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ESTIMATION OF TOTAL FACTOR PRODUCTIVITY FOR REGIONS AND SECTORS IN ITALY. A PANEL COINTEGRATION APPROACH

Abstract
In this paper a complete set of estimates of long-run production functions for 20 regions and 17 sectors in Italy is provided over the period 1970-1994. Our approach features two important aspects. First, this paper represents the first attempt to provide such a comprehensive set of estimates for the Italian economy. Moreover, we allow the estimated production functions for heterogeneity across sectors and regions. This is particularly appropriate when analysing the Italian economy since the Italian regions have been experiencing fairly different and, in certain cases, divergent development paths. Secondly, on the basis of specific panel tests, we show that there is a considerable empirical evidence which suggests the presence of unit roots in our series; therefore, we apply panel cointegration tests to guard against the spurious regression problem and to detect long-run relationships.
Evidence of long run relationships is found for most of the regions and the sectors on the basis of the cointegration tests; thus, the problem of spurious regressions is ruled out allowing us to offer rigorous inference on the estimation of regional production functions. We find that factor elasticities highly differ across regions and sectors. This is an important result since most previous studies by employing unique national elasticities introduce a serious bias in the productivity comparisons.

JEL classification: C23, D24, O47

Keywords: total factor productivity, regional gap, panel unit root test, panel cointegration test, Italy.

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1. Introduction

In the last decade there has been an upsurge of studies on international comparison of Total Factor Productivity (TFP). The empirical evidence suggests that countries differ not only in factor endowments but also, and perhaps mainly, in productivity and technology.[1] Due to the lack of long time series, especially for developing countries, the most recent studies have abandoned the original time-series approach, developed by scholars like Jorgenson and Denison, in favour of cross-section accounting approaches (Hall and Jones, 1997 and 1999; Costello, 1993). A major shortcoming of the neoclassical accounting approach is that, in order to calculate TFP levels for each economy, some restrictive and controversial assumptions have to be made. Specifically, starting from a Cobb-Douglas production function, factors elasticity can be computed as equal to the relative shares of total income paid to each input only under the assumptions of perfectly competitive factor markets and constant returns to scale in the production function. A less restrictive approach is to directly estimate differences across economies in the production function through an econometric analysis which requires the use of panel techniques (Islam, 1995; Harrigan, 1999). This approach allows to test for differences in technological knowledge across economies and also for the presence of scale economies and market imperfections.

The second important motivation for our research comes from the recent literature on economic growth which has devoted increasing attention to the differences in productivity levels across regions of the same country. A strong stylised fact that emerges from the empirical literature is that regional disparities are larger and more persistent when compared to cross countries differences, at least within the industrialised nations. A crucial point to be

1 Islam (1999) presents a comprehensive survey of the different methodologies employed to compare TFP at the international level. Other interesting contributions are, among others, van Ark (1993), Dollar and Wolff (1993), Bernard and Jones (1996).

addressed is whether such differences are due to technological levels or factors endowments. This issue is central for the Italian case since the geographical dualism between northern and southern regions has been a dominant feature of the economic development in Italy and, moreover, because the economic gap has not shown any tendency to decrease over time (Paci and Saba, 1998). However, most studies on TFP at regional level employ unique national elasticities introducing a serious bias in the regional growth accounting (Pesaran and Smith, 1995; Lee, Pesaran and Smith, 1998).

In this paper our aim is to estimate a complete set of long-run production functions, based on a Cobb-Douglas technology, for 20 Italian regions and 17 economic sectors over the period 1970-1994. The richness of this database allows for a comprehensive estimation of the production functions for the whole national economy, obtained by using the full information set in a three dimensions panel with a total of 8500 observations with fixed effects for both regions and sectors. Moreover, since we are interested in assessing whether the factors elasticities varies across regions, we estimate a production function for each region and for each sector; in the first case the panel data consists of the temporal and sectoral dimensions with 425 observations, while in the second case by making use of temporal and regional dimensions 500 observations are available.

Our approach to estimate production functions at regional and sectoral level for the Italian case features two important aspects.

Firstly, at the best of our knowledge, this paper represents the first attempt to provide a complete estimates for the Italian economy with heterogeneity across regions and sectors within the national production functions. Moreover, our large data set has the advantage of allowing to estimate distinct production functions at the regional and sectoral levels and to obtain different inputs elasticities across regions and sectors. This is particularly appropriate when analysing the Italian economy since regions have been experiencing fairly different and, in certain cases, divergent development paths, especially as far as the southern regions (the so called Mezzogiorno) are concerned.

Secondly, we show that there is a considerable empirical evidence which suggests the presence of unit roots in the series we analyse; unit roots are often removed by taking first differences, but this ignores evidence of long run relationship if the series are cointegrated (Engle and Granger, 1987). Therefore, the individual series are tested for stationarity by means of the panel unit root tests proposed by Im, Pesaran and Shin (1997); such tests, exploiting the panel dimension, should prove more powerful than the traditional tests proposed by Dickey and Fuller (1979). The recent cointegration tests proposed by Pedroni (1998) are then applied. The tests are devised for the null of no cointegration in panels for the case of multiple regressors, including regressions with individual specific fixed effects and time trends.

The paper is organised as follows. In section 2 we present the dataset and some descriptive statistics for the variables employed in this study. Section 3 deals with some methodological issues in estimating panel production functions; in particular, we describe the test performed to detect the presence of unit roots (section 3.1) and the test for cointegration (section 3.2). In section 4 the estimation results are presented for the national economy (section 4.1), for each region and for each sector (section 4.2); moreover, the issue of causality is discussed (section 4.3). Concluding remarks are in section 5.

2. Data and summary statistics

Our purpose is to estimate a production function for the regions and the sectors in Italy. We employ a general formulation of a Cobb-Douglas production function:

$$Y_{ijt} = A_{ij} K_{ijt}^{a} L_{ijt}^{b} \qquad (1)$$

where Y is value added, K is physical capital stock, L are labour units and A represents the technical level, the index i indicates regions, j the sectors and t the years.2 A log linearization of (1) yields the following estimation equation for a three-dimension panel with regional and sectoral effects:

$$y_{ijt} = a_{ij} + a k_{ijt} + b l_{ijt} + e_{ijt} \qquad (2)$$

where small letters indicate variables in logs.

In order to estimate production function relations for the Italian economic system, time series at annual frequency for regional value added, labour units and capital units have been considered over the period 1970-1994. The data employed in this analysis are obtained from the database set up by CRENoS containing time series for the main economic variables disaggregated by the 20 Italian administrative regions and by the 17 sectors covering the whole economy.[3]

In particular, the output measure is value-added, at constant 1985 prices; it is important to notice that value added has been deflated by region- and sector- specific price levels. Labour input represents total labour units and include both dependent and autonomous workers. The capital stock for the period 1970-94 at regional and sectoral level has been calculated by Paci and Pusceddu (2000) from the national series on capital stock provided by ISTAT (*Istituto Nazionale di Statistica*) for the period 1980-1994.

Tables 1 and 2 report the main indicators for our variables for both Italian regions and sectors; namely: the annual average growth rate of value added, capital and labour; and also the regional and sectoral factors productivity, relative to the Italian average, for the initial and the final year.

The annual growth rate of value added over the entire period is on average 2.6% for Italy; while across regions the same indicator ranges from 1.61% (Valle d Aosta) to 3.45% (Veneto).

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[2] In addition to traditional inputs, like physical capital and labour units, some studies have introduced other production factors such as human capital, infrastructure and R&D expenditure. The estimation of multi-factors production functions goes beyond the scope of the present paper.

[3] See the Appendix for a list of the regions and the sectors considered. The CRENoS data set on Italian regions is available at www.crenos.it

Analogously, the capital average annual growth rate ranges between 2.18% (Liguria) and 4.95% (Molise) with an average of 3.6% for Italy. Labour inputs show a very low average growth rate, the national average being equal to 0.46% with a variation from -0.34% in Liguria up to 0.9% in Lazio.

Both labour and capital productivities show a well defined geographical pattern across the regions: the highest values are associated with the northern and central regions while the southern ones are characterised by lower productivity levels. Such patterns seem to be fairly stable when comparing the initial year values with the final ones.

Considering the sectoral breakdown (Table 2), we detect a much higher variability of the value added growth rate which varies from a maximum in the Chemical products (MI9 = 8.25%), to the lowest rate in the Building and construction sector (C = -0.32%). Capital inputs show a total average growth rate of 3.6%; the highest rate (5.66%) was associated with the Metal products and machinery sector (MI10), while the lowest rate (2.24%) was found for the Agriculture (AG) sector and for the Paper and printing products (MI14) sector. Labour growth rates are negative for most of the productive sectors, they range from -2.9% for AG and MI14 sectors to 3.65% for Other market services (MS21), with the Italian average equal to 0.46%.

3. Estimation and testing methodology

The recent empirical literature has widely employed the panel approach to estimate production functions [see, among others, Islam (1995) and Harrigan (1999)], however some crucial methodological issues regarding non-stationary series in panel estimation have often been overlooked. In the context of the empirical studies on the estimation of production functions for Italy, at the best of our knowledge, no attempt has been made to assess the nonstationarity features of the variables examined and the possible problem of spurious regressions.[4] The only exception is represented by Mattana (1997), who conducted a cointegration analysis *à la* Johansen (1988) by adopting a pure time series approach but confined to the aggregate Italian economy.

Therefore, the first step of this analysis deals with a thorough investigation of the stochastic properties of regional and sectoral time series for value added, capital stock and labour units variables. The preliminary univariate analysis is carried out by applying the panel unit root test proposed by Im, Pesaran and Shin (1997), while the spurious regression problem is tackled by means of the panel cointegration tests recently designed by Pedroni (1995, 1998). It is worth noting that in the absence of cointegration and in order to avoid the spurious regression problem we can only difference the data and estimate models for variables changes (see Garcia-Mila *et al.*, 1996 and Picci, 2000); however, if the variables of interests are cointegrated a model in differences is misspecified since it ignores the long run information.

In the next section we proceed by presenting a brief description of the panel unit root and cointegration tests performed in this study along with the results obtained for the estimated regional and sectoral panels; note that for the regional panels the cross-section dimension is given by the 17 economic sectors of each region, while for the sectoral panels the individuals are represented by the 20 regions.

3.1 Panel unit root tests

The traditional Augmented Dickey-Fuller (ADF) test for nonstationarity has been extended to panel tests for nonstationarity allowing for various degrees of heterogeneity by Quah (1994), Levin and Lin (1992) (henceforth, LL) and Im, Pesaran and Shin (1997) (henceforth, IPS). The main motivation to resort to panel unit root tests is that standard nonstationarity

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[4] See, for instance, the recent papers by Bonaglia *et al.*, 2000, La Ferrara-Marcellino, 2000 and Picci, 2000, on the effects of public infrastructure on regional economic growth in Italy.

tests lack power in small samples, while an increase in power can be achieved as the number of panel series increases[5].

In panel unit root test the null hypothesis is that each series of the panel contains a unit root and therefore is difference-stationary, the specification of the alternative hypothesis differs across them. In the tests proposed by Quah (1994) and by Levin and Lin under the alternative hypothesis all the component series in the panel are stationary, while for the IPS test the alternative is that at least one of the individual series is stationary. The LL test is based on the following model, which allows only for heterogeneity in the intercept:

$$\Delta y_{it} = m_{it} + bt + gy_{i,t-1} + \sum_{j=1}^{p} f_j \Delta y_{i,t-j} + e_{it} \qquad i=1, \quad .N, \; t=1, \quad .T \qquad (3)$$

The null hypothesis is H_0:$\gamma=0$, while the alternative hypothesis is given by H_a:$\gamma<0$. Model (3) is estimated using the within or the LSDV estimator and the LL test statistic is obtained as the usual t-statistics: $t_g = \hat{g} / \hat{s}_{\hat{g}}$. Levin-Lin propose two transformations of the test that are asymptotically normally distributed as both N and $T \to \infty$.

The unit root test for dynamic heterogeneous panels suggested by Im, Pesaran and Shin is specified as follows:

$$\Delta y_{it} = m_{it} + b_i t + g_i y_{i,t-1} + \sum_{j=1}^{p} f_{i,j} \Delta y_{i,t-j} + e_{it} \quad i=1, \quad .N, \; t=1, \quad .T \qquad (4)$$

The hypothesis of common dynamics across individuals is relaxed so that the null hypothesis is reformulated as H_0:$\gamma_i=0$, while the alternative hypothesis is: H_a: $\exists i$ s.t. $\gamma_i<0$. Due to parameter heterogeneity, for each individual of the panel a

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[5] Panel unit root tests have found application in various studies, for example, to test for purchasing power parity (MacDonald, 1996; Wu, 1997; Coakley and Fuertes, 1997), to determine the stochastic properties of inflation rate (Culver and Papell, 1997) and to investigate hysteresis in unemployment (Song-Wu, 1998).

separate OLS equation is estimated and the test statistics is calculated as a studentized average of the test statistics for each equation. In this study we apply the *t*-statistic version of the IPS test, named *t*-bar statistic; it is obtained as the average of individual Dickey-Fuller τ statistics: $\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_i$, with $t_i = \frac{\hat{g}_i}{\hat{s}_{\hat{g}i}}$. Under the assumption that the panel components are independent, IPS propose a standardised *t*-bar statistic:

$$\Gamma_{\bar{t}} = \frac{\sqrt{N}\,(\bar{t} - E(t_i | g_i = 0))}{\sqrt{Var(t_i | g_i = 0)}} \qquad (5)$$

The means $E(t_i \div g_i=0)$ and the variances $Var(t_i \div g_i=0)$ are tabulated in IPS and obtained by Monte Carlo simulation. For N and $T \to\infty$ the standardised *t*-bar statistic converges weakly to a standard normal distribution[6].

Panel nonstationarity tests results. The first stage of our work focuses on the analysis of the time series properties of the data. In particular, we carry out tests for non-stationarity for the three variables included in each panel used to estimate the production functions. Tables 3a and 3b report the results obtained applying the IPS unit root test for the logarithm of value added (*y*), capital stock (*k*) and labour units (*l*). The tests are performed both on levels and on first differences (Δy, Δk, Δl) of the variables.

As previously emphasised, the unit root test proposed by IPS allows each component of the panel to have different autoregressive parameter and short-run dynamics under the alternative hypothesis of (trend-) stationarity. The test, based on the average of the standard ADF test, has been calculated

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[6] The IPS *t*-bar and LM statistics are more generally applicable than the LL test since they only require that $N/T\to k$, instead of the stronger condition $N/T\to 0$, needed for the asymptotic validity of the LL test. The simulation analysis carried out in IPS, shows the small sample superiority of both LM-bar and the *t*-bar tests over the LL test.

independently for each panel member allowing for up to five lags and simplifying the model whenever possible without inducing autocorrelation and heteroskedasticity. Under the null of nonstationarity the test is distributed as N(0,1), so that large negative numbers provide evidence in favour of stationary.

Focusing on the results for the value added variables for nearly half of the regional panels (Table 3a) we should reject the null of non-stationarity; however, this outcome can be assigned to the large negative value of some individual tests associated with some sectors. As recently shown by Karlsson and Löthgren (2000), in the context of panel data the rejection of the unit root null hypothesis can be driven by some stationary series and the whole panel may be incorrectly modelled as stationary; on the other hand, if the tests lack power the panel is treated as if it contained a common unit root, even if the majority of the individual series are stationary. Therefore, Karlsson and Löthgren suggest that also panel unit root test can be controversial and a careful joint analysis of both *individual* and *panel* unit root tests is necessary to evaluate the stationarity properties of the pooled series.

The unit root test results on the first differences of the capital stock variable point out that, for 10 regional panels out of 21, the level series should be considered as I(2) processes. However, such a conclusion may be due to the fact that ADF-type tests exhibit low power if the series are characterised by a high degree of persistence such that extensively documented in various empirical studies involving capital stock variables. Moreover, if the conclusion that capital stock is I(2) is accepted, it follows that investment is to be considered an I(1) process, which appears difficult to justify on economic grounds; for this reason we assume that the capital stock series are difference-stationary and highly persistent. The hypothesis of nonstationarity cannot be rejected for the labour units series in all the regional panels.

The above considerations can be extended to the nonstationarity analysis carried out on the sectoral panels (Table 3b) since the variables, although aggregated differently, exhibit rather similar stochastic properties.

In what follows we proceed on the assumption that all the series are difference-stationary; should such an assumption turn out to be inadequate we expect that the cointegration tests and the estimated ECM models do not support the hypothesis of a long run relationship driving the dynamic behaviour of the variables of interest (in the context of time series analysis the same argument is advanced by Kremers *et. al.*, 1992).

3.2 Panel Cointegration tests

Pedroni (1995, 1997, 1998) studies the properties of spurious panel regressions and devises tests for the null hypothesis of no cointegration for homogeneous and heterogeneous panels. The proposed tests are appropriate for both the case of common autoregressive roots under the alternative hypothesis and for the case that allows for heterogeneity of the autoregressive root, which is analogous to the IPS test in the univariate context. So far the tests introduced by Pedroni have been adopted within different literatures, in particular those related to exchange rate and growth and convergence issues, but the application has been mainly confined to single regressor cointegrating relationships. It is worth noting that in Pedroni (1998) tests are devised for the simple null hypothesis of no cointegration, without tackling the problem, which becomes relevant when dealing with more than one regressors, of how many cointegrating vectors exist and how they can be normalized. As pointed out by Pedroni, the interest is in knowing whether the variables are cointegrated and it is implicitly assumed that the researcher has in mind a particular form of normalization (e.g., for this study, a production function relation). Therefore, the main aim of panel cointegration techniques is to pool information on common long run relationships but, at the same time, allow for short-run dynamics and fixed effects to be heterogeneous across the different members of the panel. The null hypothesis of the test is that for each member of the panel the variables are not cointegrated and the alternative hypothesis is that there is a single cointegration vector which may differ across individuals.

The test is carried out in steps; in the first one residuals from the cointegrating relation of interest are calculated. In general, they are obtained from a regression specified as follows:

$$y_{it} = a_i + d_i t + q_{1i} X_{1it} + q_{2i} X_{2it} + ... + q_{Mi} X_{Mit} + e_{it} \qquad (6)$$

t=1, ., T; i=1, ., N m=1, ., M

where T refers to the number of observations over time, N to the number of individuals in the panel and M to the number of regressors. The a_i coefficients represent the fixed effects; the term $d_i t$ captures individual deterministic trends which can also be omitted depending on the application considered; the main feature is that the coefficients q_{mi} are allowed to change across the member of the panel.

Pedroni (1997) derives seven different statistics for testing the null of no-cointegration; four are based on pooling along the *within*-dimension and the remaining three are obtained by pooling along the *between*-dimension. In both cases the null hypothesis is that the first autoregressive coefficient of the residual series is equal to unity; under the alternative hypothesis, in the case of the *within*-dimension tests the same coefficient is strictly less than one and equal for all members of the panel. In the case of the *between*-dimension test, the autoregressive coefficient is less than unity but may differ across individuals.

The *within*-dimension based statistics is referred to as panel cointegration tests, while the *between*-dimension one as group mean panel statistics. In this study we report only the parametric version of both tests, the results are discussed below. Both tests after an appropriate standardization suggested by Pedroni follow a normal distribution, so that large negative values imply that the null of no cointegration is rejected. For a more technical and detailed description of how to construct the tests we refer to Pedroni (1998).

Testing for cointegration. As already stressed the tests are carried out in a model framework which allows for the highest degree of heterogeneity across members of the panel. The cointegration panel test is based on the estimation of the following linearised Cobb-Douglas production function:

$$y_{it} = c_i + a_i k_{it} + b_i l_{it} + e_{it} \qquad (7)$$

Table 4a (regions) and Table 4b (sectors) report the results for the group-ADF statistics along with the panel-ADF test which, in the univariate case, corresponds to the Levin-Lin unit root test.

The tests are calculated allowing for a lag length up to 5 years in order to check whether the results are robust with respect to different dynamic structures. In general, we find that the higher the lag order the stronger the evidence of cointegration. It is worth noting that the group-ADF statistics is always highly significant, even at lower lags; comparing the results with those for the panel-ADF tests it appears that the latter may lack power for certain regions, such as Valle d Aosta (VDA), Friuli (FVG), Puglia (PUG) and marginally Lazio (LAZ), for which we would not be able to reject the null hypothesis of no long run relationship if the inference were based only on the panel statistics; the group-ADF test, on the other hand, allows to reject such a hypothesis for all the estimated regional panels. This result might be seen as an indication of a certain degree of heterogeneity among the production sectors within the same region.

Turning to the economic sectors, both the panel-ADF and the group-ADF test are highly significant allowing to reject the hypothesis of no-cointegration for the great majority of the sectors; however for the MI9 (Chemical products) sector and the MS20 (Credit and insurance institutions) sector the tests do not provide evidence in favour of a long-run production function relationship. This finding may well be due to a lack of power of the cointegration tests, as matter of fact, when we estimate ECM models (see section 4.1 below) the long run adjustment term is highly significant for both the MI9 and the MS20 sector, so that we can cautiously conclude that also for these two sectors the variables of interest are cointegrated.

4. Estimation results

On the basis of the cointegration tests reported in the previous section, we provided evidence that the series for all regional and for most of the sectoral panels, although individually nonstationary, exhibit compatible long run dynamics; therefore, the estimated production functions are robust with respect to the spurious regression problem. This finding allows us to proceed with the analysis of the economic performance of the Italian regions and sectors.

4.1 Estimated production functions for Italy

We first focus our attention on the estimation of the production function for the national economy obtained by employing all the available information. Specifically, panel 1 in Table 5 presents the results of a three-dimension panel where individuals are represented by the 20 Italian regions and the 17 economic sectors over the period 1970-94. To allow for the maximum degree of heterogeneity in the technological levels we have included 340 regional and sectoral fixed effects, while, for the moment, the factors elasticities have been assumed to be homogeneous across sectors and regions[7].

[7] Although the estimated long run coefficients might be biased in small samples, they can be considered informative given the superconsistency property of the OLS estimator for cointegrated variables. In order to check the magnitude of the possible bias, we extend to the panel context the three step estimation procedure proposed by Engle, and Yoo (1991); the unbiased estimate of the capital elasticity for panel 1 is equal to 0.51 with a corrected *t*-statistic of 38.43, while the labour elaticity is 0.46 with a *t*-statistic of 26.70. Note that given the non-normality of the distribution of the estimated coefficients, standard *t*-

Our results exhibit a capital stock elasticity (0.52) much higher compared to the findings of the accounting approach, where capital elasticity is usually calculated in the range [0.35, 0.38]. The fact that the estimation procedure weight capital more heavily than capital s share in total income denotes the presence of imperfect competition in input markets and implies a bias in the accounting TFP approaches. It is worth noting that our result is similar to the elasticities estimated for the Italian aggregate in Mattana (1997) by employing a pure time series dataset. On the other hand our estimated elasticity for capital is quite different from the very low value found by Picci (1999).

The sum of the coefficients is almost equal to one, signalling the presence of constant return to scale (CRS) in this specification. Formal test of CRS are not carried out since, given that the estimated parameters have non-normal distributions, standard *t*-statistics are biased and cannot be used to test hypotheses concerning the long run coefficients.

From the estimated fixed effects we have calculated the antilogarithms which represents the parameters of technical efficiency for each region and sector (see Table 6). Clearly such a table is rich of information but it is not readily interpretable. Therefore, as a first step in our analysis, we focuses our attention on the averages of the technological parameters for the 20 regions and 17 sectors (the last row and column of Table 6, respectively). As far as the regions are concerned (see also the first series in Figure 1), the first result to be stressed is the presence of remarkable differences across regions in the technological knowledge levels.[8] Secondly, looking at the geographical distribution, it results that the 11 highest levels are those of the northern regions of Italy; the leader region is Emilia Romagna, with a technological parameter of 4.14. On the other hand, the

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statistics are biased, for panel 1 standard *t*-statistics were even five times higher than the corrected ones.

[8] The persistence of a technological gap between northern and southern regions in Italy is confirmed by Destefanis (2000) in a non parametric estimation (FDH) of the production function frontier.

lowest parameters are those of southern regions, with Basilicata exhibiting the lowest value (2.7). This finding clearly confirms the well-known dualism between North and South that still characterises the Italian economy.

Recently, Aiello and Scoppa (1999) have calculated the TFP for the Italian regions from a Cobb-Douglas production function with CRS, augmented to include human capital. They have applied the national capital elasticity (given by the ratio of gross profits to value added, set equal to 0.38) to all the Italian regions in order to compute the regional TFP levels. As we already stressed, this procedure, although is a common practice in this kind of studies, has a crucial weakness since it does not take into account the high heterogeneity among regions and sectors. However, it is worth noticing that the rank correlation between our regional TFP levels, calculated from the three-dimensional panel, and theirs is quite high (0.83).

In Table 6 we also report the coefficient of variation (CV) across the regional and sectoral technological levels in order to assess the degree of dispersion. It is interesting to notice that looking at the regional ranking of CV we find that the most efficient regions are those where the technological distance between sectors is lower (the coefficient of correlation between the ranks of technological levels and their sectoral variation is -0.76). In other words, it seems that a region with higher technological homogeneity among sectors enjoys a higher TFP level, probably thanks to the presence of diversity externalities.

Considering the ranking of the productive sectors, we can see from Table 6 (and also from Figure 2) that the most efficient sector in Italy is that of Credit and insurance institutions (MS20), followed by the Building and construction sector (C). Not surprisingly; agriculture (AG) results as the least efficient sector. The sectoral parameters of efficiency clearly show a much higher degree of variability (four times higher than the regions) even though the variation of TFP levels for a given sector across different regions is quite low.

In order to assess the robustness of our results and to allow comparisons to previous studies, we have then estimated two additional panels. In panel 2, together with the temporal dimension, we include in the data set the regions, while the sectoral breakdown is not considered. In this way we have reduced the heterogeneity of the parameters of technical efficiency to only 20. Both factors elasticities appears now slightly higher compared to the case in which all the information were used. It is important to underline that the regional fixed effects estimated in panel 2 show a ranking of the Italian regions that is very different from the one calculated in panel 1[9]. This point can be clearly inferred from Figure 1 where the technological levels relative to the national average estimated in panel 1 and 2 are shown; moreover, the correlation coefficients calculated on both the levels of efficiency (0.38) and the rank (0.32) are very low.

The third panel, since the individuals included are only the 17 economic sectors calculated at the national, allows to investigate the changes in factors elasticities due to the exclusion of the regional heterogeneity. In this case the elasticities of the labour and the capital are very different from the first estimate, particularly for the labour elasticity which appears surprisingly low[10]. One plausible and interesting explanation for this outcome is that by excluding the regional dimension we are not taking into account the production externalities which are locally bounded and affects positively labour productivity in a specific area.[11] On the other hand, in contrast with the estimates obtained from the regional model, the technological efficiency levels from the sectoral panel

[9] Note that by applying the Engle-Granger-Yoo three step estimation procedure we found the unbiased elasticity of capital is equal to 0.72 while the labour one drops to 0.30.

[10] The unbiased estimates for both capital and labour elasticity obtained from the Engle-Granger-Yoo procedure are very similar to the static regression ones; they are equal to 0.60 and 0.20, respectively.

[11] The influence of external economies and localised knowledge spillover in the Italian economy is assessed, within a different framework, by Paci and Usai (2000).

appear more similar to those calculated from panel 1, the correlation coefficient being equal to 0.76 for the levels and to 0.49 for the rank; this is clearly shown in figure 2, which allows for an immediate comparison of the sectoral fixed effects, relative to the aggregate total, estimated from panel 1 and panel 3.

Our findings on the estimation of the production function for Italy confirm the importance of taking into account the high level of heterogeneity that exists across regions and sectors. Indeed, we have shown how both the factors elasticities and the technological levels are strongly affected by the information included in the panel. More precisely, the value of inputs elasticities (especially the labour one) and the ranking of regions according to the technological levels from the most informative panel 1 appear much more reliable and consistent with the literature on Italian regional development.

4.2 Estimated production function for Italian regions and sectors

So far, we have not allowed factors elasticities to vary across region and sectors. Given the high number of observations in our dataset, we can now turn to the estimation of specific production functions for each of the 20 Italian regions and the 17 sectors.

In Table 7 we report the long run coefficients, obtained from a fixed effect specification of a Cobb-Douglas production function estimated at regional and sectoral level. The results obtained point out a considerable degree of heterogeneity across regions for the estimated factor elasticities. The capital elasticity ranges from 0.21, the estimated value for Basilicata, to 0.69 for Veneto; it is worth stressing that high values are associated with northern and central regions. A great variability across regions was also found for labour elasticities, they were estimated in the range 0.10 (Calabria) 0.84 (Molise). These results are particularly relevant since they call for a more rigorous regional growth analysis, robust to the bias introduced by employing unique national elasticities, as in most studies on regional TFP accounting.

Among the northern regions, Piemonte and Lombardia exhibit decreasing returns to scale (DRS), the sum of the inputs elasticities is equal to 0.70 for the first region and to 0.81 for the latter one; this is probably due to the fact that their economies are more heavily characterized by traditional mature industries. On the other hand, all the north-eastern regions along with Emilia Romagna, feature increasing returns to scale (IRS), only Friuli V.G. represents an exception. This finding is not surprising since these regions with their particular form of production organization (the so called *distretto industriale*) have proved the most dynamic and innovative ones on the national and European scene. The central regions economies show constant or slight increasing returns to scale. All the southern regions exhibit DRS, the noticeable exceptions are represented by Abruzzo and Molise for which the presence of IRS can be considered an important signal of the successful catching-up process that have been distinguishing the economic performance of these regions in the last decades.

The estimation of production functions for the sectoral panels are also characterised by considerable heterogeneity in the inputs elasticities which appear in most cases reasonable. Exceptions are the negative values of capital elasticity in the Fuel and power products (EN = -0.04) and of labour elasticity in Agriculture (AG = -0.18) and also the very high capital elasticity of Chemical products (MI9 = 1.98.) In general, the manufacturing sectors feature higher capital elasticities with respect to the market services ones. As far as labour elasticity is concerned, the highest values are found for the Non-market services (NMS = 0.86).

Within the manufacturing sectors moderate increasing returns to scale are exhibited by the MI07, MI08, MI11, MI12, MI13and MI14 sectors (on average the factor elasticities sum up to 1.15); while the MI10 (metal products and machinery) and the MI09 (chemical products) sectors features sizeable increasing returns (1.5 and 2.2, respectively). Among the market services sectors, only the transportation and communication sector, which is likely to be the most dynamic and hi-tech-keen sector, enjoys IRS; all the other sectors are characterized by DRS.

Since our analysis refers to a long period of time (more than two decade) in which several structural and institutional changes are thought to have affected the Italian economy, we applied sub-sample and recursive estimation techniques to check the stability of the estimated long-run coefficients; for most of the regional economies and the sectoral systems they turned out to be fairly stable over time[12].

4.3 Causality issue

The presence of cointegration is consistent with causality running just in one or in all possible directions; once a long-run relationship has been detected, it becomes relevant to determine the actual direction of causality. In particular, we are interested in assessing if the inputs are *Granger*-causing output or if the variables cause each other in the long run. Note that only in the first case it is correct to identify production-function kind of relationships. Given the nonstationary features of our variables, we test for causality within the framework of error correction mechanism (ECM) models. On the basis of the Granger Representation Theorem (Engle and Granger, 1987) we are allowed to represent a system of cointegrated variables in the form of a dynamic ECM model.

We estimate ECM models following a two step procedure. In the first one, the long run relationship among output, capital and labour is estimated and residuals calculated; in the second stage we estimate an ECM model for each variable of interest, as in (8):

$$\Delta y_{it} = c_1 + l_1 \hat{e}_{i,t-1} + \sum_{j=1}^{p} b_{11,j} \Delta y_{i,t-j} + \sum_{j=0}^{p} b_{12,j} \Delta k_{i,t-j} + \sum_{j=0}^{p} b_{13,j} \Delta l_{i,t-j} + u_{1it}$$

$$\Delta k_{it} = c_2 + l_2 \hat{e}_{i,t-1} + \sum_{j=1}^{p} b_{21,j} \Delta k_{i,t-j} + \sum_{j=0}^{p} b_{22,j} \Delta y_{i,t-j} + \sum_{j=0}^{p} b_{23,j} \Delta l_{i,t-j} + u_{2it}$$

(8)

[12] The results are available from the authors upon request.

$$\Delta l_{it} = c_3 + l_3 \hat{e}_{i,t-1} + \sum_{j=1}^{p} b_{31,j} \Delta l_{i,t-j} + \sum_{j=0}^{p} b_{32,j} \Delta k_{i,t-j} + \sum_{j=0}^{p} b_{33,j} \Delta y_{i,t-j} + u_{3it}$$

The term, $\hat{e}_{t-1}$, represents the previous period disequilibrium term, $\hat{e}_{t-1} = y_{it-1} - \hat{c}_i - \hat{a}k_{it-1} - \hat{b}l_{it-1}$; in the case of cointegrated series at least one of the λ parameters is expected to be significant; as noted in section 4.1 this can be considered an alternative way to test for cointegration when usual and *direct* tests lack power.

The advantage of adopting a two step procedure is that all the variables in (8) are stationary, so that standard inference on the estimated coefficients can be performed. The fact that we include the estimated error correction term, rather than the true one in (8) does not affect the properties of the estimated coefficients given the superconsistency feature of the OLS estimator in cointegrated relationships.

Note that in (8) the long-run dynamics is captured by the parameter λ and it is separate from the short-run one which is represented by the βs coefficients. It is therefore possible to pool information only from the λs coefficients without necessarily pool information on the transitional dynamics provided by the βs parameters.

Due to the small number of time-series observations, in the estimated panel ECM models we pool information on the lagged changes, as well as on the adjustment error terms. The estimated error adjustment terms are reported in Table 8 for value added, capital and labour ECM models for both regional and sectoral panels. While in all output models (*Dy*) the λ coefficient is negative and highly significant, in both the productive inputs models (*Dk*, *Dl*), it is rarely significant and much lower in magnitude. Overall these results provide further evidence in favour of the existence of a long-run relationship driving the variables of interest.

Turning to the causality issue in more detail, we carry out two kinds of causality tests. For each of the variables in the estimated regional and sectoral systems, we test whether the lagged changes of the other two variables and the error correction adjustment term are jointly equal to zero. This amounts to test the hypothesis of no effects, both in the short and in the long run, running from the explanatory variables towards the dependent one. The results of this test are not reported since the null hypothesis is always rejected for both regional and sectoral models. A preliminary conclusion is that no variable in the estimated panels evolves entirely exogenously from the others and that there is a two-way feedback between inputs and output. In order to assess whether such a feedback is relevant only in the short run, due, for instance, to business cycle or multiplier effects, we also test whether *only* the adjustment term is equal to zero in the ECM model estimated for each variable. The results are reported in table 9.

The null hypothesis of no long run effects from labour and output on capital is not rejected in most of the cases, the results for Liguria (LIG) and Basilicata (BAS) represent the only exceptions. The same kind of results were found when analysing the effects of capital and output on labour, a long run effect of the latter variables was detected only for Sicily (SIC) at the conventional 5% significance level. On the other hand, when we turn to assess the long run effect of both production inputs on output the null hypothesis is consistently rejected for all the regional panels, indicating that inputs are weakly-exogenous with respect to output. Similar results are also reported for the sectoral panels, a long run effect on labour running from output and capital was fund for five sectors, while only the capital inputs inthe MI08, the MI15 and the MS21 sector are affected by output and labour in the long run. Overall, we can argue that the estimated relationships reported in Table 7 can be confidently identified as production functions for the Italian regions and sectors.

5. Concluding remarks

In this paper we have presented a complete set of estimates of the production function for the Italian economy and also for each of the 20 regions and 17 sectors over the period 1970-94. We have devoted great attention to the estimation procedures. On the basis of specific panel tests, we have pointed out the presence of unit roots in our series and, consequently, we have applied panel cointegration tests to guard against the spurious regression problem and to detect long-run relationships. Evidence of long run relationships is found for most of the regions and the sectors; thus, the problem of spurious regressions is ruled out, allowing us to offer rigorous inference on the estimation of regional and sectoral production functions.

Considering the national estimates, our results exhibit a capital stock elasticity much higher compared with the findings of the accounting approach (where capital elasticity is assumed equal to capital s share in total income). This result suggests the presence of imperfect competition in input markets and implies a bias in the accounting approaches.

The sum of the coefficients is almost equal to one, signalling the presence of constant return to scale at the national level.

As far as the technological levels are concerned, the first result to be stressed is the presence of large differences across regions. Secondly, looking at the geographical distribution, it results that the highest levels are those of the northern regions of Italy. This finding clearly confirms the well-known dualism between North and South that still characterises the Italian economy.

Considering the estimation of individual production functions for the Italian regions and sectors, we find, as expected, that factor elasticities highly differ across regions and sectors. This in an important results since most studies on regional growth employ a unique aggregate national elasticity introducing in this way a serious bias in the regional and sectoral growth accounting.

In general, our results confirm the importance of taking into account the high level of heterogeneity that exists across regions and sectors and clearly show that factors elasticities and technological levels are highly sensitive to the information included in the panel. More precisely, inputs elasticities (especially the labour one) and regional technological ranking appear much more reliable - and consistent with the literature on Italian regional growth - when the most informative set of data is considered.

Several factors have been pointed out by the growth literature as causes of the backwardness of Mezzogiorno s regions and may help in explaining the lower level of technological efficiency we have detected in the southern regions. Some of them (human capital, infrastructure, R&D expenditure, social capital) can be considered as productive factors and thus included explicitly in a multi-factor production function. In this case the lower factor endowment of the Mezzogiorno regions can be simply seen as the cause of their lower efficiency and the policy implications are clearly defined. However, it may be also the case that the inefficiency in the southern regions derives from other elements (pervasive presence of organised crime, inefficiency in the credit market and in the public administration) which influence negatively the local environment and determine external *dis-economies* for the firms.

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Appendix

The main source of the data analysed in this work is the databank on the Italian regions set up by the Centre for North South Economic Research (CRENoS): http://www.crenos.it

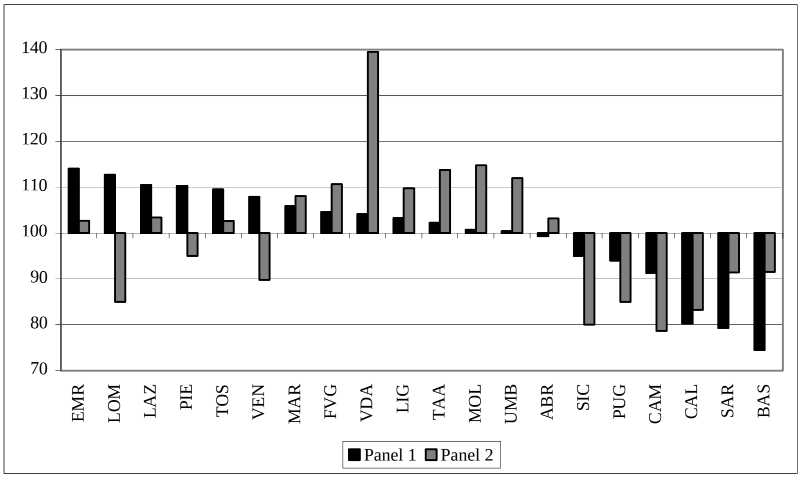
List of the Italian administrative regions

1	PIE	Piemonte	11	MAR	Marche
2	VDA	Valle D Aosta	12	LAZ	Lazio
3	LOM	Lombardia	13	ABR	Abruzzo
4	TAA	Trentino Alto Adige	14	MOL	Molise
5	VEN	Veneto	15	CAM	Campania
6	FVG	Friuli Venezia Giulia	16	PUG	Puglia
7	LIG	Liguria	17	BAS	Basilicata
8	EMR	Emilia Romagna	18	CAL	Calabria
9	TOS	Toscana	19	SIC	Sicilia
10	UMB	Umbria	20	SAR	Sardegna

List of economic sectors

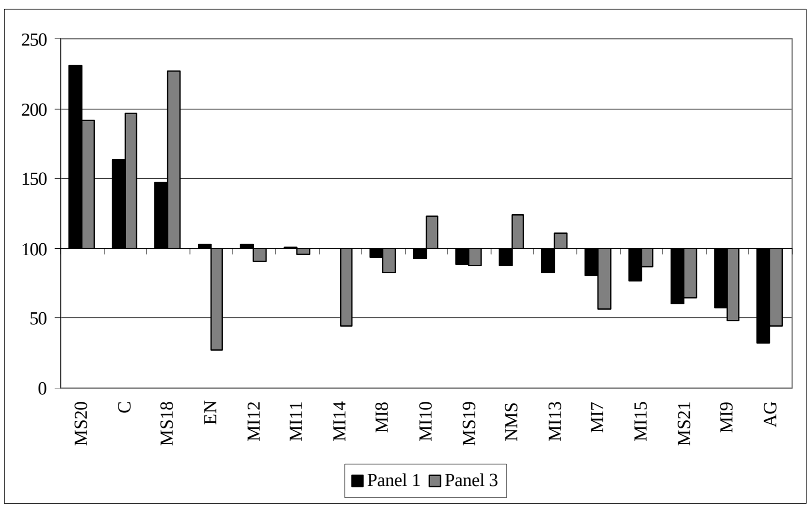
1	AG	Agriculture
2	EN	Fuel and power products sector
3	MI7	Ferrous and non-ferrous mineral and metals
4	MI8	Minerals and non-metallic mineral products
5	MI9	Chemical products
6	MI10	Metal products and machinery
7	MI11	Transport equipment
8	MI12	Food, beverages, tobacco
9	MI13	Textiles and clothing, leather and footwear
10	MI14	Paper and printing products
11	MI15	Wood, rubber and other industrial products
12	C	Building and construction sector
13	MS18	Trade, hotels and public establishment
14	MS19	Transport and communication services
15	MS20	Credit and insurance institutions
16	MS21	Other market services
17	NMS	Non-market services

Figure 1. Technological efficiency in the Italian regions (index: Italy = 100)



(calculated from estimates reported in Table 5)

Figure 2. Technological efficiency in the Italian sectors (index: total = 100)



(calculated from estimates reported in Table 5)

Table 1 Summary statistics for the Italian regions

	Average annual growth 1970-94			Y/L (index: Italy=100)		Y/K (index: Italy=100)	
	Value Added	Capital	Labou r	1970	1994	1970	1994
Piemonte	2.00	3.57	-0.05	105	103	122	105
Valle d Aosta	1.61	3.20	0.36	123	99	72	62
Lombardia	2.75	3.36	0.31	108	116	102	111
Trentino A.A.	3.09	4.42	1.19	100	94	96	88
Veneto	3.45	3.22	1.05	97	102	83	111
Friuli V.G.	2.79	3.42	0.03	97	112	93	100
Liguria	1.79	2.18	-0.34	116	115	94	107
Emilia R.	2.93	3.96	0.59	104	109	118	116
Toscana	2.38	3.57	0.44	103	98	118	112
Umbria	2.93	2.64	0.86	94	92	74	99
Marche	2.90	3.71	0.60	91	95	99	103
Lazio	2.68	4.69	0.90	121	110	129	101
Abruzzo	3.16	3.96	0.65	84	92	85	89
Molise	3.09	4.95	0.03	69	86	86	69
Campania	2.60	3.64	0.81	90	83	87	85
Puglia	2.77	3.58	0.12	78	88	92	95
Basilicata	2.13	3.28	-0.07	78	79	70	67
Calabria	1.94	3.22	0.01	79	75	79	73
Sicilia	2.26	3.67	0.43	90	83	93	83
Sardegna	2.22	2.90	0.57	98	87	73	78
ITALY	2.62	3.57	0.46	100	100	100	100

Table 2 Summary statistics for the Italian sectors

	Average annual growth 1970-94			Y/L (index: Italy=100)		Y/K (index: Italy=100)	
	Value Added	Capital	Labour	1970	1994	1970	1994
AG	0.66	2.24	-2.90	33	46	58	50
EN	1.15	4.27	0.01	407	319	21	12
MI07	0.48	2.73	-1.51	197	189	144	106
MI08	3.14	4.58	-0.79	72	110	159	142
MI09	8.25	2.93	-0.48	35	169	30	136
MI10	4.41	5.66	-0.53	60	117	204	190
MI11	0.55	5.16	-0.96	116	99	291	121
MI12	3.59	4.20	-0.57	82	133	150	163
MI13	2.87	3.99	-0.91	53	78	225	216
MI14	0.66	2.24	-2.90	33	46	58	50
MI15	3.42	3.33	-0.48	61	92	146	188
C	-0.32	4.71	-0.96	107	74	749	282
MS18	2.72	4.53	1.56	110	87	375	306
MS19	4.19	5.31	1.49	109	125	110	106
MS20	3.29	4.19	3.49	475	270	314	318
MS21	3.61	3.37	3.65	241	142	32	43
NMS	1.85	2.85	1.83	124	74	131	129
Total	2.62	3.57	0.46	100	100	100	100

Table 3a *Regional* Panel Unit Root Tests

	y	*k*	*l*	*Dy*	*Dk*	*Dl*
Valle d Aosta	-1.69	4.61	1.06	-13.02	-2.05	-14.26
Piemonte	-0.30	0.20	0.65	-13.87	-2.37	-10.22
Lombardia	-0.24	0.76	2.21	-11.99	-1.10	-8.45
Trentino A.A.	-2.13	5.14	0.72	-16.25	-3.58	-15.38
Veneto	0.17	1.60	1.08	-13.34	-1.52	-12.70
Friuli V.G.	-2.68	3.60	1.37	-14.76	-1.16	-13.72
Liguria	-3.35	-2.15	-3.38	-16.46	-2.31	-13.89
Emilia R.	-5.76	1.98	-1.58	-13.44	-0.07	-8.07
Toscana	-3.33	1.70	-0.40	-16.18	0.00	-10.97
Umbria	-3.21	-2.11	-0.34	-15.48	-5.49	-12.79
Marche	-2.57	6.91	1.12	-15.16	-1.18	-13.83
Lazio	0.07	1.67	2.61	-15.38	-3.52	-11.88
Abruzzo	-1.54	2.47	0.24	-13.93	-3.47	-15.27
Molise	-0.78	2.83	0.30	-20.77	-4.40	-14.74
Campania	1.73	3.47	4.06	-14.50	-1.21	-9.63
Puglia	-3.51	4.42	1.17	-13.80	-0.85	-9.39
Basilicata	-2.78	3.78	-0.08	-16.01	-4.44	-13.50
Calabria	-2.08	2.39	0.15	-22.55	-4.55	-15.08
Sicilia	-1.34	5.60	3.67	-15.26	-1.70	-10.65
Sardegna	1.53	1.30	-0.21	-15.29	-3.46	-13.80
ITALY	0.85	2.67	2.02	-11.04	0.15	-4.96
The test statistics are asymptotically distributed as N(0,1) under the null hypothesis of non-stationarity						

Table 3b *Sectoral* Panel Unit Root Tests

	y	*k*	*l*	*Dy*	*Dk*	*Dl*
AG	-8.27	3.71	-1.81	-26.65	-0.91	-18.42
EN	-3.18	-0.27	4.75	-19.93	-8.61	-13.18
MI07	-4.22	-4.26	1.26	-17.74	-2.55	-12.67
MI08	-2.12	3.88	-2.97	-13.54	-2.21	-14.82
MI09	5.66	3.06	-0.45	-15.64	-2.19	-12.31
MI10	-0.53	2.71	-2.70	-15.50	-0.38	-14.32
MI11	-0.89	4.77	-0.70	-19.71	-5.67	-12.52
MI12	-3.32	2.45	-0.27	-19.45	-8.13	-17.53
MI13	-3.02	7.30	-1.09	-16.13	-1.82	-16.22
MI14	-2.64	3.03	-2.08	-19.60	-5.94	-16.55
MI15	-3.31	0.55	-1.13	-17.12	-4.22	-15.25
C	-2.79	7.41	-2.08	-14.74	2.54	-16.83
MS18	1.86	0.63	6.00	-13.49	-0.85	-13.15
MS19	-2.83	3.20	7.54	-18.50	0.17	-7.53
MS20	-1.80	2.06	4.00	-13.21	-0.99	-4.50
MS21	1.39	2.87	2.56	-14.78	-0.63	-13.36
NMS	-1.79	2.42	1.69	-7.77	-2.35	-8.74
Total	0.66	1.15	5.71	-14.17	0.09	-9.36

The test statistics are asymptotically distributed as N(0,1) under the null hypothesis of non-stationarity

Table 4a Regional Panel Cointegration Tests

	Panel ADF-statistics					Group ADF statistics				
Lags	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Valle d Aosta	0.43	-0.05	-0.40	-1.02	-1.48	0.81	-0.08	-1.25	-2.48	-7.62
Piemonte	0.09	-0.21	-0.80	-2.17	-3.47	-0.99	-1.07	-1.57	-6.72	-9.60
Lombardia	-2.05	-2.21	-2.63	-2.83	-2.91	-1.85	-2.29	-4.08	-6.53	-6.60
Trentino A.A.	-4.36	-4.39	-4.75	-5.51	-7.29	-6.77	-7.12	-7.84	-8.81	-12.41
Veneto	-2.28	-2.28	-3.24	-3.31	-3.62	-3.23	-3.23	-5.71	-5.69	-6.51
Friuli V.G.	-0.57	-0.77	-1.19	-1.29	-1.29	-2.17	-3.17	-5.04	-5.27	-5.27
Liguria	-2.15	-2.11	-2.68	-3.59	-4.07	-2.45	-2.37	-3.62	-6.68	-7.12
Emilia R.	-2.46	-2.46	-3.04	-3.04	-3.33	-2.49	-2.49	-3.64	-3.64	-4.38
Toscana	-4.79	-5.30	-7.13	-7.57	-8.15	-6.05	-6.55	-9.44	-10.81	-10.74
Umbria	-2.22	-2.53	-3.97	-3.97	-4.69	-4.15	-5.25	-8.32	-8.32	-11.65
Marche	-4.84	-5.14	-6.07	-6.07	-7.43	-6.21	-6.61	-7.23	-7.23	-9.71
Lazio	-1.22	-1.21	-1.47	-1.83	-1.97	-2.15	-2.14	-2.75	-3.25	-3.37
Abruzzo	-2.20	-2.33	-3.62	-3.71	-4.05	-3.76	-3.73	-5.52	-6.09	-6.27
Molise	-3.01	-3.01	-3.48	-3.96	-4.10	-4.29	-4.29	-6.10	-7.37	-8.29
Campania	-0.62	-1.59	-1.63	-2.31	-2.83	-1.45	-2.85	-2.89	-4.81	-6.29
Puglia	0.48	0.22	-0.02	-0.02	-0.13	-4.77	-5.46	-6.50	-6.50	-7.15
Basilicata	-1.19	-1.59	-1.64	-1.85	-2.04	-3.46	-5.01	-5.49	-6.67	-10.78
Calabria	-4.79	-4.93	-6.22	-6.01	-5.95	-11.18	-11.19	-14.11	-17.27	-16.76
Sicilia	-1.67	-1.89	-2.39	-2.53	-2.88	-1.95	-2.55	-3.31	-3.94	-5.28
Sardegna	-0.05	-0.59	-1.03	-1.05	-2.00	-0.61	-0.78	-2.10	-2.72	-5.05
ITALY	-0.71	-0.71	-1.41	-1.44	-2.03	-0.79	-0.79	-1.87	-1.99	-3.93

The test statistics are distributed as N(0,1) under the null hypothesis of no cointegration.

Table 4b Sectoral Panel Cointegration Tests

	Panel ADF-statistics					Group ADF statistics				
lags	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
AG	-10.21	-10.54	-10.54	-11.06	-11.84	-17.79	-18.21	-18.21	-22.29	-22.21
EN	-3.06	-3.16	-3.61	-3.61	-3.98	-3.59	-4.12	-5.41	-5.41	-4.99
MI07	-3.04	-3.03	-3.48	-4.95	-5.73	-3.59	-3.65	-4.43	-8.41	-10.42
MI08	-2.94	-3.27	-4.44	-6.06	-6.20	-4.43	-5.54	-7.67	-9.96	-10.09
MI09	1.59	1.54	1.43	1.35	1.30	1.00	1.00	0.89	0.75	-1.58
MI10	-0.87	-1.82	-2.99	-3.76	-4.08	-4.83	-5.30	-7.38	-9.67	-11.19
MI11	-1.31	-1.81	-2.48	-2.91	-3.58	-0.65	-1.49	-3.16	-3.65	NA
MI12	-4.24	-5.86	-5.95	-5.95	-7.20	-6.87	-9.01	-9.21	-9.21	-16.17
MI13	-2.56	-3.12	-4.07	-4.44	-5.24	-3.48	-3.89	-5.58	-8.42	-9.38
MI14	-6.78	-7.56	-9.28	-9.28	-9.28	-8.12	-9.55	-12.36	-12.36	-12.36
MI15	-0.29	-0.29	-0.83	-1.10	-1.43	-2.39	-2.39	-4.93	-6.83	-8.18
C	-1.46	-1.74	-2.35	-2.48	-3.14	-1.33	-1.85	-3.83	-4.41	-5.26
MS18	-0.47	-0.58	-0.90	-1.16	-1.42	-1.37	-1.69	-3.22	-3.90	-4.35
MS19	-3.12	-3.14	-4.07	-4.07	-4.32	-3.35	-3.60	-5.57	-5.57	-6.83
MS20	0.45	0.30	0.14	0.14	0.04	1.03	0.94	0.87	0.87	1.04
MS21	-1.35	-1.56	-2.52	-2.59	-3.62	-1.85	-1.96	-4.37	-4.94	-7.08
NMS	-2.55	-2.63	-3.60	-3.93	-4.77	-2.48	-2.48	-4.87	-7.43	-9.28
Total	-1.46	-1.87	-2.30	-3.50	-3.51	-1.47	-2.71	-3.72	-6.77	-6.90
The test statistics are distributed as N(0,1) under the null hypothesis of no cointegration.										

Table 5 Estimated production function for Italy

Variable	**Panel 1**	**Panel 2**	**Panel 3**
Capital stock: K	0.52	0.60	0.61
Labour: L	0.47	0.59	0.18
Information included in panel:			
Time: 1970 - 1994	Yes	Yes	Yes
Regions: 20	Yes	Yes	No
Sectors: 17	Yes	No	Yes
Total panel observations	8500	500	425

Table 6. Technological efficiency for the Italian regions and sectors (Fixed effects estimated from Panel 1 with 8500 observations, 1970-94, 20 regions, 17 sectors)

	PIE	VDA	LOM	TAA	VEN	FVG	LIG	EMR	TOS	UMB	MAR	LAZ	ABR	MOL	CAM	PUG	BAS	CAL	SIC	SAR	St. Dev.	CV	Aver.
AG	1.08	0.58	1.32	1.33	1.39	1.05	1.34	1.77	1.10	0.95	1.04	1.48	1.07	0.72	1.30	1.52	0.65	0.98	1.53	1.12	0.31	0.26	1.17
EN	3.83	3.42	5.25	4.11	2.90	3.00	4.19	3.59	3.79	3.55	3.88	3.71	6.59	3.77	3.91	2.22	2.93	2.24	4.42	3.14	0.98	0.26	3.72
MI7	3.13	2.93	3.56	3.42	3.62	3.01	2.82	3.88	3.38	2.92	3.33	4.26	2.60	4.10	2.41	1.88	1.16	2.14	2.97	1.37	0.83	0.28	2.94
MI8	4.08	3.60	3.83	4.36	3.78	3.80	3.55	4.00	4.15	3.37	3.50	3.32	3.28	3.94	2.85	3.00	1.86	2.70	2.57	2.68	0.64	0.19	3.41
MI9	2.32	2.17	2.97	2.37	2.32	2.34	2.14	2.27	2.54	2.01	2.21	2.83	2.59	2.29	2.11	1.47	0.98	1.23	1.60	0.93	0.56	0.27	2.08
MI10	3.99	3.64	3.95	3.69	4.02	3.53	4.38	4.52	4.24	3.26	3.80	3.76	2.72	2.44	2.84	2.49	2.31	2.42	2.94	2.29	0.74	0.22	3.36
MI11	4.28	4.56	3.86	3.45	4.50	3.62	4.52	4.65	4.33	4.08	4.48	3.26	3.04	3.38	2.97	3.80	2.22	2.16	4.21	1.74	0.87	0.24	3.66
MI12	3.83	4.08	3.91	3.84	4.19	3.96	3.40	3.99	4.27	3.78	4.06	3.55	3.16	4.08	2.69	3.93	2.32	3.39	4.57	3.31	0.54	0.15	3.72
MI13	3.84	3.23	3.56	4.01	3.65	3.53	3.30	4.16	4.45	3.46	3.83	3.30	2.69	1.98	2.28	2.30	1.13	1.26	2.21	1.65	0.99	0.33	2.99
MI14	3.77	4.73	4.15	3.47	3.97	3.66	3.71	3.25	3.58	3.23	3.14	4.46	3.52	5.73	3.47	3.22	4.27	2.02	2.45	2.57	0.83	0.23	3.62
MI15	3.43	2.43	3.57	3.64	3.41	3.49	2.49	3.50	3.55	3.21	3.46	2.53	2.98	2.47	2.38	2.04	1.75	1.80	1.76	1.75	0.71	0.26	2.78
C	6.09	8.23	6.51	7.59	7.03	8.41	3.95	7.01	5.46	7.65	6.75	4.35	5.32	4.52	4.64	5.64	5.07	3.31	4.64	6.12	1.46	0.25	5.91
MS18	7.00	4.85	6.16	3.78	5.69	5.24	4.48	5.57	4.22	4.31	6.00	6.88	4.94	6.21	5.81	6.03	4.94	5.65	4.93	4.27	0.90	0.17	5.35
MS19	2.50	2.58	2.63	3.82	3.24	3.58	3.20	3.74	2.95	2.58	3.22	3.47	3.86	4.48	2.59	4.31	3.32	3.77	2.44	1.96	0.68	0.21	3.21
MS20	9.27	9.35	8.70	5.55	7.50	7.34	10.43	8.38	9.26	8.14	7.34	9.72	7.81	7.64	8.55	8.16	6.59	9.05	9.96	8.92	1.19	0.14	8.38
MS21	2.42	1.62	2.57	2.22	2.52	2.13	2.51	2.71	2.71	2.11	2.25	2.70	2.04	1.86	1.90	1.95	1.84	1.87	1.96	2.25	0.33	0.15	2.21
NMS	3.18	2.27	3.02	2.48	2.88	2.81	3.28	3.38	3.60	3.33	3.06	4.60	3.03	2.54	3.62	4.04	2.57	3.51	3.44	2.85	0.56	0.18	3.17
St. Dev.	1.92	2.21	1.74	1.38	1.58	1.78	1.93	1.62	1.67	1.80	1.60	1.86	1.68	1.76	1.73	1.83	1.65	1.95	2.03	2.00			
CV	0.48	0.58	0.42	0.37	0.40	0.47	0.52	0.39	0.42	0.49	0.42	0.46	0.47	0.48	0.52	0.54	0.61	0.67	0.59	0.70			
Aver.	4.00	3.78	4.09	3.71	3.92	3.79	3.75	4.14	3.98	3.64	3.84	4.01	3.60	3.66	3.31	3.41	2.70	2.91	3.45	2.88			

Table 7 Estimated Production Functions for Italian regions and sectors. 1970-94

Regions*					Sectors**				
	ε_K	ε_L	$\varepsilon_K+\varepsilon_L$	RS♦		ε_K	ε_L	$\varepsilon_K+\varepsilon_L$	RS♦
Valle d Aosta	0.41	0.58	0.99	C	AG	0.10	-0.18	-0.08	--
Piemonte	0.46	0.24	0.70	D	EN	-0.04	0.85	0.81	D
Lombardia	0.62	0.18	0.80	D	MI07	0.38	0.70	1.08	I
Trentino A.A.	0.59	0.44	1.03	I	MI08	0.61	0.76	1.37	I
Veneto	0.69	0.47	1.16	I	MI09	1.98	0.18	2.16	I
Friuli V.G.	0.49	0.22	0.71	D	MI10	0.79	0.72	1.51	I
Liguria	0.56	0.29	0.85	D	MI11	0.37	0.70	1.07	I
Emilia R.	0.61	0.42	1.03	I	MI12	0.76	0.48	1.24	I
Toscana	0.47	0.62	1.09	I	MI13	0.57	0.47	1.04	I
Umbria	0.65	0.46	1.11	I	MI14	0.59	0.52	1.11	I
Marche	0.42	0.56	0.98	D	MI15	0.84	0.07	0.91	D
Lazio	0.58	0.49	1.07	I	C	0.03	0.31	0.34	D
Abruzzo	0.51	0.76	1.27	I	MS18	0.28	0.71	0.99	C
Molise	0.31	0.84	1.15	I	MS19	0.55	0.67	1.22	I
Campania	0.54	0.41	0.95	D	MS20	0.43	0.27	0.70	D
Puglia	0.50	0.36	0.86	D	MS21	0.29	0.65	0.94	D
Basilicata	0.21	0.60	0.81	D	NMS	0.08	0.86	0.94	D
Calabria	0.50	0.10	0.60	D					
Sicilia	0.48	0.24	0.72	D					
Sardegna	0.41	0.58	0.99	C					

*Panel estimation across time and sectors with sectoral fixed effects.
**Panel estimation across time and regions with regional fixed effects.
♦RS=returns to scale; C=constant; D=decreasing: I=increasing.

Table 8 Estimated long run adjustment terms in ECM panel models

Regions						
	Δy		Δk		Δl	
	λ_1	t-test	λ_2	t-test	λ_3	t-test
VDA	-0.17	-5.09	0.00	0.86	0.00	-0.07
PIE	-0.09	-4.40	0.00	0.55	-0.01	-0.78
LOM	-0.06	-3.23	0.00	0.69	0.00	-0.18
TAA	-0.16	-3.43	0.01	1.56	-0.02	-0.77
VEN	-0.09	-4.04	0.00	0.19	-0.01	-0.33
FVG	-0.12	-3.69	0.00	0.56	0.00	-0.25
LIG	-0.22	-6.75	-0.01	-2.61	-0.02	-1.10
EMR	-0.11	-3.45	0.00	-0.11	0.00	0.18
TOS	-0.14	-3.76	0.00	0.27	0.00	0.01
UMB	-0.15	-5.61	0.01	0.63	-0.03	-1.79
MAR	-0.13	-3.50	-0.01	-1.43	-0.03	-1.26
LAZ	-0.08	-3.22	0.00	1.08	0.02	1.62
ABR	-0.13	-4.85	0.01	1.57	-0.01	-0.57
MOL	-0.09	-2.57	0.01	0.73	0.03	1.78
CAM	-0.10	-4.27	0.00	1.02	0.01	1.77
PUG	-0.12	-4.73	0.00	0.75	-0.03	-1.40
BAS	-0.17	-5.47	-0.02	-3.18	-0.01	-0.74
CAL	-0.24	-10.71	-0.01	-0.87	-0.03	-1.61
SIC	-0.18	-6.62	0.00	-0.82	-0.03	-2.63
SAR	-0.13	-5.66	0.01	1.19	-0.03	-1.70
ITALY						
Panel 1	-0.16	-15.24	0.02	4.05	0.04	6.14
Panel 2	-0.15	-5.45	0.03	3.10	0.03	1.58
Panel 3	-0.09	-4.02	0.00	0.96	0.01	1.09

Sectors						
	Δy		Δk		Δl	
	λ_1	t-test	λ_2	t-test	λ_3	t-test
AG	-0.37	-5.96	0.01	1.47	-0.04	-1.91
EN	-0.32	-6.16	0.01	0.92	0.01	0.61
MI07	-0.41	-6.30	0.01	0.80	0.04	1.58
MI08	-0.19	-5.60	0.03	1.97	0.19	5.79
MI09	-0.09	-5.07	0.01	1.72	0.02	1.71
MI10	-0.21	-5.39	0.07	1.83	0.04	1.42
MI11	-0.21	-5.03	0.03	1.75	0.04	1.10
MI12	-0.21	-4.42	0.03	1.62	0.01	0.39
MI13	-0.15	-3.61	0.05	1.69	0.03	1.26
MI14	-0.25	-4.03	0.03	1.56	-0.00	0.05
MI15	-0.12	-3.76	0.04	1.94	0.03	1.42
C	-0.25	-6.21	0.01	1.25	0.10	2.95
MS18	-0.18	-5.83	0.01	1.10	0.12	4.06
MS19	-0.25	-7.55	0.01	1.29	0.04	2.01
MS20	-0.17	-5.56	0.01	0.70	0.01	0.50
MS21	-0.18	-5.89	0.02	2.81	0.22	5.78
NMS	-0.15	-4.78	0.06	1.57	0.15	4.44

Table 9 Tests of Granger causality, *p*-values

H_0: $\lambda_h = 0$				h=1,2,3			
Regions				Sectors			
Model	Δy	Δk	Δl		Δy	Δk	Δl
VDA	0.00	**0.39**	**0.95**	AG	0.00	**0.14**	**0.06**
PIE	0.00	**0.58**	**0.44**	EN	0.00	**0.36**	**0.55**
LOM	0.00	**0.49**	**0.85**	MI07	0.00	**0.43**	**0.11**
TAA	0.00	**0.12**	**0.44**	MI08	0.00	0.05	0.00
VEN	0.00	**0.85**	**0.74**	MI09	0.00	**0.09**	**0.09**
FVG	0.00	**0.58**	**0.80**	MI10	0.00	**0.07**	**0.16**
LIG	0.00	0.00	**0.27**	MI11	0.00	**0.08**	**0.27**
EMR	0.00	**0.91**	**0.86**	MI12	0.00	**0.11**	**0.69**
TOS	0.00	**0.79**	**1.00**	MI13	0.00	**0.09**	**0.21**
UMB	0.00	**0.53**	**0.07**	MI14	0.00	**0.12**	**0.96**
MAR	0.00	**0.15**	**0.21**	MI15	0.00	0.02	**0.16**
LAZ	0.00	**0.28**	**0.11**	C	0.00	**0.21**	0.00
ABR	0.00	**0.12**	**0.57**	MS18	0.00	**0.27**	0.00
MOL	0.01	**0.47**	**0.08**	MS19	0.00	**0.20**	**0.05**
CAM	0.00	**0.31**	**0.08**	MS20	0.00	**0.49**	**0.61**
PUG	0.00	**0.45**	**0.16**	MS21	0.00	0.01	0.00
BAS	0.00	0.00	**0.46**	NMS	0.00	**0.12**	0.00
CAL	0.00	**0.38**	**0.11**				
SIC	0.00	**0.41**	0.01				
SAR	0.00	**0.23**	**0.09**				
ITALY							
Panel 1	0.00	0.00	0.00				
Panel 2	0.00	0.00	**0.12**				
Panel 3	0.00	**0.34**	**0.28**				

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