Società italiana di economia pubblica
XVI CONFERENZA

POLITICHE PUBBLICHE, SVILUPPO E CRESCITA

Pavia, Università, 7 - 8 ottobre 2004

NEOCLASSICAL VERSUS TECHNOLOGICAL CONVERGENCE: AN EMPIRICAL ANALYSIS APPLIED TO ITALIAN REGIONS

CARLUCCIO BIANCHI E MARIO MENEGATTI

pubblicazione internet realizzata con contributo della COMPAGNIA di San Paolo

Neoclassical versus Technological Convergence: An Empirical Analysis Applied to Italian Regions

Carluccio Bianchi

Dipartimento di Economia Politica e Metodi Quantitativi, Università di Pavia

Mario Menegatti

Dipartimento di Economia, Università di Parma

PRELIMINARY VERSION

Abstract. This work tests for the existence of neoclassical and/or technological catching up between Italian regions in last three decades. The tests are performed by means of a modified β-convergence equation and of a model founded on the decomposition of output growth. The results imply that while the first convergence mechanism occurred, the second one failed. The paper also provides a possible explanation for these results and analyses their policy implications, suggesting that a complete convergence between Italian regions may be achieved only by promoting technological transfers and by increasing research investment in poorer regions.

Keywords: Convergence, catching up, TFP, Italian regions
JEL Classification: O41, O47, O49

1. **Introduction**

The examination of Italian regional accounts shows that in the last three decades the growth of GDP per worker has been on average higher in the poorer than in the richer regions. This phenomenon has led to a reduction in GDP per worker differences, thus causing a form of convergence between regions. The experienced convergence, however, has been only partial, since the GDP per worker of the least developed regions is still quite below that of the most developed ones.

The presence of a negative relationship between initial GDP per worker and subsequent growth is a phenomenon largely documented in the literature with reference to both cross-countries and cross-regions analyses. A large evidence on this phenomenon was firstly provided by the well-known papers by Abramovitz (1986), Baumol (1986), Barro (1991) and Mankiw, Romer and Weil (1992), and was then confirmed by a wide literature applying different techniques and examining different data sets (as, for instance, in Barro and Lee (1994), Barro and Sala-i-Martin (1995), Sala-i-Martin (1996) and Temple (1999)).[1]

It is interesting to notice that the theoretical foundations of the idea that poor economies should catch up the rich ones can be traced indifferently to two alternative kinds of approach. On the one hand, the neoclassical Solow-Swan growth model implies that least developed economies should exhibit higher investment rates because of the assumption of a decreasing marginal productivity of capital. On the other hand, the technological catching up approach (firstly introduced by Abramovitz (1986), Baumol (1986) and Dowrick and Nguyen (1989), and recently examined in an endogenous growth model by Howitt (2000)) suggests that the catching up should occur because of the capability of follower economies to easily imitate the production technology of the leader.

Unfortunately the empirical tests about the two alternative theories described above have usually been performed in the literature by means of the same econometric procedure and specification, i.e. by simply examining the previously cited relationship between the initial level of output per worker and its subsequent growth (actually the other way round, with growth being the variable

[1] Recent surveys on this field are Temple (1999) and Islam (2003).

to be explained). The use of the initial output as a regressor, however, has two different interpretations according to the two alternative kinds of theoretical literature. In the approach founded on the Solow-Swan model it is a proxy for the level of the initial capital per worker, while in the technological catching up approach it proxies the level of the initial technology. A negative relationship between the initial GDP per worker and its subsequent growth is thus seen in the two cases respectively as an indication either that poorer economies exhibit higher growth (because of their larger capital accumulation) or that they grow faster because they can easily imitate the technology of the most developed economies.

The potential ambiguity of the convergence literature with reference to the theoretical mechanisms at its basis was firstly noted by Stokey (1994) and Temple (1999). A first attempt to solve this problem was proposed by Rogers and Dowrick (2002), who tried to distinguish and test separately the two possible convergence mechanisms in a cross-section of countries, by introducing in the estimated equation both a measure of capital accumulation and the initial value of output per worker, as a proxy of the initial TFP level.

The aim of this work is to try to distinguish and identify the factors underlying neoclassical convergence and/or technological catching up in the partial convergence process occurred between Italian regions in the last thirty years. The analysis will be based on a theoretical model and an empirical specification of it, capable of completely separating the two possible alternative mechanisms at work. Differently from Rogers and Dowrick (2002), indeed, this work proposes to use direct measures both for the initial regional capital per worker and for the initial regional TFP. The first measure is provided by the estimates made either by Paci and Pusceddu (2000) or by Bonaglia and Picci (2000). The valuation of the initial technology is instead a microeconomic proxy computed on the basis of a data sample of almost 23,000 firms surveyed by Mediocredito Centrale (1977).

The analysis proposed clearly indicates that the convergence process experienced between Italian regions was due to the dynamics of capital accumulation, as suggested by standard neoclassical theory, while on the contrary the technological catch up did not occur. It will be claimed that this conclusion is relevant for two different reasons. On the one hand it is important since it

describes the true cause behind the experienced convergence. On the other hand it reveals what mechanism did not work, thus indicating, by consequence, what kind of policy interventions ought to be implemented in order to complete or improve the convergence process.

The paper is organized as follows. Section two shows the empirical evidence about convergence between Italian regions in the period 1970-2001 and examines its potential sources. Section three discusses and compares the neoclassical and technological convergence mechanisms. Section four examines a possible explanation for the failure of the technological catching up between Italian regions. Section five analyses the policy implications that can be derived from the empirical results found. Section six concludes.

2. The convergence process and its possible sources

A simple test for the possible existence of a convergence process between Italian regions can be performed by using the so-called absolute β-convergence equation firstly studied by Baumol (1986), Barro (1991) and Barro and Sala-i-Martin (1991). This equation simply studies a cross-countries (or cross-regions) relationship between the growth of GDP per worker in a given period and the initial level of GDP per worker. If the relationship is found to be negative, it is claimed that poorer economies grow faster than richer ones, thus implying that a convergence process in the level of output per worker has occurred. The *absolute b-convergence equation* is thus given by

$$\ln\left(\frac{y_t}{y_s}\right) = \alpha + \beta \ln(y_s) \qquad \text{with } t > s \qquad [1]$$

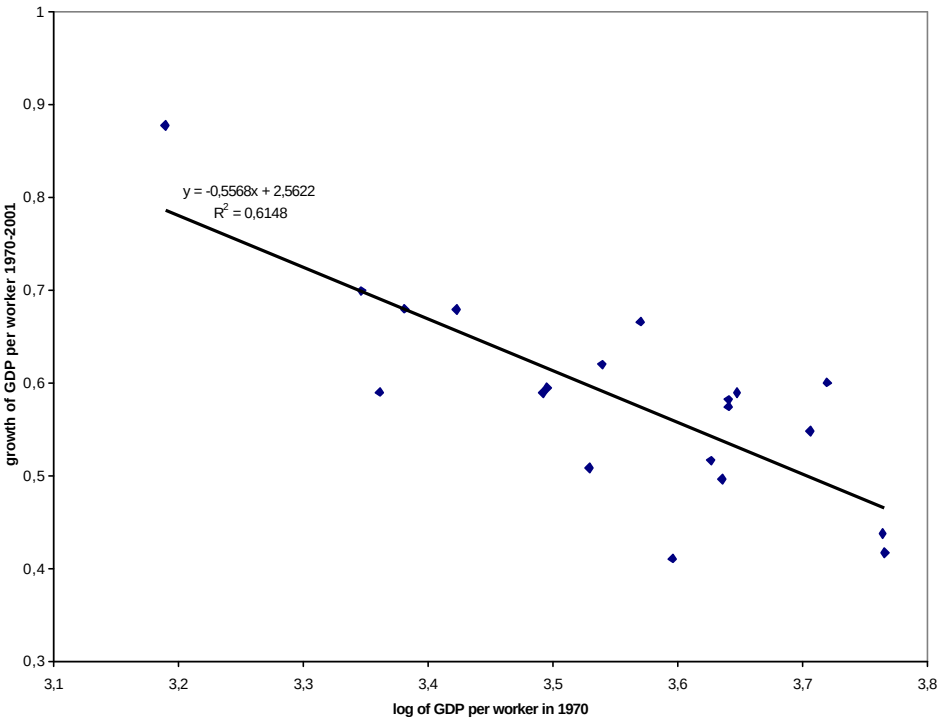
where y_t is GDP per worker in the final year and y_s is GDP per worker in the initial year.

This equation has been estimated for the period 1970-2001 using Italian regional data. The estimated value of coefficient β is –0.557, which is statically

significant at the 1% level.[2] This result supports the claim that a convergence process between Italian regions has taken place in the period under consideration.[3] A similar evidence is shown in figure 1, where a scatter plot between the two relevant variables and the derived regression line are reported. A confirmation of this result is also finally given by the dynamics of the regional coefficient of variation, whose value decreases from 0.15 to 0.10 in period 1970-2001.[4]

Although a convergence process has occurred, it can be easily shown that the experienced catch up is far from being complete. Indeed, the 2001 values of GDP per worker in the five poorest regions are still 80% of the same values in the five richest ones.

Figure 1. Convergence between Italian regions in the period 1970-2001



This phenomenon of partial convergence can be theoretically justified by two different mechanisms. On one hand it is possible that poorer regions grew

[2] The associated t-statistic is –5.36.

[3] Similar results were found in other works with reference to different periods. In particular, Paci and Pigliaru (1997) found a negative relationship between initial GDP per worker and its subsequent growth in the period 1970-92, while Bianchi and Menegatti (1997) found some evidence of absolute β-convergence in the period 1970-94.

faster than richer ones because of a decreasing rate of capital accumulation, as suggested by the Solow-Swan growth model. On the other hand, the experienced convergence could be due to technological transfers from rich to poor economies, enabling the latter ones to improve their production techniques. These two alternative convergence mechanisms, and their actual working, can be easily illustrated in a simple theoretical framework.

Consider a closed economy where firms produce a single good Y using a Cobb-Douglas production function:

$$Y_t = A_t K_t^{\theta} L_t^{1-\theta} \qquad [2]$$

where Y_t is output, K_t capital, L_t labour, and A_t the level of technology. Assuming, as usual, constant return to scale, this equation implies

$$y_t = A_t k_t^{\theta} \qquad [3]$$

where y_t is output per worker and k_t capital per worker.

Assume furthermore that capital depreciates through time at the constant rate d, while population grows at the constant rate n and saving is a constant fraction s of output. Under these assumptions capital accumulation is described by the usual dynamic equation:

$$\dot{k}_t = sy_t - (d+n)k_t \quad \text{with} \quad 0 < s < 1 \qquad [4]$$

Finally assume that technology improves at the constant rate g so that

$$A_t = A_0 e^{gt} \qquad [5]$$

The rate of technological progress g is however assumed to be different in different economies.

---

[4] This is the bulk of the so-called *s-covergence analysis*.

Substituting equation [5] into [3], differentiating with respect to time and dividing by y_t we get

$$\frac{\dot{y}_t}{y_t} = \theta \frac{\dot{k}_t}{k_t} + g \qquad [6]$$

The technological catching up approach suggests that there are technological transfers from the economy with the superior technology to the other ones. This hypothesis can be formalised by assuming that the features of technological progress for any economy are described by the following equation:

$$g = \varphi + \psi \ln\left(\frac{A^*}{A}\right) \qquad [7]$$

where j and y are constant terms and A^* is the higher value of A in the group of economies under examination. Substituting [7] into [6] we get then:

$$\frac{\dot{y}_t}{y_t} = \theta \frac{\dot{k}_t}{k_t} + \left(\varphi + \psi \ln\left(\frac{A^*}{A}\right)\right) \qquad [8]$$

The two terms in [8] illustrate the two possible catching up mechanisms at work. The first term shows that the growth of output per worker depends upon capital accumulation. Since, according to equation [4] and by the assumption of decreasing return to capital in [2], accumulation is larger in poorer economies, this term implies that these regions will exhibit a larger output per worker growth (*neoclassical catching up*). The second term shows instead that a greater distance from the technological leader will generate a larger output growth, so that economies with a lower initial technological level will grow faster (*technological catching up*). Obviously the two mechanisms can work either separately or together.

The analysis in the next section will test for the existence of these two mechanisms in the convergence process of Italian regions, by using an appropriate

econometric specification. Before implementing this test, however, it seems useful to perform an analysis of *absolute b-convergence*, studied by means of equation [1], in order to compare its results with those of *conditional b-convergence*. The latter analysis is performed, as usual, by examining the relationship between the initial level of GDP per worker and its subsequent change, after controlling for all other variables capable of characterizing the different steady states of the economies under examination or, in general, of all other variables capable of affecting economic growth.[5] The equation to be estimated in this case is

$$\ln\left(\frac{y_t}{y_s}\right) = \alpha + \beta \ln(y_s) + \gamma X \qquad \text{with } t > s \qquad [9]$$

where *g* is a vector of parameters and *X* is a vector of control regressors. Vector *X* usually includes several variables, such as: the investment ratio (INV), the labour force growth (N) and the stock of human capital (H) (the Appendix provides a detailed description of these variables).[6] Our data set also includes a microeconomic measure of the initial regional TFP, which can be used to test the hypothesis of technological catching up. This measure is computed from a data set referred to a sample of 23,000 firms surveyed by Mediocredito Centrale (1977).[7]

When equation [9] is estimated, the coefficient β is equal to –0.898 and is statistically significant in a strong way.[8] This result can be interpreted as a further confirmation of the existence of absolute convergence, as indicated by equation [1].[9] Moreover the estimate for the parameter associated with variable A is equal to 0.181 and is also strongly significant from a statistical standpoint.[10] This further

[5] This kind of analysis was firstly implemented by Barro (1991) and Barro and Sala-i-Martin (1991). For more details on this approach see also Barro and Sala-i-Martin (1995).
[6] Note that the data for human capital are the average values in the period 1970-94. The same data are used in the regressions in table 1.
[7] The data concern production, employees and the capital stock for each firm in 1973. Starting from this type of information and collecting data for each region, one can compute the value of regional TFPs by assuming that the production function is Cobb-Douglas and the factors of production elasticities are equal to their shares in regional income. The same measure was firstly used in Bianchi and Menegatti (1997).
[8] The associated t is –6.96
[9] The presence of *absolute b-convergence* obviously implies the existence of *conditional b-convergence*.
[10] The associated t-statistic is 3.27.

result has two implications. Firstly it shows that differences in the initial technology are relevant for growth, thus implying that technology transfers can be a potentially relevant source of convergence. Secondly it indicates that the steady states of Italian regions are different, with the obvious implication that, even if the neoclassical convergence mechanism had worked completely, a full convergence between Italian regions could have been achieved only if a technological catch up had occurred too.

3. **Neoclassical versus technological convergence**

On the basis of the results of previous analysis we can now compare the relevance of neoclassical and technological convergence mechanisms. For this purpose we use two different econometric specifications. First we start with estimating a simple modification of a *conditional b-convergence* equation, where the two catching up mechanisms are distinguished. Equation [9] examines the possible existence of a catching up phenomenon by simply introducing the initial output per worker among the regressors. In order to test separately the hypotheses of neoclassical and technological catching up, we introduce a different additional regressor in order of being capable of taking care of each of the two alternative explanations. A test for assessing and comparing the validity of the two alternative mechanisms of convergence under scrutiny can therefore be obtained by estimating the equation

$$\ln\left(\frac{y_t}{y_s}\right) = \alpha + \beta\ln(k_s) + \gamma\ln\left(\frac{A_s^*}{A_s}\right) + \delta X \qquad \text{with } t > s \qquad [10]$$

The variable $ln(k_S)$ is the logarithm of the initial capital per worker. A negative coefficient associated with this variable would confirm the neoclassical conjecture that capital accumulation is larger in poorer regions, thus favouring a faster growth of theirs. In our analysis we make use of two alternative estimates of the initial capital stock, taken respectively from the two series produced by Paci

and Pusceddu (2000) and by Bonaglia and Picci (2000). These two alternative estimates of the regional capital stocks are labelled respectively INK1 and INK2.

The variable $\ln\left(\frac{A_s^*}{A_s}\right)$, called DIFA, is a measure of the distance between the initial TFP of any region (A_s) and the TFP of the region being the technological leader (A_s^*). A positive coefficient associated with this variable would confirm the conjecture that the least developed regions partially converge to the richer ones because they can easily improve their technological level by imitating the technology of the leader economy. The methodology used in the construction of the data set referring to this variable has been described in section two.

The most relevant coefficient estimates appearing in equation [10] are shown in table 1; in particular, the table summarises the estimates for the parameters b and g, obtained in regressions using a different set of control variables. The period examined is from 1970 to 2001.

Table 1. Neoclassical vs. technological catching up in b-convergence regressions

Regressors	Estimate for β	Estimate for γ	Adjusted R^2
INK1, DIFA	-2.80[a] (-2.36)	0.121 (1.35)	0.24
INK1, DIFA, INV, N, H	-0.398[b] (-3.49)	-0.017 (-0.16)	0.43
INK2, DIFA	-0.084 (-0.97)	0.016 (1.55)	0.05
INK2, DIFA, INV, N, H	-0.280[a] (-2.55)	0.005 (0.05)	0.34

[a] significant at the 5% level; [b] significant at the 1% level

An inspection of the results of the estimates shows that the coefficient for the initial GDP per worker is negative and strongly significant in both regressions using the capital stock measures provided by Paci and Pusceddu. The estimates performed by using the capital stock measures supplied by Bonaglia and Picci both show a negative b coefficient, which is however significant only in the regression where control variables are introduced. The overall results, considered

together, give then a strong indication in favour of the existence of a neoclassical convergence mechanism.

The coefficient for the differences in initial TFP, on the contrary, while positive, as predicted by the technological catching up theory, is never significant in all four regressions. The results obtained, therefore, clearly reject the conjecture that a technology catching up has occurred between Italian regions.

A possible shortcoming of the previous approach is given by the fact that each of the estimated regressions is not a specification directly coming from an explicit economic model, but is just founded upon an equation including a group of variables affecting growth.[11] A possible solution to this potential problem is obtained by using a second econometric specification, provided by a modification of that proposed by Dowrick and Rogers (2002) and directly derived by the simple model described in section two. In fact, if one considers the logarithm of the ratio $\frac{y_t}{y_s}$ and uses the production function [3] and a modification of equation [7] (where the average growth of A is substituted by the total growth of A), one gets

$$\log\left(\frac{y_t}{y_s}\right) = \theta \log\left(\frac{k_t}{k_s}\right) + \varphi + \psi \ln\left(\frac{A_s^*}{A_s}\right) \qquad [11]$$

Given this result we can study neoclassical and/or technological convergence by estimating the equation

$$\log\left(\frac{y_t}{y_s}\right) = \alpha + \beta \log\left(\frac{k_t}{k_s}\right) + \gamma \ln\left(\frac{A_s^*}{A_s}\right) \qquad [12]$$

The value of coefficient b can be used to test the presence of a neoclassical catching up due to diminishing return to capital, while the value of coefficient g

[11] These are the so-called "informal growth regressions (Temple, 1999), which are one of the most largely used technique to empirically study the sources of growth.

can be used to test the presence of a technological catching up due to technological transfers.

Moreover the previous equation can also be studied by introducing human capital per worker (*h*) in the production function. We have in this case

$$\log\left(\frac{y_t}{y_s}\right) = \alpha + \beta\log\left(\frac{k_t}{k_s}\right) + \gamma\ln\left(\frac{A_s^*}{A_s}\right) + \delta\log\left(\frac{h_t}{h_s}\right) \qquad [13]$$

The estimates of the most relevant coefficients in equations [12] and [13] are reported in the first four lines of table 2. [12] The table shows the results obtained by using different capital stock series (the Paci and Pusceddu (2000) series, called GRK1, and the Bonaglia and Picci (2000) series, called GRK2). Since both the series are supplied until the middle of the '90s, the performed estimates refer to the period 1970-94.

Table 2. Neoclassical vs. technological catching up in growth rate decomposition regressions

Regressors	Estimate for β	Estimate for γ	Adjusted R^2
GRK1, DIFA	0.296[a,c] (2.32)	0.015 (0.18)	0.16
GRK1, DIFA, GRH	0.263[a,c] (2.23)	0.069 (0.86)	0.30
GRK2, DIFA	0.340[a,c] (2.26)	0.012 (0.14)	0.15
GRK2, DIFA, GRH	0,356[a,c] (2.77)	0.119 (0.94)	0.38
GRK3, DIFA	0,306[a,c] (2.42)	0.022 (0.27)	0.18
GRK3, DIFA, GRH	0,274[a,c] (2.36)	0.075 (0.94)	0.31
GRK4, DIFA	0.377[a,c] (2.51)	0.020 (0.24)	0.20
GRK4, DIFA, GRH	0.399[b,c] (3.17)	0.080 (1.13)	0.44

[a] significant at the 5% level; [b] significant at the 1% level; [c] The hypothesis that the coefficient is 1 is rejected at the 1% level.

[12] Residuals computed using the sum of patents in the two subperiods generate results similar to those shown in the table.

The estimates again support the claim for the existence of a neoclassical convergence mechanism, while they reject the occurrence of a technological catching up. These results thus confirm the previously reached conclusions: convergence between Italian regions has depended upon capital accumulation, while technological catching up has not been a relevant phenomenon.

A possible problem with the previous specifications is related to the possibility that technical progress is somehow embodied in new capital goods. If, indeed, improvements in technology are introduced in the production process by substituting old equipments with new ones, then the growth rate of capital (GRK1 or GRK2) can include both the sheer increase in capital accumulation and the improvements in the technology used.[13] In order to try to solve this potential shortcoming we propose a different measure of the capital growth, deducting the effect of technical progress from the increase in the capital stock. This variable is obtained as the residuals of the regression between capital growth (referred to either the Paci and Pusceddu or the Bonaglia and Picci data) and a proxy for the specific technological progress at the regional level. This possible proxy for the rate of technical progress is given by the number of patents registered in each region. A dataset by Crenos (1999), in particular, provides information on the number of registered patents in the two periods from 1981 to 1985 and from 1990 to 1994. The growth rates of the capital stock computed by using the residuals of the two just recalled regressions are labelled respectively GRK3 and GRK4.

The tests about the validity of the neoclassical and technological convergence mechanisms performed using the new capital growth series excluding embodied technical progress are shown in the last four lines of table 2. These tests clearly confirm the existence of neoclassical convergence, while rejecting the hypothesis of technological catching up.

4. The failure of the technological catching up

The analysis developed in the previous section indicates that the partial convergence process occurred between Italian regions, described in section two,

[13] Note that this potential shortcoming is not present using the specification shown in equation [10] where just the level of the initial capital stock is introduced.

has been due to the neoclassical catching up mechanism relying on the features of capital accumulation. The effect of a technological catch up, on the contrary, was substantially not relevant for the experienced phenomenon of convergence.

The aim of this section is to deepen the analysis of this last result examining the relationship between the state of the initial technology and the subsequent technical progress. This analysis is important for two different reasons. Firstly it is necessary to confirm the conclusion reached above concerning the failure of a technological catching up. If, indeed, this conclusion is correct it means that technical progress has been larger in the regions with a higher initial TFP. This conjecture is tested in this section. Secondly, when the conclusion is confirmed, the examination of the relationship between the initial technology and the subsequent technical progress is useful in order to understand the specific reasons why the technological catching up did not occur and what kind of intervention may be necessary in order to make it work in the future.

The simplest way to test whether the level of technology has grown at a larger rate in regions characterised by a higher initial level is to compare the values of regional TFPs in different instants in time. Unfortunately we have just one observation for TFP, since the surveys by Mediocredito Centrale made after 1977 do not provide the information necessary to replicate the experiment.

Even if a direct comparison of TFP in different periods is not possible, we can try to infer some information about the dynamics of technology by examining the data on some variables related to the size and intensity of regional technical progress. In particular, in order to see whether the technological progress has been more rapid in the regions with a larger initial TFP, it is possible to examine the relationship between the number of registered patents and the initial TFP.[14] The results obtained with this enquiry are summarised in the first two lines of table 3.

The estimates performed clearly indicate the presence of a positive relationship between the initial level of regional TFP and the subsequent number of registered patents. This result confirms the conjecture that regions with a larger

[14] The two regressions examine the relationships between initial TFP and respectively the number of patents in period 1981-85 and in the period 1990-94. A result similar to those reported is obtained using the sum of patents in the two periods.

initial TFP have experienced a higher pace of technical progress, thus providing an explanation for the failure of a technological catching up.

Table 3. Initial regional TFP and patents or research expenditure in subsequent years

Regressor	Estimate of the parameter (t-student)	R^2
PAT8185	0.007[a] (3.06)	0.31
PAT9094	0.002[a] (2.98)	0.29
RESEXP	0.0002[a] (2.33)	0.19

[a] significant at the 5% level

The phenomenon just described could finally be explained by examining the choice made in each region with reference to the resources devoted to promote technological improvements. Some information on this issue can be obtained by examining the relationship between the average share of regional GDP devoted to research expenditure[15] and the initial TFP. The estimate obtained pursuing this approach is shown in the last line of table 3, which indicates the presence of a positive and strong relationship between the two variables. This result, together with the previous one, yields a possible final conclusion about the failure of technological convergence: the technological catching up did not happen since the regions with a larger initial TFP experienced a more rapid technical progress because of the larger fraction of their resources devoted to research, which also led to a higher number of innovations and patents.

5. Policy implications

The analysis proposed in the previous sections examined the sources of the partial convergence phenomenon experienced by Italian regions, comparing the two possible catching up mechanisms suggested by the relevant economic theory. The results obtained are important not only for a correct understanding of the factors behind the convergence process that occurred but also for the

identification of the means that could help policy interventions to promote a complete or more intense recovery of poorer regions.

In order to examine these implications let us reconsider the previously reached conclusions together. Firstly the analysis at the end of section two showed the existence of significant differences in regional technology levels in 1970. This result clearly indicates that a complete convergence between Italian regions can occur only if these differences are eliminated. The comparison between catching up mechanisms, furthermore, suggests that a neoclassical catching up of poor regions occurred in last decades while a technological one did not. Capital accumulation dynamics were thus able to generate convergence while technological transfers were not.

The obvious implication of these two conclusions is that, since a process of technology homogeneization is not autonomously generated by technology imitation, a complete convergence between Italian regions will be possible only if this process is stimulated by a specific public policy. This policy should act in two directions. On the one hand it should favour the transfer of technology from more developed areas to poorer ones. On the other hand it should promote an increase in the share of resources devoted to research especially in poorer regions. Policies acting on the dynamics of physical capital, on the contrary, seem less useful to increase convergence since a catching up due to capital accumulation has already occurred.

6. Conclusions

The Italian regions experienced in last three decades a phenomenon of partial convergence leading to a reduction in the differences between regional values of GDPs per worker. This paper tried to show which of the possible mechanism proposed by the relevant economic theory was responsible for generating the experienced convergence results, by comparing in an empirical analysis neoclassical and technological catching up.

[15] The data published by Istat on this variable are available since 1978.

The test about the validity of the two alternative mechanism was performed using two different possible econometric specifications and a few different measures of the capital stock. The results indicate in all cases the presence of a neoclassical convergence mechanism, excluding, on the contrary, the existence of a technological catching up. The empirical investigation performed thus clearly indicates that the convergence phenomenon experienced between Italian regions has been completely due to capital accumulation.

The analysis presented proposes a possible explanation for this conclusion. An investigation of the relationship between the initial regional TFP and the data concerning patents and research expenditure showed, indeed, that the technological catching up did not occur because the regions initially provided with a better technology were also characterised by a greater number of innovations and a higher investment share in research.

The study of the sources of convergence between Italian regions has some quite relevant policy implications. The empirical analysis and results clearly indicate, in fact, that the effort to reduce regional differences in GDP per worker in Italy should be concentrated in promoting technological transfers between regions and in increasing the amount of resources dedicated to research in poor areas, rather than insisting in stimulating increases in their capital accumulation.

7. References

Abramovitz M. (1986), "Catching up, Forging Ahead and Falling Behind", *Journal of Economic History,* 46, 385-406

Barro R. J. (1991), "Economic Growth in a Cross Section of Countries", *Quarterly Journal of Economics*, 106, 407-433.

Barro R. J. and Sala-i-Martin (1991), "Convergence across States and Regions", Brooking papers on economic activity, 1, 107-182.

Barro R. J. and Lee J.-W. (1994), "Sources of Economic Growth", *Carnegie-Rochester Conference Series on Public Policy*, 40, 1-46.

Barro R. J. e Sala-i-Martin X. (1995), "*Economic Growth*", McGraw-Hill, New York.

Baumol W. J.(1986), "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show", *American Economic Review*, 76 (5), 1072-1085.

Bianchi C. and Menegatti M. (1997), "Differenziali regionali di produttività e crescita economica: un riesame della convergenza in Italia nel periodo 1970-94", *Studi Economici*, vol. 63, 15-42.

Bianchi C. and Menegatti M. (1999) "La convergenza fra le regioni del Nord Italia: una verifica empirica", *Rivista Internazionale di Scienze Sociali*,107, 165-191.

Bonaglia F. and Picci L. (2000), "Lo stock di capitale nelle regioni italiane", Working paper n. 374, DSE, Università di Bologna

Crenos (1999), "Data bank on regional patents", Cagliari

Dowrick S. and Rogers M. (2002), "Classical and Technological Convergence: Beyond the Solow-Swan Growth Model", *Oxford Economic Papers*, 54, 369-385.

Dowrick S. and Nguyen D. T. (1989), "OECD comparative economic growth 1950-85: catch up and convergence", *America Economic Review*, 79, 1010-1030.

Howitt (2000), "Endogenous Growth and Cross-Countries Income Differences", *American Economic Review*, 90, 829-846.

Islam, N. (2003), "What Have we Learnt from the Convergence Debate?", *Journal of Economic Surveys*, 17, 309-362.

Mankiw N. G., Romer D. and Weil D. N. (1992), "A Contribution to the Empirics of Economic Growth", *Quarterly Journal of Economics*, 107, 407-437.

Mediocredito centrale (1977), "*Indagine sulle imprese manifatturiere, 1973*", Roma

Paci R. e Pigliaru F. (1997), "Structural change and convergence: an Italian regional perspective", Structural Change and Economic Dynamics, 8, 297-318.

Paci R. and Pusceddu N. (2000), "Stima dello stock di capitale nelle regioni italiane: 1970-1994", *Rassegna Economica, Quaderni di ricerca*, 4, 97-118.

Sala-i-Martin (1996), "The classical approach to convergence", *Economic Journal*, 106, 1019-1036.

Solow R. M. (1956), "A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, 70, 65-94.

Stokey N. (1994),"Sources of Economic growth: comments on Barro-Lee", *Carnegie Rochester Conference on Public Policy*, 40, 47-57

Swan T. W. (1956), "Economic Growth and Capital Accumulation", *Economic Record*, 32, 334-361.

Temple J. (1998), "Equipment Investment in Solow Model", *Oxford Economic Papers*, 50, 39-62

Temple J. (1999), "The New Growth Evidence", *Journal of Economic Literature*, 37, 112-156.

8. Appendix

We summarise in this section the exact description and sources of the regressors used in this paper.

Table A1. Regressors description and sources

Variable	Description	Source
INK1	Per worker capital stock in 1970	Estimates by Paci and Pusceddu (2000)
INK2	Per worker capital stock in 1970	Estimates by Bonaglia and Picci (2000)
INV	Average of the ratio investment/GDP in the period 1970-2000	Istat
N	Average growth rate of employment (in ULS) in the period 1970-2001	Istat
H	Partecipation in secondary school in the period 1970-94	Istat
A	TFP in 1973	Estimates based on data by Mediocredito Centrale (1977)
GRK1	Capital growth in period 1970-94	Estimates by Paci and Pusceddu (2000)

Table A1 (continued)

GRK2	Capital growth in period 1970-94	Estimates by Bonaglia and Picci (2000)
GRK3	Residuals of the regressions of GRK1 on PAT8185 and PAT9094	
GRK4	Residuals of the regressions of GRK2 on PAT8185 and PAT9094	
GRH	Growth of partecipation in secondary school in the period 1970-1994	Istat
DIFA	Logarithm of the ratio between the largest value of A and the value of A in the region	
PAT8185	Number of patents in the period 1980-85	Crenos (1999) Data bank on regional patents
PAT9094	Number of patents in the period 1980-85	Crenos (1999) Data bank on regional patents
RESEXP	Share of GDP devoted to research in the period 1978-1994	Istat