DEPFID
DEPARTMENT OF ECONOMIC POLICY, FINANCE AND DEVELOPMENT
UNIVERSITY OF SIENA

DEPFID WORKING PAPERS

Pierpaolo Pierani

Multilateral comparison of total factor productivity and convergence in Italian agriculture (1951-2002)

2 / 2009

DIPARTIMENTO DI POLITICA ECONOMICA, FINANZA E SVILUPPO
UNIVERSITÀ DI SIENA

DEPFID Working Papers – 2 / March 2009

Multilateral comparison of total factor productivity and convergence in Italian agriculture (1951-2002)

Pierpaolo Pierani

Abstract

This article uses the index number approach to estimate the regional differences of agricultural output, input and total factor productivity (TFP) in Italy. Data cover the period 1951 to 2002 and are taken from Agrefit, which is a new database of Italian agriculture at regional level. Comparisons across space and time are constructed in two steps: first, bilateral Fisher indexes, which are not transitive, are spatially chained to obtain transitivity, using the EKS method, then, multilateral indexes are linked chronologically over time by means of the so-called TFGG method, which satisfies temporal fixity. The second focus of the paper is to test for convergence in agricultural productivity. We consider the problems of heterogeneity and stability of cross-section growth regressions using a hierarchical Bayesian method based on panel data.

KEYWORDS: Index number approach, Agricultural TFP, Multilateral comparisons, Panel data, Regional convergence.

JEL CLASSIFICATION: Q11, C43, O47

ADDRESS FOR CORRESPONDENCE: pierani@unisi.it

ACKNOWLEDGEMENTS: I wish to thank P.L. Rizzi for his insightful comments and constant support. The usual disclaimers apply.

Dipartimento di Politica Economica, Finanza e Sviluppo – Università di Siena

1. INTRODUCTION

The main purpose of this article is to provide multilateral comparisons of agricultural output, input and productivity for the Italian regions, using the index number approach. Data cover the years 1951 to 2002 and are taken from Agrefit, which is a new database of Italian agriculture at regional level (Rizzi and Pierani, 2006). Throughout the period, Italian agriculture has experienced an unprecedented productivity growth resulting from a unique combination of multiple technological advances as well as major policy reforms and institutional changes[1]. In particular, we discuss some methodological problems relating to multilateral indexes and estimate the differences in relevant economic indicators across regions and time (Caves *et al.*, 1982; Hill, 1997, 2004; Shiu, 2003). These longitudinal comparisons are constructed in two steps: first, bilateral indexes, which are not transitive, are spatially chained to obtain transitivity, then, multilateral indexes are linked chronologically over time.

There is a variety of celebrated formulas that can be used to aggregate the multiplicity of outputs and inputs. In this paper, the bilateral comparisons are obtained from the Fisher ideal index given its desirable properties under the economic and axiomatic criteria (Diewert, 1976; 1992). One serious drawback with bilateral indexes in a multilateral context, though, is that they are not transitive. This is a limitation because unlike a time series setting where it is usual to chain indexes of adjacent periods chronologically, there is no similar ordering in the context of cross section data.

The *EKS* method (Eltetö and Köves, 1964; Szulc, 1964) provides a possible criterion to achieve transitivity of Fisher bilateral indexes. The method recognizes that each binary index has a specific reliability attached to it and uses this information to chain consistently over the examined regions. However, despite its remarkable properties, the *EKS* index has always been overlooked in favor of the translog multilateral index, which was regarded as having a sounder economic foundation (Caves *et al.*, 1982). Only recently Fox (2003) was able to set out an economic justification for its use, proving that the technology implied by the *EKS* multilateral index is flexible, hence very general. Eventually, we construct longitudinal comparisons by means of the so-called *temporally fixed grid graph* (*TFGG*) method which satisfies temporal fixity, whereby the results are unaffected by the inclusion of new time periods (Hill, 2002; 2004).

[1] The end of the sharecropping system, which was prevalent in Central regions, is just an example. Its conversion was enforced in the early 1980s but actually occurred quite gradually during the 1970s. The establishment of Regions as political and administrative entities in the early 1970s, with significant financial autonomy, is another example. The effect of these institutional changes on productivity, definitely important, did not take place abruptly.

The second focus of our analysis is to test for convergence. This subject has been the focus of a large literature[2], given the well-known persistent and fundamental dualism of regional growth in Italy. Despite inescapable differences in methodology, investigation period and type of data, the common evidence of these empirical studies is that there exists a period of strong regional convergence, which was limited to the years 1960 to 1975; afterwards, such a process stopped and the later period registered a long term clustering of Northern and Southern regions along divergent paths.

The present study represents a contribution in a number of aspects. Although there are several studies analyzing productivity in Italy[3], there is no such an extended analysis on agriculture at regional level, spanning more than half a century from 1951 to 2002. In fact, only few deal with the primary sector and, due to data limitation, mostly consider partial productivity measures. The only comparable study stops in 1984 (Pierani, 1989). Second, regarding convergence, we use panel data tests in order to increase the power of time series unit root tests (Chang, 2002) and deal with the issues of heterogeneity and stability of cross-region growth regressions, using a hierarchical Bayesian method (Maddala *et al*., 1997). Almost all studies use pooled regressions, under the assumption that individual cross-sectional units may have different efficiency levels but do share the same convergence rate (Islam, 2003). In fact, the null of the same slope coefficient across units is often rejected. The hypothesis of a stable convergence rate may not be tenable, too, given such an extended historical period.

The rest of the paper is organized as follows. The next section provides a description of the methodology of the *EKS* multilateral index extended to a panel data. Section 3 gives detailed information about data and variable definitions used in this study. Then, Section 4 compares relative levels and growth rates of agricultural output, inputs and *TFP* among the twenty Italian regions for the period 1951 to 2002. Section 5, examines β-convergence and σ-convergence using cross-section growth regressions and cross sectional dispersion of agricultural *TFP* over time, respectively. Section 6 and Section 7 deal with stochastic convergence of Italian regions based on panel data. The former implements a non-linear *IV* unit root test, which is robust to cross-sectional dependence, the latter considers the issue of pooling, allowing for spatial heterogeneity and temporal instability. The final section underscores the main findings and suggests some logical extensions of this study.

[2] Byrne *et al.* (2009), Costantini and Arbia (2006), Di Liberto *et al*. (2003), Lanzafame (2005), Leonida *et al*. (2004), Maffezzoli (2006), Paci and Pigliaru (1997), Paci and Saba (1998) and Terrasi (1999), to cite a few.

[3] Aiello and Scoppa (2001), Bernini Carri (2005), Byrne *et al.* (2009), Di Liberto *et al*. (2003), Esposti (2008), Leonida *et al*. (2004), Paci and Saba (1998), among others.

2. METHODOLOGY

In general, a productivity index is defined as the ratio of an output index to an input index. There are a number of alternative formulas, i.e. different weighting criteria that can be used to aggregate the multiplicity of output and input quantities into an index. The productivity measures presented here are obtained from Fisher ideal indexes of outputs and inputs, given their desirable properties under the economic and axiomatic criteria (Diewert, 1976; 1992).

Let $p_{kt} >> 0_N$ and $q_{kt} \geq 0_N$ denote the price and quantity vectors for region *k* (*k* = 1, …, *K*) in period *t* (*t* = 1, …, *T*). The Fisher bilateral quantity index is defined as the geometric mean of the Paasche and Lapeyres indexes:

$$Q^F_{jt,kt} = \left(\frac{p'_{kt} q_{kt}}{p'_{kt} q_{jt}} \frac{p'_{jt} q_{kt}}{p'_{jt} q_{jt}} \right)^{\frac{1}{2}}$$

where the subscripts indicate that the spatial comparison is between region *j* and region *k* in time period *t*. The difficulty with bilateral indexes in a multilateral context is that they cannot be consistently chained as, in general, they are not transitive (Rao *et al*., 2002). In other words, the direct application of the above formula to K regions would yield $K(K-1)/2$ pairs of spatial comparisons[4], which however need not be internally consistent. For example, if we take three regions *j*, *k* and *l*, the direct comparison between quantities *j* and *l* and the indirect comparison via quantity *k*, i.e. obtained by linking together the quantity index between *j* and *k* and that between *k* and *l*, yields a different result, i.e., $Q^F_{jt,lt} \neq Q^F_{jt,kt} \times Q^F_{kt,lt}$. To overcome this drawback a number of multilateral formulae have been devised (Balk, 1996; Hill, 1997; Diewert, 1999). Here we use the *EKS* method (Eltetö and Köves, 1964; Szulc, 1964) whose basic idea is to achieve transitivity of bilateral indexes through indirect comparisons of each region and a reference meta-region. In the present context, the quantity index of region *k* in time period *t* is calculated as the geometric mean of the *K* bilateral Fisher quantity indexes[5] of the examined region with respect to all other regions:

$$Q_{kt} = \prod_{i=1}^{K} \left[\left(Q^F_{it,kt} \right)^{1/K} \right]$$

---

[4] In fact, the pairs of spatial comparisons are K^2, which reduce to $K(K-1)/2$ due to the reversal property of the Fisher index $\left(Q^F_{it,kt} = 1/Q^F_{kt,it} \right)$, which states that when the prices and quantities for the two regions are interchanged, the resulting index will be the reciprocal of the original one, and to the identity property $Q^F_{it,it} = 1$.

[5] The so-called *CCD* method, instead, uses the Törnqvist quantity index formula to make each bilateral comparison (Caves *et al*., 1982).

Noticing that the Fisher index has the region reversal property, the bilateral comparison of region *j* relative to region *k* is calculated as the geometric mean of *K* indirect symmetrical comparisons of *j* and *k* with respect to all other regions:

$$Q_{jt,kt}^{EKS} = \prod_{i=1}^{K}\left[\left(Q_{jt,it}^{F} \times Q_{it,kt}^{F}\right)^{1/K}\right]$$

Multilateral *EKS*-type indexes satisfy transitivity and minimize the distance from the binary Fisher comparisons (Rao and Banerjee, 1984)[6]. The weights defined by 1/*K* are named *democratic* by Diewert (1999), since they are the same across regions. Numerous weighting procedures can be used to aggregate consistently over regions, each of which reflects the relative (economic) importance of the examined region and/or the reliability of a given binary comparison. An incomplete list comprehends: Paasche-Laspeyeres spread (Balk, 2001; Hill, 2002; 2004), (dis)similarity indexes (Diewert, 2005a), *plutocratic* and own share systems (Diewert, 1999), which correspond to the regional value share and regional quantity share weights, respectively.

Comparing simultaneously quantity levels across regions and time requires the extension of the above formula to a panel data set. Hill (2002; 2004) proposes a number of alternative methods for constructing longitudinal comparisons, i.e., multilateral indexes of regions at two different periods of time, each of which will yield different results along with a set of criteria to discriminate among them. Namely, temporal and spatial fixity, which requires that the results be unaffected by the inclusion of new time periods and other regions, respectively; temporal and spatial consistency, which subsumes separability of panel results, i.e., that the temporal (spatial) comparisons for each country (year) do not depend on the other countries (years); finally, temporal displacement, which is the time interval between two subsequent *EKS* spatial comparisons. The last definition is inversely related to the notion of characteristicity (Drechsler, 1973), given that a longer time span implies a lower characteristicity of comparisons. Standard multilateral methods violate most of them, since in a panel data context temporal and spatial dimensions are always conflicting. So, choosing between them is arduous as there is no a general criterion of ordering, rather each approach has to be valued on a case-by-case basis having in mind the properties of the data, i.e., which comparison (spatial or temporal) is more reliable, and the objective of the study.

[6] *EKS*-type indexes do not satisfy the so-called additivity condition, which implies that regional quantity levels sum up to the quantity level of the total set of regions. Although national accountants have always regarded this as a distinctive feature of their methodology, recently Istat (2008), following Eurostat (2008), has published *EKS* price indexes in the main Italian cities for selected goods, which amount to more than one third of the total expenditure of Italian households.

For example[7], Ball *et al*. (2001; 2002; 2004), in their influential articles on farm sector productivity for the United States and other European countries, construct *EKS* relative productivity indexes for all countries in a base year and project them backward and/or forward in time by chaining them to intertemporal Fisher quantity indexes for the individual countries. Pierani (1989) estimates agricultural productivity of Italian regions for the years 1970 to 1984 and obtains the transitivity of productivity measures by applying the *CCD* method directly to the whole panel of region-time periods, i.e., treating time and space dimensions symmetrically. Hill (1999) compares price indexes across countries using the Kruskal's *MST* algorithm, which selects the bilateral comparisons worth to be linked using a minimum spanning tree, a concept derived from graph theory.

Following Hill (2002; 2004), in this study we construct longitudinal indexes by means of the so-called *temporally fixed grid graph* (*TFGG*), which tries to reconcile temporal and spatial variations. In essence the method is as follows. The *EKS* relative quantity indexes are calculated at five-year intervals whereas the temporal comparisons for the intervening years are made by chaining Fisher quantity indexes except in the year that a new *EKS* regional comparison is made. In such years only the chronological chain of one region is used to link between subsequent intervals. We repeat this using each region in turn and, finally, to overcome the lack of regional invariance, we take the geometric mean of the whole sets of results. This method, which is referred to as *GM* (*TFGG*), violates both temporal consistency (unless the temporal displacement equals the number of time periods *T*) and spatial consistency (unless the temporal displacement is zero, i.e., the *EKS* comparisons are calculated every year). However, it satisfies temporal fixity. Moreover, it is advocated over temporally consistent methods when *T* is large. Given that spatial comparisons are updated regularly and not extrapolated over longer and longer spans of time, the risk of unaccounted regional drifts years away from the reference period is drastically reduced.

3. DATA

The study covers the years from 1951 to 2002. Data are taken from Agrefit, which is a new database of Italian agriculture at regional level (Rizzi and Pierani, 2006)[8]. Each variable is arrived at as a superlative Fisher index. In short, total output aggregates quantities of sixteen

[7] This paper does not attempt any systematic survey of the literature. Thus, my reference to it is necessarily selective and may leave out some contributions.
[8] The Italian regions are: Valle d'Aosta (VA), Piemonte (PI), Lombardia (LO), Liguria (LI), Trentino A.A. (TR), Friuli V.G. (FR), Veneto (VE), Emilia R. (ER), Toscana (TO), Umbria (UM) Marche (MA), Lazio (LA), Abruzzo (AB), Molise (MO), Campania (CA), Puglia (PU), Basilicata (BA), Calabria (CL), Sicilia (SI) and Sardegna (SA).

commodities. Quantity data include categories like self-produced inputs that are used on the farm. Prices reflect the value of specific outputs to the producer, that is, production subsidies are added to market values, and are net of indirect taxes.

Intermediate inputs consist of goods and services used in production during the calendar year, whether purchased from outside or produced within the farm sector, as long as they appear in output as well. The feed costs amount to outlays on compounds forages, feed grains and so forth; the remaining intermediate inputs mainly include agricultural chemicals, seeds, energy, veterinary costs, as well as overheads, i.e. repair and maintenance costs of building and capital equipment, insurance and rent.

Capital input aggregates several asset types. The capital stocks of depreciable assets, such as machinery and equipment, building and structure, are the sum of all past investments adjusted for discards of worn-out assets and efficiency loss over their service life. The efficiency loss is approximated with a hyperbolic function whose concavity to the origin is asset specific. In order to determine the actual amount of capital available for production, we assume that each asset type has a stochastic service life, distributed as a normal truncated at two standard deviation points around the mean (Ball *et al*., 1997). The rental price estimates for each asset type are arrived at implicitly, based on the correspondence between the purchase price and the discounted value of future service flows for that asset (Harper *et al*., 1989) with some admittedly simplifying assumptions (Diewert, 2005b). Concerning breeding livestock and land ad hoc working assumptions have been adopted.

Labour input is expressed in equivalent fully employed workers. It distinguishes between self-employed and hired labour but it is not cross-stratified by any other characteristics, e.g., gender, age, education, and so forth. Average annual compensation per worker, gross of contributions to social security and other supplements, is based on wage and salary income for employees from National Account. Since average compensation is not available for self-employed and family labour, we compute it implicitly; namely, each self employed worker is imputed the mean wage obtained by dividing the net operating surplus, i.e., gross operating surplus minus the rental value of capital service flows, by the number of self employed workers.

4. Relative levels and growth of output, input and productivity

In this section, our purpose is to compare relative levels and growth rates of output, inputs and agricultural total factor productivity (*TFP*) among the twenty Italian regions for the period

1951 to 2002[9]. These comparisons are based on multilateral *EKS* indexes, which are a weighted geometric mean of binary Fisher indexes[10]. The multilateral *EKS* transitive comparisons are calculated every five years and chain-linked forward in time according to the *GM* (*TFGG*) approach discussed above. For the sake of presentation all values are shown relative to Piemonte in 1951. Annual rates of growth are given for the full period and five sub-periods in the right panel of each table. They are estimated fitting a semilog model on a piecewise linear trend with knots at the turn of each decade. As we preferred to work with annual observations instead of using moving average transformations,[11] this seems appropriate to smooth out the idiosyncratic unpredictable variability of agricultural data.

Output is presented in table 1. Among the twenty regions, Toscana and Marche were the only regions to have lower levels of real output relative to Piemonte in 2002 than they had in 1951. Valle d'Aosta, Umbria and Molise were about the same, whereas the other regions had higher levels of real output. The most dramatic gain was for Puglia, with output almost doubling and Lombardia and Veneto increasing more than thirty percent relative to Piemonte between 1951 and 2002 (obtained by dividing the regional values by Piemonte in 2002).

Turning to capital input (table 3), all the northern and central regions, with the exception of Valle d'Aosta and Trentino, had substantially lower levels of capital input relative to Piemonte in 2002 than they had at the beginning of the period, while the southern regions, with the exception of Calabria and Sardegna, had higher levels. The largest reduction, of about one third or more, was for Lombardia and Emilia Romagna, which began with the highest levels relative to Piemonte in 1951 at about 1.6. Veneto was the only region above Piemonte at the beginning of the period at 1.3, which has lost steadily ever since, ending with a relative level of capital in 2002 lower than unity.

As for labour (table 4), there was a generalized dramatic decline in absolute terms, although only in Toscana, Umbria, Marche, Abruzzo and Molise, labour input fell substantially relative to Piemonte. The remaining regions increased their relative labour input over this period.

Table 5 shows levels of intermediate input. Lombardia and Emilia Romagna had the highest intermediate input levels relative to Piemonte in 1951 at 1.5 and 1.2, respectively, which increased to about 1.8 and 1.5 in 2002. Valle d'Aosta, Liguria and Molise had the lowest intermediate input levels among the twenty Italian regions in 1951 at between 2 and 9 per cent.

---

[9] To save space we report only selected years. The complete set of results as well as the TSP programs for the computation of the Fisher, *EKS* and *GM*(*TFGG*) indexes are available upon request.

[10] Comparing the indexes obtained with the democratic, plutocratic and own share criteria, it turns out that they are not that sensitive to the choice of the alternative weighting systems. Some notable erratic differences emerge instead if we use similarity and PLS weights. Eventually, we opted for the plutocratic weighting system.

[11] We have repeated the exercise with the data transformed into five-year moving averages, and the overall results (not reported here) remain basically unchanged.

Finally, table 6 presents relative levels of total factor productivity. These indexes are also normalized so that the productivity of Piemonte in 1951 is one. Of the twenty Italian regions, only a few (Valle d'Aosta, Emilia Romagna, Puglia, Calabria, Sicilia and Sardegna) decreased productivity levels relative to Piemonte. Apparently, the largest loss was for the two Islands. They began the period in 1951 with a higher level of productivity than Piemonte and well above any other region (excluded Valle d'Aosta). By the end of the period in 2002, they had been overtaken or reached by practically all regions. Valle d'Aosta, which is the smallest Italian region, began the study period with the highest relative level of productivity at 1.6, whereas Liguria, Toscana, Umbria, Marche and Abruzzo had the lowest relative levels of productivity at between 0.6 and 0.7. (By 2002, the range of relative levels of total factor productivity had narrowed significantly – from 2.5 for Toscana to 3.4 for Valle d'Aosta). Aiello and Scoppa (2000) explain these regional differences with certain development indicators, such as infrastructures and State intervention, the functioning of the financial system and agglomeration economies.

The growth rates of output, inputs and productivity are mostly statistically significant and show a marked variability. The few non significant figures are sparse without an apparent spatial or temporal pattern. In summary, we can say that on average total output has grown at a rate of about 1.21% annually, whereas total input diminished at an average rate of about 1.03 (table 2), so that the resulting rate of growth of the residual is 2.24% per year[12]. Excluding the first decade, the aggregate input has declined steadily during the investigation period as result of the contrasting tendencies of its components. Given the structure of Italian agriculture and hence the relative importance of input shares on total cost, the migration of labour force from agriculture, which has proceeded at a rate higher than 3.5% a year, finished to prevail. The average growth of both capital (2.8%) and intermediate consumption (1.3%) could not balance the decline of the aggregate input.

Throughout, the outflow of agricultural workers reached the strongest intensity in the Centre (-4.9%), on average two percentage points more than the South (-2.9%) and well above the national rate (-3.6%). The capital growth of the central regions has been somewhat below average, thus the aggregate input in the Centre has declined at the highest pace (2.2%). During the 1960s migration outside the primary sector in search of better job opportunities was a generalized phenomenon and proceeded at the historically highest speed and, though at a relented pace, it never stopped ever since.

[12] Using the *CCD* index number framework and basically the same geographical and commodity aggregation level, Pierani (1989) finds that regional *TFP* has improved annually at an average rate of 2.2% over the years 1970-84. Istat (1995) estimates a higher average growth for the period 1980-1994, namely 2.7%.

As opposed to the persistent decline of labour, capital accumulation is characterized by greater variability and trend segmentations. In this respect, the 1980s represent a turning point, with the slowdown followed by a trend inversion of the flow of capital services, reflecting the concomitant drop of real investment in Italian agriculture. It is a phenomenon that in the North has lasted for about a decade whereas in Central and Southern regions has persisted a bit longer and eventually brought the level of agricultural capitalization back to the late 1970s.

In table 7 we rank the regions by the level of agricultural *TFP* in 1951. Also, included are their rank in 2002 and the implied average annual percentage growth. The information is completed with an index of the productivity gap and its standard error. The regional gap is defined as the ratio of the productivity level in the leading region to that of the other regions, which is then averaged over all twenty regions.

The results suggest a few stylized facts. First, contrary to common expectation Northern agriculture was not the most efficient in the initial year of the study. Among the five leading positions, there is only Valle d'Aosta, which is the smallest Italian region characterized by an Alpine economy and a negligible agricultural sector (see table 1) and that is why it is often disregarded in this kind of analysis as an outlier (Di Liberto *et al.*, 2003). The reasons for this peculiar result are manifold: the already mentioned idiosyncratic variability of agricultural data, the reconstruction phase after the WWII, which had long lasting implications with technologically advanced niches and less developed areas coexisting in the same region, and, finally, the information quality of reconstructed data which may possibly deteriorate going far back in time.

Second, every region exhibits a positive and generally substantial productivity growth. There is considerable variability, however. The reported rates of growth ranged from 0.95 for Sardegna to 3.35 for Umbria. About two third of the regions had productivity growths averaging more than 2 percent per year. The average rate of productivity growth was 2.23 percent per year.

Third, the disparity of growth rates over the investigation period resulted in substantial changes in the regional rankings. Figure 1 gives a graphical representation of the shifts between 1951 and 2002, with regions below (above) the 45^0 indifference line that improved (worsened) their initial position. For example, Umbria and Abruzzo made the largest relative gains in *TFP*, the former rising from twentieth to eighth, the latter from seventeenth to fifth. On the opposite, Sicilia and Puglia fell from the third and fourth to the nineteenth and seventeenth, respectively. Valle d'Aosta and Veneto were first and thirteen, respectively, throughout the period.

Fourth, the average productivity gap narrowed from 1.8 in 1951 to 1.5 in 2002 and its dispersion, measured by the standard deviation, has fallen by two third, from 0.55 to 0.19.

Apparently, gap reduction has not proceeded at constant pace during the half-century. Esposti (2008) finds that interregional spillover and learning and public R&D are the major driving forces of *TFP* growth, whereas the idiosyncratic component and intraregional spillover are negligible.

5. σ - CONVERGENCE AND β -CONVERGENCE

The shuffling of relative positions due to the different rates of growth has implied some convergence process. Evidence of such productivity convergence can be seen in figure 2, which plots for each year the standard deviation of log productivity levels for all regions (σ_t)[13]. Set at 1 in 1951, σ_t declines steadily to about 0.13 in 1995. Thereafter the narrowing of regional productivity levels stops abruptly.

The extent to which this convergence process is statistically significant is measured by a formal test proposed by Carree and Klomp (1997). Under the null of no σ-convergence, i.e. that the variances in the first and last periods are equal, their test statistic T_3 has asymptotically a standard normal distribution and is computed as follows:

$$T_3 = \frac{\sqrt{N}\left(\sigma_1^2 / \sigma_T^2 - 1\right)}{2\sqrt{1-(1-\hat{\beta})^2}}$$

where σ_1 and σ_T are the standard deviations of log productivity across the regions in the first and last period, respectively, and $\hat{\beta}$ is the least squares estimate of the convergence rate in the growth-initial level regression, i.e.,

$$\ln y_{iT} = \alpha + (1-\beta)\ln y_{i1} + \varepsilon_i$$

with 0 indicating no convergence and 1 implying complete convergence. The estimates of the rate of β-convergence for regional productivity along with the corresponding *t*-values are presented in table 8. For the whole period the estimated rate of β-convergence is about 0.82, which is significant at the 1% level. Moving to sub-periods, convergence takes place at an increasing and statistically significant rate during the 1960s, 1970s and 1980s. The fourth and fifth column of table 8 report the standard deviations in the first and last year of the period. A decrease of this value indicates that productivity differences across regions have declined over

[13] We use this measure to show that there was a marked clustering of the range of productivity levels. Another indicator of cross section dispersion commonly used is the coefficient of variation (the ratio of the standard deviation to the mean). The two measures can lead to conflicting results, the reason being that they assign different weights to individual region's growth performance (Dalgaard and Vastrup, 2001). In our case, the standard deviation and the coefficient of variation overlap one another, so we dropped the coefficient of variation.

that period. In the last column the T_3-statistic is presented. According to this statistic only the whole investigation period and the 1970s decade show a significant σ-convergence at the 1% level, while there is basically no change or σ-divergence elsewhere. As a matter of fact, each period with a significant positive value of the T_3-statistic also has a significant positive value of β. However, there are also periods, the 1960s and 1980s, which show significant β-convergence despite a statistically irrelevant decrease in the value of σ_t. Moreover, the spread of the rate of convergence across periods is notable, being the highest during the decade of the 1980s. One of the reasons for this spread is the variety and timing of public intervention in favour of the regions lagging behind in terms of productivity. The fact that some region grew more rapidly than others and yet the cross-section dispersion decreased implies that the regions that grew faster were those with lower initial level of productivity, a finding consistent with technological catch up.

On the whole, these findings reassert that until the end of the 1960s, both the variance reduction and at a lesser extent the speed of adjustment towards the equilibrium do not gain momentum; thereafter the process of σ-convergence has been lasting for about twenty years, loosing significance only during the 1980s. The results confirm that σ-convergence implies β-convergence, but that the contrary is not true (Carree *et al.*, 2000; Wodon and Yitzhaki, 2006).

6. β-CONVERGENCE BASED ON PANEL DATA

To complete our analysis we report β-convergence estimates based on panel data. It is by now a generally accepted argument that the commonly used unit root tests based on a single time series suffer of power deficiency and that using panel data unit root tests is one way of increasing their power. Chang (2002) proposes a simple alternative to the tests for unit roots based on cross-sectional independence of panel data: the non-linear IV test.

The non-linear IV unit root test is robust to cross-sectional dependence and is based on IV estimation of the usual ADF type regression for each cross-sectional unit, using as instruments non-linear transformations of lagged levels. The actual test statistic is simply defined as a standardized sum of individual IV *t*-ratios, which is asymptotically distributed as standard normal even for unbalanced panels with general cross-sectional dependencies. This average IV *t*-ratio statistics performs better as compared, for example, to the commonly used *t*-bar test by Im *et al*. (2003) in terms of both finite sample size and power.

In practice, the test is based on the estimates of the autoregressive coefficients from the following regression for each cross-sectional unit

$$\ln y_{it} = \alpha_i \ln y_{i,t-1} + \sum_{\tau=1}^{p_i} \alpha_{i,\tau} \Delta \ln y_{i,t-\tau} + \varepsilon_{it}$$

For testing the unit root null $H_0 : \alpha_i = 1$ for $i = 1, ..., N$, we construct the non-linear IV *t*-ratio as $Z_i = (\hat{\alpha}_i - 1) / s.e.(\hat{\alpha}_i)$ where $s.e.(\hat{\alpha}_i)$ is the standard error of the IV estimator $\hat{\alpha}_i$. The rejection of the null hypothesis implies that the productivity index is mean reverting; i.e., given that the transitivity of the *EKS* indexes is arrived at via indirect comparisons of each region and a reference meta-region, under the alternative any deviation from the reference should dampen over time, suggesting that the productivity gap is temporary and hence convergence.

The actual statistics to test the joint unit root hypothesis $H_0 : \alpha_1 = ... = \alpha_N = 1$, is based on the individual *t*-ratios and it is defined as

$$S_N = \sum_{i=1}^{N} Z_i / \sqrt{N}$$

To test for contemporaneous spatial dependence we apply both the Lagrange multiplier (LM) test proposed by Breusch and Pagan (1980) and a simple alternative (CD) suggested by Pesaran (2004). The CD test is based on average of pair-wise correlation coefficients of the OLS residuals[14] from the individual regressions in the panel rather than their squares used in the LM test; it has the correct size in very small samples and satisfactory power and it is quite robust to the presence of unit roots and structural breaks. The CD statistic is asymptotically standard normal whereas the LM statistic is asymptotically distributed as chi-squared with $N(N-1)/2$ degrees of freedom.

Table 9 summarizes the results of panel unit root and spatial dependence tests within region groupings. The pair of tests consistently rejects the hypothesis that total factor productivity indexes are spatially independent for all groups. The findings also indicate a weakening of the intensity of cross section correlation in northern and central regions and, generally, over the more recent period (not reported here). The highest degree of spatial correlation is found to be within all regions as well as the South. Therefore, the use of the non-linear IV test under cross-sectional dependence of panel data is justified in this study. Although the models may have different AR orders for individual cross-sectional units, in estimation we consider homogeneous dynamic structures of order 2 for all regions, and use demeaned relative productivity time series by construction. The first column of table 9 suggests that the unit root null hypothesis is rejected group wise. In particular, the value of S_N = -6.65 strongly rejects, in spite of the IV *t*-ratio Z_i, which is statistically significant only in nine cases. This is not surprising, as erratic responses of a few regions need not alter the outcome of the panel unit root test, namely that regional

[14] For each region, the OLS residuals are computed from the *AR*(2) regression in the log productivity index with an intercept and a linear trend.

productivities are jointly stationary (Das and Bhattacharya, 2008). In other words, given that any efficiency shock will not drive regional productivities away from their mean the test supports convergence of regional productivities.

7. CONVERGENCE BY REGION AND PERIOD

Almost all studies use pooled regressions, under the assumption that individual cross-sectional units may have different efficiency levels but do share the same convergence rate (Islam, 2003), i.e., the same slope coefficient for all the cross-sectional units. The latter may not be a tenable assumption and in fact the null of slope parameter homogeneity across units is often rejected. This section considers the subject of pooling, allowing for spatial heterogeneity and temporal instability, using a hierarchical Bayesian method (Maddala *et al.*, 1997).

In short, the statistical setup is as follows. Let consider the autoregressive model:

$$\ln y_{it} = \alpha_i + \rho_i \ln y_{i,t-1} + \varepsilon_{it}$$

where y_i is the *i*th demeaned relative productivity index, ε_i is i.i.d. $N\left(0, \sigma_i^2 I_T\right)$ and $\beta_i^{'} = \left(\alpha_i, \rho_i\right)$ is a parameter vector, whose prior distribution is $N\left(\mu, \Sigma\right)$, i.e., each parameter vector is region specific while their mean is a constant. In the Bayesian framework, if μ, σ_i^2 and Σ are known, the posterior distribution of β_i is asymptotically normal with mean given by

$$\beta_i^* = \left(\frac{1}{\sigma_i^2} X_i^{'} X_i + \Sigma\right)^{-1} \left(\frac{1}{\sigma_i^2} X_i^{'} X_i \hat{\beta}_i + \Sigma^{-1} \mu\right)$$

where $\hat{\beta}_i$ is the OLS estimate of β_i, X_i is a matrix whose first column is a vector of ones and second column is the lagged productivity index. In practice, given that the above relevant parameters are unknown, no closed form solution exists for the posterior means. Thus, the empirical Bayes estimator has to be computed iteratively, with the initial iteration using the OLS estimator $\hat{\beta}_i$ to compute approximations to vague priors of μ, σ_i^2 and Σ (Smith, 1973). These estimates are also known as shrinkage estimators (Maddala and Wu, 2000). What we get are the shrinkage estimators of βs for each region as well as the mean of βs.

To investigate heterogeneity and instability issues, the previous autoregressive equation is estimated under different regimes. We split the sample up into five sub periods each of which is marked off by specific technological, policy and/or institutional events. In terms of selected CAP related episodes, for example, the first regime (1951/60) depicts the foundation phase; in the second regime (1961/70) the first common market organisations were adopted, including initial levels of cereals prices, and the Mansholt Plan envisaged the first structural reform of the agricultural sector; during the 1970s the first enlargement took place to include Denmark, Ireland and the UK; in the fourth regime (1981/90) milk production quotas and stabilisers on CAP spending were introduced; the final regime (1991/02) is a period of policy concerns and tentative reforms due to budgetary and trade pressures, which materialized in cuts in some support prices with compensatory direct payments (MacSharry reform) as well as in the introduction of support for rural development (Agenda 2000 reform). Of course, one could refine the above intervals according to technological advance and/or business cycle arguments as well as the already mentioned institutional changes. Definitely though those events have had a differential impact on Italian regions due to specific resource endowments and structures and have affected their convergence paths and steady states.

Empirically, we first allow α_i and ρ_i to be different across regions but constant in time; second, α_i can vary across regions and over time; third, we let both parameters be different across regions and over time. Apparently, one robust conclusion is that the convergence rates are higher than those obtained from pooled regressions under the assumption of homogeneity and that there is temporal instability in the relationships. Table 10 presents the results for the whole half century (1951-2002) and includes the estimates of α s and ρ s, the implied convergence rates, steady states, and half lives for the twenty Italian regions and their mean.

The estimates of the means of α and ρ are -0.002 and 0.816, with standard errors (reported only for the mean parameters) equal to 0.000 and 0.267, respectively. This information can be possibly used to construct confidence intervals. These findings imply an average convergence rate of 18.4% per year and a half life of 3.8 years, whereby Italian agriculture would take about four years to bridge half gap towards the steady state efficiency level. In fact, the table shows a wide spectrum of α s and ρ s. Looking at those half lives, we see that Lombardia, Veneto, Puglia and Basilicata have the lowest half lives which are less than 2 years. On the other hand, Valle d'Aosta (North), Umbria (Centre) and Sardegna (Island) have the highest half lives of more than 15 years. The convergence rates range from 3.5% per year for Umbria to 50% per year for Puglia, with four of the southern regions (Molise, Campania, Puglia and Basilicata) and four of the northern regions (Piemonte, Lombardia, Trentino and Veneto) growing faster than the average.

On the whole, such differentiated rates of growth do not lead Italian agriculture toward a common efficiency level, rather the implied steady states suggest that 50 years has not been a long enough period to close the agricultural efficiency gap especially between the dynamic and relented groupings of Italian regions.

For the sake of comparison, the last row and column of the table contain the estimates of the convergence rate and steady states resulting from the conventional fixed-effect model[15]. The convergence rate in the pooled model is about 2.5 percentage points lower than the unconstrained Bayesian parameter, which it can be argued is the consequence of imposing the homogeneity constraint.

These results seem to support the hypothesis that there is a heterogeneous (conditional) convergence process, which is stable over time though. To investigate the instability issue and see whether regional agricultures head all the way to their fixed steady state, we estimate the autoregressive model letting each individual intercept vary every 10 years or so.

The estimated convergence rates, half lives and steady states by regime are reported in table 11. We have now a β equal to 15.1% per year and a corresponding 4.6 year half life, which is similar to the fixed effect model. The relative position of efficiency gains remain practically the same with the notable differences of three central regions (Umbria, Marche and Lazio), whose growth rates are much faster than those in table 10 and Emilia Romagna whose β fell to less than two percent a year. We observe also that mean steady states are different in different regimes. This cyclical adjustment of long term equilibrium does imply a monotonic improvement of efficiency starting from the 1960s. Since each region can grow at different rate even in the steady state, the discrepancy among regional productivities in Italian agriculture is likely to persist over time as can be seen from the diversity of steady state levels.

To complete the stability analysis we estimate the model for different regimes separately. From table 12 we observe that the assumption that the convergence rate can vary over time is supported by data. In particular, there is a generalized increase of convergence rate moving from the first to the second sub-period. The mean convergence rate jumps from 10.84% per year and a corresponding 6.4 year half life to 32.33% per year and a corresponding 2.1 year half life. The remaining three periods have a relatively smaller and declining convergence rates.

8. CONCLUSION

This paper has focused on two main topics. First, it has applied a methodology for constructing panel indexes to agricultural productivity of Italian regions. Throughout, longitudinal comparisons have been constructed using the *GM* (*TFGG*) method, which combines the temporal and spatial dimensions of index numbers by satisfying temporal fixity. The method

[15] The pooled model with regional dummies is estimated with a 2SLS estimator, which uses as instrument a non-linear transformation of the lagged productivity level (Chang, 2002).

recognizes that each binary comparisons has a specific reliability attached to it and uses this information to aggregate consistently over the examined regions.

The second focus of the paper has been to assess the existence of some convergence process in Italian regions. We consider the standard deviation of agricultural log productivity for each year as indicator of regional dispersion as well as the problems of heterogeneity and stability of cross-section growth regressions using a hierarchical Bayesian method based on panel data.

Data are taken from Agrefit, which is a new database of Italian agriculture at regional level over the period 1951-2002. Besides providing practitioners with a unique set of multilateral comparisons of agricultural output, inputs and productivity for Italian regions over the last half century, the main findings of this study can be summarized as follows:

a) at the national level, from 1951 to 2002, agricultural productivity tripled; on average it grew by 2.2% per annum, reflecting an output growth of 1.2% per annum and a decrease in input use of 1% per annum. These aggregate figures, however, are far from constant, e.g., productivity growth ranged from 3.6% during the 1960s to around 1% during the 1970s, and mask notable variations across regions. The average growth rates stretched from 0.95% for Sardinia to 3.35% for Umbria. The wide disparity in growth rates resulted in notable changes in the rank order and diminished significantly regional differences. In the pursuit of higher efficiency levels mainly Central and Southern regions have improved their positions;
b) for the full 1951-2002 period, the average convergence rate of Italian agriculture is 18.4% per year, whereby it would take about four years to bridge half gap towards the steady state productivity level; however, allowing for regional heterogeneity results in convergence rates that extend from 3.5% to 50% per year and a spectrum of half lives ranging from 2 to 20 years;
c) in fact, such conditional convergence process is not stable over time. First, one can observe different steady states in subsequent decades. This cyclical adjustment of long term equilibrium does imply a continuous improvement of regional productivity since the 1960s. Given that each region can grow at different rate even in the steady state, the discrepancy among regional productivities in Italian agriculture is likely to persist over time as can be seen from the diversity of steady state levels. Finally, there is a generalized increase of convergence rate moving from the first to the second sub-period, whereas later on they get smaller and smaller.

There are a number of logical extensions for this study. First, given that alternative weighting systems of the binary Fisher indexes are likely to produce some effect on the final EKS transitive comparisons of output, input and productivity, future research needs to be conducted on this critical step, which otherwise is left to subjective choice. Second, the reliability of our estimates needs to be confronted with some measure of statistical confidence, e.g., bootstrapped confidence intervals or standard errors. Third, in this paper we have only dealt with the measurement but not with the explanation of technology levels and growth. It would be interesting to examine in a regression framework as to what are the sources of growth and convergence other than the region-specific initial productivity level and spatial dependence, e.g., public R&D, infrastructures and EU regional policies, whose impact has been discussed and increasingly questioned (Cappelen *et al.*, 2003; Esposti, 2007). The exploration of these challenging topics is left to future research.

REFERENCES

F. AIELLO, V. SCOPPA (2000), Uneven Regional Development in Italy: Explaining Differences in Productivity Levels. *Giornale degli Economisti e Annali di Economia*, Vol. 60, No. 2, 270-298.

B.M. BALK (1996), A Comparison of Ten Methods for Multilateral International Price and Volume Comparison. *Journal of Official Statistics*, Vol. 12, No. 2, 199-222. .

B.M. BALK (2001), Aggregation Methods in International Comparisons: What Have We Learned? *ERIM Report Series*, ERS-2001-41-MKT.

V.E. BALL, J.C. BUREAU, R. NEHRING, A. SOMWARU (1997), Agricultural Productivity Revisited. *American Journal of Agricultural Economics*, 79, 1045-1063.

V.E. BALL, J.C. BUREAU, J.P. BUTAULT, R. NEHRING (2001), Levels of Farm Sector Productivity: An International Comparison. *Journal of Productivity Analysis*, 15, 5-29.

V.E. BALL, J.P. BUTAULT, R. NEHRING (2002), U.S. Agriculture, 1960-96: A Multilateral Comparison of Total Factor Productivity, in V.E. BALL, G.W. NORTON (eds.), *Agricultural Productivity: Measurement and Sources of Growth*, Kluwer Academic Publishers, 11-36.

V.E. BALL, C. HALLAHAN, R. NEHRING (2004), Convergence of Productivity: An Analysis of the Catch-up Hypothesis within a Panel of States. *American Journal of Agricultural Economics*, Vol. 85, No. 5, 1315-1321.

C. BERNINI CARRI (2003), Il processo di convergenza delle produttività agricole delle regioni italiane: 1980-1999. *Rivista di Economia Agraria*, Vol. 58, No. 21, 189-218.

T.S. BREUSCH, A.R. PAGAN (1980), The Lagrange Multiplier Test and its Application to Model Specifications in Econometrics, *Review of Economic Studies*, 47, 239-253.

J. BYRNE, G. FAZIO, D. PIACENTINO (2009), Convergence in TFP among Italian Regions:Panel Unit Roots with Heterogeneity and Cross Sectional Dependence. *Regional Studies*, Vol. 43, No. 1, 63-76.

CAPPELEN, F. CASTELLACCI, J. FAGERBERG, B. VERSPAGEN (2003), The Impact of EU Regional Support on Growth and Convergence in the European Union. *Journal of Common Market Studies*, Vol. 41, No. 4, 621-644.

M. CARREE, L. KLOMP (1997), Testing the Convergence Hypothesis: A Comment. *The Review of Economics and Statistics*, Vol. 79, No. 4, 683-686.

M. CARREE, L. KLOMP, A.R. THURIK (2000), Productivity convergence in OECD manufacturing industries. *Economics Letters*, 66, 337-345.

D.W. CAVES, L.R. CHRISTENSEN, W.E. DIEWERT (1982), Multilateral Comparisons of Output, Input and Productivity using Superlative Index Numbers. *The Economic Journal*, 92, 73-86.

Y. CHANG (2002), Nonlinear IV unit root tests in panels with cross-sectional dependency. *Journal of Econometrics*, 110, 261-292.

M. COSTANTINI, G. ARBIA (2006), Testing the stochastic convergence of Italian regions using panel data. *Applied Economics Letters*, Vol. 13, No. 12, 775-783.

C.J. DALGAARD, J. VASTRUP (2001), On the measurement of σ-convergence. *Economics Letters*, 70, 283-287.

S. DAS, K. BHATTACHARYA (2008), Price convergence across regions in India. *Empirical Economics*, 34, 299-313.

W.E. DIEWERT (1976), Exact and Superlative Index Numbers. *Journal of Econometrics*, 4, 114-145.

W.E. DIEWERT (1992), Fisher Ideal Output, Input, and Productivity Indices Revisited. *Journal of Productivity Analysis*, 3, 211-248.

W.E. DIEWERT (1999), Axiomatic and Economic Approaches to International Comparisons, in A. ESTON, R.E. LIPSEY (eds.), *International and Interarea Comparisons of Income, Output and Prices*, NBER, The University of Chicago Press, Chicago, 13-87.

W.E. DIEWERT (2005a), Similarity Indexes and Criteria for Spatial Linking, in D.S. PRASADA RAO (ed.), *Purchasing Power Parities of Currencies: Recent Advances in Methods and Applications*, Edward Elgar, Cheltenham, UK.

W.E. DIEWERT (2005b), Issues in the Measurement of Capital Services, Depreciation, Asset Price Changes and Interest Rates, in C. CORRADO, J. HALTIWANGER, D. SICHEL (eds.), *Measuring Capital in the New Economy,* The University of Chicago Press, Chicago, 479-542.

DI LIBERTO, R. MURA, F. PIGLIARU (2003), A panel technique for the analysis of technology convergence: The case of Italian regions. ERSA conference paper, *mimeo*.

L. DRECHSLER (1973), Weighting of Index Numbers in Multilateral International Comparisons. *Review of Income and Wealth*, Vol. 19, No. 1, 17-34.

O. ELTETÖ, P. KÖVES (1964), On a Problem of Index Number Computation Relating to International Comparison, *Statisztikai Szemele*, 42, 507-518.

R. ESPOSTI (2007), Regional Growth and Policies in the European Union: Does the Common Agricultural Policy have a Counter-Treatment Effect? *American Journal of Agricultural Economics*, Vol. 89, No. 1, 116-134.

R. ESPOSTI (2008), Why Should Regional Agricultural Productivity Growth Converge? Evidence from Italian Regions. Contributed Paper, *XII Congress of the European Association of Agricultural Economists*, Copenhagen.

EUROSTAT (2008), GDP per capita, consumption per capita and comparative price levels in Europe, *Statistics in Focus*, 3.

K.J. FOX (2003), An Economic Justification for the EKS Multilateral Index. *Review of Income and Wealth*, Vol. 49, 407-413.

M.J. HARPER, E.R. BERNDT, D.O. WOOD (1989), Rates of Return and Capital Aggregation using Alternative Rental Prices, in D.W. JORGENSON, R. LANDAU (eds.), *Technology and Capital Formation*, Cambridge, MA, The MIT Press, 331-72.

R.J. HILL (1997), Taxonomy of Multilateral Methods for Making International Comparisons of Prices and Quantities. *Review of Income and Wealth*, Vol. 43, No. 1, 49-69.

R.J. HILL (1999), Comparing Price Levels Across Countries Using Minimum Spanning Trees. *The Review of Economics and Statistics*, Vol. 81, No. 1, 135-142.

R.J. HILL (2002), Measuring Price Differences Across Space and Time: The Case of the European Union's Harmonized Index of Consumer Prices. *Discussion Paper,* School of Economics, The University of New South Wales.

R.J. HILL (2004), Constructing Price Indexes across Space and Time: The Case of the European Union. *The American Economic Review*, Vol. 94, No. 5, 1379-1410.

K.S. IM, M.H. PESARAN, S. SHIN (2003), Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115, 53-74.

N. ISLAM (2003), What have we learnt from the convergence debate? *Journal of Economic Surveys*, Vol. 17, No. 3, 309-362.

ISTAT (1995), Investimenti, stock di capitale e produttività dei fattori: anni 1980-94. *Note e relazioni*, No. 2.

ISTAT (2008), Differenze nel livello dei prezzi tra i capoluoghi nelle regioni italiane per alcune tipologie di beni, http://www.istat.it/salastampa/comunicati/non_calendario/20080422_00/.

M Lanzafame (2005), *Economic Structure, Technology Diffusion and Convergence: The Case of the Italian Regions*. Department of Economics, University of Kent, Studies in Economics, No. 0507.

L. LEONIDA, C. PETRAGLIA, L.R. MURILLO-ZAMORANO (2004), Total factor productivity and the convergence hypothesis in the Italian regions. *Applied Economics*, Vol. 36, No. 19, 2187-2193.

G.S. MADDALA, R.P. TROST, H. LI, F. JOUTZ (1997), Estimation of Short-Run and Long-Run Elasticities of Energy Demand From Panel Data Using Shrinkage Estimators. *Journal of Business & Economic Statistics*, Vol. 15, No. 1, 90-100.

G.S. MADDALA, S. WU (2000), Cross-country growth regressions: Problems of heterogeneity, stability and interpretation. *Applied Economics*, 32, 635-642.

M. MAFFEZZOLI (2006), Convergence Across Italian Regions and the Role of Technological Catch-Up. *The B.E. Journal of Macroeconomics*, Vol. 6, No.1, Article 15.

R. PACI, F. PIGLIARU (1997), Structural change and convergence: an Italian regional perspective. *Structural Change and Economic Dynamics*, Vol. 8, No. 3, 297-318.

R. PACI, A. SABA (1998), The Empirics of Regional Economic Growth in Italy. 1951-1993. *Rivista Internazionale di Scienze Sociali ed Economiche*, Vol. 45, No. 3, 515-542.

M.H. PESARAN (2004), *General diagnostic tests for cross-sectional dependence in panels*. CESifo Working Paper, No. 1229.

P. PIERANI (1989), Numeri indice superlativi e produttività totale delle risorse nell'agricoltura italiana: un'analisi regionale. *Rivista di Economia Agraria*, Vol. 44, No. 2, 243-283.

D.S.P. RAO, K.S. BANERJEE (1984), A Multilateral Index Number System Based on the Factorial Approach. *Statistische Hefte*, 27, 297-313.

D.S.P. RAO, C.J. O'DONNELL, V.E. BALL (2002), Transitive Multilateral Comparisons of Agricultural Output, Input, and Productivity: A Nonparametric Approach, in V.E. BALL, G.W. NORTON (eds.), *Agricultural Productivity: Measurement and Sources of Growth*, Kluwer Academic Publishers, 85-116.

P.L. RIZZI, P. PIERANI (2006), *AGREFIT: Ricavi, costi e produttività dei fattori nell'agricoltura delle regioni italiane (1951-2002)*, Franco Angeli, Milano.

A. SHIU (2003), Multilateral Comparisons of Productivity, Terms of Trade and Factor Accumulation. *Review of Income and Wealth*, Vol. 49, No. 1, 35-52.

A.F.M. SMITH (1973), A General Bayes Linear Model. *Journal of the Royal Statistical Society B*, 35, 67-75.

B.J. SZULC (1964), Indices for Multiregional Comparisons. *Przeglad Statystyczny*, 3, 239-254.

M. TERRASI (1999), Convergence and divergence across Italian regions. *The Annals of Regional Science*, Vol. 33, 491-510.

Q. WODON, S. YITZHAKI (2006), Convergence forward and backward? *Economics Letters*, 92, 47-51.

Table 1. Output relative to 1951 level for Piemonte (selected years) and average annual growth[&]

Region	Output level						Growth rate(%)					
	1951	1960	1970	1980	1990	2002	1951/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	1.000	1.241	1.434	1.623	1.581	1.475	0.74	2.49	0.97	1.33	**-0.22**	**-0.12**
VA	0.025	0.026	0.027	0.032	0.032	0.032	0.63	1.80	**-0.31**	2.06	-0.52	0.61
LO	1.438	1.811	2.176	2.509	2.556	2.657	1.16	2.46	1.41	1.72	**0.27**	0.45
LI	0.171	0.216	0.304	0.266	0.331	0.328	1.45	3.58	4.00	-2.55	3.47	**0.40**
TR	0.173	0.201	0.259	0.321	0.451	0.481	2.32	2.64	1.15	3.21	3.27	**0.59**
FR	0.224	0.264	0.397	0.415	0.431	0.484	1.31	1.58	2.76	1.34	**-0.09**	1.25
VE	1.009	1.347	1.757	1.985	1.934	2.046	1.15	3.15	2.12	1.23	-0.45	1.06
ER	1.393	1.788	2.323	2.513	2.475	2.313	0.84	2.90	1.65	1.52	-0.79	**-0.14**
TO	0.561	0.736	0.905	0.932	0.808	0.879	0.47	3.11	1.43	**0.31**	-0.99	**0.25**
UM	0.204	0.283	0.339	0.354	0.377	0.350	0.88	4.03	**0.47**	1.15	**0.55**	**-0.31**
MA	0.400	0.515	0.642	0.619	0.645	0.556	0.47	3.53	1.08	**-0.12**	**0.20**	-0.72
LA	0.476	0.655	0.911	1.051	1.017	1.012	1.35	4.02	2.86	1.35	**-0.04**	**-0.23**
AB	0.255	0.325	0.436	0.509	0.449	0.534	1.21	3.73	3.04	0.86	-0.58	0.59
MO	0.104	0.120	0.155	0.156	0.179	0.172	0.84	3.25	1.63	**-0.50**	1.45	**-0.30**
CA	0.582	0.803	1.250	1.306	1.381	1.358	1.45	4.47	4.27	0.63	**-0.01**	-0.66
PU	0.670	0.817	1.179	1.632	1.230	1.673	2.06	4.02	3.28	1.16	1.62	1.53
BA	0.153	0.143	0.241	0.309	0.202	0.270	1.23	1.75	3.20	**1.14**	-1.25	2.32
CL	0.318	0.382	0.498	0.665	0.463	0.872	1.82	3.37	3.04	2.29	**-0.86**	2.76
SI	0.776	0.909	1.322	1.533	1.386	1.337	1.41	2.56	3.57	**0.31**	1.69	-0.99
SA	0.308	0.402	0.500	0.541	0.498	0.662	1.33	3.12	2.15	**0.14**	0.84	2.17
Average	0.512	0.649	0.853	0.964	0.921	0.975	1.21	3.08	2.19	0.93	0.38	0.53

[&] Log regression on segmented trend; the bold figures are not statistically significant at 5% level.

Table 2. Total input relative to 1951 level for Piemonte (selected years) and average annual growth[&]

Region	Total input level						Growth rate(%)					
	1951	1960	1970	1980	1990	2002	1951/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	1.000	1.121	1.009	0.895	0.680	0.545	-1.55	1.56	-1.59	-1.17	-2.70	-2.05
VA	0.015	0.013	0.011	0.012	0.012	0.007	-0.69	-1.21	-3.03	2.10	**0.40**	-4.07
LO	1.324	1.372	1.299	1.307	1.157	0.910	-0.84	0.51	-1.14	**0.28**	-1.39	-2.39
LI	0.247	0.253	0.231	0.206	0.126	0.135	-1.70	0.75	-0.91	-1.95	-4.05	**0.15**
TR	0.175	0.195	0.169	0.193	0.174	0.165	-0.23	0.87	-1.33	1.10	-0.92	-0.55
FR	0.311	0.314	0.278	0.235	0.180	0.160	-1.66	**0.25**	-1.68	-1.46	-2.71	-1.34
VE	1.212	1.208	1.112	1.049	0.856	0.704	-1.24	**-0.07**	-1.17	-0.42	-2.18	-2.01
ER	1.164	1.180	1.181	1.133	0.998	0.773	-0.88	**0.13**	**-0.31**	-0.70	-1.06	-2.44
TO	0.908	0.952	0.743	0.625	0.402	0.332	-2.51	**0.51**	-3.06	-1.36	-4.47	-2.27
UM	0.338	0.378	0.305	0.228	0.178	0.118	-2.47	1.69	-2.95	-2.89	-2.36	-3.59
MA	0.559	0.626	0.532	0.387	0.274	0.206	-2.45	1.38	-2.05	-3.08	-3.22	-2.81
LA	0.650	0.679	0.619	0.591	0.483	0.376	-1.28	0.57	-1.24	**-0.26**	-2.47	-2.37
AB	0.363	0.382	0.358	0.295	0.218	0.173	-1.82	0.49	-0.60	-2.44	-2.58	-2.63
MO	0.093	0.096	0.081	0.088	0.077	0.050	-1.06	**0.41**	-1.89	0.67	-1.18	-3.79
CA	0.559	0.620	0.628	0.656	0.545	0.404	-0.62	1.35	**0.19**	0.31	-1.75	-2.94
PU	0.503	0.587	0.566	0.774	0.680	0.623	0.50	1.59	**0.14**	2.28	-0.66	-1.05
BA	0.160	0.172	0.149	0.170	0.119	0.092	-0.95	0.76	-1.38	0.73	-1.74	-3.19
CL	0.259	0.254	0.209	0.253	0.199	0.247	0.22	**-0.17**	-1.43	2.26	**0.09**	**-0.69**
SI	0.518	0.579	0.546	0.656	0.641	0.526	0.27	0.88	**-0.07**	1.36	0.62	-2.32
SA	0.195	0.223	0.195	0.237	0.242	0.225	0.39	1.64	-1.71	2.27	0.63	-1.15
Average	0.528	0.560	0.511	0.500	0.412	0.339	-1.03	0.69	-1.36	-0.12	-1.68	-2.18

[&] Log regression on segmented trend; the bold figures are not statistically significant at 5% level.

Table 3. Capital input relative to 1951 level for Piemonte (selected years) and average annual growth[&]

Region	Capital level						Growth rate(%)					
	1951	1960	1970	1980	1990	2002	1951/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	1.000	1.623	2.903	3.788	3.406	4.336	2.48	6.08	5.77	2.56	-1.57	2.04
VA	0.006	0.006	0.007	0.014	0.029	0.019	4.25	**-0.65**	1.90	8.67	7.78	-3.90
LO	1.783	2.592	3.841	4.695	4.128	5.204	1.67	4.33	4.11	1.90	-1.80	1.81
LI	0.185	0.230	0.321	0.509	0.456	0.452	1.95	3.05	3.69	4.15	-1.40	**0.10**
TR	0.187	0.263	0.454	0.746	0.749	1.000	3.23	3.77	6.37	4.57	-0.77	2.33
FR	0.224	0.323	0.526	0.820	0.817	0.850	2.66	4.49	5.05	4.29	-0.54	0.22
VE	1.321	2.018	3.019	3.893	3.658	4.306	1.97	4.65	4.09	2.46	-1.07	1.41
ER	1.646	2.529	3.904	4.458	4.186	4.849	1.67	5.16	4.25	1.16	-0.93	1.06
TO	0.648	0.916	1.291	1.716	1.586	1.541	1.65	4.07	3.56	2.76	-1.15	-0.12
UM	0.215	0.323	0.518	0.792	0.782	0.754	2.62	5.16	4.56	4.29	-0.24	-0.22
MA	0.418	0.648	1.035	1.464	1.278	1.561	2.26	5.23	4.62	3.52	-1.88	1.56
LA	0.651	0.995	1.391	2.123	2.186	2.087	2.42	5.07	3.33	4.12	0.36	-0.35
AB	0.220	0.332	0.597	1.225	1.098	1.054	3.42	4.93	6.06	7.32	-1.65	-0.40
MO	0.096	0.136	0.206	0.477	0.543	0.442	3.79	3.75	4.34	8.77	1.12	-2.10
CA	0.559	0.744	1.127	2.395	2.670	2.504	3.51	3.70	4.18	7.43	0.87	-0.73
PU	0.604	0.788	1.221	2.926	3.105	3.544	3.90	3.51	4.45	8.89	**0.01**	**0.34**
BA	0.132	0.199	0.289	0.827	0.911	0.790	4.25	4.43	3.80	11.41	**0.14**	-1.95
CL	0.228	0.283	0.377	0.562	0.575	0.536	1.95	3.35	2.06	4.26	**0.20**	-0.55
SI	0.686	0.943	1.345	2.920	3.827	3.157	3.83	4.40	3.61	7.59	2.90	-1.90
SA	0.555	0.707	0.926	1.668	1.843	1.753	2.71	3.12	2.67	5.91	0.76	-0.29
Average	0.568	0.830	1.265	1.901	1.892	2.037	2.81	4.08	4.12	5.30	0.06	-0.08

[&] Log regression on segmented trend; the bold figures are not statistically significant at 5% level.

Table 4. Labor input relative to 1951 level for Piemonte (selected years) and average annual growth[&]

Region	Labor level						Growth rate (%)					
	1951	1960	1970	1980	1990	2002	1951/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	1.000	0.934	0.567	0.401	0.225	0.139	-4.32	-0.69	-5.24	-3.63	-5.53	-4.29
VA	0.017	0.013	0.008	0.005	0.005	0.003	-3.37	-3.04	-4.78	-4.46	-0.51	-4.21
LO	1.174	0.953	0.551	0.432	0.409	0.283	-2.88	-2.20	-6.06	-2.35	**-0.31**	-3.85
LI	0.464	0.426	0.287	0.193	0.091	0.078	-4.28	-0.64	-4.41	-4.05	-7.14	-1.74
TR	0.212	0.204	0.122	0.109	0.088	0.065	-2.47	-0.90	-5.13	-1.13	-1.99	-2.71
FR	0.386	0.310	0.184	0.110	0.074	0.057	-4.21	-2.05	-5.98	-5.27	-2.85	-3.07
VE	1.407	1.056	0.641	0.482	0.336	0.229	-3.71	-3.33	-5.11	-2.90	-3.30	-4.05
ER	1.113	0.900	0.590	0.497	0.385	0.242	-3.05	-2.58	-4.24	-2.38	-2.08	-4.46
TO	1.397	1.177	0.621	0.444	0.220	0.152	-5.07	-2.08	-7.07	-2.57	-7.60	-4.17
UM	0.455	0.426	0.206	0.116	0.082	0.041	-5.36	**-0.46**	-7.79	-5.99	-3.78	-6.02
MA	0.657	0.630	0.349	0.191	0.111	0.060	-5.27	-0.59	-5.69	-5.97	-5.37	-5.86
LA	0.850	0.692	0.448	0.333	0.223	0.148	-3.81	-2.60	-4.61	-2.45	-4.95	-3.92
AB	0.528	0.456	0.303	0.161	0.092	0.065	-4.90	-1.94	-3.89	-7.30	-4.94	-3.48
MO	0.101	0.085	0.053	0.036	0.019	0.009	-4.88	-2.47	-4.51	-5.00	-5.52	-5.54
CA	0.754	0.709	0.537	0.415	0.288	0.154	-3.12	-0.66	-3.07	-2.11	-3.87	-5.33
PU	0.633	0.644	0.453	0.503	0.397	0.276	-1.51	**-0.17**	-3.20	**0.38**	-1.88	-2.73
BA	0.184	0.166	0.100	0.081	0.032	0.026	-3.95	**-1.40**	-4.56	-3.17	-5.45	-3.41
CL	0.327	0.263	0.151	0.149	0.102	0.122	-1.49	-2.89	-4.93	**0.80**	**-0.56**	**-1.31**
SI	0.588	0.562	0.385	0.385	0.315	0.215	-1.76	-1.22	-3.39	**-0.38**	-0.84	-3.82
SA	0.162	0.152	0.101	0.090	0.073	0.062	-1.88	-1.05	-4.31	-1.11	-0.56	-2.38
Average	0.620	0.538	0.333	0.257	0.178	0.121	-3.56	-1.65	-4.90	-3.05	-3.45	-3.82

[&] Log regression on segmented trend; the bold figures are not statistically significant at 5% level.

Table 5. Intermediate input relative to 1951 level for Piemonte (selected years) and average annual growth[&]

Region	Intermediate input level						Growth rate(%)					
	1951	1960	1970	1980	1990	2002	1951/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	1.000	1.286	1.629	1.871	1.875	1.608	0.95	3.37	1.85	1.40	**0.15**	-1.42
VA	0.024	0.029	0.035	0.046	0.038	0.029	0.60	3.07	0.88	2.95	-1.86	-1.59
LO	1.537	1.984	2.937	3.710	3.416	2.944	1.31	2.85	3.60	2.53	-1.05	-1.49
LI	0.063	0.094	0.111	0.149	0.148	0.183	1.84	5.20	1.24	2.20	1.28	1.04
TR	0.135	0.179	0.241	0.349	0.359	0.377	2.06	3.33	2.71	3.34	0.56	0.40
FR	0.245	0.308	0.442	0.516	0.449	0.458	1.00	2.59	3.60	2.05	-2.59	**0.17**
VE	0.983	1.323	1.986	2.372	2.262	2.072	1.38	3.55	3.55	2.19	-0.95	-0.86
ER	1.253	1.611	2.555	2.866	2.770	2.385	1.23	3.22	3.81	1.03	**-0.08**	-1.34
TO	0.512	0.712	0.907	0.915	0.800	0.711	0.36	4.11	1.75	**0.29**	-1.07	-1.46
UM	0.247	0.333	0.449	0.446	0.396	0.313	0.34	4.18	2.40	**-0.06**	-0.86	-2.32
MA	0.467	0.619	0.800	0.765	0.681	0.568	0.23	3.63	1.98	**-0.44**	-0.70	-1.65
LA	0.346	0.536	0.803	1.075	1.025	0.959	1.34	4.36	3.21	1.94	**-0.35**	-1.64
AB	0.217	0.309	0.445	0.533	0.505	0.424	1.26	4.37	3.51	1.72	**-0.15**	-2.59
MO	0.088	0.122	0.149	0.197	0.222	0.186	1.49	4.36	1.36	2.74	1.26	-2.05
CA	0.346	0.536	0.803	1.075	1.025	0.959	1.90	5.15	4.26	2.57	**-0.14**	-1.51
PU	0.353	0.537	0.828	1.145	1.064	1.182	2.31	4.93	4.27	2.57	1.02	-0.63
BA	0.140	0.184	0.257	0.326	0.281	0.264	1.37	3.30	2.89	2.42	**0.06**	-1.96
CL	0.199	0.275	0.397	0.576	0.493	0.547	1.97	4.64	3.25	3.17	**0.19**	-0.89
SI	0.472	0.663	1.039	1.184	1.179	1.100	1.65	3.49	4.78	1.06	0.56	-1.35
SA	0.235	0.332	0.439	0.623	0.618	0.675	1.95	4.39	2.58	3.20	**-0.12**	0.68
Average	0.443	0.599	0.863	1.037	0.980	0.897	1.33	3.91	2.87	1.94	-0.24	-1.12

[&] Log regression on segmented trend; the bold figures are not statistically significant at 5% level.

Table 6. Total factor productivity relative to 1951 level for Piemonte (selected years) and average annual growth[&]

Region	Total factor productivity						Growth rate(%)					
	1951	1960	1970	1980	1990	2002	1951/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	1.000	1.107	1.421	1.813	2.326	2.706	2.29	0.93	2.56	2.51	2.48	1.93
VA	1.661	1.906	2.453	2.756	2.550	4.446	1.32	3.00	2.72	**-0.05**	-0.93	4.68
LO	1.086	1.320	1.676	1.919	2.209	2.920	2.00	1.95	2.55	1.45	1.66	2.84
LI	0.692	0.853	1.314	1.291	2.621	2.421	3.15	2.83	4.90	**-0.60**	7.53	**0.25**
TR	0.987	1.032	1.539	1.669	2.600	2.920	2.55	1.77	2.48	2.11	4.19	1.14
FR	0.719	0.841	1.431	1.761	2.396	3.032	2.97	1.34	4.44	2.80	2.62	2.59
VE	0.833	1.114	1.580	1.892	2.258	2.905	2.39	3.22	3.28	1.65	1.73	3.07
ER	1.197	1.515	1.967	2.219	2.478	2.992	1.72	2.77	1.96	2.22	**0.27**	2.29
TO	0.618	0.773	1.218	1.491	2.010	2.652	2.98	2.59	4.49	1.67	3.48	2.52
UM	0.604	0.749	1.113	1.556	2.121	2.962	3.35	2.35	3.42	4.04	2.90	3.28
MA	0.715	0.822	1.207	1.599	2.353	2.699	2.92	2.15	3.13	2.97	3.42	2.09
LA	1.040	1.295	1.992	1.991	2.535	3.357	2.63	3.45	4.11	1.61	2.43	2.15
AB	0.703	0.851	1.218	1.726	2.061	3.090	3.03	3.24	3.64	3.30	2.00	3.22
MO	1.113	1.255	1.921	1.775	2.336	3.412	1.90	2.84	3.52	-1.17	2.63	3.50
CA	1.040	1.295	1.992	1.991	2.535	3.357	2.07	3.12	4.08	0.32	**1.74**	2.28
PU	1.332	1.393	2.081	2.109	1.808	2.683	1.56	2.43	3.14	-1.13	2.28	2.58
BA	0.956	0.829	1.615	1.811	1.702	2.929	2.17	**0.98**	4.58	**0.40**	**0.49**	5.51
CL	1.226	1.503	2.384	2.629	2.323	3.528	1.60	3.54	4.47	**0.03**	**-0.95**	3.45
SI	1.498	1.570	2.421	2.338	2.161	2.545	1.15	1.68	3.64	-1.05	1.07	1.33
SA	1.583	1.806	2.560	2.281	2.057	2.937	0.95	1.48	3.87	-2.13	**0.21**	3.32
Average	1.030	1.191	1.755	1.931	2.272	3.025	2.23	2.38	3.55	1.05	2.06	2.70

[&] Log regression on segmented trend; the bold figures are not statistically significant at 5% level.

Table 7. Regions ranked by 1951 level of agricultural productivity

Region	1951		2002		Annual growth 1951/02	
	Rank	Level	Rank	Level	Rank	Rate (%)
VA	1	1.661	1	4.446	18	1.32
SA	2	1.583	9	2.937	20	0.95
SI	3	1.498	19	2.545	19	1.15
PU	4	1.332	17	2.683	17	1.56
CL	5	1.226	2	3.528	16	1.60
ER	6	1.197	7	2.992	15	1.72
MO	7	1.113	3	3.412	14	1.90
LO	8	1.086	11	2.920	13	2.00
CA	9	1.040	4	3.357	12	2.07
PI	10	1.000	14	2.706	10	2.29
TR	11	0.987	12	2.920	8	2.55
BA	12	0.956	10	2.929	11	2.17
VE	13	0.833	13	2.905	9	2.39
LA	14	0.731	16	2.689	7	2.63
FR	15	0.719	6	3.032	5	2.97
MA	16	0.715	15	2.699	6	2.92
AB	17	0.703	5	3.090	3	3.03
LI	18	0.692	20	2.421	2	3.15
TO	19	0.618	18	2.652	4	2.98
UM	20	0.604	8	2.962	1	3.35
Average gap		1.80 (0.55)		1.51 (0.19)		

Table 8. Rate of convergence of regional productivity in Italy by period

Period	$\hat{\beta}$	$t_{\hat{\beta}}$	σ_1	σ_T	T_3
1951/02	0.820	8.946^{c}	0.315	0.135	10.106^{c}
1951/60	0.111	1.583	0.315	0.295	0.674
1961/70	0.127	2.478^{b}	0.294	0.264	1.080
1971/80	0.437	5.241^{c}	0.284	0.189	3.415^{c}
1981/90	0.930	4.868^{c}	0.143	0.116	1.147
1991/02	0.179	0.496	0.078	0.135	-2.618

Note: The superscripts b and c mean significant convergence at the 5% and 1% levels, respectively.

Table 9. Panel unit root and spatial dependence tests (within region groupings)

1951/02	S_N	*LM*	*CD*
Northern regions (8)	-3.78 (-1.96)	157.33 (41.34)	7.51 (1.96)
Central regions (4)	-2.77 (-1.96)	61.13 (12.59)	7.56 (1.96)
Southern regions (8)	-5.44 (-1.96)	214.96 (41.34)	12.66 (1.96)
All regions (20)	-6.65 (-1.96)	796.34 (223.16)	13.23 (1.96)

Note: 5% critical values are given in parentheses

Table 10. Shrinkage estimator of regional growth regression (1951-2002)

Region	α	ρ	Convergence rate (%)	Half life (years)	Steady state	Panel steady state
PI	-0.013	0.776	22,42	3,09	-0.060	-0.080
VA	0.007	0.956	4,35	15,93	0.161	0.308
LO	0.002	0.596	40,43	1,71	0.006	0.000
LI	-0.009	0.909	9,13	7,59	-0.103	-0.224
TR	-0.007	0.816	18,37	3,77	-0.037	-0.053
FR	-0.008	0.882	11,83	5,86	-0.065	-0.111
VE	-0.015	0.554	44,62	1,55	-0.035	-0.028
ER	0.009	0.870	12,98	5,34	0.073	0.104
TO	-0.009	0.927	7,32	9,47	-0.125	-0.214
UM	0.000	0.965	3,48	19,90	0.004	-0.202
MA	-0.006	0.943	5,70	12,16	-0.101	-0.172
LA	-0.010	0.861	13,89	4,99	-0.074	-0.088
AB	-0.004	0.926	7,39	9,38	-0.050	-0.114
MO	0.011	0.735	26,51	2,61	0.042	0.068
CA	0.015	0.801	19,93	3,48	0.077	0.094
PU	0.008	0.498	50,23	1,38	0.016	0.008
BA	-0.017	0.565	43,51	1,59	-0.039	-0.078
CL	0.010	0.847	15,32	4,52	0.065	0.157
SI	-0.001	0.940	5,96	11,63	-0.013	0.113
SA	0.000	0.957	4,34	15,96	-0.008	0.162
Average	-0.002 (0.000)	0.816 (0.267)	18,39	3,77	-0.010	-0.017
Panel		0.842 (0.017)	15.775	4.394		

Table 11. Shrinkage estimator of regional steady states in different regimes

Region	Convergence rate (%)	Half life (years)	Steady state				
			1951/60	1961/70	1971/80	1981/90	1991/02
PI	18,22	3,80	-0,140	-0,199	-0,034	0,028	-0,029
VA	2,80	24,75	0,391	0,282	0,091	-0,569	0,091
LO	22,35	3,10	0,041	-0,027	0,009	-0,005	-0,007
LI	6,85	10,12	-0,322	-0,240	-0,306	0,372	-0,127
TR	16,21	4,28	-0,166	-0,160	-0,104	0,113	-0,033
FR	19,92	3,48	-0,316	-0,296	-0,085	0,026	-0,005
VE	34,45	2,01	-0,073	-0,093	-0,013	-0,027	0,007
ER	1,80	38,42	0,423	-0,600	0,507	-0,511	-0,215
TO	7,41	9,35	-0,324	-0,324	-0,100	-0,055	-0,026
UM	13,31	5,21	-0,466	-0,487	-0,099	-0,014	0,016
MA	13,06	5,31	-0,360	-0,381	-0,098	0,036	-0,024
LA	15,95	4,35	-0,158	-0,159	-0,042	-0,012	-0,026
AB	17,81	3,89	-0,295	-0,312	-0,056	-0,037	0,015
MO	17,50	3,96	0,118	0,133	-0,026	0,009	-0,004
CA	6,52	10,63	0,262	0,112	0,023	0,110	-0,106
PU	43,38	1,60	0,148	0,162	0,020	-0,041	0,003
BA	15,75	4,40	-0,136	-0,071	-0,021	-0,216	0,073
CL	8,00	8,67	0,399	0,389	0,066	-0,172	0,003
SI	11,77	5,89	0,324	0,333	0,006	0,009	-0,049
SA	8,97	7,73	0,369	0,422	0,004	-0,162	0,035
Average	15,10	4,59	-0,054	-0,066	-0,031	-0,020	-0,007

Table 12. Shrinkage estimator of convergence rates in different regimes

Region	Convergence rate (%)					Half life (years)				
	1951/60	1961/70	1971/80	1981/90	1991/02	1951/60	1961/70	1971/80	1981/90	1991/02
PI	19.19	38.89	28.06	32.91	19.16	3.61	1.78	2.47	2.11	3.62
VA	7.58	30.61	18.60	12.83	12.42	9.14	2.26	3.73	5.40	5.58
LO	7.21	29.83	17.67	19.03	9.01	9.62	2.32	3.92	3.64	7.69
LI	6.96	30.24	17.33	23.89	4.81	9.96	2.29	4.00	2.90	14.42
TR	13.46	36.18	23.41	29.75	11.17	5.15	1.92	2.96	2.33	6.21
FR	4.04	27.37	14.51	20.24	4.60	17.14	2.53	4.78	3.43	15.08
VE	28.31	44.82	35.99	37.68	30.24	2.45	1.55	1.93	1.84	2.29
ER	-3.85	21.08	7.86	7.46	-0.72	-	3.29	8.82	9.29	-
TO	10.08	29.56	19.33	22.34	12.52	6.88	2.34	3.59	3.10	5.54
UM	7.57	28.70	16.98	24.03	8.57	9.16	2.42	4.08	2.88	8.09
MA	6.94	28.92	16.86	22.75	7.54	9.98	2.40	4.11	3.05	9.19
LA	12.76	33.49	22.33	25.48	14.03	5.43	2.07	3.10	2.72	4.94
AB	10.55	31.15	19.91	24.76	12.17	6.57	2.22	3.48	2.80	5.69
MO	7.95	31.05	18.75	17.94	9.34	8.71	2.23	3.70	3.86	7.42
CA	17.62	39.96	27.57	29.69	17.63	3.93	1.73	2.51	2.33	3.93
PU	15.24	35.68	25.15	21.70	18.15	4.55	1.94	2.76	3.19	3.82
BA	14.01	31.73	22.93	19.95	19.58	4.95	2.18	3.02	3.47	3.54
CL	17.69	38.07	27.51	22.38	22.40	3.92	1.82	2.52	3.10	3.09
SI	9.45	32.51	20.49	16.24	11.96	7.34	2.13	3.38	4.27	5.80
SA	4.07	26.62	15.19	8.34	8.99	17.03	2.60	4.56	8.31	7.71
Average	10.84	32.33	20.83	21.97	12.68	6.40	2.14	3.33	3.15	5.47

Figure 1. Scatter plot of regional productivity rankings: initial vs. final year

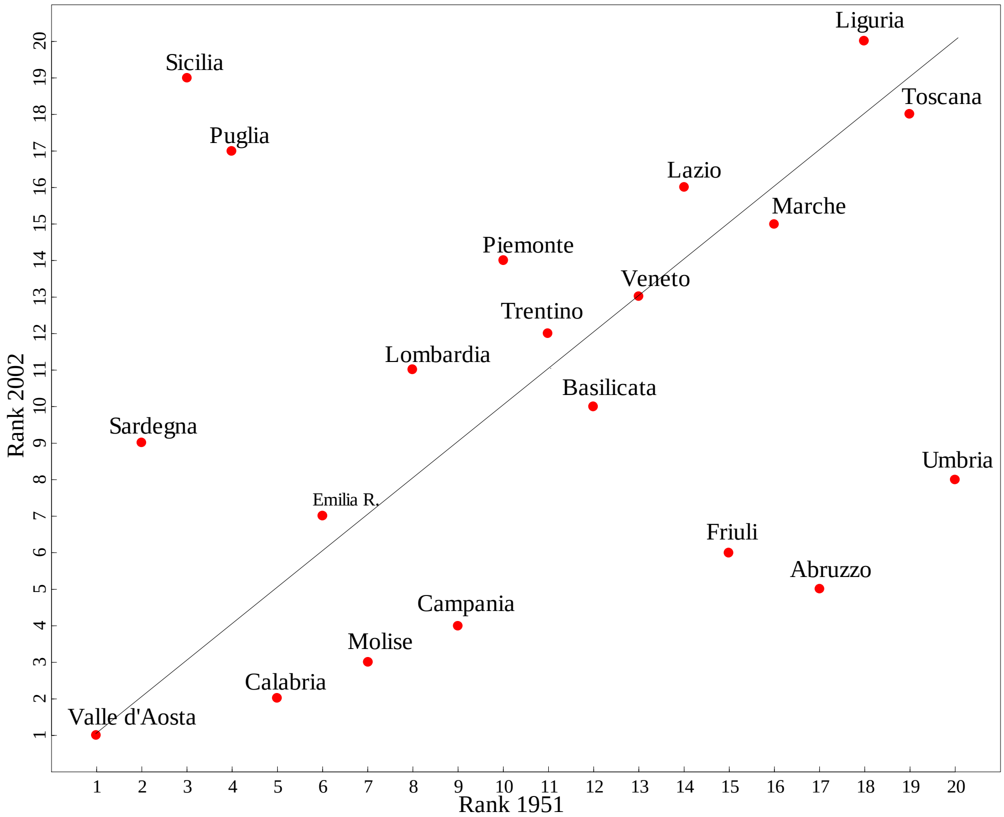
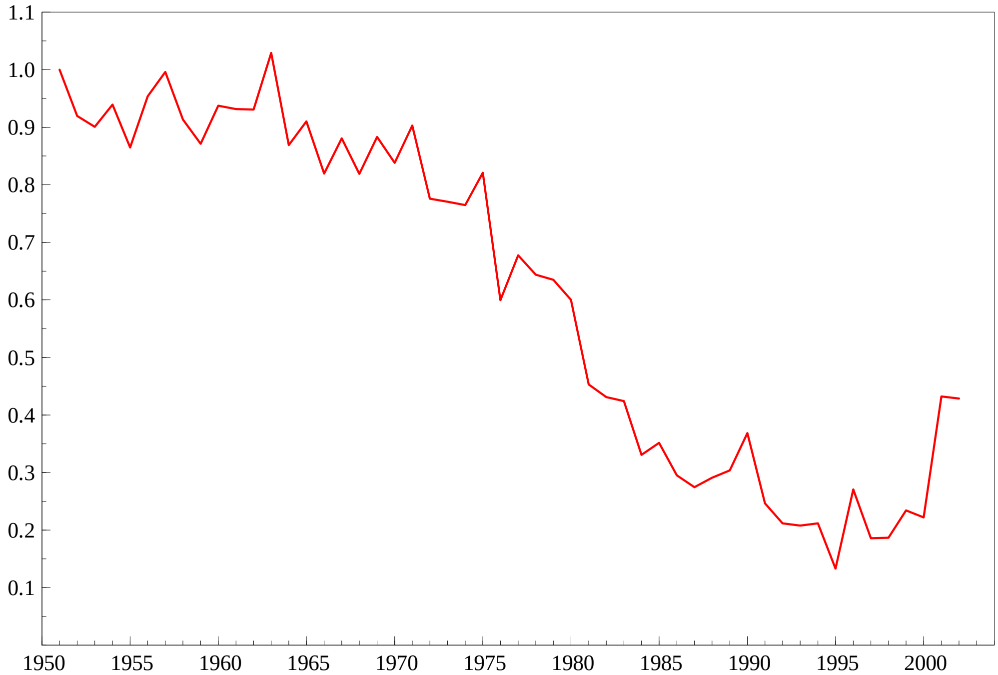


Figure 2. Standard deviation of log productivity (1951 = 1)



DEPFID WORKING PAPERS

DIPARTIMENTO DI POLITICA ECONOMICA, FINANZA E SVILUPPO
UNIVERSITÀ DI SIENA
PIAZZA S. FRANCESCO 7 I- 53100 SIENA
http://www.depfid.unisi.it/WorkingPapers/
ISSN 1972 - 361X