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TECHNOLOGICAL CATCH-UP OR NEOCLASSICAL CONVERGENCE? IDENTIFYING THE CHANNELS OF CONVERGENCE FOR ITALIAN REGIONS

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Technological Catch-up or Neoclassical Convergence? Identifying the Channels of Convergence for Italian Regions

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We investigate whether Italian regions have converged in terms of output per worker because of physical capital accumulation, human capital accumulation or thanks to technological catch-up. In order to identify channels of convergence we adopt the methodology recently proposed by Wong (2007) and Feyrer (2007) which combine growth accounting with convergence regressions. Merging two datasets of regional economic accounts (ISTAT and CRENoS) to obtain longer time series, we show that convergence has been realized mainly thanks to technological catch-up and, to some extent, through human capital accumulation. On the other hand, physical capital has been a factor of divergence. These results are robust to model specifications, sets of data and alternative assumptions on parameters value.

Keywords: Absolute and Conditional Convergence; Channels of Convergence Technological Catch-up; Capital Accumulation; Italian regions.

JEL classification: O470; E230; E130

1. Introduction

A fundamental question tackled in recent empirical researches on growth is whether rich economies produce higher levels of income because they employ a greater amount of physical and human capital or because they use better technologies and employ inputs more efficiently. Hall and Jones (1999), Klenow and Rodriguez-Clare (1997), Caselli (2005), among many others, have found that technological differences are the main causes of the uneven levels of development across countries, whereas less than half of the differences in development can be explained by different levels of accumulation of physical or human capital.[1]

A distinct but related question – which has received much less investigation – is whether countries tend to *converge* thanks to factor accumulation or technological catch-up, that is, whether poor economies accumulate more rapidly human and physical capital and whether technical knowledge tends to flow across countries or instead differences in technologies tend to persist over time.

According to the standard growth theories, less developed economies grow faster than rich ones for two fundamental reasons: 1) Because of diminishing returns to capital, poor

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[1] However, other studies (Mankiw, Romer and Weil, 1992, Barro and Sala-i-Martin, 1995, Young, 1995) argue that the accumulation of factors plays a key role.

countries – which have lower endowment of capital – accumulate greater physical or human capital and, in addition, capitals tend to flow towards these economies characterized by higher returns (*Neo-classical convergence* or *capital deepening*); 2) Poor countries may adopt technologies and knowledge available in more advanced countries (*technological catch-up*).

Little evidence exists on this point mainly for the difficulties to separate empirically technological progress from capital deepening. In fact, in standard growth regressions the use of the initial level of output as explanatory variable may be interpreted both as a proxy for the endowment of capital and as a proxy for the level of technological efficiency of the economy. Therefore, it is not clear how much of the convergence that we observe is due to diffusion of technology rather than capital deepening of less developed countries (Bernard and Jones, 1996). Dowrick and Nguyen (1989) studying this aspect at cross-country level and adopting the strong assumption of a common capital-output ratio for all countries find a strong process of TFP convergence.[2] Recently, Wong (2007) has proposed an innovative method to study these aspects, finding that the growth of TFP has been the predominant factor of convergence across countries.

The aim of this paper is to investigate whether Italian regions in the last forty years have shown convergence because of physical capital accumulation, human capital accumulation or thanks to technological catch-up.[3] We adopt the methodology used by Wong (2007) and Feyrer (2007) in order to identify channels of convergence. This methodology is based on a combination of growth accounting analysis and convergence regressions and allows to separately estimate the contributions of physical and human capital and technology in the convergence process.

In the analysis, in order to make more significant comparisons over longer periods of time, we build economic series by merging two available datasets of regional economic accounts (ISTAT and CRENoS[4]) which cover different time periods.

We confirm that Italian regions have shown a (weak) process of convergence (measured both as absolute and conditional convergence) and we are able to show that this convergence has been realized mainly thanks to technological catch-up and in part through human capital accumulation. On the other hand, physical capital has not contributed at all to convergence and, according to some specifications, it seems to have led to divergence.

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[2] Other works documenting TFP convergence across countries are Dougherty and Jorgenson (1996) and Wolf (1991) who determine TFP levels across countries through a growth accounting exercise.

[3] At the level of Italian regions, Aiello and Scoppa (2000), Maffezzoli (2006) and Di Liberto, Pigliaru and Mura (2008) have shown that TFP differences are fundamental in explaining differences in output *levels* for recent years. Scoppa (2007) finds that TFP differences are considerably less important if one takes into account regional differences in the quality of human and physical capital.

[4] ISTAT is the Italian National Statistical Institute (Rome) and CRENoS is the Center for North-South Economic Research (Cagliari).

A number of sensitivity analyses are carried out. We check that our results are robust to different values of parameters of the production function, to the use of homogeneous datasets and different sample periods, to different model specifications.

Our results are in line with Di Liberto, Pigliaru and Mura (2008) and with Maffezzoli (2006) who – using different methodologies and studying different sample periods – find that TFP convergence has contributed to more similar levels of product per worker among Italian regions.

The paper is organized as follows. In Section 2 we briefly present the methodology used for identifying channels of convergence. In section 3 we present the data and discuss how we merge the datasets of ISTAT and CRENoS. In Section 4 we present our main results. Section 5 carries out a number of robustness exercises. Section 6 concludes.

2. The Methodology for Identifying Channels of Convergence

We follow the methodology of "channel decomposition" proposed by Wong (2007) (see also Feyrer, 2007) in order to identify the channels of convergence.

This methodology combines the traditional growth accounting analysis (see Solow, 1957) – in which the growth of output is decomposed into the contributions due to the growth of capital and to technological progress (the "Solow residual") – with the growth regressions *à la* Barro (in which the output growth is regressed on the initial level of output). The aim of "channel decomposition" is to establish how much of the convergence that we observe in a sample of economies is due to capital accumulation and how much is generated by technological catch-up.

We use a standard Cobb-Douglas aggregate production function with constant returns to scale, as in Hall and Jones (1999), to describe the production process in each region:

$$[1] \qquad Y = K^{\alpha}\left(AhL\right)^{1-\alpha}$$

where Y is the aggregate level of output, K is the stock of physical capital, h denotes the human capital per worker, L is the number of workers, A is a measure of technological efficiency or Total Factor Productivity (TFP) and α is the output elasticity of capital, equal to the capital share of income under the assumption that factors are paid their social marginal product.

By dividing both sides of [1] for Y^{α}, then dividing by L and rearranging:

$$[2] \qquad \frac{Y}{L} = \left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}} Ah$$

Taking logs of both sides yields:

$$[3] \qquad \ln\left(\frac{Y}{L}\right) = \frac{\alpha}{1-\alpha}\ln\left(\frac{K}{Y}\right) + \ln(h) + \ln(A)$$

Taking derivatives of both sides with respect to time we obtain:

$$g\left(\frac{Y}{L}\right)=\frac{\alpha}{1-\alpha}g\left(\frac{K}{Y}\right)+g(h)+g(A)=g(k)+g(h)+g(A) \qquad [4]$$

where $g(h)=\partial\ln(h)/\partial t$ denotes the growth rate of human capital, $g(A)=\partial\ln(A)/\partial t$ denotes the growth rate of TFP, and we define $g(k)=\frac{\alpha}{1-\alpha}g\left(\frac{K}{Y}\right)$ as the growth rate of physical capital. Equation [4] represents the typical decomposition provided by the growth accounting approach.

On the other hand, in convergence regressions the rate of growth of output per worker is regressed on a constant and on the initial level of output (in log):

$$g\left(\frac{Y}{L}\right)=c+\beta\ln\left(\frac{Y}{L}\right)_{t0} \qquad [5]$$

The estimation of a statistically significant parameter $\beta<0$ implies that poor regions tend to grow faster than rich ones. This result is defined "absolute β convergence", since it is implicitly assumed that regions converge to the same steady-state. Alternatively, it is possible to analyze the existence of "conditional β convergence" taking into account in equation [5] additional variables which proxy for different levels of steady-states of the economies.

The methodology of Wong (2007) is based on the following simple intuition. Since $g\left(\frac{Y}{L}\right)$, on the left-hand side of [5], is identically equal to the sum of three components in equation [4], we can regress separately each single component in [4] as in equation [5], that is:

$$g(k)=c_k+\beta_k\ln\left(\frac{Y}{L}\right)_{t0} \qquad [6]$$

$$g(h)=c_h+\beta_h\ln\left(\frac{Y}{L}\right)_{t0} \qquad [7]$$

$$g(A)=c_A+\beta_A\ln\left(\frac{Y}{L}\right)_{t0} \qquad [8]$$

By using a linear estimator it is possible to show that the sum of the β coefficients obtained in the separate regressions [6], [7] and [8] is equal to the β coefficient in equation [5], that is:

$$\beta\equiv\beta_k+\beta_h+\beta_A \qquad [9]$$

To see this more clearly, consider that by estimating equation [5] by OLS yields:

$$\beta=\frac{COV(g(y);\ln(y_{t0}))}{Var(\ln(y_{t0}))} \qquad [10]$$

where we use $y = Y/L$. By substituting $g(y) = g(k) + g(h) + g(A)$ in [10] we obtain: $\beta = \frac{COV(g(k) + g(h) + g(A); \ln(y_{t0}))}{Var(\ln(y_{t0}))}$. This can be written as:

[11] $$\beta = \frac{COV(g(k); \ln(y_{t0}))}{Var(\ln(y_{t0}))} + \frac{COV(g(h); \ln(y_{t0}))}{Var(\ln(y_{t0}))} + \frac{COV(g(A); \ln(y_{t0}))}{Var(\ln(y_{t0}))}$$

It is easy to ascertain that the first term corresponds to β_k, the second term to β_h and the last term to β_A.

Therefore, given a certain value of β implying absolute (or conditional) convergence, the relative magnitudes of the β_j coefficients will indicate the importance of each channel in determining the convergence, that is, we can interpret β_k as the contribution of the accumulation of physical capital to convergence, β_h as the contribution of human capital and β_A as the contribution of technological catch-up.

3. The Data

The main data sources we use are ISTAT (2005), "Regional Economic Accounts", containing the main economic variables for Italian regions for the period 1980-2004, the new Regional Economic Accounts for the period 2000-2007 (ISTAT, 2008), and CRENoS (2000) dataset "Regio-IT" covering the period 1960-1996.[5] The variables of interest are Gross Domestic Product, employment and investments.

Analyses of regional development are plagued by the problem of short time series, since ISTAT periodically revises the criteria followed in the building of the economic series, but it does not rebuild series for the past for a sufficient long period using the same criteria.

In order to overcome this problem we merge the two datasets we have available: ISTAT and CRENoS series overlap for the period from 1980 to 1996. The correlation between these series is very high, equal to 0.99 for output and employment and to 0.98 for investments.

For each variable *X*, we exploit the overlapping period between the two series to determine, for each region, a coefficient $\hat{\psi}$ from the following regression:

$$X\_istat_t = \psi(X\_crenos_t) \qquad \text{for } t = 1980..1996$$

By forcing the constant to be zero, in practice we determine a factor of proportionality between the two series.[6] Subsequently, the estimated coefficient $\hat{\psi}$ is used to generate homogeneous data X_istat_t for the period 1960-1979 on the basis of CRENoS data:

[5] The datasets are freely available respectively at www.istat.it and www.crenos.it

[6] The *t*-stat of ψ coefficients are typically extremely high (the median *t*-stat is about 100).

$$X\_istat_t = \hat{\psi}\left(X\_crenos_t\right) \qquad \text{for } t = 1960..1979$$

We use the same procedure to combine data from the new ISTAT dataset (2000-2007) with the old dataset (1980-2004), exploiting the 5 overlapping data (2000-2004) to impute homogenous data for 2005-2007.

Finally, the new series are formed with the original ISTAT data for the period 1980-2004, and with the generated data for the period 1960-1979 and for 2004-2007. In figure 1 we show for larger Italian regions the new series of GDP (continue line over the range 1960-2007), and the other original series (CRENoS: 1960-1996 and ISTAT:2000-2007: the two broken lines).

Furthermore, we combine with the same method average years of education among labour force, exploiting data provided by Ciccone (2004), based on Census data, for the period 1961-2001 with data provided by ISTAT Labour Force Survey (for the period 1982-2007).

An analogous strategy in order to merge two datasets with partial overlapping data has been followed, for example, by Acemoglu, Johnson and Robinson (2002, p. 1237).

Nevertheless, as robustness checks our analysis has been also carried out using time-homogeneous economic series, employing ISTAT data for the period 1980-2004 (see Section 5).

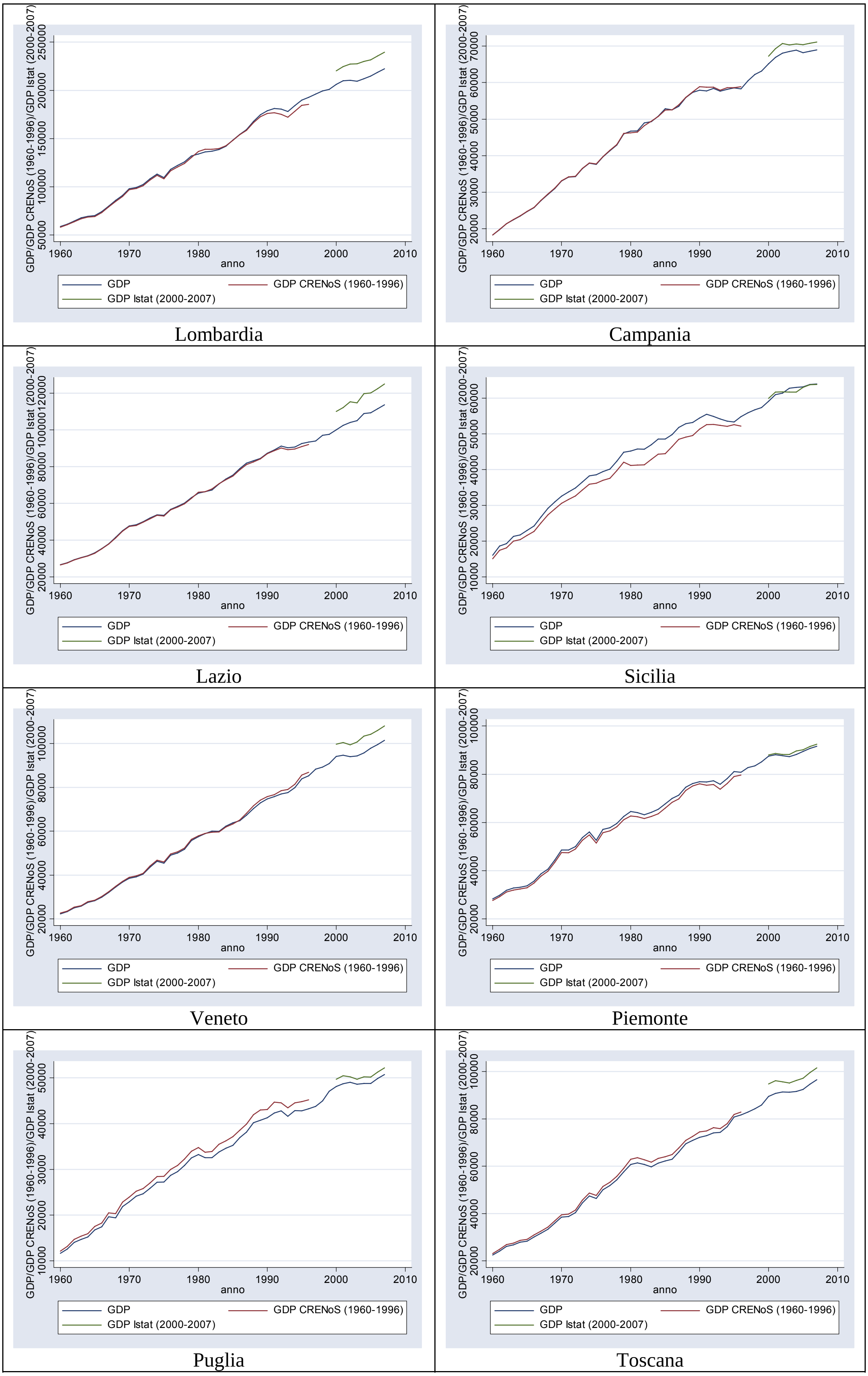

Figure 1. GDP series for major regions: CRENoS, ISTAT and newly built series

Measuring Output per Worker, Physical capital and Human Capital

All the variables are computed at constant 1995 price. The variable y is output per worker calculated as the ratio between regional Gross Domestic Product (Y) and the number of workers (L) (expressed in full-time standard measure).

Regional capital stocks K_t are calculated through the perpetual inventory method, through the equation $K_{t+1} = (1-\delta)K_t + I_t$, where I_t is total regional investment and δ is the rate of depreciation. The rate δ is set equal to 4%, in line with the effective average rate of depreciation, as calculated by ISTAT (2007).

The initial capital stock for each region in 1960 – as standard in the literature – is set to $K_{1960} = I_{1960}/(n+g+\delta)$, where n and g are the average growth of, respectively, employment and productivity. Note that to avoid attributing excessive weight to the initial data of capital stock, we start considering data from 1970.

The capital share of income α is calculated from the ISTAT National Economic Accounts as one minus the labour share, which in turn is determined as the ratio between labour income earned by employees and self-employed[7] over total income: $\alpha = 1 - \frac{Labour\_income}{Total\_income}$.[8] The value of α we use is 0.302. This value is in line with to the one estimated by Gollin (1992) and Bernanke and Gurkaynak (2001) for Italy (in their estimates α ranges between 0.29 to 0.35) and with the value determined by Mankiw, Romer and Weil (1992) in their cross-country analysis (α=0,30).

As is standard in literature (see Hall and Jones, 1999), human capital per worker is calculated through the Mincerian earnings functions. The stock of human capital per worker is determined as: $h = e^{\phi(s)}$ where s represents the average years of schooling per worker and $\phi'(s)$ indicates the rate of return on each year of schooling. In our baseline specification we assume that $\phi(s)$ is a linear function $\phi(s) = 0.068 * s$, using the average rate of return of education (6.8%) among OECD countries.

4. The Role of Capital Accumulation and Technological Catch-Up in Convergence

In this section we firstly determine the growth rates of output per worker, human capital and

[7] Self-employed workers are supposed to earn a labour income equal to employees.
[8] A very similar figure (0.304) is obtained by the ratio of gross profits to the value-added (at factor cost), taken as average over 1995-2007 period.

physical capital and then calculate the TFP growth rate as a Solow residual according to the growth accounting equation [4]. Growth rates are calculated as differences between the log of the respective variable in 2007 minus the log value of 1970. We do not use data from 1960 since we are not very confident about the reliability of data on capital stocks for this period.

Output per worker has grown cumulatively of about 57% (or 1.55% per year). The growth of physical capital ratio has been equal to 5.5% or 0.15% per year. Human capital has increased of 36% (0.97% per year). Finally, TFP has grown of 16% (or 0.43% per year).[9]

Using these growth rates we then estimate, respectively, equations [5], [6], [7] and [8] to determine the β coefficients and infer which factors contribute more to the convergence process across Italian regions. In all the regressions the observations are weighted in accordance with regional population[10] and standard errors are robust to heteroskedasticity.

Table 1. Channels of Convergence (Absolute Convergence). OLS estimates.

	Dependent Variables: Growth Rates (1970-2007) of:			
	Output per Worker (1)	Physical Capital (2)	Human Capital (3)	TFP (4)
Output per Worker 1970 (log)	-0.450***	0.078	-0.154**	-0.374*
	(0.100)	(0.093)	(0.056)	(0.193)
Constant	2.006***	-0.193	0.849***	1.350**
	(0.313)	(0.294)	(0.180)	(0.599)
Observations	20	20	20	20
R-squared	0.459	0.031	0.479	0.218

In all the regressions we use as weights the number of inhabitants in the regions. Growth rates are measured as logarithmic differences. Standard errors (corrected for heteroskedasticity) are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

In column (1) of Table 1 the typical absolute convergence regression is estimated. The coefficient on the initial level of output per worker takes a value of –0.45 and it is strongly statistically significant. Figure 1 shows the relationship of the growth rate of income per worker (from 1970 to 2007) to the log of output per worker in 1970: it clearly emerges a standard process of absolute convergence.

[9] Starting from 1960 output has grown at an annual rate of 2.53% while human capital has grown at a rate of 0.85%.

[10] We also run un-weighted regressions (not reported) finding similar results.

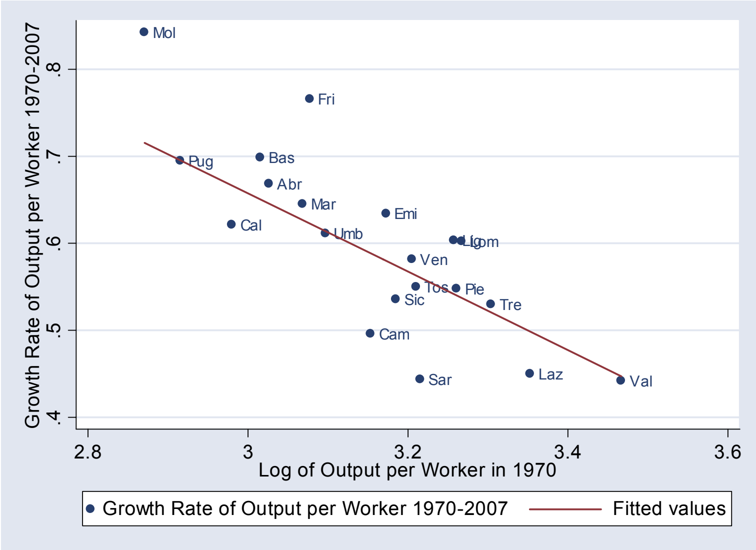

Figure 2. Absolute Convergence across Italian Regions

Although a process of convergence has taken place among Italian regions during the period 1970-2007, convergence has not been very rapid: the implied speed of convergence[11] (λ) is equal to 1.61%, implying that poor regions tend to close half of their output gap with respect to rich regions in about 43 years. This explains why large gaps among regions still exist today.

Regressions (2)-(4) of Table 1 help to understand how the estimated convergence has been obtained. Recall that the sum of $\beta_k + \beta_h + \beta_A$ is equal to β. The coefficient β_k (column 2) is positive but not significantly different from zero. This implies that the accumulation of physical capital has not contributed at all to the convergence process. This is essentially due to the fact that in the early Seventies physical capital was not more abundant in richer regions, in contrast with what a neoclassical model of growth would predict. In fact, from Figure 2 it emerges that in 1970 less-developed regions tended to have higher capital-output ratios (the correlation between the capital-output ratio and output per worker in 1970 is equal to –0.42).

[11] The speed of convergence is calculated as $\lambda = -\ln(1+\beta)/T$ where T is the number of years (see Mankiw, Romer and Weil, 1992).

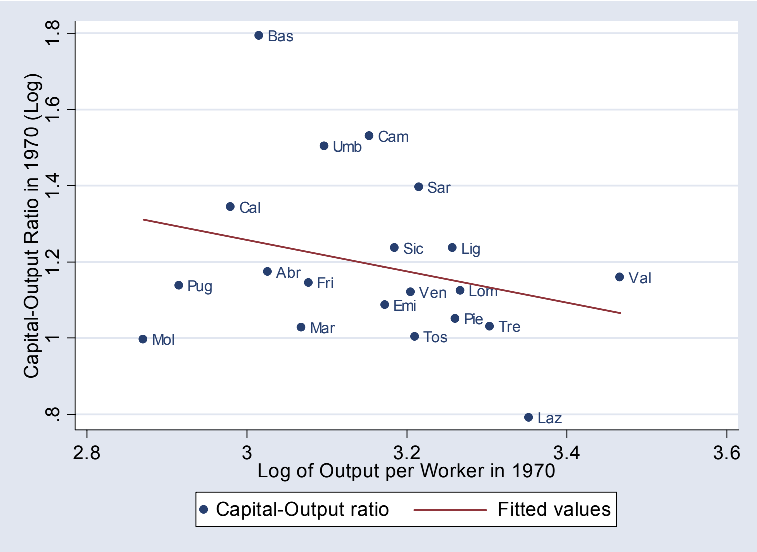

Figure 3. The negative relation between capital-output ratio and output per worker in 1970

More importantly, the regions which have recorded higher rates of growth of physical capital are not the regions who have grown more in terms of product per worker. In fact, regressing the growth of output on the growth of physical capital ratio, we find no statistically significant relation.

In our opinion, these findings are likely the consequences of errors and badly designed development policies followed by Italian governments in the post-war period, consisting in large investments by public-owned firms in capital-intensive industries, huge subsidies to investments by private firms often in declining sectors to protect employment, bad management of public funds, wastes, corruption and so on (see Golden and Picci, 2005). As argued by Pritchett (2000), under these circumstances investments realized by governments fail to reflect in productive capital.

As regards human capital, estimates in column (3) of Table 1 show that human capital has contributed significantly to convergence ($\beta_h = -0.15$). From the ratio β_h / β, a percentage of 34.2% can be attributed to human capital. In the early Seventies poorer regions had lower levels of human capital – the correlation rate between output per worker and human capital in 1970 is equal to 0.82– and poor regions have increased more intensely their educational levels (the correlation between human capital growth and its level in 1970 is equal to –0.74).

Finally, in column (4) of Table 1 we show that the convergence imputable to technological catch-up accounts for most of the total convergence occurred in the period under examination ($\beta_A = -0.37$): a considerable 83% (β_A / β) of convergence is due to technological catch-up.

On the whole, our results show that Italian regions have become more similar over time not for the accumulation of physical capital but mainly because of technological catch-up and in part for human capital. TFP growth, not factor accumulation, is what has driven convergence.

Conditional convergence

We have considered in the previous sections absolute convergence, not controlling for variables proxying for different steady-state levels: for regions within a country fundamental differences in institutions or preferences should be less important than across countries. The parsimonious specification also avoids to lose degrees of freedom given our small sample size (20 regions).

Nevertheless, given the historical dualism of Italian economy, as robustness exercise we now consider conditional convergence. Table 2 reports the β coefficients in a framework of conditional convergence, that is, we include macro-area dummies *North* and *Center* (the reference category is *South*) as proxies for steady-state values.[12]

As regards channels of convergence, results in the conditional convergence framework are not dissimilar to the ones obtained with absolute convergence. In column (1) we show that – as expected – convergence is more pronounced when we control for steady-state proxies ($\beta = -0.73$ and the implied speed of convergence is now 3.5%). Controlling for the initial level of output, regions in the North and Center appear to grow more rapidly.

Column (2) regarding physical capital growth shows that the accumulation of physical capital has not contributed to convergence since β_k is not different from zero. On the contrary, human capital has been a significant factor of convergence (column 3, $\beta_h = -0.15$). Finally, column (4) shows that most of the convergence $(\beta_A = -0.62)$ has been led by technological catch-up.

Table 2. Channels of Convergence in a Conditional Convergence Framework. OLS estimates.

	Dependent Variables: Growth Rates (1970-2007) of:			
	Output per Worker (1)	Physical Capital (2)	Human Capital (3)	TFP (4)
Output per Worker 1970 (log)	-0.726***	0.044	-0.152**	-0.618***
	(0.069)	(0.118)	(0.058)	(0.121)
North	0.131***	0.007	-0.009	0.133***
	(0.025)	(0.038)	(0.009)	(0.039)
Center	0.065**	0.024	0.013	0.027
	(0.023)	(0.043)	(0.011)	(0.037)
Constant	2.816***	-0.091	0.844***	2.063***
	(0.205)	(0.354)	(0.186)	(0.373)
Observations	20	20	20	20
R-squared	0.860	0.053	0.575	0.566

In all the regressions we use as weights the number of inhabitants in the regions. Growth rates are measured as logarithmic differences. Standard errors (corrected for heteroskedasticity) are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

[12] North includes the following regions: Piedmont, Valle d'Aosta, Lombardy, Liguria; Veneto, Trentino Alto Adige, Friuli Venezia Giulia, Emilia Romagna; Centre includes: Tuscany, Lazio, Marche, Umbria; South includes: Abruzzi, Campania, Apulia, Molise, Basilicata, Calabria, Sicily and Sardinia.

Pooled regressions

In Table 3 we split the period from 1970 to 2007 into several sub-periods of span τ. We use first a time span of 9 years (panel a) (obtaining 20*4=80 observations; until year 2005) and then a time span of 5 years (panel b) (with 20*7=140 observations; until year 2004). We calculate the growth rate of our dependent variables over each sub-period and estimate pooled regressions in which the dependent variable is the initial level of output per worker in the respective sub-period. Furthermore, we control for the macro-area dummies *North* and *Center*.

The results obtained in pooled regressions widely confirm our previous findings. Regions have converged (conditionally); physical capital has not contributed at all (or it has been a factor of divergence) to the convergence process; human capital has significantly contributed to convergence although the magnitude of its contribution appears not very high; finally, the growth of TFP is the predominant engine of convergence.

Table 3. Channels of Convergence: Pooled regressions with sample divided in sub-periods

	Dependent Variables: Growth Rates over each sub-period of:			
	Output per Worker	Physical Capital	Human Capital	TFP
	(1)	(2)	(3)	(4)
a. Sample divided in sub-periods of 9 years each				
Initial Output per Worker (log)	-0.330***	0.048**	-0.023***	-0.355***
	(0.022)	(0.021)	(0.008)	(0.033)
North	0.060***	-0.005	-0.004	0.068***
	(0.011)	(0.009)	(0.005)	(0.016)
Center	0.035**	0.001	0.001	0.033*
	(0.013)	(0.010)	(0.004)	(0.017)
Constant	1.254***	-0.153**	0.170***	1.237***
	(0.077)	(0.072)	(0.025)	(0.112)
Observations	80	80	80	80
R-squared	0.740	0.128	0.215	0.666
b. Sample divided in sub-periods of 5 years each				
Initial Output per Worker (log)	-0.165***	0.018	-0.012***	-0.170***
	(0.021)	(0.015)	(0.004)	(0.033)
North	0.033***	-0.002	-0.002	0.037**
	(0.010)	(0.007)	(0.002)	(0.016)
Center	0.017	0.002	0.001	0.015
	(0.012)	(0.007)	(0.003)	(0.017)
Constant	0.638***	-0.054	0.091***	0.600***
	(0.072)	(0.051)	(0.014)	(0.111)
Observations	140	140	140	140
R-squared	0.407	0.022	0.113	0.260

In all the regressions we use as weights the number of inhabitants in the regions. Growth rates are measured as logarithmic differences. Standard errors (corrected for heteroskedasticity) are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

Analyzing σ-Convergence in TFP Levels

To corroborate the evidence of TFP convergence we analyze if there has been σ-convergence in TFP levels, that is, if the standard deviation of TFP across regions has shown a tendency to reduce over time. We determine the level of TFP across regions for each year from 1970 to 2007 considering equation [3] as:

[12] $$\ln(A) = \ln\left(\frac{Y}{L}\right) - \frac{\alpha}{1-\alpha}\ln\left(\frac{K}{Y}\right) - \ln(h)$$

In Figure 3 we show that there has been σ-convergence for TFP, that is, that dispersion of TFP – apart from an initial period in the Seventies – has been declining over time (technological catch-up).[13]

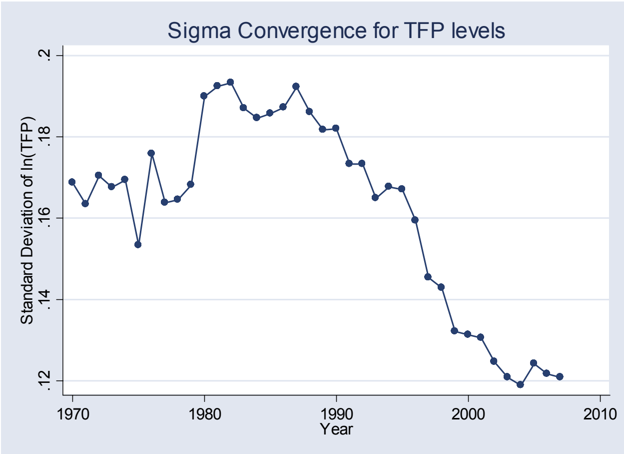

Figure 4. σ-Convergence for TFP levels

5. Robustness Checks

In this section we carry out a number of robustness checks in order to verify if our findings about channels of convergence are sensitive to the choice of parameters, functional forms, measurement of variables, datasets, and periods of analysis.

First of all, we verify if the coefficients estimated in the previous section are robust to the assumptions of different values for parameters. The first row of Table 4 reports β coefficients related to our baseline specification of Table 1. In the following rows we experiment with alternative assumptions on rates of return on education. First of all, the rate of return on human capital ϕ is assumed equal to 5.7%, the private rate of return estimated by Brunello and Miniaci (1999) for Italy using individual data from the Survey of Household Income and Wealth of Bank of Italy. In row (2) we show that the role of human capital is

[13] Furthermore, we are able to show that the growth rate of TFP of each region is strongly negatively correlated to the initial level of TFP.

slightly reduced ($\beta_h = -0.13$), but nothing relevant is changed. Alternatively, we follow Hall and Jones assuming $\phi(s)$ is a piecewise linear function with rates of return taken by Psacharopulos (1994): a rate of 13.4% for the first 4 years of schooling, 10.1% for the next 4 years and 6.8% for years of schooling beyond the eighth year. Using these rates (row 3), we see that the role of human capital appears much higher ($\beta_h = -0.28$): almost half of the convergence realized seems to be due to human capital, while the role of TFP is correspondingly diminished.

As regards physical capital, we firstly let the capital share α range between 0.20 to 0.50. As shown in rows (4)-(6) of Table 4 results change little. The β_k coefficient in the physical capital equation remains positive, confirming a tendency to divergence due to physical capital (β_k increases as α becomes larger). Similar results are obtained if we let the depreciation rate δ change between 2% and 10% (rows 7-8).

Table 4. Sensitivity of β coefficients to the choice of different parameter values

	β (Output eq.)	β_k (Physical Capital eq.)	β_h (Human Capital eq.)	β_A (TFP eq.)
(1) Baseline specification: $\alpha = 0.30$; $\delta = 0.04$; $\phi(s) = 0.068 * s$	-0.450***	0.078	-0.154**	-0.374*
Rates of returns to schooling:				
(2) $\phi(s) = 0.057 * s$	-0.450***	0.078	-0.129**	-0.399**
(3) $\phi(s)$ piecewise linear function (Psacharopulos estimates)	-0.450***	0.078	-0.280***	-0.247*
Capital share:				
(4) $\alpha = 0.20$	-0.450***	0.045	-0.154**	-0.341**
(5) $\alpha = 0.40$	-0.450***	0.120	-0.154**	-0.416*
(6) $\alpha = 0.50$	-0.450***	0.181	-0.154**	-0.476
Depreciation rate:				
(7) $\delta = 0.02$	-0.450***	0.031	-0.154**	-0.327*
(8) $\delta = 0.10$	-0.450***	0.198*	-0.154**	-0.494**
Initial Stock of Capital				
Regional shares of capital for:				
(9) 1979 (Maffezzoli, 2006)	-0.450***	-0.096	-0.154**	-0.199*
(10) 1980 (Paci and Pusceddu, 2000)	-0.450***	-0.041	-0.154**	-0.254*
(11) 1970 (Paci and Pusceddu, 2000)	-0.450***	0.125	-0.154**	-0.421**
(12) 1970 (Bonaglia and Picci, 2000)	-0.450***	0.268*	-0.154**	-0.564 **

The Table reports the β coefficients estimated from equation [4]- [7] changing, in turn, the values of parameters indicated on the respective row. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

Finally, we experiment if our results are robust to the determination of the initial level of capital stock. Instead of imputing the steady-state value for the regional capital stock in 1960, we proceed alternatively exploiting estimates of Paci and Pusceddu (2000), Bonaglia and Picci

(2000) and Maffezzoli (2006) who determine regional capital shares for the years 1970, 1979 and 1980.

We proceed as follows: first, we estimate for year 1980 the ratio κ between net capital stock and GDP at national level using recent estimates of investments and capital stocks provided by ISTAT (2007). The national capital-output ratio is about 3. Then we determine the national stock of capital consistent with our series of data by multiplying Italian GDP in 1980 (obtained as the sum of regional GDP) by κ. The stock of capital obtained in this way is then divided among the 20 regions using the regional shares calculated by Paci and Pusceddu (2000) for the year 1980 and Maffezzoli (2006) for the year 1979. Once we have determined the initial capital stock for each region we use the perpetual inventory method to determine capital stocks for the following or the preceding years (in the latter case defining $K_{t-1} = (K_t - I_t)/(1-\delta)$). A similar procedure is used for the year 1970 exploiting Paci and Pusceddu (2000) and Bonaglia and Picci (2000) estimates of regional shares of capital for this year.[14]

Results are shown in rows (9)-(12) of Table 4. Notwithstanding in two cases the β_k coefficient in the physical capital equation becomes negative, it is never significantly different from zero, implying that the accumulation of physical capital has not contributed to the convergence process of Italian regions, regardless of the way we measure the initial stock of physical capital.

Time-homogeneous dataset

In this sub-section we run our regressions using a homogeneous dataset provided by ISTAT (2005) covering the period from 1980 to 2004, which is not affected by possible distortions caused by the merger of two different datasets.

Estimates are reported in Table 5. Results confirm the convergence of regions in terms of output per worker (at a rate of 1.53%). This convergence has been obtained thanks to human capital and to technological catch-up, while physical capital turns out to be a factor of divergence (the coefficient β_k is positive and, in this case, is statistically significant).

Table 5. Channels of convergence with time-homogeneous data (ISTAT 1980-2004).

	Dependent Variables: Growth Rates (1980-2004) of:			
	Output per Worker (1)	Physical Capital (2)	Human Capital (3)	TFP (4)
Output per Worker 1980 (log)	-0.302***	0.247**	-0.093***	-0.456***
	(0.070)	(0.094)	(0.030)	(0.153)
Constant	1.349***	-0.809**	0.543***	1.615***
	(0.237)	(0.313)	(0.104)	(0.513)
Observations	20	20	20	20

[14] In this case, the national stock of capital in 1970 is determined by using the perpetual inventory method with ISTAT data, starting from 1980 backward.

R-squared	0.524	0.354	0.399	0.451

In all the regressions we use as weights the number of inhabitants in the regions. Growth rates are measured as logarithmic differences. Standard errors (corrected for heteroskedasticity) are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

Growth accounting in terms of capital per worker

Growth accounting can be carried out in terms of capital per worker rather than in terms of the capital-output ratio. We follow this approach in this section. Starting from equation [1], dividing by L we obtain: $Y/L = (K/L)^{\alpha}(Ah)^{1-\alpha}$. Taking logs of both sides and the derivative with respect to time we obtain:

[13] $$g\left(\frac{Y}{L}\right) = \alpha g\left(\frac{K}{L}\right) + (1-\alpha)g(h) + (1-\alpha)g(A)$$

Regressing separately the three right-hand side components on the initial level of output per worker (in 1970) we obtain the results reported in Table 6. Results are again consistent with our previous estimates. Human capital and TFP emerge as important factors of convergence while physical capital per worker (although now the coefficient is negative) does not appear to affect convergence.

Table 6. Channels of convergence. Growth accounting in terms of capital per worker

	Dependent Variables: Growth Rates (1970-2007) of:			
	Output per Worker (1)	Capital per Worker (2)	Human Capital (3)	TFP (4)
Output per Worker 1970 (log)	-0.450***	-0.081	-0.108**	-0.261**
	(0.100)	(0.055)	(0.039)	(0.135)
Constant	2.006***	0.468**	0.594***	0.944**
	(0.313)	(0.177)	(0.126)	(0.418)
Observations	20	20	20	20
R-squared	0.459	0.055	0.479	0.218

In all the regressions we use as weights the number of inhabitants in the regions. Growth rates are measured as logarithmic differences. Standard errors (corrected for heteroskedasticity) are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

6. Concluding remarks

In this paper we have adopted the methodology recently proposed by Wong (2007) and Feyrer (2007) – which combines growth accounting with convergence regressions – to individuate the channels of convergence for Italian regions. We provide evidence that for Italian regions a moderate process of convergence in terms of output per worker has taken place in the last forty years, but that physical capital accumulation has not contributed to the relative growth of poorer regions, whereas human capital (partially) and technological catch-up (predominantly) played a crucial role in convergence.

We have examined convergence both in an absolute and conditional framework finding very similar results. Furthermore, the main result of a dominant role of technological catch-up in guiding the convergence process among Italian regions has been shown to be robust to model specifications, sets of data and alternative assumptions on parameters value.

Our result of a sustained process of technological catch-up is consistent with the recent analyses of Di Liberto, Pigliaru and Mura (2008) and Maffezzoli (2006). The former authors recover regional TFP values from regional fixed effects in panel estimations and then compare TFP levels in 1960 with TFP in 1990: they find that regions are converging as regards to TFP. Maffezzoli (2006) use Data Envelopment Analysis (DEA) to estimate regional relative efficiency in 1980 and 2004. He finds that less efficient regions in 1980 have recorded higher growth rates of efficiency, that is, convergence in TFP, whereas human and physical capital have increased uniformly regional product but without contributing to convergence.

Scoppa (2007) has shown that the role of TFP levels in explaining productivity differences is less relevant if one takes into account differences in the quality of physical and human capital existing across regions. Unfortunately, whereas some proxies of quality of capital is available for recent years (for example, measures of performance of students in international test scores such as PISA or TIMSS to gauge effective skills acquired at schools) no reliable data on the dynamics of such proxies along time is available. This prevents us to analyze whether changes in the *quality* of human and physical capital has contributed or not to the convergence process and whether we are attributing improvements in the quality of factors to technological convergence.

References

Acemoglu, D., Johnson, and Robinson (2002), "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution", *Quarterly Journal of Economics*, November, pp. 1231-1294.

Aiello, F. and Scoppa, V. (2000), Uneven Regional Development in Italy: Explaining Differences in Productivity Levels, *Giornale degli Economisti e Annali di Economia*, 60, 2, 270-98.

Barro, R. and Sala-i-Martin, X., (1992), "Convergence," *Journal of Political Economy*, April, 100, 2, pp. 223–251.

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

Bernanke, B. and Gurkaynak, R., (2001) "Is Growth Exogenous? Taking Mankiw-Romer-Weil seriously", NBER Working Paper no. 8365.

Bernard, A. and Jones, C. (1996), "Technology and Convergence", *Economic Journal*, 107, 1037-44.

Bils, M. and Klenow, P., (2000), "Does Schooling Cause Growth?", *American Economic Review*, December, 90, 1160-83.

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

Brunello, G. and Miniaci, R. (1999), "The Economic Returns to Schooling for Italian Men: An Evaluation based on Instrumental Variables", *Labour Economics*, 509-19.

Caselli, F. (2005) "Accounting for Cross-Country Income Differences", forthcoming in P.

Aghion and S. Durlauf (eds.) *The Handbook of Economic Growth*, North Holland, Amsterdam: 2005.

Ciccone, A., (2004), Human Capital as a Factor of Growth and Employment at the Regional Level: The Case of Italy, *mimeo*.

Ciccone, A., Cingano, F., and Cipollone, P. (2004) The Private and Social Return to Schooling in Italy, *Giornale degli Economisti e Annali di Economia*, 63, 227-247.

CRENoS (2000), "REGIO-IT 1960-96. Data-base on Italian regions", Cagliari.

Di Liberto, A., Pigliaru, F. and Mura, R., (2008), "How to measure the unobservable: A panel technique for the analysis of TFP Convergence", *Oxford Economic Papers*, 60, pp. 343-368.

Dougherty, C. and Jorgenson, D. (1996), "International Comparison of Sources of Growth", *American Economic Review* 86, 25–29.

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. (1989), "OECD Comparative Economic Growth1950–85: Catch-Up and Convergence", *American Economic Review*, 79, 1010–30.

Feyrer, J., (2007), "Demographics and Productivity", *Review of Economics and Statistics*, 89, 1, pp. 100-109.

Golden M., and Picci L., (2005), "Proposal for a New Measure of Corruption. Illustrated with Italian Data", *Economics and Politics*, March, 17 (1), 37-75.

Gollin, D. (2002) Getting Income Shares Right, *Journal of Political Economy*, 110(2), 458-74.

Hall, R. and Jones, C. (1999) Why do Some Countries Produce So Much More Output per Worker than Others?, *Quarterly Journal of Economics*, 114, 83-116.

ISTAT (2005), Regional Economic Accounts (Conti Economici Regionali: 1980-2004), Roma.

ISTAT (2007), "Investments and Capital Stocks: 1970-2005", Roma.

ISTAT (2008), Regional Economic Accounts (Conti Economici Regionali: 2000-2007), Roma.

Klenow, P. and Rodriguez-Clare, A. (1997), "The Neoclassical Revival in Growth Economics: Has It Gone Too Far?", *NBER Macroeconomics Annual*, 12, 73-103.

Maffezzoli, M. (2006), "Convergence Across Italian Regions and the Role of Technological Catch-Up", *B.E. Journal in Macroeconomics – Topics,6, 1*, Article 15.

Mankiw, G., Romer, D. and Weil, D. (1992), "A Contribution to the Empirics of Growth", *Quarterly Journal of Economics*, 107, 408-37.

Paci, R., Pusceddu, (2000), "Una stima dello stock di capitale per le regioni Italiane: 1970-1994", *Rassegna Economica - Quaderni di Ricerca*,

Pritchett, L., (2000), "The Tyranny of Concepts: CUDIE (Cumulated, Depreciated, Investment Effort) Is Not Capital", *Journal of Economic Growth*, 5, 361-84.

Psacharopoulos, G. (1994), "Returns to Investment in Education: a Global Update", *World Development*, 22, 1325-43.

Scoppa, V., (2007), "Quality of Human and Physical Capital and Technological Gaps across Italian Regions", *Regional Studies*, 41, 5, pp. 585-599.

Solow, R., (1957), "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, 39, pp. 312–320.

Wolf, E., (1991), "Capital Formation and Productivity Convergence", *American Economic Review*, 81, pp. 565-579.

Wong W. (2007), "Economic Growth: A Channel Decomposition Exercise," *The B.E. Journal of Macroeconomics: Vol. 7: Iss. 1 (Topics)*, Article 4.

Young, A. (1995) The Tyranny of Numbers. Confronting the Statistical Realities of the East Asian Growth Experience, *Quarterly Journal of Economics*, 110, 641-80.