	*1.009*	*1.011*	*0.998*	*1.004*	*0.994*

Fig. 4. Labour productivity growth decomposition for groups of regions

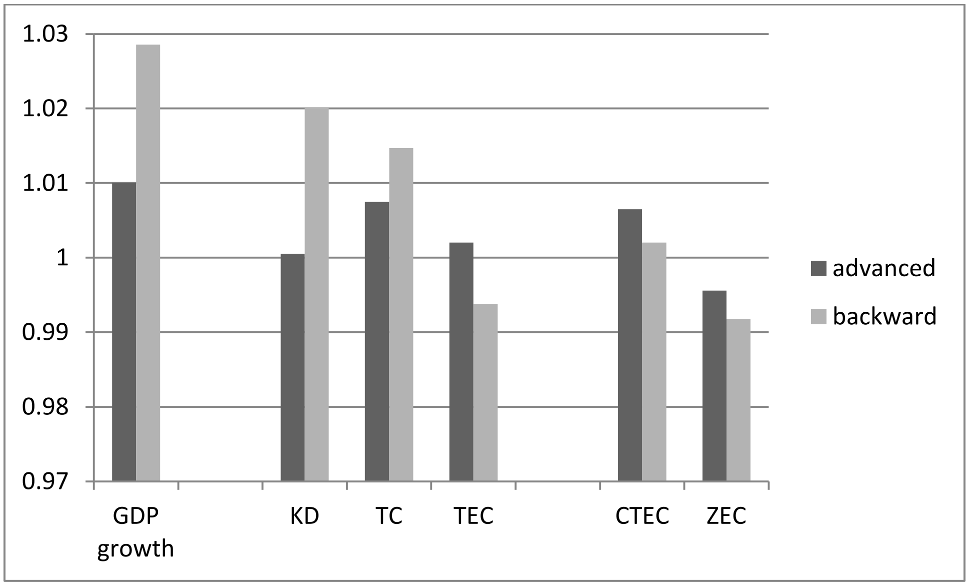


*Fig. 5. Technical efficiency (TE), technology gap (ZE) and conditional technical efficiency (CTE), (TE=ZE*CTE), annual values over the 15 years period*

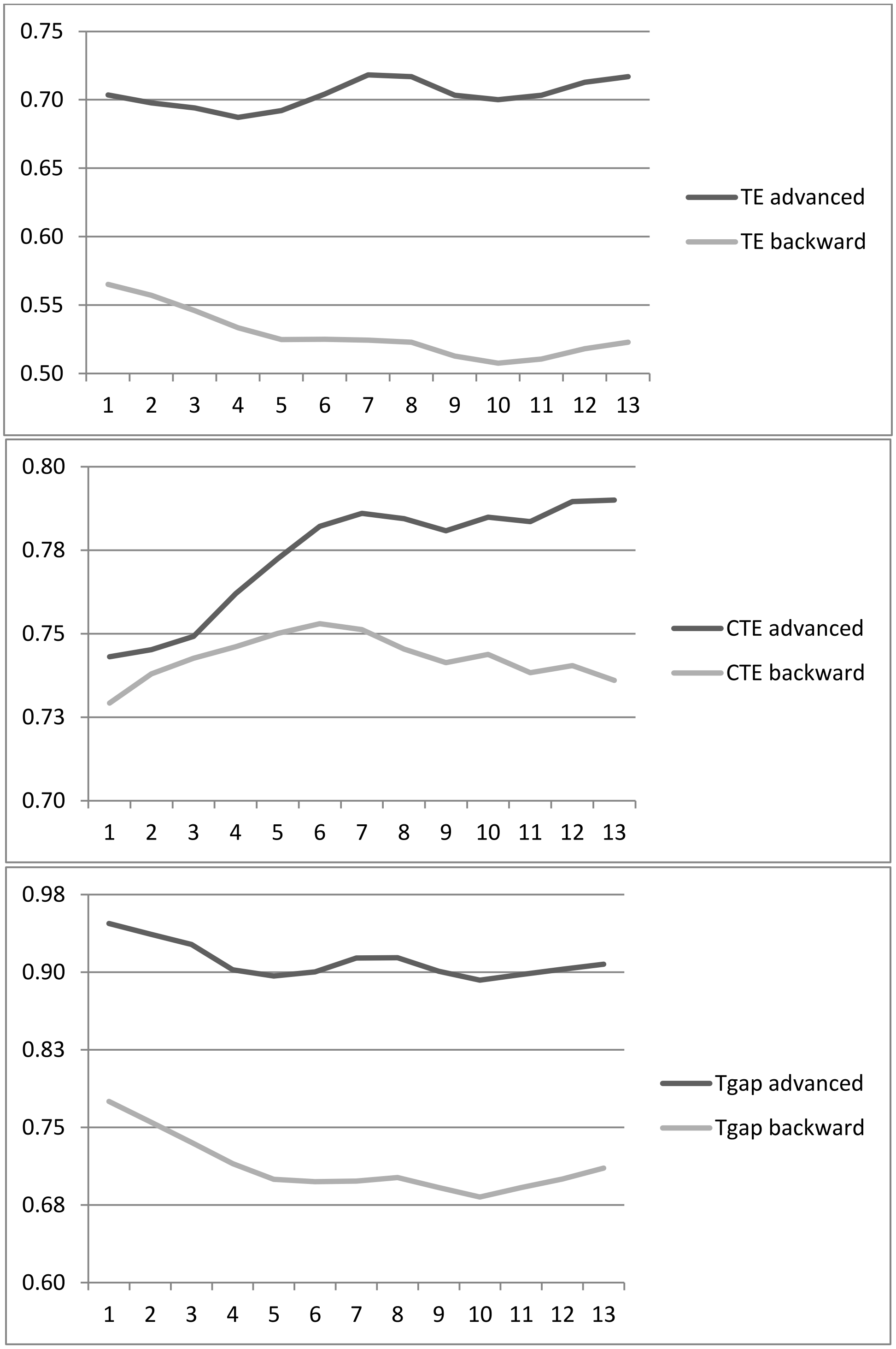
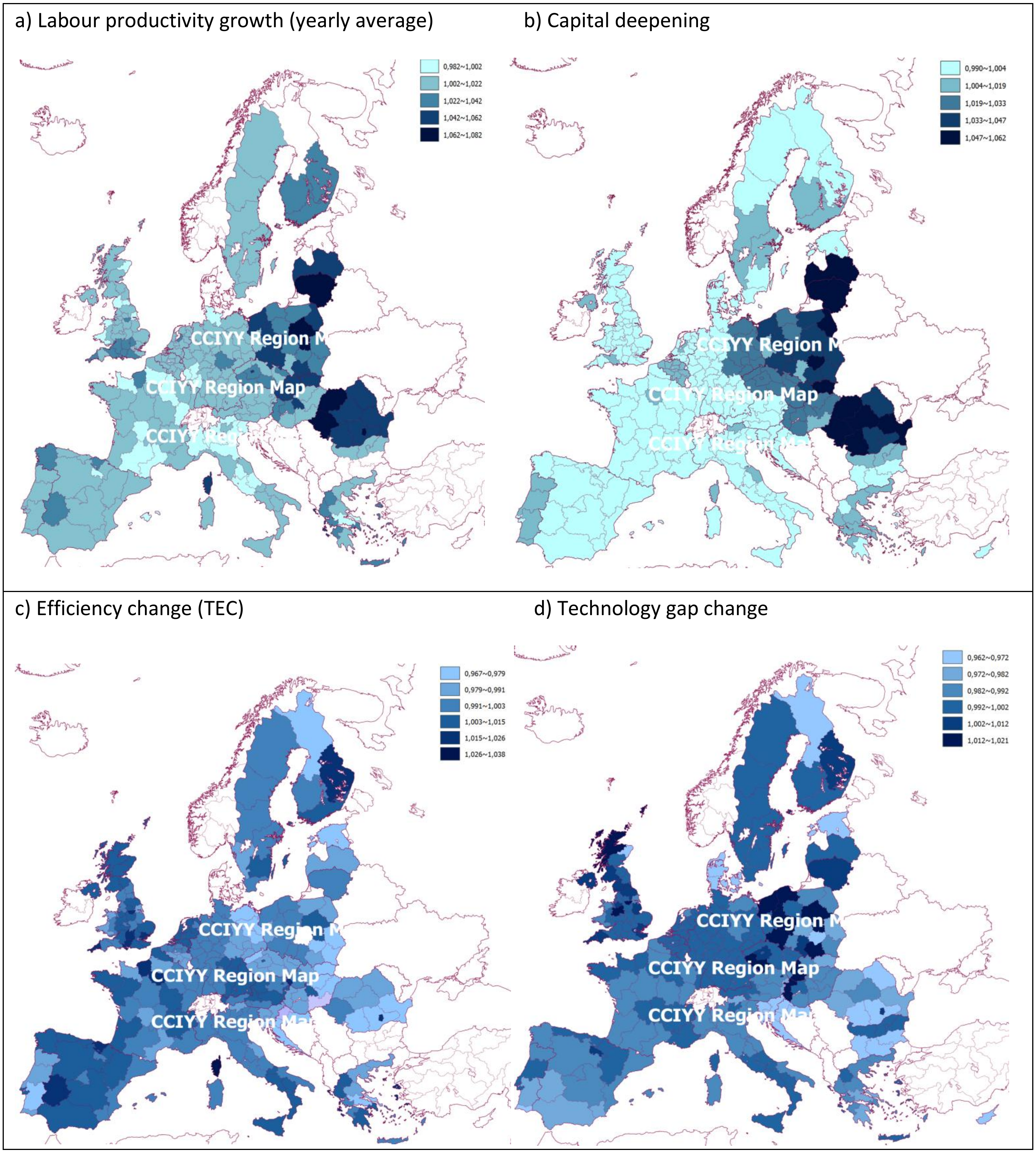


Figure 6. Regional performances in the period 1995-2007



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