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RELATIVE CONTRIBUTIONS TO CONVERGENCE IN LABOUR PRODUCTIVITY. FRONTIER APPROACH EVIDENCE ON ITALIAN REGIONS

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ABSTRACT

Regional disparities within Italian economy is a well known but always of great interest issue. To interpret its complexity, it seems suitable to employee an approach based on DEA production frontiers that allows to decompose labour productivity growth in efficiency change, technological progress and capital effects and analyse their relative contributions to economic convergence of productivity amongst Italian regions. The set of conventional inputs benefits of some improvements such as the inclusion of public physical capital and the correction of labour factor by a measure of human capital. The results show a tendency to economic polarisation from the beginning of 1980s to the end of 1990s and the main source of this evidence seems to be imputed to regional differences in efficiency change.

The paper is consequence of mutual care, but it can be shared out like this: section 2 and subsection 4.2 are attributable to D.Piacentino; section 3 and Appendix to E.Vassallo, while section 1, subsection 4.1 and section 5 to both the Authors.

1 INTRODUCTION

Recently, OECD (2007, p.33) has highlighted the persistency of regional economic disparities in Italy, asserting that: «[…] Italy thus highlights the paradox that convergence across countries is often faster than that within countries, where regional differences can become deep seated […]». This issue has been treated in many empirical works during the last decade and from their results it emerges a general consensus that convergence in labour productivity occurred amongst Italian regions only over a short periods (i.e. 1960-1975) and that divergence between richer regions, geographically located in the Centre-North, and poorer regions, in the South, represents the long run trend (see among the others, Di Liberto, 1994; Mauro and Podrecca, 1994; Paci and Pigliaru, 1995; Paci and Saba, 1998; Margani and Ricciuti, 2001; Aiello and Scoppa, 2006). Thus, Italian economy seems to show a spatial model of polarisation and this tendency appears to become more marked over time. Looking at this evidence, the debate among policymakers is currently focused on possible strategies to reverse this trend. Then, more investigations on the sources of (the lack of) convergence are needed in order to support policymakers in planning the best strategies. To this end, an approach based on DEA-CRS production frontiers allows to decompose labour productivity growth in efficiency change (change of the distance from the best-practice frontier), technological progress (shifts of the frontier) and capital effects (movements along the frontier due to changes in the level of physical capital) (Kumar and Russell, 2002); it allows, besides, to analyse their relative contributions to economic convergence. Moreover, we extend the traditional set of inputs including the stock of public capital and correct labour factor by means of human capital (Henderson and Russell, 2005); as well, we relax CRS (Constant Returns to Scale) hypothesis for VRS (Variable Returns to Scale) and use a Malmquist approach to study in detail the presence of scale effects (Simar and Wilson, 1998).
At the end, the results provide some interesting evidence on the role that regional differences in efficiency change have had in making an polarisation in Italy over recent periods. Notwithstanding, some evidence of β-convergence can be obtained but we have to note that this approach can often yield misleading results. As regards unexpected results, we observe that capital deepening affects negatively the growth of labour productivity when human capital is admitted.
Therefore, the paper is organized as follows. Section 2 introduces some first evidence about the labour productivity distributions and regional convergence in Italy; section 3 describes the nonparametric technique used in the paper, section 4 discusses the main results and section 5 concludes. Appendix lists some useful estimates.

2 FIRST EVIDENCE ON CONVERGENCE IN LABOUR PRODUCTIVITY AMONGST ITALIAN REGIONS

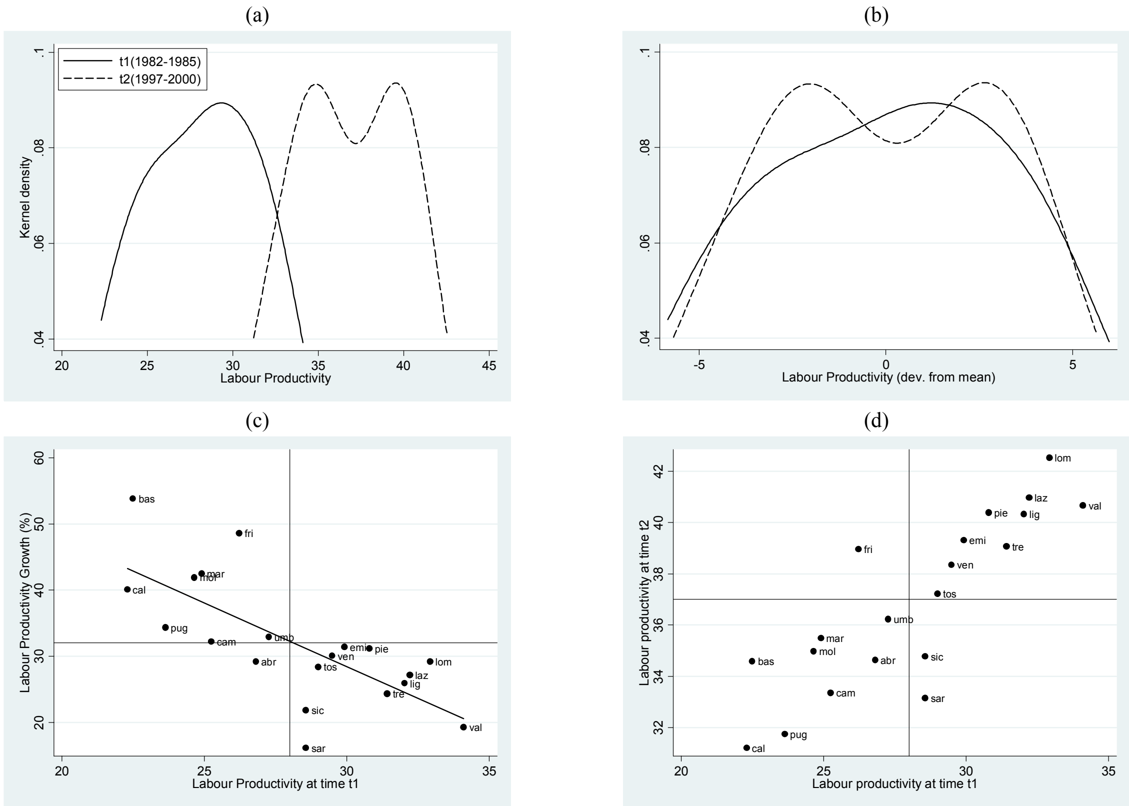
As referred in Introduction, many empirical studies have shown that a prevailing divergence occurred among Italian regions from mid-1970s onwards. To be clearer, part of literature by means of cross-country or panel regressions has found some evidence of convergence but in "conditional" terms, i.e. convergence of each region towards its own level of steady state (see, for instance, Aiello and Scoppa, 2006). However, conditional convergence can be seen as a "virtual convergence" because it results even if economic differences among regions are not reduced over time. In order to shed light on this issue, more recent researches seem to move on new directions of investigation. First, it appears more interesting to investigate on spatial patterns of growth (for instance, patterns of polarisation) rather than to test convergence by traditional cross-country regressions (Iezzi, 2006). Second, the persistency of the economic gap among Italian regions suggests to apply approaches that allow to investigate more in depth on the sources of convergence (see for Italian regions: Leonida *et al.*, 2004; Maffezzoli, 2006; for EU countries: Salinas-Jiménez *et al.*, 2006; for international economies: Kumar and Russell, 2002; Henderson and Russell, 2005). Our work takes into account both of these aims. Indeed, we employ an approach of kernel density to study convergence that allows to analyse the change in the cross-region distribution of labour productivity in the period under scrutiny. In this way, we can observe if there is been a tendency to specific spatial patterns. Then, we investigate on the sources of convergence by means of Kumar-Russell's approach to decompose labour productivity growth in efficiency change, technological progress and capital deepening (i.e. change in the ratio between capital and labour).

Figure 1 provides some first evidence on convergence in labour productivity amongst the 20 Italian regions. In order to control for cyclical fluctuations, we have considered as initial year t_1 the average value in the first four years 1982-1985 and as final year t_2 the average value in the last four years 1997-2000. Figure 1 is divided into four panels. In (a) and (b), it is respectively plotted the cross-region distribution of labour productivity (i.e. value-added at constant prices per worker in full-time standard measure) in levels and in deviations from the cross-sectional mean in t_1 and in t_2. Then, labour productivity in t_1 is plotted against its growth rate in percentage terms (panel c) and against its level in t_2 (panel d).

From Figure 1, it emerges a clear evidence of polarisation, likely due to the increasing distance between Southern regions and the rest of Italy. This evidence is shown from the change of distribution from unimodal in t_1 to bimodal in t_2 (panel a). The distribution of labour productivity expresses in deviation from the cross-sectional mean does not reveal evidence of σ-convergence, namely decrease of dispersion between initial and final period, but confirm the presence of polarisation with possible tendency to converge only within macro-areas (panel b). In panel (c), we visually investigate on absolute β-convergence *à la*

Barro and Sala-i-Martin (1991), namely strong negative correlation between the initial level of labour productivity and its subsequent growth rate. It is evident that regression line hardly fits the data, then no evidence of a “real” convergence seems to be revealed. It is worth noting that the use of this last approach is less suitable than the former to analyse spatial patterns of growth; moreover, it can yield misleading results when a relevant polarisation is present in the cross-country distribution (see Magrini, 2007). Panel (d) supports our first results on the polarisation of Italian economy. Indeed, Italy appears perfectly divided into two groups: Southern regions relegated in the lower-left corner of the graph and the rest of Italy in the upper-right one.
These first results are confirmed by Iezzi (2006) that, using different spatial-scales, finds an evident tendency to polarisation among Italian regions during the last 50 years. However, some studies seem to be in contrast with our evidence; it results in Maffezzoli (2006) that, in the period 1980-2004, Italian regions exhibit a tendency to converge in GDP per worker without strong evidence of polarisation.

Figure 1 Labour productivity distribution and evidence on convergence



Summing up, according to our results the distribution of regional labour productivity in Italy seems to show a change towards a spatial pattern of polarisation (the economic dualism North-South is become more marked in recent years) and no evidence of convergence is revealed in the period under scrutiny (probably processes of clubs convergence are occurring

but we feel to exclude tendencies to catching-up between South and North). Then, it appears interesting to analyse the sources of this trend in order to suggest strategies to reverse it. To this end, we employ the Kumar-Russell's approach grounded on DEA production frontiers and a decomposition of labour productivity growth in specific components. In next section, we describe the method and techniques employed to analyse the growth of labour productivity at regional level.

3 PRODUCTION FRONTIER AND DECOMPOSITION OF LABOUR PRODUCTIVITY GROWTH: METHOD AND TECHNIQUE

3.1 Data Envelopment Analysis (DEA)

Our interest is the construction of the regional production frontier and so calculate the efficiency values how distances from the frontier in a nonparametric framework; the DEA method represents an optimal choice: the main advantage is the absence of a specific functional form between inputs and outputs, but the main disadvantages is the excessive dependence on data and irregular values; in fact, this is a data-driven approach. There is a wide literature about the DEA and different versions are been proposed over time (see, among the others, Charnes *et al.,* 1978; Charnes *et al.,* 1985; Cooper *et al.,* 2004; Cooper *et al.,* 2007).

In our case, we calculate the efficiency of the $N = 20$ Italian regions with two inputs (labour and capital) and one output (value-added Y) for two periods. The years cover the largest available period for all statistical information used in the paper including labour, private and public capital, value-added and human capital. As asserted in section 2, we use average values for the first and the last four years to reduce the effects of a short-term fluctuation. Then, we obtain the efficiency estimates for years 1982-1985 (base period t_1) and years 1997-2000 (current or final period t_2).

Our analysis uses DEA nonparametric techniques based on the Shepard-output distance function (Shephard, 1970), that allows to measure the technical (in)efficiency of a region relative to a convex combination of the best-pratice regions. The output distance function gives a measure of how much a regional output can be proportionately increased given the observed levels of its inputs. Alternatively, input distance functions measure the proportionate reduction of inputs given the output, but for our case this last is clearly not appropriate; often, the choice of orientation is implemented arbitrarily but it provides dissimilar results if the returns to scale are not constant (CRS).

In general way, we consider N regions with n inputs to produce m outputs over T time periods. For the i-th region ($i = 1,...,N$), let $x_i^t \in \Re_+^n$ and $y_i^t \in \Re_+^m$ denote input and output vectors for time t.

Then, the usual production set Ψ^t is

$$\Psi^t = \left\{(x^t, y^t) \mid x^t \text{ can produce } y^t\right\} \tag{1}$$

Ψ^t is assumed closed and convex for all (x^t, y^t). In addition, we assume that all production requires use of some inputs and that both inputs and outputs are strongly disposable.

If this, the Shephard- output distance function corresponding to region i is defined as

$$D_i^{t|t} \equiv \inf\left\{\theta \mid (x_i^t, y_i^t/\theta) \in \Psi^t\right\} \tag{2}$$

and measures the output-efficiency of region i at time t relative to the technology existing at time t.

If the i-th region is on the boundary of the production set, it is technically efficient so $D_i^{t|t} = 1$ otherwise $D_i^{t|t} < 1$.

We can also measure the efficiency of region i at time t_1 relative to the technology at time t_2 by defining the distance function as

$$D_i^{t_1|t_2} \equiv \inf\left\{\theta \mid (x_i^{t_1}, y_i^{t_1}/\theta) \in \Psi^{t_2}\right\} \tag{3}$$

and similarly

$$D_i^{t_2|t_1} \equiv \inf\left\{\theta \mid (x_i^{t_2}, y_i^{t_2}/\theta) \in \Psi^{t_1}\right\} \tag{4}$$

We estimate the production set by the convex hull of the observations, so that

$$\widehat{\Psi}^t = \left\{(x^t, y^t) \mid y^t \leq Y^t q, x^t \geq X^t q, \vec{1}q = 1, q \in \Re_+^N\right\} \tag{5}$$

where N is the number of regions, $Y^t = \left[y_1^t, y_2^t, \dots, y_N^t\right]$, $X^t = \left[x_1^t, x_2^t, \dots, x_N^t\right]$, $\vec{1}$ is a $(1xN)$ vector of ones, q is a $(Nx1)$ vector of intensity variables useful for the form of returns to scale. If $\vec{1}q = 1$, i.e. with a constraint of convexity as in (5), the technology shows Variable Returns to Scale (VRS); if $\vec{1}q = 1$ is omitted the Returns to Scale are Constant (CRS), and if $\vec{1}q \leq 1$ the Returns to Scale are Non Incremental (NIRS).

Given an estimate of the production set as in (5), the output distance function $D_i^{t|t}$ for region i is estimated by substituting Ψ^t in (2) from (5). So, it needs to solve the Linear Programming problem

$$\left(\widehat{D}_i^{t|t}\right)^{-1} = \max\left\{\theta_i \mid X^t q_i \leq x_i^t, Y^t q_i \geq \theta y_i^t, \vec{1}q = 1, q_i \in \Re_+^n\right\} \tag{6}$$

$\widehat{D}_i^{t|t}$ provides an estimate of the technical efficiency of region i at time t relative to the technology in the same time. If we want to measure the efficiency of region i at time t_1 relative to the technology at time t_2, the formula (6) becomes

$$\left(\widehat{D}_i^{t_1|t_2}\right)^{-1} = \max\left\{\theta_i \mid X^{t_2} q_i \leq x_i^{t_1}, Y^{t_2} q_i \geq \theta y_i^{t_1}, \vec{1}q = 1, q_i \in \Re_+^n\right\} \tag{7}$$

and likewise for $\left(\widehat{D}_i^{t_2|t_1}\right)^{-1}$.

Evidently, $\widehat{D}_i^{t_1|t_2}$ or $\widehat{D}_i^{t_2|t_1}$ may show values larger than 1, since the set for time t_1 does not necessarily contain (x_i, y_i) for t_2 and vice versa. It is to note that for some i, the distance functions $\widehat{D}_i^{t_1|t_2}$ or $\widehat{D}_i^{t_2|t_1}$ can't be obtained for impracticability of constraints.

3.2 Malmquist productivity index and main decomposition

The Malmquist productivity index measures productivity changes from time t_1 to time t_2 (Malmquist, 1953; Caves *et al.*, 1982). For the technology at time t_1, the index is

$$\Delta prod^{t_1} \equiv \frac{D^{t_2|t_1}}{D^{t_1|t_1}} \tag{8}$$

and similarly for technology at time t_2, is

$$\Delta prod^{t_2} \equiv \frac{D^{t_2|t_2}}{D^{t_1|t_2}} \tag{9}$$

Which is the "right time" to compute the Malmquist productivity index? Both of them is a good answer. So, it is appropriate to use (8) and (9) jointly with a geometric mean

$$\Delta prod^{t_1 t_2} = \left(\frac{D^{t_2|t_1}}{D^{t_1|t_1}} \cdot \frac{D^{t_2|t_2}}{D^{t_1|t_2}} \right)^{1/2} \tag{10}$$

This new index (10) can be decomposed into changes in efficiency and changes in technology

$$\Delta prod^{t_1 t_2} = \frac{D^{t_2|t_2}}{D^{t_1|t_1}} \times \left(\frac{D^{t_2|t_1}}{D^{t_2|t_2}} \cdot \frac{D^{t_1|t_1}}{D^{t_1|t_2}} \right)^{1/2} \tag{11}$$

The first term in the right-hand member of (11) represents the change in output technical efficiency between periods t_1 and t_2 ($\Delta eff^{t_1 t_2}$), while the second term, a mean of two shifts in technology, represents a measure of technical change ($\Delta tech^{t_1 t_2}$).
Consequently,

$$\Delta prod^{t_1 t_2} = \Delta eff^{t_1 t_2} \times \Delta tech^{t_1 t_2} \tag{12}$$

The (11) is always determined with CRS; this involves that true technology exhibits constant returns to scale everywhere. But if CRS is not the case, it can happen that Malmquist index indicates a statistically incorrect measure of productivity, so Simar and Wilson (1998) suggest to compute the distances anyhow with VRS to eliminate the risk of a mistake. If V represents the similar distance D but with Variable Returns to Scale (VRS), it is

$$\text{(VRS) } \Delta prod^{t_1 t_2} = \frac{V^{t_2|t_2}}{V^{t_1|t_1}} \times \left(\frac{V^{t_2|t_1}}{V^{t_2|t_2}} \cdot \frac{V^{t_1|t_1}}{V^{t_1|t_2}} \right)^{1/2} \tag{13}$$

and the first on the right-hand side is always a measure of efficiency change and the second a measure of technology change.
The formula (11) or (13) is the basic decomposition of a Malmquist productivity index, probably at present the most applied formula despite recent expressions, more detailed, can help to better interpret the analysed phenomenon; for this reason, the next subsection presents further decompositions of the Malmquist index.

3.3 Further Malmquist decompositions

The Malmquist productivity index can be decomposed with wider detail than (11) or (13). In particular, the term $\Delta eff^{t_1t_2} = V^{t_2|t_2} / V^{t_1|t_1}$ can be written as

$$\Delta eff^{t_1t_2} = \left(\frac{D^{t_2|t_2}}{D^{t_1|t_1}}\right) \times \left(\frac{V^{t_2|t_2}/D^{t_2|t_2}}{V^{t_1|t_1}/D^{t_1|t_1}}\right) \tag{14}$$

where the first is a term of pure efficiency change ($\Delta pureeff^{t_1t_2}$) and the second is a measure of scale change ($\Delta scale^{t_1t_2}$).

Notwithstanding this, Simar and Wilson (1998) show that other problems can occur and the enhanced Malmquist index results unsatisfactory too. To remedy, $\Delta tech^{t_1t_2}$ can be decomposed in two parts

$$\Delta tech^{t_1t_2} = \left(\frac{D^{t_2|t_1}}{D^{t_2|t_2}} \cdot \frac{D^{t_1|t_1}}{D^{t_1|t_2}}\right)^{1/2} \times \left(\frac{V^{t_2|t_1}/D^{t_2|t_1}}{V^{t_2|t_2}/D^{t_2|t_2}} \cdot \frac{V^{t_1|t_1}/D^{t_1|t_1}}{V^{t_1|t_2}/D^{t_1|t_2}}\right)^{1/2} \tag{15}$$

The first term is named $\Delta puretech^{t_1t_2}$ and the second $\Delta scaletech^{t_1t_2}$. The term $\Delta puretech^{t_1t_2}$ (change in pure technology) is a geometric mean of two ratios. The first ratio measures the shift in the true technology relative to the production unit's position at time t_2, while the second ratio measures the shift in the true technology relative to the production unit's position at time t_1. The term $\Delta scaletech^{t_1t_2}$ also is a geometric mean of two ratios. The denominator in the first of these ratios is a measure of scale efficiency for the production unit at time t_2, and is identical to the numerator in $\Delta scale^{t_1|t_2}$; the term in the numerator of the first ratio in $\Delta scaletech^{t_1|t_2}$ is similar. The first ratio measures the change in the scale, or shape, of the technology between times t_1 and t_2 for i-th region at time t_2; the second ratio in $\Delta scaletech^{t_1t_2}$ measures the change in the scale, or shape, of the technology between times t_1 and t_2 for i-th region at time t_1. Then, $\Delta scaletech^{t_1t_2}$ describes the change in the scale, or shape, of the technology at two fixed points. The changes $\Delta scale^{t_1t_2}$ may be caused by changes in the shape of the technology, changes in the location of the region in input/output space between t_1 and t_2 or combination of both changes. Whereas $\Delta scale^{t_1t_2}$ indicates changes in the scale efficiency of the region, any changes indicated by $\Delta scaletech^{t_1t_2}$ can only be due to changes in the shape of the technology since the reference points are fixed.

Following Ray and Desli (1997), they name $SCH^{t_1t_2}$ the product $\Delta scale^{t_1t_2} \times \Delta scaletech^{t_1t_2}$

$$SCH^{t_1t_2} = \left(\frac{V^{t_2|t_1}/D^{t_2|t_1}}{V^{t_1|t_2}/D^{t_1|t_2}} \cdot \frac{V^{t_2|t_2}/D^{t_2|t_2}}{V^{t_1|t_1}/D^{t_1|t_1}}\right)^{1/2} \tag{16}$$

Once more, $SCH^{t_1t_2}$ is a geometric mean of two ratios. In the first ratio, the numerator represents scale efficiency in t_2 as regards time t_1, and similarly the denominator; instead, the second ratio is $\Delta scale^{t_1t_2}$.

Lastly, we can contemplate four decomposition of a Malmquist productivity index

- as in Färe *et al.* (1992)

$$\Delta prod^{t_1t_2} = \Delta eff^{t_1t_2} \times \Delta tech^{t_1t_2} \tag{17}$$

- as in Färe *et al.* (1994)

$$\Delta prod^{t_1t_2} = \Delta pureeff^{t_1t_2} \times \Delta scale^{t_1t_2} \times \Delta tech^{t_1t_2} \quad (18)$$

- as in Ray and Desli (1997)

$$\Delta prod^{t_1t_2} = \Delta pureeff^{t_1t_2} \times \Delta puretech^{t_1t_2} \times SCH^{t_1t_2} \quad (19)$$

- as in Simar and Wilson (1998)

$$\Delta prod^{t_1t_2} = \Delta pureeff^{t_1t_2} \times \Delta scale^{t_1t_2} \times \Delta puretech^{t_1t_2} \times \Delta scaletech^{t_1t_2} \quad (20)$$

These four formula (17, 18, 19 and 20) will be used here to study in detail a specific decomposition about the increase of labour productivity in Italian regions from 1982-1985 (t_1) to 1997-2000 (t_2) years. It is useful to indicate immediately that decompositions of labour productivity presented in next subsections are implemented under CRS hypothesis while these Malmquist decompositions (the formula 17, 18, 19 and 20) require a more general hypothesis of Variable Returns to Scale (VRS); this is only an apparent contradiction since the classic Malmquist index can be obtained with Constant Returns to Scale (formula (10)).

3.4 A specific decomposition of labour productivity growth without human capital

In order to decompose the change of labour productivity for the 20 Italian regions from base (initial) time t_1 (1982-1985) to current (final) time t_2 (1997-2000), we follow the approach of Kumar and Russell (2002).

We assume a simple regional production approach with one output (value-added) and two inputs (labour and capital) consistently with a simple but admissible description of real world. We also suppose Constant Returns to Scale (CRS), so that it is proper to reduce the production space in a two-dimensional framework between the ratio *value-added / labour*, i.e. labour productivity or $y = Y/L$, and the ratio *capital / labour*, i.e. capital intensity or $k = K/L$.

Now, if e are the regional DEA-CRS efficiency values with output orientation (max output given the two inputs, more logical than opposite in our case), remembering the output-Farrell approach (Farrell, 1957),

$$e = Y/Y_{\max} = Y/Y_{\max}(L/L) = (Y/L)/(Y_{\max}/L) = y/\overline{y} \quad (21)$$

At base time t_1 is

$$e_{t_1} = y_{t_1}/\overline{y}_{t_1} \quad (22)$$

and in a similar way at current time t_2 is

$$e_{t_2} = y_{t_2}/\overline{y}_{t_2} \quad (23)$$

Consequently, the growth index of labour productivity between time t_1 and time t_2 is

$$\Delta prodlab^{t_1t_2} \equiv \frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}\,\overline{y}_{t_2}}{e_{t_1}\,\overline{y}_{t_1}} \quad (24)$$

Now, we calculate again the efficiency e at different technology: t_2 for data in t_1 and t_1 for data in t_2 obtaining $e_{t_1|t_2}$ and $e_{t_2|t_1}$; so, with appropriate transformation, $\overline{y}_{t_1|t_2}$ and $\overline{y}_{t_2|t_1}$ are

derived. Rewriting with identical meaning the notation $\bar{y}_{t_1}$ in $\bar{y}_{t_1|t_1}$ and $\bar{y}_{t_2}$ in $\bar{y}_{t_2|t_2}$, with technology t_1 is

$$\frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}\bar{y}_{t_2|t_2}}{e_{t_1}\bar{y}_{t_1|t_1}} \times \frac{\bar{y}_{t_2|t_1}}{\bar{y}_{t_2|t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \frac{\bar{y}_{t_2|t_2}}{\bar{y}_{t_2|t_1}} \times \frac{\bar{y}_{t_2|t_1}}{\bar{y}_{t_1|t_1}} \tag{25}$$

or, with technology t_2

$$\frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}\bar{y}_{t_2|t_2}}{e_{t_1}\bar{y}_{t_1|t_1}} \times \frac{\bar{y}_{t_1|t_2}}{\bar{y}_{t_1|t_2}} = \frac{e_{t_2}}{e_{t_1}} \times \frac{\bar{y}_{t_2|t_2}}{\bar{y}_{t_1|t_2}} \times \frac{\bar{y}_{t_1|t_2}}{\bar{y}_{t_1|t_1}} \tag{26}$$

The choice of the technology is arbitrary. Since the results can differ, it is opportune to consider both formula (25) and (26) jointly in a geometric mean, to say a Fisher index

$$\frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \left(\frac{\bar{y}_{t_2|t_2}}{\bar{y}_{t_2|t_1}} \cdot \frac{\bar{y}_{t_1|t_2}}{\bar{y}_{t_1|t_1}}\right)^{1/2} \times \left(\frac{\bar{y}_{t_2|t_1}}{\bar{y}_{t_1|t_1}} \cdot \frac{\bar{y}_{t_2|t_2}}{\bar{y}_{t_1|t_2}}\right)^{1/2} \tag{27}$$

It is easy to verify that first ratio on the right-hand in (27) is a measure of efficiency change and the second term is a measure of technology change between t_1 and t_2; besides, the product of both of them is a Malmquist productivity index as in (12). Therefore, for this, the decompositions (17), (18), (19) and (20) are valid; in fact, the question becomes now: what does it happen to the components of this Malmquist index if VRS is an admissible hypothesis for returns to scale?

The last term is a measure of capital accumulation ($kacc \equiv \Delta cap^{t_1t_2}$) because represents the effect of the change in the capital-labour ratio K/L; $\Delta cap^{t_1t_2}$ is, with other words, the capital deepening (see, Kumar and Russell, 2002). Then

$$\Delta prodlab^{t_1t_2} = \Delta eff^{t_1t_2} \times \Delta tech^{t_1t_2} \times \Delta cap^{t_1t_2} = \Delta prod^{t_1t_2} \times \Delta cap^{t_1t_2} \tag{27bis}$$

In the next subsection we use a similar decomposition taking into account a correction for the human capital.

3.5 A specific decomposition of labour productivity growth with human capital

We can expand the decomposition (27) adding a measure of human capital like in Henderson and Russell (2005) and Henderson *et al.* (2007).

Following the Authors and the approach of Bils and Klenow (2000), we define labour in efficiency units in region i at time t as product between the classic labour measure L and an augmentation factor H due to effects of human capital and based on returns of a earnings function. It is

$$\hat{L}_{it} = H_{it}L_{it} = h(\varepsilon_{it})L_{it} = e^{f(\varepsilon_{it})}L_{it} \tag{28}$$

with, in general terms,

$$f(\varepsilon_{it}) = \frac{\theta}{1-\psi}\varepsilon_{it}^{1-\psi} \tag{29}$$

where ε_{it} are the average years of schooling and θ and ψ are appropriate constants. To determine $H = e^{f(\varepsilon_{it})}$ we use the Italian regional estimates of the gross Mincerian returns to

education (edu) in Ciccone (2004); then, $f(\varepsilon_{it}) = (\varepsilon_{it} \cdot edu)$. The H index-values at times t_1 and t_2 are listed in Table A1 in Appendix.

Now we decompose the growth of labour productivity y_{t_2}/y_{t_1} in changes in efficiency, changes in technology, capital deepening (change in capital-labour ratio) and human capital accumulation ($hacc \equiv \Delta hum^{t_1 t_2}$).

If $\hat{y} = Y/\hat{L}$ and $\hat{k} = K/\hat{L}$ where $\hat{L} = HL$, similarly to (24)

$$\frac{\hat{y}_{t_2}}{\hat{y}_{t_1}} = \frac{e_{t_2}\hat{\bar{y}}_{t_2}}{e_{t_1}\hat{\bar{y}}_{t_1}} \tag{30}$$

With $\tilde{k}_{t_2} = K_{t_2}/(L_{t_2}H_{t_1})$ and $\tilde{k}_{t_1} = K_{t_1}/(L_{t_1}H_{t_2})$, it is possible to obtain the corresponding optimal values $\tilde{\bar{y}}_{t_2}$ and $\tilde{\bar{y}}_{t_1}$ for technology at same or different time. Then, likewise at previous subsection, we have $\hat{\bar{y}}_{t_1|t_1}$, $\hat{\bar{y}}_{t_1|t_2}$, $\hat{\bar{y}}_{t_2|t_2}$, $\hat{\bar{y}}_{t_2|t_1}$ and $\tilde{\bar{y}}_{t_1|t_1}$, $\tilde{\bar{y}}_{t_1|t_2}$, $\tilde{\bar{y}}_{t_2|t_2}$, $\tilde{\bar{y}}_{t_2|t_1}$; some of these expressions are used to decompose the productivity growth in two equivalent formula

$$\frac{\hat{y}_{t_2}}{\hat{y}_{t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \frac{\hat{\bar{y}}_{t_2|t_2}}{\hat{\bar{y}}_{t_2|t_1}} \times \frac{\tilde{\bar{y}}_{t_2|t_1}}{\hat{\bar{y}}_{t_1|t_1}} \times \frac{\hat{\bar{y}}_{t_2|t_1}}{\tilde{\bar{y}}_{t_2|t_1}} \tag{31}$$

or

$$\frac{\hat{y}_{t_2}}{\hat{y}_{t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \frac{\hat{\bar{y}}_{t_1|t_2}}{\hat{\bar{y}}_{t_1|t_1}} \times \frac{\hat{\bar{y}}_{t_2|t_2}}{\tilde{\bar{y}}_{t_1|t_2}} \times \frac{\tilde{\bar{y}}_{t_1|t_2}}{\hat{\bar{y}}_{t_1|t_2}} \tag{32}$$

Since $\hat{y} = Y/\hat{L}$ and $y = Y/L$

$$\frac{y_{t_2}}{y_{t_1}} = \frac{H_{t_2}}{H_{t_1}} \cdot \frac{\hat{y}_{t_2}}{\hat{y}_{t_1}} \tag{33}$$

and, consequently,

$$\frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \frac{\hat{\bar{y}}_{t_2|t_2}}{\hat{\bar{y}}_{t_2|t_1}} \times \frac{\tilde{\bar{y}}_{t_2|t_1}}{\hat{\bar{y}}_{t_1|t_1}} \times \left(\frac{\hat{\bar{y}}_{t_2|t_1}}{\tilde{\bar{y}}_{t_2|t_1}} \cdot \frac{H_{t_2}}{H_{t_1}} \right) \tag{34}$$

or

$$\frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \frac{\hat{\bar{y}}_{t_1|t_2}}{\hat{\bar{y}}_{t_1|t_1}} \times \frac{\hat{\bar{y}}_{t_2|t_2}}{\tilde{\bar{y}}_{t_1|t_2}} \times \left(\frac{\tilde{\bar{y}}_{t_1|t_2}}{\hat{\bar{y}}_{t_1|t_2}} \cdot \frac{H_{t_2}}{H_{t_1}} \right) \tag{35}$$

Applying the usual Fisher index, the formula (34) and (35) are combined together in

$$\begin{aligned} \frac{y_{t_2}}{y_{t_1}} = \frac{e_{t_2}}{e_{t_1}} \times \left(\frac{\hat{\bar{y}}_{t_2|t_2}}{\hat{\bar{y}}_{t_2|t_1}} \cdot \frac{\hat{\bar{y}}_{t_1|t_2}}{\hat{\bar{y}}_{t_1|t_1}} \right)^{1/2} \times \left(\frac{\tilde{\bar{y}}_{t_2|t_1}}{\hat{\bar{y}}_{t_1|t_1}} \cdot \frac{\hat{\bar{y}}_{t_2|t_2}}{\tilde{\bar{y}}_{t_1|t_2}} \right)^{1/2} \times \\ \left[\left(\frac{\hat{\bar{y}}_{t_2|t_1}}{\tilde{\bar{y}}_{t_2|t_1}} \cdot \frac{H_{t_2}}{H_{t_1}} \right) \cdot \left(\frac{\tilde{\bar{y}}_{t_1|t_2}}{\hat{\bar{y}}_{t_1|t_2}} \cdot \frac{H_{t_2}}{H_{t_1}} \right) \right]^{1/2} \end{aligned} \tag{36}$$

At last, y_{t_2}/y_{t_1} is decomposed in four elements: change in efficiency, change in technology, capital deepening and human capital accumulation,

$$\Delta prodlab^{t_1t_2} = \frac{y_{t_2}}{y_{t_1}} = \Delta eff^{t_1t_2} \times \Delta tech^{t_1t_2} \times \Delta cap^{t_1t_2} \times \Delta hum^{t_1t_2} = \Delta prod^{t_1t_2} \times \Delta cap^{t_1t_2} \times \Delta hum^{t_1t_2} \quad (37)$$

The product between $\Delta eff^{t_1t_2}$ and $\Delta tech^{t_1t_2}$ is again a Malmquist productivity index ($\Delta prod^{t_1t_2}$) and, so, the decompositions (17, 18, 19 and 20) are valid if VRS becomes an admissible hypothesis.

3.6 Some specifications about the estimates

Before looking at the empirical results, it is necessary to discuss some points on the estimates.
First. The classic DEA estimates (here it is used the standard model) are obtained with CRS and output-orientation for only 20 units (regions): the number of observations is very low and this can statistically bias the frontier estimate and, so, the efficiency scores. The correction implemented through Monte Carlo methods (i.e., Fazio *et al.*, 2006) does not provide always prominent economic interpretations; all the same, the bias is often small with a few inputs and outputs that escape the "curse of dimensionality": in fact, here we use only one output (value-added) and two inputs (capital and labour). Anyway, a bootstrap DEA is carried out as check of robustness and it does not indicate specific differences, serious inaccuracy or worrying outliers (but the classic DEA is prefered also because we are in a deterministic context, not interested in inference and, so, it is difficult to justify a bootstrap procedure).
Second. Differently to the decompositions of Malmquist in (17), (18), (19) and (20), for the Kumar-Russell and Henderson-Russell approach in (27bis) and (37), we need to assume that returns to scale are constant; this could be an inappropriate hypothesis. In order to verify this risk, the efficiency scores are been obtained also with VRS and then compared with CRS: the values appear slightly different and this rendes admissible the remark of results for the wide Malmquist decompositions (17), (18), (19) and (20). But the differences are not strong, so, on the other hand, this does not exclude to accept also the CRS approach of Kumar-Russell and Henderson-Russell (27bis) and (37): in fact, the kernel densities of the virtual distributions $\overline{y}_i^{crs} = y_i / e_i^{crs}$ in CRS and $\overline{y}_i^{vrs} = y_i / e_i^{vrs}$ in VRS for $i = t_1, t_2$ are compared through the Bowman and Azzalini test (1997) - the indirect comparison of efficiency scores is necessary to avoid the drawbacks of kernel densities for bounded values; the differences are never statistically significant and, consequently, allow reasonably the CRS decomposition of the labour productivity growth. Then, it is useful to read jointly the respective tables; the Appendix lists the main estimates. The next section analyses the main results.

4 EMPIRICAL RESULTS

4.1 Data and efficiency scores

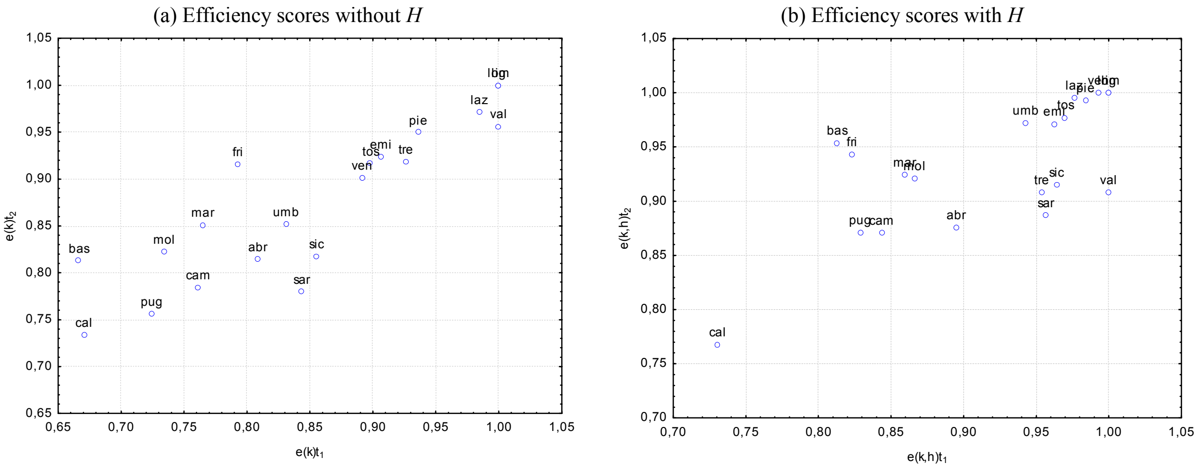
In table A1 of the Appendix, we have listed in index-terms all the variables used in this paper at time t_1 (average value for the period 1997-2000) and at time t_2 (average value for the period 1997-2000); it is interesting to note immediately the difference between Centre-North (cn) and South-Islands (me).

In respect to data, the regional labour productivity is obtained using the series of value-added (Y) and workers in full-time standard measure (L) provided by Italian Office of Statistics (Istat, 2005), while the other series are the result of studies *ad hoc*: the stock of private physical capital (K) at regional level has been recently reconstructed by Maffezzoli (2006) starting from official series on gross investments; the stock of public physical capital (PK) is provided by Piacentino (2007) that applies the methodology suggested in Paci and Saddi (2002) to official data on the expenditures in finished public works and, finally, the augmentation factor of human capital (H) is obtained using the data on years of schooling provided by Scoppa (2007) and the regional gross Mincerian returns to education elaborated in Ciccone (2004).

Table A2 lists the labour productivity and its growth; again, it is manifest the difference between Centre-North and South-Islands.

Table A3 reports the CRS regional efficiency scores obtained including firstly only K and L as inputs and, then, also H and PK (for the inclusion of H see subsection 3.5, while, for public capital, PK is simply summed to K); similarly in Table A4 but with VRS hypothesis. The scores, region by region, show a moderate dissimilarity between CRS and VRS (see subsection 3.6).

Figure 2 Scatterplot between DEA-CRS regional efficiency scores without and with correction for human capital at base (abscissa) and current (ordinate) time

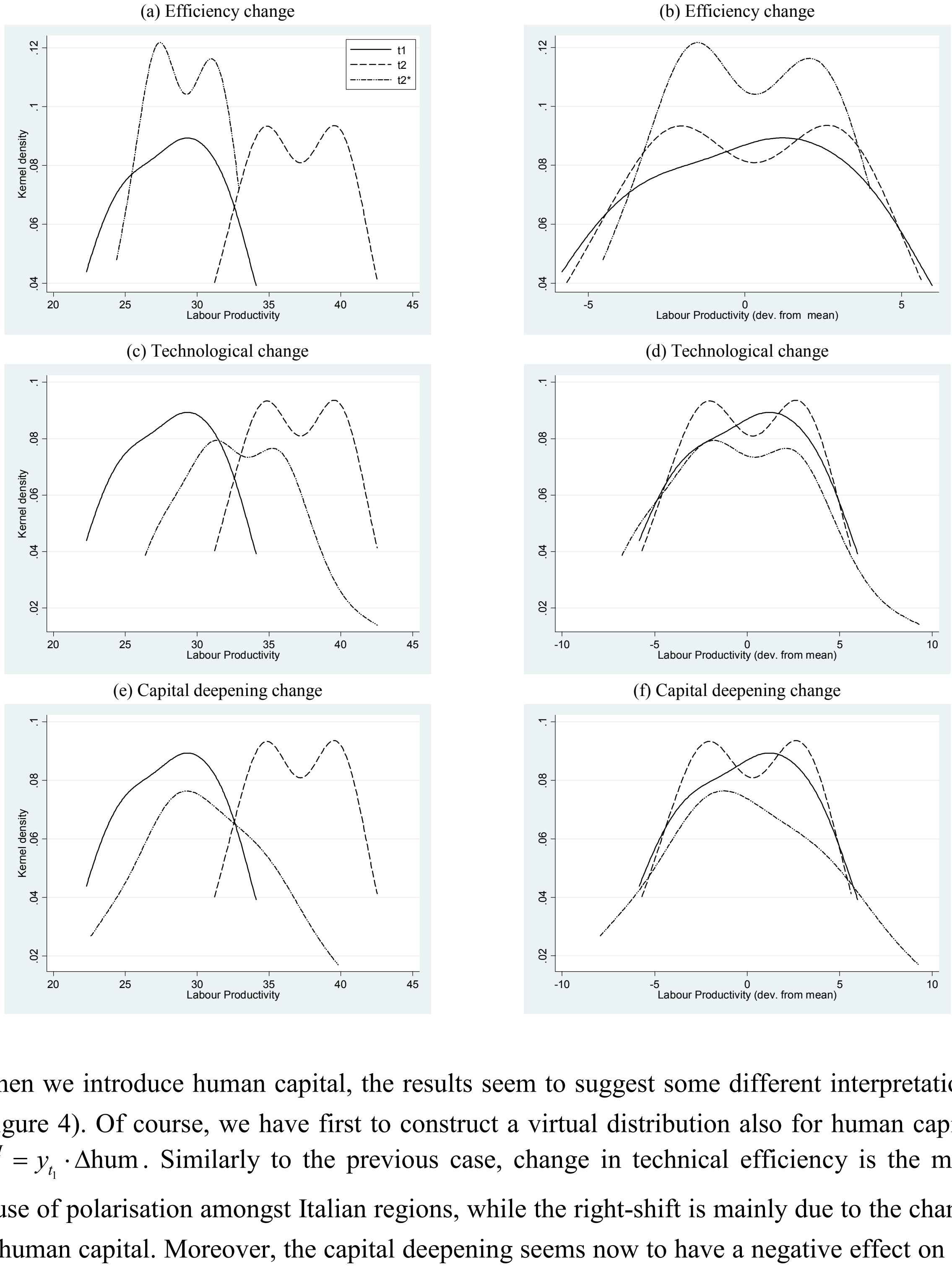


It is worth noting that part of the estimated inefficiency in the "basic" model (the $e(k)$ in Table A3) comes from the absence of correction for human capital; indeed, when we include H, the efficiency scores of all the regions increase. In any case, the values are not homogeneous among the 20 regions: the existence of spatial clusters is well-manifest both without and with human capital (Figure 2).
Surprisingly, the inclusion of PK does not yield notable gain of efficiency (we compare $e(k)$ with $e(k, pk)$ in Table A3). Analogously, its inclusion in the decomposition of labour productivity would not lead to different results; then, for the sake of brevity, we prefer to exclude PK from the analysis on productivity and convergence. However, we think that the modest influence of the public capital on the gains of regional efficiency could be due to the difficult estimate and to the way of including it (i.e. a simple sum to the private capital), so we reserve ourselves to treat it differently and more accurately in further researches.
The estimate of efficiency scores is only a first useful step for the analysis of labour productivity growth among the Italian regions. Next subsection focuses on the sources of convergence.

4.2 Relative contributions to convergence amongst Italian regions

In Table A5 and Table A6, we have reported the decomposition of the labour productivity growth respectively without and with correction for human capital. In order to look at the contribution of each component to convergence in labour productivity amongst Italian regions, we have employed the kernel density approach as in section 2 (Gaussian kernel with optimal bandwidth is been applied).
In Figure 3, we have plotted the results coming from the decomposition without human capital. We have at the same time shown the distribution of labour productivity at time t_1 and time t_2 firstly in levels and then in deviations from the cross-sectional mean.
Moreover, we have plotted in each graph a counterfactual distribution, i.e. the distribution of labour productivity at time t_2 under the hypothesis that only one component is changed over time from t_1 to t_2 (i.e. t_2^*). In other word, we have made the following virtual distributions $y_{t_2}^E = y_{t_1} \cdot \Delta\text{eff}$, $y_{t_2}^T = y_{t_1} \cdot \Delta\text{tech}$, and $y_{t_2}^K = y_{t_1} \cdot \Delta\text{cap}$; these are highlighted with a asterisk in Figure 3. Comparing each of these distributions with the baseline (y_{t1}), we can see the relative contribution of each component to convergence in labour productivity from t_1 to t_2.
Then, it seems evident that the tendency to polarisation of labour productivity is mainly due to the different change in efficiency that Italian regions have had in the period under scrutiny. On the other hand, technological progress and capital deepening cause the shift of labour productivity towards upper levels. Summing-up, the main source of regional economic convergence in Italy does not seem related to the regional endowment of physical capital and technology but to the way how each region employs its inputs, i.e. to technical efficiency.

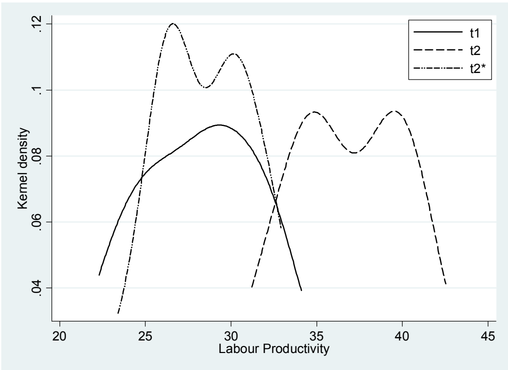
Figure 3 Counterfactual distribution and convergence amongst Italian regions without correction for human capital



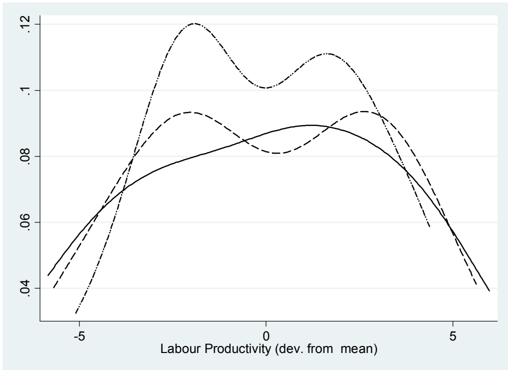
When we introduce human capital, the results seem to suggest some different interpretations (Figure 4). Of course, we have first to construct a virtual distribution also for human capital $y_{t_2}^{H} = y_{t_1} \cdot \Delta\text{hum}$. Similarly to the previous case, change in technical efficiency is the main cause of polarisation amongst Italian regions, while the right-shift is mainly due to the change in human capital. Moreover, the capital deepening seems now to have a negative effect on the growth of labour productivity. In other words, the previous increase of capital intensity is now completely explained by improvements of human capital.

Figure 4 Counterfactual distribution and convergence amongst Italian regions with human capital

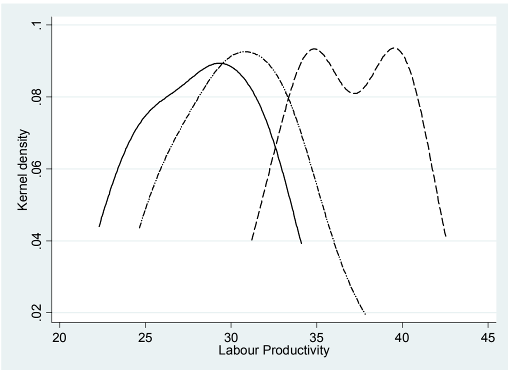
(a) Efficiency change



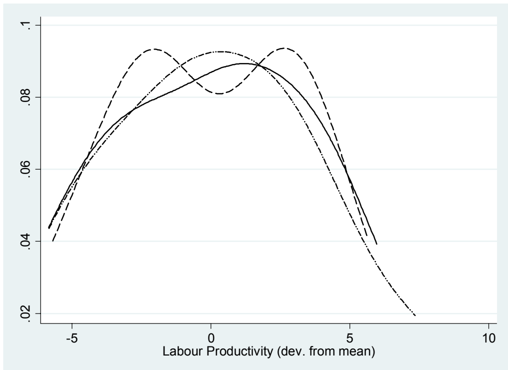
(b) Efficiency change



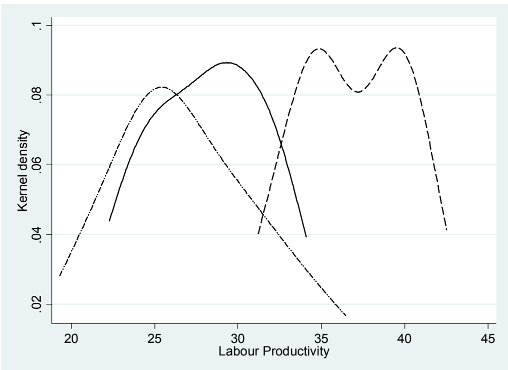
(c) Technological change



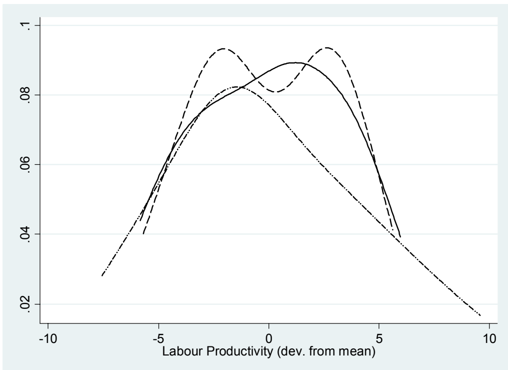
(d) Technological change



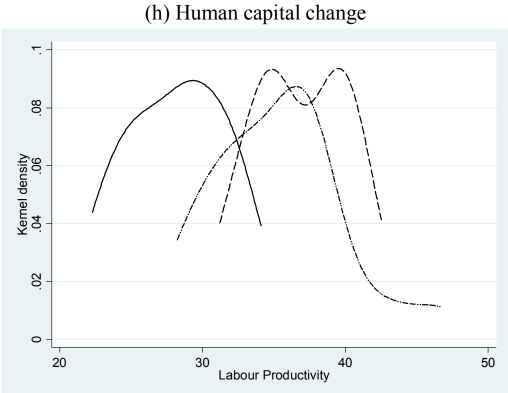
(e) Capital deepening change



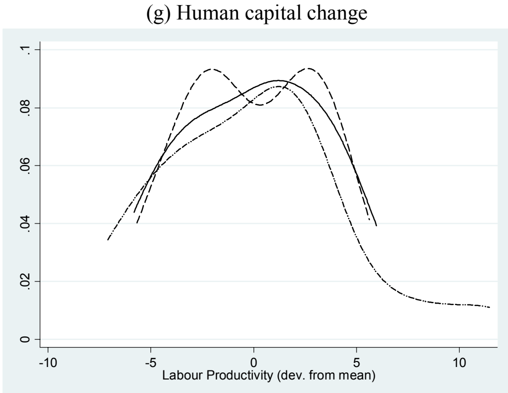
(f) Capital deepening change



(h) Human capital change



(g) Human capital change



As discussed in subsection 3.6, the approach of decomposition employed in this work is grounded on the binding hypothesis that returns to scale are constant. In order to provide some additional considerations, we have used a Malmquist decomposition that allows to separate the part of change in efficiency (Δeff) due to scale effects (Δscale) from the pure efficiency (Δpureeff); a similar decomposition can be used to separate change in technology (Δtech) due to scale effects (Δscaletech) from the pure technology (Δpuretech). Confirming the expectations, from Table A7 we can see that prevailingly the effects of scale are enough moderate (near to 1), only few exceptions are present (for example, Valle d'Aosta or Molise, Liguria and Lombardia).

Summing up, we can underline that labour productivity is always increasing from a minimum of 16,12% in Sardegna (South-Islands) to a maximum of 53,81% in Basilicata (again South-Islands). The range of capital deepening in the reduced model is 1,000-1,2433 (see Table A5) and it becomes 0,8581-1,1381 with several values lower than 1 when we extend the model (Table A6); while the effect of human capital varies from 1,1549 to 1,3919. In other words, the influence of capital intensity on the growth of labour productivity becomes negative in most regions after controlling for human capital. The inclusion of public capital does not lead to different results, but this point deserves deeper investigations. We note also that the hypothesis of constant returns to scale, needed to employ the approaches of Kumar and Russell (and, of course, that of Henderson and Russell), is convincing for Italian regions in the period under scrutiny. Indeed, the effects of scale appear enough small, except for few regions that can represent an interesting matter for further research.

5 CONCLUSIONS

In this paper, we have investigated on the hypothesis of convergence in labour productivity amongst Italian regions over a time span that comes from the beginning of 1980s to the end of 1990s. In empirical literature, there is a clear evidence of economic convergence among Italian regions in the period 1960-1975, but the portrait appears less evident from the end of 1970s onwards and the results seem enough conditioned to the approach applied. Indeed, applying to our data the approach of β-convergence, it results some evidence of convergence, even if not much strong. This result seems to be in contrast with a common opinion in Italy that the economic gap between Centre-North and South-Islands is not decreased. Indeed, a distributional approach based on kernel densities seems reveals more reasonably a tendency to economic polarisation among Italian regions in the period under scrutiny. Taking this evidence as robust, the paper attempts to investigate on the sources of this alerting tendency. To this end, we employ the approach of Kumar and Russell (2002) to decompose labour productivity growth in efficiency change, technological progress and capital deepening; and successively we remade the analysis applying a correction for human capital as in Henderson

and Russell (2005). Again, we use the distributional approach in order to look at the relative contribution of each component to regional convergence in labour productivity. The results point out the prominent role of efficiency changes to produce a pattern of spatial polarisation within Italy, while technological progress and capital deepening appear to affect moderately the change of shape in the cross-region distribution of labour productivity between the initial and final period. On the other hand, these two components seem to yield the main cause of the right-shift of the distribution over time. When we augment the model for human capital, it emerges however that capital deepening hides inside the effects of human capital on labour productivity growth. Indeed, in the augmented model, human capital is the main determinant of the right-shift. Finally, the hypothesis of constant returns to scale, needed to carry out the analysis above, is supported by means of some robustness checks.

6 APPENDIX: DATA AND MAIN ESTIMATES (*)

(*) Incidental differences in reassembling values to totals are produced by numerical rounding off.

Table A1 Index-values at base 100 or 1 on total or mean for Italy, geographical order from North to South

nr	regions	code	area	va8285	va9700	ul8285	ul9700	k8285	k9700	pk8285	pk9700	h8285	h9700
12	Piemonte	pie	cn	8,98	8,67	8,52	8,18	8,16	8,12	4,81	5,89	1,02	1,03
19	ValledAosta	val	cn	0,31	0,27	0,27	0,25	0,40	0,41	0,79	1,00	1,11	1,12
9	Lombardia	lom	cn	19,57	20,49	17,37	18,36	16,76	17,16	12,79	12,58	1,08	1,09
17	TrentinoAltoAdige	tre	cn	2,12	2,13	1,97	2,08	2,80	2,85	3,63	3,96	1,07	1,08
20	Veneto	ven	cn	8,51	9,25	8,43	9,19	8,72	9,04	3,77	5,22	0,97	0,96
6	FriuliVeneziaGiulia	fri	cn	2,14	2,36	2,39	2,30	2,47	2,41	4,07	3,73	1,04	1,04
8	Liguria	lig	cn	3,43	3,01	3,13	2,85	2,33	2,33	3,62	3,48	1,06	1,07
5	EmiliaRomagna	emi	cn	8,43	8,78	8,23	8,51	8,24	8,15	6,47	6,91	1,02	1,03
16	Toscana	tos	cn	6,92	6,71	6,97	6,87	5,64	5,73	5,35	5,55	0,98	0,98
18	Umbria	umb	cn	1,41	1,41	1,52	1,49	1,42	1,44	2,13	1,76	0,95	0,93
10	Marche	mar	cn	2,42	2,58	2,84	2,77	2,48	2,47	1,80	1,95	0,95	0,98
7	Lazio	laz	cn	9,96	10,04	9,03	9,34	8,27	8,56	7,61	8,48	1,08	1,06
1	Abruzzo	abr	me	1,90	1,87	2,07	2,06	2,23	2,19	2,88	2,66	0,98	0,99
11	Molise	mol	me	0,44	0,45	0,52	0,49	0,65	0,63	0,92	0,87	0,93	0,95
4	Campania	cam	me	6,96	6,49	8,06	7,41	8,64	8,35	10,63	9,24	0,98	0,96
13	Puglia	pug	me	4,69	4,64	5,80	5,57	5,18	5,05	6,22	5,72	0,93	0,92
2	Basilicata	bas	me	0,72	0,75	0,93	0,83	1,25	1,21	2,11	2,18	0,90	0,91
3	Calabria	cal	me	2,19	2,18	2,87	2,66	3,18	3,11	4,09	4,11	1,00	1,02
15	Sicilia	sic	me	6,57	5,78	6,72	6,34	7,92	7,60	9,51	8,96	0,97	0,95
14	Sardegna	sar	me	2,30	2,13	2,35	2,45	3,27	3,19	6,78	5,75	0,97	0,94
			ITALY	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	1,00	1,00
			cn	74,22	75,70	70,67	72,19	67,69	68,68	56,86	60,50	1,03	1,03
			me	25,78	24,30	29,33	27,81	32,31	31,32	43,14	39,50	0,96	0,95

Legend

regions	name of the 20 Italian regions
code	regional code
area	Center-North (cn) or South and Islands (me)
va8285	value-added (*Y*) at time t_1 (1982-1985), original data in million euros at constant prices ‘95 (a)
va9700	value-added (*Y*) at time t_2 (1997-2000), original data in million euros at constant prices ‘95 (a)
ul8285	total workers in full-time standard measure (*L*) at time t1 (1982-1985), original data in thousands (a)
ul9700	total workers in full-time standard measure (*L*) at time t2 (1997-2000), original data in thousands (a)
k8285	stock of physical private capital (*K*) at time t_1 (1982-1985), original data in million euros at constant prices ‘95(b)
k9700	stock of physical private capital (*K*) at time t_2 (1997-2000), original data in million euros at constant prices ‘95(b)
pk8285	stock of physical public capital (*PK*) at time t_1 (1982-1985), original data in mil.euros at constant prices ‘95(c)
pk9700	stock of physical public capital (*PK*) at time t_2 (1997-2000), original data in mil.euros at constant prices ‘95(c)
h8285	augmentation factor of human capital (*H*) at time t_1 (1982-1985), index (d)
h9700	augmentation factor of human capital (*H*) at time t_2 (1997-2000), index (d)

Our elaborations on data from:

(a)	Italian Office of Statistics (Istat, 2005)
(b)	Maffezzoli (2006)
(c)	Paci and Saddi (2002), Piacentino (2007)
(d)	Ciccone (2004)

Table A2 Labour productivity at time t_1 and time t_2 and its growth in percentage terms (total and annual mean), geographical order from North to South

nr	regions	code	area	y_{t1}	y_{t2}	Δprodlab y_{t2}/y_{t1}	y_{t2}/y_{t1}m
12	Piemonte	pie	cn	30,79	40,39	31,19	1,52
19	ValledAosta	val	cn	34,10	40,66	19,25	0,98
9	Lombardia	lom	cn	32,92	42,52	29,18	1,43
17	TrentinoAltoAdige	tre	cn	31,42	39,06	24,33	1,22
20	Veneto	ven	cn	29,49	38,35	30,05	1,47
6	FriuliVeneziaGiulia	fri	cn	26,22	38,96	48,60	2,22
8	Liguria	lig	cn	32,03	40,32	25,90	1,29
5	EmiliaRomagna	emi	cn	29,92	39,31	31,39	1,53
16	Toscana	tos	cn	29,00	37,22	28,35	1,40
18	Umbria	umb	cn	27,26	36,23	32,91	1,59
10	Marche	mar	cn	24,90	35,48	42,48	1,99
7	Lazio	laz	cn	32,21	40,96	27,17	1,34
1	Abruzzo	abr	me	26,81	34,63	29,17	1,43
11	Molise	mol	me	24,65	34,98	41,91	1,96
4	Campania	cam	me	25,24	33,36	32,17	1,56
13	Puglia	pug	me	23,63	31,75	34,35	1,65
2	Basilicata	bas	me	22,49	34,59	53,81	2,42
3	Calabria	cal	me	22,29	31,21	40,05	1,89
15	Sicilia	sic	me	28,56	34,78	21,78	1,10
14	Sardegna	sar	me	28,56	33,16	16,12	0,83
			ITALY	29,21	38,11	30,45	1,49
			cn	30,68	39,96	30,25	1,48
			me	25,67	33,30	29,70	1,46

Table A3 DEA-CRS efficiency scores (21) at time t_1 and time t_2 in space (Y, L, K) with or without H and PK, regional values and average scores for Italy, Centre-North (cn) and South-Islands (me), geographical order from North to South

nr	regions	code	area	e(k,h)t_1	e(k,h)t_2	e(k)t_1	e(k)t_2	e(k,pk,h)t_1	e(k,pk,h)t_2	e(k,pk)t_1	e(k,pk)t_2
12	Piemonte	pie	cn	0,9840	0,9930	0,9361	0,9498	0,9842	0,9915	0,9394	0,9498
19	ValledAosta	val	cn	1,0000	0,9079	1,0000	0,9562	1,0000	0,9079	1,0000	0,9562
9	Lombardia	lom	cn	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
17	TrentinoAltoAdige	tre	cn	0,9537	0,9084	0,9261	0,9185	0,9545	0,9084	0,9300	0,9185
20	Veneto	ven	cn	0,9928	1,0000	0,8914	0,9017	0,9937	1,0000	0,8942	0,9017
6	FriuliVen.Giulia	fri	cn	0,8233	0,9432	0,7928	0,9162	0,8229	0,9413	0,7900	0,9162
8	Liguria	lig	cn	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
5	EmiliaRomagna	emi	cn	0,9627	0,9712	0,9065	0,9243	0,9630	0,9685	0,9070	0,9243
16	Toscana	tos	cn	0,9699	0,9771	0,8980	0,9166	0,9705	0,9735	0,9026	0,9478
18	Umbria	umb	cn	0,9428	0,9722	0,8310	0,8519	0,9425	0,9722	0,8262	0,8519
10	Marche	mar	cn	0,8592	0,9243	0,7647	0,8509	0,8593	0,9228	0,7687	0,8634
7	Lazio	laz	cn	0,9760	0,9953	0,9843	0,9713	0,9761	0,9916	0,9841	0,9632
1	Abruzzo	abr	me	0,8947	0,8758	0,8084	0,8144	0,8949	0,8758	0,8076	0,8144
11	Molise	mol	me	0,8662	0,9211	0,7343	0,8227	0,8667	0,9211	0,7350	0,8227
4	Campania	cam	me	0,8435	0,8709	0,7612	0,7844	0,8436	0,8709	0,7607	0,7844
13	Puglia	pug	me	0,8287	0,8713	0,7243	0,7564	0,8286	0,8662	0,7216	0,7467
2	Basilicata	bas	me	0,8126	0,9539	0,6663	0,8133	0,8126	0,9539	0,6665	0,8133
3	Calabria	cal	me	0,7306	0,7678	0,6706	0,7340	0,7307	0,7678	0,6703	0,7340
15	Sicilia	sic	me	0,9640	0,9152	0,8552	0,8178	0,9646	0,9152	0,8562	0,8178
14	Sardegna	sar	me	0,9565	0,8867	0,8433	0,7798	0,9565	0,8867	0,8418	0,7798
	ITALY			0,9181	0,9328	0,8497	0,8740	0,9182	0,9318	0,8501	0,8753
	cn			0,9554	0,9661	0,9109	0,9298	0,9556	0,9648	0,9119	0,9328
	me			0,8621	0,8828	0,7580	0,7904	0,8623	0,8822	0,7575	0,7891

Table A4 DEA-VRS efficiency scores at time t_1 and time t_2 in space (Y, L, K) with or without H and PK, regional values and average scores for Italy, Centre-North (cn) and South-Islands (me), geographical order from North to South

nr	regions	code	area	$e(k,h)t_1$	$e(k,h)t_2$	$e(k)t_1$	$e(k)t_2$	$e(k,pk,h)t_1$	$e(k,pk,h)t_2$	$e(k,pk)t_1$	$e(k,pk)t_2$
12	Piemonte	pie	cn	0,9843	0,9944	0,9364	0,9505	0,9843	0,9931	0,9397	0,9505
19	ValledAosta	val	cn	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
9	Lombardia	lom	cn	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
17	TrentinoAltoAdige	tre	cn	0,9579	0,9166	0,9502	0,9229	0,9579	0,9166	0,9502	0,9229
20	Veneto	ven	cn	0,9947	1,0000	0,8951	0,9023	0,9947	1,0000	0,8951	0,9023
6	FriuliVen.Giulia	fri	cn	0,8237	0,9579	0,7937	0,9201	0,8237	0,9491	0,7937	0,9201
8	Liguria	lig	cn	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
5	EmiliaRomagna	emi	cn	0,9637	0,9729	0,9082	0,9249	0,9637	0,9705	0,9082	0,9249
16	Toscana	tos	cn	0,9704	0,9814	0,9704	0,9557	0,9768	0,9800	0,9768	0,9560
18	Umbria	umb	cn	0,9429	1,0000	0,8342	0,8785	0,9429	0,9985	0,8318	0,8832
10	Marche	mar	cn	0,8598	0,9382	0,7657	0,8618	0,8614	0,9421	0,7706	0,8736
7	Lazio	laz	cn	0,9880	0,9976	0,9880	0,9716	0,9854	0,9942	0,9854	0,9675
1	Abruzzo	abr	me	0,8963	0,8848	0,8111	0,8183	0,8963	0,8848	0,8111	0,8183
11	Molise	mol	me	0,8679	0,9742	0,7355	0,8446	0,8679	0,9742	0,7355	0,8615
4	Campania	cam	me	0,8454	0,8715	0,7662	0,7851	0,8454	0,8715	0,7662	0,7851
13	Puglia	pug	me	0,8291	0,8754	0,7245	0,7589	0,8291	0,8689	0,7225	0,7553
2	Basilicata	bas	me	0,8154	0,9859	0,6764	0,8238	0,8154	0,9859	0,6764	0,8238
3	Calabria	cal	me	0,7321	0,7731	0,6751	0,7366	0,7321	0,7731	0,6751	0,7366
15	Sicilia	sic	me	0,9675	0,9165	0,8667	0,8187	0,9675	0,9165	0,8667	0,8187
14	Sardegna	sar	me	0,9610	0,8944	0,8644	0,7829	0,9610	0,8944	0,8644	0,7829
	ITALY			0,9200	0,9467	0,8581	0,8829	0,9203	0,9457	0,8585	0,8842
	cn			0,9571	0,9799	0,9202	0,9407	0,9576	0,9787	0,9210	0,9418
	me			0,8643	0,8970	0,7650	0,7961	0,8643	0,8962	0,7647	0,7978

Table A5 Decomposition of y_{t2}/y_{t1} from formula (27) and (27bis), private capital without human capital

nr	regions	code	area	Δprodlab	Δprod	Δeff	Δtech	Δcap	Δhum
1	Abruzzo	abr	me	1,2917	1,2234	1,0074	1,2145	1,0557	--
2	Basilicata	bas	me	1,5381	1,5302	1,2206	1,2536	1,0052	--
3	Calabria	cal	me	1,4005	1,3458	1,0945	1,2295	1,0406	--
4	Campania	cam	me	1,3217	1,2482	1,0305	1,2112	1,0589	--
5	EmiliaRomagna	emi	cn	1,3139	1,2037	1,0196	1,1806	1,0915	--
6	FriuliVeneziaGiulia	fri	cn	1,4860	1,3790	1,1557	1,1933	1,0776	--
7	Lazio	laz	cn	1,2717	1,1168	0,9868	1,1318	1,1387	--
8	Liguria	lig	cn	1,2590	1,0126	1,0000	1,0126	1,2433	--
9	Lombardia	lom	cn	1,2918	1,1621	1,0000	1,1621	1,1115	--
10	Marche	mar	cn	1,4248	1,2285	1,1127	1,1041	1,1598	--
11	Molise	mol	me	1,4191	1,4070	1,1204	1,2558	1,0086	--
12	Piemonte	pie	cn	1,3119	1,1715	1,0146	1,1547	1,1198	--
13	Puglia	pug	me	1,3435	1,1663	1,0443	1,1168	1,1519	--
14	Sardegna	sar	me	1,1612	1,1572	0,9247	1,2514	1,0035	--
15	Sicilia	sic	me	1,2178	1,1877	0,9563	1,2420	1,0254	--
16	Toscana	tos	cn	1,2835	1,0760	1,0207	1,0542	1,1928	--
17	TrentinoAltoAdige	tre	cn	1,2433	1,2401	0,9918	1,2503	1,0026	--
18	Umbria	umb	cn	1,3291	1,1733	1,0252	1,1445	1,1328	--
19	ValledAosta	val	cn	1,1925	1,1925	0,9562	1,2471	1,0000	--
20	Veneto	ven	cn	1,3005	1,2117	1,0116	1,1979	1,0733	--

Table A6 Decomposition of y_{t2}/y_{t1} from formula (36) and (37), private capital with human capital

nr	regions	code	area	Δprodlab	Δprod	Δeff	Δtech	Δcap	Δhum
1	Abruzzo	abr	me	1,2917	1,0822	0,9789	1,1056	0,9305	1,2827
2	Basilicata	bas	me	1,5381	1,3027	1,1739	1,1097	0,8581	1,3760
3	Calabria	cal	me	1,4005	1,1624	1,0509	1,1061	0,9291	1,2967
4	Campania	cam	me	1,3217	1,1408	1,0325	1,1049	0,9167	1,2638
5	EmiliaRomagna	emi	cn	1,3139	1,0999	1,0088	1,0903	0,9761	1,2238
6	FriuliVeneziaGiulia	fri	cn	1,4860	1,2572	1,1456	1,0973	0,9707	1,2177
7	Lazio	laz	cn	1,2717	1,0679	1,0198	1,0472	1,0310	1,1549
8	Liguria	lig	cn	1,2590	0,9437	1,0000	0,9437	1,1381	1,1722
9	Lombardia	lom	cn	1,2918	1,0701	1,0000	1,0701	1,0193	1,1843
10	Marche	mar	cn	1,4248	1,1609	1,0758	1,0791	1,0166	1,2073
11	Molise	mol	me	1,4191	1,1800	1,0634	1,1097	0,8640	1,3919
12	Piemonte	pie	cn	1,3119	1,0953	1,0091	1,0853	1,0010	1,1966
13	Puglia	pug	me	1,3435	1,1467	1,0514	1,0906	0,9807	1,1947
14	Sardegna	sar	me	1,1612	1,0287	0,9270	1,1097	0,8581	1,3155
15	Sicilia	sic	me	1,2178	1,0543	0,9494	1,1105	0,8744	1,3211
16	Toscana	tos	cn	1,2835	1,0398	1,0074	1,0321	1,0566	1,1682
17	TrentinoAltoAdige	tre	cn	1,2433	1,0571	0,9525	1,1098	0,8649	1,3599
18	Umbria	umb	cn	1,3291	1,1323	1,0312	1,0981	0,9687	1,2118
19	ValledAosta	val	cn	1,1925	1,0075	0,9079	1,1096	0,8628	1,3719
20	Veneto	ven	cn	1,3005	1,1117	1,0073	1,1037	0,9338	1,2527

Table A7 Malmquist decomposition from formula (17, 18, 19 and 20), private capital with human capital (a)

nr	regions	code	area	Δprod	Δeff	Δtech	Δpureeff	Δscale	Δpuretech	Δscaletech	SCH
1	Abruzzo	abr	me	1,0822	0,9789	1,1056	0,9872	0,9916	1,0889	1,0154	1,0068
2	Basilicata	bas	me	1,3027	1,1740	1,1096	1,2091	0,9709	1,0759	1,0314	1,0014
3	Calabria	cal	me	1,1624	1,0510	1,1060	1,0560	0,9952	1,0969	1,0084	1,0035
4	Campania	cam	me	1,1408	1,0325	1,1048	1,0309	1,0016	1,1068	0,9982	0,9998
5	EmiliaRomagna	emi	cn	1,0999	1,0088	1,0903	1,0095	0,9993	1,0884	1,0017	1,0010
6	FriuliVen.Giulia	fri	cn	1,2572	1,1457	1,0973	1,1629	0,9852	1,0787	1,0172	1,0022
7	Lazio	laz	cn	1,0679	1,0197	1,0473	1,0097	1,0099	1,0252	1,0215	1,0316
8	Liguria	lig	cn	0,9437	1,0000	0,9437	1,0000	1,0000	0,9242	1,0211	1,0211
9	Lombardia	lom	cn	1,0701	1,0000	1,0701	1,0000	1,0000	1,1811	0,9061	0,9061
10	Marche	mar	cn	1,1609	1,0758	1,0791	1,0912	0,9859	1,0659	1,0124	0,9982
11	Molise	mol	me	1,1800	1,0634	1,1096	1,1225	0,9474	0,9824	1,1296	1,0701
12	Piemonte	pie	cn	1,0953	1,0092	1,0853	1,0103	0,9990	1,0791	1,0057	1,0047
13	Puglia	pug	me	1,1467	1,0514	1,0906	1,0558	0,9958	1,0871	1,0032	0,9990
14	Sardegna	sar	me	1,0287	0,9271	1,1096	0,9307	0,9961	1,1040	1,0051	1,0012
15	Sicilia	sic	me	1,0543	0,9494	1,1105	0,9473	1,0022	1,1135	0,9973	0,9995
16	Toscana	tos	cn	1,0398	1,0074	1,0322	1,0113	0,9961	1,0117	1,0203	1,0163
17	TrentinoAltoAdige	tre	cn	1,0571	0,9525	1,1098	0,9569	0,9954	1,1031	1,0060	1,0015
18	Umbria	umb	cn	1,1323	1,0311	1,0981	1,0606	0,9723	1,0480	1,0478	1,0187
19	ValledAosta	val	cn	1,0075	0,9079	1,1096	1,0000	0,9079	NA	NA	NA
20	Veneto	ven	cn	1,1117	1,0072	1,1037	1,0053	1,0019	1,1047	0,9992	1,0010

(a) NA = information not available
(Analogous table without human capital is not listed for the sake of brevity.
For the same reason, all the tables with public capital are omitted in this Appendix).

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