The Quality of Human and Physical Capital and Technological Gaps among Italian Regions

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This paper evaluates the relative contribution of factor accumulation and technology in explaining output per worker differences among Italian regions. The contributions of physical and human capital are separately estimated through the variance decomposition of output per worker. Whereas from a basic analysis of development accounting with crude data TFP emerges as a fundamental determinant of output per worker, when more accurate data are used in the estimations of human and physical capital, results change radically, showing a higher importance of factor accumulation with respect to previous standard estimations. Several measures of quality of human and physical capital are introduced: a) individuals' cognitive skills as measured in international test scores; b) region specific rate of return of human capital; c) public investments and public-subsidized investments are weighted differently from private investment in physical capital stock. We show that better measurement of factor inputs allows a reduction in the solowian "measure of our ignorance".

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1. Introduction

A hot controversy is raging among growth economists about the ultimate causes of cross-countries differences in per worker (or per capita) income level. There is no general consensus about whether rich countries are so because they employ a greater amount of physical and human capital or because they use better technologies and employ factors of production more efficiently. This question is sometime called as "A vs. K"[1] or "idea gaps vs. object gaps" debate (Romer, 1993).

Whereas Mankiw, Romer and Weil (1992), Barro and Sala-i-Martin (1995) and Young (1995) argue that something like 80 percent of differences in development are explained by factors accumulation (their findings have been dubbed "a neoclassical revival"), Hall and Jones (1999), Klenow-Rodriguez-Clare (1997), Caselli (2005), Gundlach, Rudman and Woessmann (2002), Easterly and Levine (2001), among many others, have found instead that technological differences are the main causes of the uneven levels of development across countries.

The issue of the relative role of factor inputs and technology is strictly related to the validity of the neoclassical growth theory, which assumes that technology is a public good

[1] Technology or TFP is usually indicated in formal models with "A", while "K" represents capital accumulation.

which is freely available to all countries and, as a consequence, concludes that cross-countries differences in development levels are due to a different degree of factors accumulation.

Fundamental policy implications derive from this debate on the causes of development. In fact, if factors are important, then policies to encourage investments in physical capital or in education should be implemented, while if a crucial role is played by technology or efficiency then policy interventions should be aimed to stimulate transfers of knowledge and of technology and the adoption of the most efficient productive and organizational process.

The main aim of this paper is to apply the "development accounting"[2] methodology – used recently by Caselli (2005), Klenow and Rodriguez-Clare (1997) and Gundlach, Rudman, Woessmann (2002) in cross-countries differences analysis – to evaluate in which proportion the wide differences in output per worker existing among Italian regions can be imputed to different levels of accumulation of physical and human capital or to a different level of efficiency (Total Factor Productivity or TFP).

While recently some works have estimated regional TFP levels and have pointed out its wide variability and the correlation between TFP and labor productivity (Aiello and Scoppa, 2001; Marrocu, Paci and Pala, 2000; Di Liberto, Mura and Pigliaru, 2004), the decomposition of differences in output per worker in the contribution due to physical capital, human capital and Total Factor Productivity is new for Italian regions.

The method of variance decomposition of output is used to measure the contribution of factors of production and, as a residual, the contribution of technology. The methodology is based on *calibration* which, differently from an econometric analysis, allows to evaluate the impact of different values of parameters, various functional forms and a variety of procedures to measure output and inputs. In fact, since development accounting exercises tend to be very sensitive to the assumptions on functional forms and parameters, we aim to evaluate how the findings obtained are influenced by the way factors are measured or by the functions and parameters used.

Particular attention is devoted to the measurement of the quality of factors of production. Firstly, human capital is measured not only on the basis of the average years of schooling of the labor force, as standard in the literature, but taking into account the effective cognitive skills acquired by students at school, as measured by international test scores. Secondly, region specific rate of return of human capital are used instead of a common national rate. As regards to physical capital, public and public-subsidized investments are disaggregated from the stock of physical capital and given a different weight (under the assumption that their relative productivies could be lower than pure private investments).

To a first approximation, we confirm the importance of differences in TFP (with a weight of about 80%), finding that it is robust to changes in standard parameters. However, we

[2] The definition of "development accounting" is increasingly used to refer to the analysis in terms of level rather than in rates of growth (which is instead traditionally defined as "growth accounting").

show that when human and physical capital are measured in a more accurate and comprehensive way, the proportion explained by these factors is much higher and TFP role is considerable reduced (at around 30%). Physical and human capital appear differenced across regions and much more related to productivity. In practice, it emerges that mismeasurement of factors was driving the weight attributed to TFP. The solowian "measure of our ignorance" is considerably attenuated through an improvement in the measurement of the quality of inputs.

In the concluding remarks we speculate that if better measures of factors become available also at international level, the estimated preponderance of TFP can be reduced and differences would be ascribed directly to factors generating them.

The paper is organized as follows. In Section 2 we present the method of variance decomposition and the assumptions on the production function. Section 3 describes the data and the building of variables used in our analysis and shows the baseline results. Several robustness checks are presented in Section 4. Section 5 and 6 evaluates the impact of the introduction of more far-reaching changes in the measurement of human and physical capital. Concluding remarks are presented in Section 7.

2. The variance decomposition of output

The aggregate production function used in the analysis to describe the production process in each region is a standard Cobb-Douglas function with constant returns to scale:

[1] $$Y = AK^{\alpha}(hL)^{1-\alpha}$$

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 income capital's share under the assumption of perfect competition.

In our basic framework we assume Hicks-neutral productivity (instead of Harrod-neutral or labor-augmenting productivity) and hence output per worker is written as a function of the capital-labor ratio (K/L) (as in Caselli, 2005).[3] Dividing the production function [1] by L:

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^{\alpha} h^{1-\alpha}$$

[3] On the contrary, Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) assume labor-augmenting technical progress and express output per worker as a function of the ratio capital/output (K/Y). The substantial difference between the two approaches is the power of A: it is equal to 1 in case of Hicks-neutrality, while it is equal to $(1-\alpha)$ in case of Harrod-neutrality. As shown by Gundlach, Rudman and Woessmann (2002), in the decomposition of output the assumption of Harrod-neutrality gives more weight to technology, fundamentally because of the fact that any increase of technology, which originates also a variation of capital, is attributed to productivity instead of capital (since (K/Y) does not change).

Defining $y = \frac{Y}{L}$; $\tilde{k} = \left(\frac{K}{L}\right)^{\alpha}$; $\tilde{h} = h^{1-\alpha}$, the production function can be written simply as: $y = A\tilde{k}\tilde{h}$. Taking logs of both sides:

[2] $$\ln(y) = \ln(\tilde{k}) + \ln(\tilde{h}) + \ln(A)$$

The aim of the development accounting analysis is to find out the relative contribution of *k*, *h* and *A* in explaining *y*. The methodology of decomposition of output per worker in factor inputs and technology (or efficiency) follows Klenow and Rodriguez-Clare (1997). They show that the variance of output per worker (in log), taking into account equation [2], can be decomposed as follows:

$$Var(\ln(y)) = Cov(\ln(y), \ln(y)) = Cov\left(\ln(y), \ln(\tilde{k}) + \ln(\tilde{h}) + \ln(A)\right)$$

from which:

$$Var(\ln(y)) = Cov\left(\ln(y), \ln(\tilde{k})\right) + Cov\left(\ln(y), \ln(\tilde{h})\right) + Cov(\ln(y), \ln(A))$$

Dividing both sides by $Var(\ln(y))$, one obtains:

[3] $$\frac{Cov\left(\ln(y), \ln(\tilde{k})\right)}{Var(\ln(y))} + \frac{Cov\left(\ln(y), \ln(\tilde{h})\right)}{Var(\ln(y))} + \frac{Cov(\ln(y), \ln(A))}{Var(\ln(y))} = 1$$

Therefore, the first and second term represent the fraction of dispersion in output per worker which can be statistically attributed respectively to differences in physical capital and in human capital. The third term, computed as a residual, measures the weight of technology in explaining differences in output.

Let us define c_k as the contribution of physical capital in explaining productivity differentials: $c_k = \frac{Cov\left(\ln(y), \ln(\tilde{k})\right)}{Var(\ln(y))}$; c_h as the contribution of human capital: $c_h = \frac{Cov\left(\ln(y), \ln(\tilde{h})\right)}{Var(\ln(y))}$; and $c_A = \frac{Cov(\ln(y), \ln(A))}{Var(\ln(y))}$ as the contribution of technology.

As it is evident from their expressions, the terms c_k and c_h in the above decomposition are equal to the Ordinary Least Squares (OLS) coefficients of the following two regressions:

$$\ln(\tilde{k}) = \text{constant} + c_k \ln(y) \qquad\qquad \ln(\tilde{h}) = \text{constant} + c_h \ln(y)$$

In this formulation, c_k (c_h) shows how much higher is physical (human) capital in a region in which one observes a higher 1% output.

2.1. The alternative index used by Caselli (2005)

It is useful to compare our approach with the slightly different strategy adopted by Caselli (2005). Defining *X* the composite of physical and human capital[4]: $X = \tilde{k}\tilde{h} = \left(\frac{K}{L}\right)^{\alpha} h^{1-\alpha}$, Caselli starts from the identity:

$$Var(\ln(y)) = Var(\ln(A) + \ln(X)) = Var(\ln(A)) + Var(\ln(X)) + 2Cov(\ln(A), \ln(X))$$

Under the assumption of the neoclassical growth model that technology is uniform among countries, from which $Var(\ln(A)) = 0$ and $Cov(\ln(A), \ln(X)) = 0$, the implication of this "factor-only" model is that $Var(\ln(X))/Var(\ln(y))$ should be 1.

Therefore, an indicator of how successful is the neoclassical approach is given by the variable defined *success* in Caselli (2005):

$$success = \frac{Var(\ln(X))}{Var(\ln(y))}$$

If *success* is close to 1, then factor inputs explain almost all differences in income, while if *success* is near zero then the greater part of variability should be imputed to the adoption of different technologies.

Let us point out how the approach of Klenow and Rodriguez-Clare (1997), that we follow, is different from Caselli (2005). The contribution we impute to factor inputs $(c_h + c_k)$ is the following: $\frac{Cov(\ln(y), \ln(\tilde{k}\tilde{h}))}{Var(\ln(y))}$ which can be written as:

[4]
$$\frac{Cov(\ln(\tilde{k}\tilde{h}) + \ln(A), \ln(\tilde{k}\tilde{h}))}{Var(\ln(y))} = \frac{Var(\ln(\tilde{k}\tilde{h})) + Cov(\ln(\tilde{k}\tilde{h}), \ln(A))}{Var(\ln(y))}$$

Comparing [4] with the definition of *success*, note that the measure we use $(c_h + c_k)$ and the measure used in Caselli result identical if the covariance between *A* and $\tilde{k}\tilde{h}$ is equal to zero. On the contrary, if $Cov(\ln(\tilde{k}\tilde{h}), \ln(A)) > 0$ (as it effectively emerges from data), a higher contribution is attributed to factor inputs in our approach because the variance decomposition we are using impute half of co-movements between *X* and *A* to factor inputs (in other words, the covariance term is split between factor and technology). In practice, the two measures do not result much different, and, for completeness, we often report both of them.

2.2. A further measure: the inter-quartile differential across regions

[4] In Caselli (2005) there is no separate evaluation of the contribution of physical and human capital.

In order to check the robustness of our results, similarly to Hall and Jones (1999) and Caselli (2005), we use a second indicator, the inter-quartile differential, that is, the ratio between the results of the five most productive regions (the geometric average of their variables is indicated with *b*) and those of less productive five (their geometric average is indicated with *w*):

$$y_b = A_b \tilde{k}_b \tilde{h}_b \quad \text{and} \quad y_w = A_w \tilde{k}_w \tilde{h}_w$$

Dividing the first expression by the second we get the following ratio: $\frac{y_b}{y_w} = \frac{A_b \tilde{k}_b \tilde{h}_b}{A_w \tilde{k}_w \tilde{h}_w}$. Taking logs, we can write: $\ln\left(\frac{y_b}{y_w}\right) = \ln\left(\frac{\tilde{k}_b}{\tilde{k}_w}\right) + \ln\left(\frac{\tilde{h}_b}{\tilde{h}_w}\right) + \ln\left(\frac{A_b}{A_w}\right)$. Dividing both members by $\ln\left(\frac{y_b}{y_w}\right)$ we have:

[5]
$$\frac{\ln\left(\frac{\tilde{k}_b}{\tilde{k}_w}\right)}{\ln\left(\frac{y_b}{y_w}\right)} + \frac{\ln\left(\frac{\tilde{h}_b}{\tilde{h}_w}\right)}{\ln\left(\frac{y_b}{y_w}\right)} + \frac{\ln\left(\frac{A_b}{A_w}\right)}{\ln\left(\frac{y_b}{y_w}\right)} = 1$$

Again, we can interpret the first term as a measure of the gap of output per worker attributable to differences in physical capital, the second term as the contribution of human capital and the residual term as the weight of TFP differences.

3. Data, assumptions and baseline results

We use a data set recently made available by the Italian National Statistical Institute (ISTAT) containing the main economic variables for Italian regions (for the period 1980-2002) built using the new Eurostat criteria (SEC95). Variables are computed at constant 1995 price. In order to neutralize cyclical effects, we take the geometric average of variables over a period of 5 years (from 1998 to 2002). In addition, we use micro data from Bank of Italy's "Survey on Household Income and Wealth" (SHIW) and data on the capital stock from ISTAT "Investimenti e stock di capitale".

The variable *y* is output per worker calculated as the ratio between regional Gross Domestic Product (*Y*) and total labour units (*L*).

Physical capital

Regional capital stocks are calculated through the perpetual inventory method, through the equation $K_{t+1} = (1-\delta)K_t + I_t$, where I_t is regional total investment and δ is the rate of depreciation.

The rate δ is calculated at national level by dividing, year by year, the effective amount of depreciation (from ISTAT estimates) by total capital stock (δ ranges between 3.9% and 4.5%). The initial capital stock for each region in 1980 is obtained by multiplying the regional shares of national capital stock (obtained from Paci and Pusceddu, 1999) to the existing capital stock of Italy (from ISTAT, "Investimenti e stock di capitale").

The capital's share of income α=0,304 is calculated as the ratio of gross profits to the value–added (averaged over 1996-2002 period)[5]. Similarly, Gollin (2002) estimates the capital share for Italy to be equal to 0,293 (see more details below, Section 4.1).

Human capital

As standard in literature (see Hall and Jones, 1999; Bils and Klenow, 2000), human capital per worker is calculated through the Mincerian *earnings functions*. Therefore, indicating with *s* the average years of schooling per worker and with ϕ the rate of return to each year of schooling, the stock of human capital per worker is determined as: $h = e^{\phi s}$.

Data on years of schooling are calculated from the Bank of Italy's dataset SHIW. In order to determine regional average years of education among employed workers, we pool together the three latest available waves (1998, 2000 and 2002). The rate of return of human capital ϕ is assumed equal to 5.7%, as estimated by Brunello and Miniaci (1999) with Instrumental Variables on SHIW data (this is a private rate of return on net wages).

Table 1 shows descriptive statistics on regional per worker output, capital and education.

Table 1. Regional output, capital and years of schooling per worker

Regions and macro-areas	Output per worker	Capital per worker	Years of schooling
Piemonte	45.156	149.399	10.547
Valle d'Aosta	47.697	196.680	10.830
Lombardia	47.701	135.412	11.311
Trentino-Alto Adige	44.451	167.534	10.977
Veneto	43.111	130.556	10.745
Friuli-Venezia Giulia	44.154	144.071	11.137
Liguria	46.179	139.088	11.923
Emilia-Romagna	44.468	130.937	11.099
Toscana	42.397	116.725	10.898
Umbria	40.342	134.759	11.015
Marche	40.298	122.791	10.834
Lazio	45.350	124.186	11.306
Abruzzo	39.854	142.595	11.510
Molise	39.562	160.874	9.744
Campania	37.599	144.396	10.509
Puglia	36.392	121.107	10.779
Basilicata	39.827	178.954	8.850
Calabria	35.982	145.935	10.510
Sicilia	40.140	152.878	10.440
Sardegna	38.092	162.266	9.650
Italy	43.039	136.568	10.900
North-West	46.854	140.139	11.165
North-East	43.870	135.586	10.947
Center	43.321	122.277	11.097
South	38.091	144.528	10.427

[5] "Quota dei profitti lordi sul valore aggiunto al costo dei fattori" from "Rapporto annuale 2002 - Tavola A.3.1 - Attività produttiva, costi e prezzi - Totale economia".

3.1. Baseline results

Considering the variables *y*, *k*, and *h*, determined in the previous Section, we evaluate in this Section how important are, respectively, factors of production and technological efficiency to explain differences in output. All the assumptions on parameters values will be subject to scrutiny in the next Section.

It is interesting to look first at the variances and covariances of variables. From Table 2, it emerges that the variances of *k* and *h* are much smaller than the variance of *y*, that is, factor inputs tend to be distributed among regions much more homogenously than output. The correlations of *y* with *k* and *h* results also quite low.

Table 2. Variances and covariances matrix (variables are in logs)

	Y/L	K/L	h
Y/L	0.0071		
K/L	0.0003 (0.08)	0.0016	
h	0.0011 (0.49)	-0.0005 (-0.50)	0.0008

Correlation coefficients are in parentheses

The same indications can be obtained from the ratios of most productive regions with respect to the less productive ones: output per worker is 21% higher in the five most productive regions, while human capital is only slightly higher in more advanced regions (4%) and there exist no appreciable differences in physical capital.[6]

Using the methodology explained above and the definitions of c_k, c_h and c_A and eq. [5] for the ratio b_5/w_5, we obtain the following results:

Table 3. The contribution of inputs and technology in explaining productivity differentials

Variability explained by:	c_i	b_5/w_5
Physical Capital	3.8%	0.9%
Human Capital	15.6%	17.6%
TFP	80.6%	81.5%

Success of factor-only model: 17.5%

From our first baseline estimate in Table 3, the results are quite surprising: factor inputs explain only a marginal share of differences in output per worker. In particular, physical capital per worker appears to have almost no influence (3.8%), while a limited influence is exercised by human capital (15.6%). Since differences in physical and human capital among regions appear quite limited, they could not explain much of the differences in development. Regional Total Factor Productivity is the preponderant determinant of output per worker (80.6%).

[6] The ratios are $\ln(y_b/y_w)=0.21$; $\ln(\tilde{k}_b/\tilde{k}_w)=0.001$; $\ln(\tilde{h}_b/\tilde{h}_w)=0.04$.

It is worthwhile to note that the second measure we use, the ratio of the most productive to the least productive regions, confirms almost exactly the finding of a very large contribution of TFP (81.5%).

It is useful a comparison with the variable "success" used by Caselli (2005) to evaluate the "factor-only" model (which compares the counterfactual dispersion of output if all the regions had the same level of TFP with the observed dispersion). Using this measure, calculated as $Var\left(\ln\left(\tilde{k}\tilde{h}\right)\right)/Var\left(\ln(y)\right)$, we obtain that the joint contribution of human and physical capital is equal to a modest 17.5%, leaving again more than 80% to technological differences.

Comparing the results for Italian regions with the international debate, these data seem completely in contrast with the so-called "neoclassical revival". For example, Mankiw, Romer and Weil (1992) estimate that physical capital can explain 29% of differences, human capital 49%, while technology accounts for only the remaining 22%. On the contrary, our estimates are in line with Klenow and Rodriguez-Clare (1997) (for whom physical capital explain 23%; human capital 11%; and TFP 66%) and Hall and Jones (1999) (19% is their estimated contribution of physical capital, 21% is imputed to human capital and 60% to TFP).

4. Robustness checks

In this Section, we aim to verify how robust are the baseline results of Section 3, that is, we check how the results on the relative contribution of factors and technology change when crucial assumptions and parameters are modified and other reasonable values are imputed.[7] The modifications here are quite standard, while in the next Section a more radical approach is undertaken and fundamental changes in the measurement of human and physical capital are introduced.

4.1. Physical capital

The impact of physical capital depends essentially on the assumptions regarding: 1) the capital income share α; 2) the depreciation rate δ; 3) the initial capital stock K_0.

Capital share

In Table 4 we show that there are no substantial modifications of results of variance decomposition when capital share is ranged from 0.20 a 0.50. The contribution of capital is slightly increased with α, until a maximum of 6.3%, while the opposite happens for the human capital contribution (recall that $1-\alpha$ is the exponent of human capital). This is due fundamentally to the fact that capital is not much differenced across regions.

[7] In commenting Klenow and Rodgriduez Clare's paper, Mankiw (1997) warns that this kind of analysis is too sensitive to parameters whose values we do not know.

Table 4. The contribution of inputs and technology as a function of the capital share α

Capital share α	20%	25%	30%	35%	40%	45%	50%
Physical Capital	2.5%	3.2%	3.8%	4.4%	5.1%	5.7%	6.3%
Human Capital	17.9%	16.8%	15.7%	14.6%	13.4%	12.3%	11.2%
TFP	79.5%	80.0%	80.5%	81.0%	81.5%	82.0%	82.5%

Estimates by Gollin (2002) and Bernanke and Gurkaynak (2001) show that, according to the methods used to attribute to labour some share of the self-employed income, the capital share ranges between 0.29 to 0.35.[8] In this range, physical capital contribution is no more than 5%.

Depreciation rate

In Table 5 we impute to the depreciation rate δ different values in the range 1% to 25%. The contribution of physical capital changes from 1.5% when depreciation rate is only 1% to a value of 18.3%, (with a correspondent reduction in the contribution of technology), assuming the extremely high depreciation rate of 25%.

Table 5. The contribution of factor accumulation and technology as a function of depreciation rate

Depreciation rate (δ)	1%	5%	7%	10%	15%	20%	25%
Physical Capital	1.5%	4.5%	6.2%	8.9%	12.9%	16.1%	18.3%
Human Capital	15.6%	15.6%	15.6%	15.6%	15.6%	15.6%	15.6%
TFP	82.9%	79.9%	78.2%	75.5%	71.5%	68.3%	66.1%

A high depreciation rate gives more weight to recent investments in determining the regional stock of capital. The figures in Table 5 show that if capital is calculated on the basis of recent investments then it is much more related to productivity, while if a high weight is given to past investments, a lower correlation with production emerges. This suggests that in recent years investment rates have been higher in richer regions, so that the capital stock results more correlated to output and, as a consequence, appears to explain a large fraction of development differences. Past investments were only weakly correlated to output, that is, poor regions invested a lot, probably as a result of a heavily public subsidized system.

However, if we exclude unrealistic high depreciation rates, we can conclude that the contribution of physical capital remains rather limited in explaining regional development differences.

Initial capital stock

Finally, we try to see what are the consequences of an alternative method of calculation of the initial capital stock. Instead of insert K_0 as calculated by Paci and Pusceddu (1999), we determine it following the standard approach in growth accounting, that is, assuming that it is

[8] Gollin's preferred estimate for Italy is $\alpha = 29.3\%$.

equal to its steady-state level, that is: $K_0 = \frac{I}{n + g + \delta}$, where I is the geometric average of the flow of investment, n is the growth rate of number of workers, g is the average rate of productivity growth and δ is the depreciation rate.

Table 6. The contribution of inputs and technology with a different initial capital stock

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	2.4%	-2.8%
Human Capital	15.6%	17.6%
TFP	82.0%	85.2%

Again, the results in Table 6 are not much different from our baseline estimations. Moreover, the series of capital stock obtained assuming different initial stocks show a correlation of 0.99.

4.2. Human capital

As regards to the human capital, we conduct two preliminary checks aimed to evaluate how results change using an alternative measure of average years of education and taking into account different rates of return to schooling.

Years of education among the labour force

Regional average years of schooling can be calculated on the basis of labour force, drawn from "ISTAT Labour Force Survey",[9] instead of employed workers from the Survey of Bank of Italy.

Table 7. Human capital accumulation among labour force

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	3.8%	0.9%
Human Capital	6.3%	8.0%
TFP	89.9%	91.1%

Table 7 shows that the relative contribution of human capital is even less relevant. However, since we aim to explain output per worker it is reasonable to use a measure of workers' education rather than a measure of labour forces' education.

Considering alternative rates of return to human capital

In Section 3, we have assumed that the rate of return of schooling is equal to 5.7%: $\phi(s) = 0.057s$. This is an estimate of the individual rate of return, while we should ideally take into account the social rate of return, which is hard to determine. The social return could be

[9] In the Labour Force Survey, the level of education of employed worker is not available.

higher if externalities tend to prevail, but it could be even lower if the signalling function of education is prevailing (see, among others, Acemoglu and Angrist, 2000, and Pritchett, 2004).

In this sub-section we determine what happens to our estimates when we consider alternative rates of return (we let ϕ range from 1 to 20%).

Table 8. The contribution of human capital with different rates of return

Rate of returns ϕ	**1%**	**3%**	**5%**	**6.8%**	**10.1%**	**12%**	**15%**	**20%**
Physical Capital	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
Human Capital	2.7%	8.2%	13.7%	18.6%	27.6%	32.8%	41.1%	54.7%
TFP	93.4%	88.0%	82.5%	77.5%	68.5%	63.3%	55.1%	41.4%

As expected, since richer regions possess a greater level of education, the role of human capital enhances if the rate of return is increased (Table 8). However, for rates of return not far from plausible ones – note that from estimates of Psacharopulos (1994) the world average is 10.1 percent, and the OECD average is 6.8 percent – the role of human capital in explaining Italian regional differences is around 20-25%.

Decreasing marginal return to schooling

Instead of a constant rate of return to schooling, one could consider, on the basis of evidence from many labour studies, a decreasing marginal return. To this aim, Bils and Klenow (2000) propose the following function for the determination of human capital:

$$h = \frac{\theta}{1-\psi} s^{1-\psi}$$

with the following estimations of parameters: $\theta = 0.32$ and $\psi = 0.58$.

Using this formulation (see Table 9), human capital results less important in explaining development (10.9%).[10]

Table 9. The contribution of human capital with decreasing marginal return to schooling

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	3.8%	0.9%
Human Capital	10.9%	12.1%
TFP	85.3%	87.0%

Summing up this Section, we can point out that the standard robustness checks carried out show that estimates of the high relative contribution of technology (and low role for factors accumulation) are confirmed assuming different values for a number of parameters.

5. Improvements in human capital measurement

[10] Hall and Jones (1999) use a piece-wise linear function with decreasing marginal return to school. However, given the relative homogeneity of educational levels across regions, using this function would imply the same rate of return for all the regions.

In this Section, some more radical attempts in improving the measurement of human capital are made. The aim is to consider not just quantity of human capital, but also its quality. Traditional growth studies at cross-countries level have commonly taken into account a quantitative measure of schooling, that is, the average years of education in the population or school attainments, ignoring its effective productivity or quality.

However, it is reasonable to assume that one year of schooling does not increase productivity regardless of its quality or regardless of the knowledge acquired by individuals in different educational systems, which strongly differ in their effectiveness. In order to take into account quality, we consider three different measures that have been proposed in the growth literature (see Woessmann, 2003 for a survey):

1) direct measures of cognitive abilities of students in Mathematics, Sciences and Reading Comprehension as measured by international test scores;
2) country-specific rates of return to education, assuming that in the labour market different rates of return reflect differences in the quality of education acquired by students;
3) educational inputs, such as the amount of spending on schooling, the students-teacher ratio, school size, the quality of teacher (measured by their educational level, experience or wage level), the amount of resources devoted to books, computers and other teaching facilities, etc.

We attempt to take into account the first and second method respectively in Sections 5.1 and 5.2. As regards to the third approach, a number of empirical analysis (mainly from the US, but also from other countries) show that resources or inputs employed do not significantly affect students' performance. Hanushek (1996) – after reviewing almost 100 empirical works which estimate production functions for education – concludes that the amount of resources dedicated to schooling has little, if any, influence on the knowledge learned by students. The main reason of this puzzle is that resources are often not used effectively by schools, because of agency problems and informational asymmetries among agents. Secondly, for our specific purpose, the highly centralized educational system in Italy does not allow for relevant differences in inputs employed in education (see Brunello, Checchi and Comi, 2002).

5.1. School quality and cognitive skills measured in test scores

As evidenced at international level, the most promising way forward in considering quality of human capital appears to be the direct measurement of the skills acquired by students (see Hanushek and Kimko, 2002).

In fact, one year of education in different regions cannot be considered equally productive regardless of the effective knowledge acquired by students. Regional human capital is accumulated at different rates according to cognitive ability effectively acquired by students. This acquisition depends on a number of factors: the quality and motivation of teachers, parents and students' effort, type of examination, etc. One way to gauge differences in the students' knowledge is to consider the students' performance in test scores.

Several international organizations conduct periodically in many countries standardized tests in order to assess the knowledge acquired in Mathematics, Science and Reading Comprehension by students. The International Association for the Evaluation of Educational Achievement (IEA) with the program "Trend in International Mathematics and Science Study" (TIMSS), the OECD with the "Program for International Student Assessment" (PISA) provide data on students' cognitive skills of many countries. Moreover, OECD measures the literacy among adult population in the "International Adult Literacy Survey" (IALS in the mid-90s).[11] These tests show that there exist large differences among countries in the skills acquired by individuals.

At international level, when human capital is measured taking into account these qualitative differences, according to different formulations, the role of human capital appears to be very large. Through this method, combining in a measure of quality the results of 26 international test scores, Hanushek and Kimko (2000) have found that quality of schooling is highly significant in growth regressions (even when the quantity of schooling loses significance) and Gundlach, Rudman and Woessmann (2002) and Woessman (2003) have estimated the role of human capital corrected for quality to be in the range of 45 to 61%.

The above mentioned international tests scores contain results at macro-regions level as regards to Italy.[12] Lacking reliable single regional data for each region, at each region is imputed the value corresponding to the macro-region it belongs to. We have test scores on the following five recent surveys: PISA (years 2000 and 2003); TIMSS (1999; 2003) and IALS (1998). Each test is re-parameterized on a scale 0-100 and we combine these test scores – through geometric average – in a single measure of quality, denoted with q.

The scores show the existence of huge differences among Italian regions (Table 10): Lombardia and Trentino, for example, reach a level in mathematics and science tests comparable to the world best performers (Finland, Korea, Hong Kong), whereas Southern regions attain a level in line with the worst performers, usually non-OECD countries (Mexico, Turkey).

[11] The OECD more recently is realizing the Adult Literacy and Life Skills (ALL).

[12] Unfortunately, the Italian surveys contain usually results only for five macro-areas: Northwest, Northeast, Center, South and Islands (Sardinia and Sicily). In some surveys, data for particular regions are available (which we use in our computations).

Table 10. Students' test scores (q)

Piemonte	95.45	*Molise*	83.84
Valle d'Aosta	96.75	*Campania*	83.15
Lombardia	97.25	*Puglia*	83.84
Trentino-Alto Adige	100.00	*Basilicata*	83.84
Veneto	97.61	*Calabria*	83.15
Friuli-Venezia Giulia	97.68	*Sicilia*	81.48
Liguria	96.75	*Sardegna*	81.48
Emilia-Romagna	97.68	*Italy*	89.61
Toscana	91.65	*North-West*	96.75
Umbria	90.28	*North-East*	97.68
Marche	90.28	*Center*	90.28
Lazio	90.28	*South*	83.84
Abruzzi	83.84	*Islands*	81.48

Geometric averages of results of PISA, TIMSS, IALS.

Following standard assumptions in the literature (see, for example, Hanushek and Kimko, 2002) we suppose that educational institutions and quality of education change only slowly along time and therefore the performance of present students reflect the knowledge possessed also by previous generations of students, that is, the present stock of workers. This is also confirmed by the strong correlation existing between students' achievement in test and the results emerged from the test on literacy conduct among Italian adult population (the OECD-IALS).

In order to take into account quality of human capital, following Caselli (2005), the equation of determination of human capital is assumed to be the following: $h = Qe^{\phi s}$, where $Q = e^{\pi q}$ represents the efficiency (or quality) of human capital, which is variable across regions. The parameter π represents the rate of return to quality of schooling and it is drawn from some micro-econometric studies which estimate the impact of test scores on individual wages, in addition to the influence of completed years of education (Murnane, Willett and Levy, 1995; Currie and Thomas, 1999; Hanushek and Kimko, 2002). As reported by Caselli (2005), according to these studies π can vary from 0.08% (0.0008) and 1.02% (0.012).

This implies that, considering for example $\pi = 0.5\%$, an increase of 10 points in the skills quality q (i.e., changing from the Sicilian performance (the lowest) to the Umbria's performance (around Italian average)) leads to an increase of 5% of wage (and hence of productivity under our assumptions).

From the estimates of Denny, Harmon and O'Sullivan (2004) which use IALS-OECD data and determine a rate of return for Italy, a rate of $\pi = 0.4\%$ can be inferred.[13]

Table 11. The contribution of inputs and technology as a function of return to human capital quality

Rate of return to quality π	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	0.9%	1.0%
Physical Capital	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
Human Capital	20.2%	24.8%	29.4%	33.9%	38.5%	43.1%	47.7%	52.3%	56.9%	61.5%
TFP	76.0%	71.4%	66.8%	62.2%	57.6%	53.0%	48.5%	43.9%	39.3%	34.7%
"Success" of factor-only model	19.3%	21.6%	24.5%	28.0%	32.1%	36.7%	41.9%	47.7%	54.0%	61.0%

[13] According to their estimates, improving on skills from the worst performer to the best (Trentino) corresponds more or less to the returns of two years of education.

Table 11 clearly shows the importance of human capital when its quality is properly taken into account. While when capital is measured considering only years of education, it contributes to explain a mere 15% in Italian regional development differentials, introducing a correction in its measurement to consider the effective quality of the labour force skills increases largely its weight as a factor of development. Human capital can explain almost half of the differences in the level of development, becoming the most important production factor, even considering very low rates of return on quality (in the range 0.5%-1%).

Gundlach, Rudman and Woessmann (2002) adopt an alternative method to introduce quality in the determination of human capital. First, they determine the quality index $\tilde{q}_i$ for each country by dividing its effective test score to that of a reference country (United States). Then, they calculate *h* multiplying quality $\tilde{q}$ by quantity *s*: $h = e^{\phi s \tilde{q}}$. We follow their approach in order to check the robustness of previous estimates.[14] We divide the test scores of each macro-region for the Italian average, then we average through different available measures. The results are reported in Table 12.

Table 12. Human capital's weight in development using the methodology of Gundlach et al. (2002)

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	3.8%	0.9%
Human Capital	46.9%	44.7%
TFP	49.2%	54.4%

Table 12 substantially confirms the results obtained following Caselli's approach, that is, when human capital is adjusted to include quality it appears as one of the main determinant in explaining differences in development among Italian regions.

While regional differences in quantity of schooling are not much relevant, considering also quality it emerges that about half of the differences in development among Italian regions can be imputed to the different skills of labour force.

5.2. Region-specific rates of return to education

The second method to take into account qualitative differences in human capital is based on the econometric estimation of a rate of return of schooling for each single region.[15] In theory, a better quality of education should make workers more productive and in competitive labor

[14] In this approach, the marginal return to $\tilde{q}$ is ϕs. Since the average *s* is 10.9 and $\tilde{q} \approx (1/100)q$ this is equivalent to assume $\pi = 0.62\%$ in Table 11.

[15] At international level, this method is affected by measurement errors. Many countries do not have reliable data to measure rate of return to education as confirmed by huge differences in country-specific rates of return (see Psacharopoulos, 1994 for a review).

markets this should lead to a higher return to schooling. Therefore, instead of using direct measures on acquired skills, it is appropriate to consider regional specific rate of return to schooling (ϕ_i), to take into account different level of quality across regions.

In order to estimate human capital, we amend the human capital function of Section 3, to take into account that regions can differ in their rate of return to education, in the following way: $h_i = e^{\phi_i S_i}$, where ϕ_i represents the specific rate of return to school for region *i*.

To this aim, we use the regional rates of returns to education calculated by Ciccone (2004), using Bank of Italy's Survey (SHIW) for a series of waves (since 1987 to 2000, totaling over 45000 individual observations).[16] Results are reported in Table 13. Ciccone (2004) estimates for each region a different mincerian wage equation and adjusts the returns for gross wages.[17]

Table 13. Regional rates of return to school (gross wages) (Ciccone, 2004).

Piemonte	7.16	Molise	6.41
Valle d'Aosta	8.14	Campania	6.50
Lombardia	7.57	Puglia	6.28
Trentino-Alto Adige	7.68	Basilicata	6.22
Veneto	6.55	Calabria	7.02
Friuli-Venezia Giulia	7.02	Sicilia	6.43
Liguria	7.22	Sardegna	6.55
Emilia-Romagna	7.04		
Toscana	6.72	Italy	6.88
Umbria	5.90	North-West	7.41
Marche	6.63	North-East	7.04
Lazio	6.81	Center	6.62
Abruzzi	6.66	South	6.55

Using this new series for human capital, we obtain the results shown in Table 14 (first two columns). Since estimations of regional return could be not robust because of a small number of observations in each region, in the last two columns are taken in account only the return estimated for macro-regions, who appear more robust (according to Ciccone, Cingano, Cipollone, 2005, differences among macro-regions are significantly at 1% level).

Table 14. Human capital's contribution in development using regional rates of return to school

Percentage variability explained by:	c_i	b_5/w_5	Returns for macro-regions c_i	Returns for macro-regions b_5/w_5
Physical Capital	3.8%	0.9%	3.8%	0.9%
Human Capital	51.7%	50.3%	44.3%	45.8%
TFP	44.5%	48.8%	51.9%	53.3%
Success of factory-only model	70.6%		43.9%	

[16] See also the related work of Ciccone, Cingano and Cipollone, 2005.

[17] In the last part of this paper, the author estimates the private return to school as the discount rate that equalizes the present value of the private costs and benefits generated by an increase in the educational attainment. In our context this rate is less appropriate since among individual benefits is included the probability of finding employment which is not related to the labor productivity we are interested to determine.

The results change significantly with respect to the assumption of a homogenous rate of return across regions: human capital is able to explain a considerable share of regional differences in development (45-50%). The evidence from Section 5.1 and 5.2 implies that failure to take into account of labor quality tends to overestimate technology contribution.

6. Quality of physical capital: public and public-subsidised investment

The stock of physical capital calculated in previous Sections through perpetual inventory method used all private and public investment, simply summing all the expenditure made for investment. As sustained forcefully by Pritchett (2000) and others growth economists, it is not reasonable to suppose that all the expenditure in investment is transformed directly in productive capital, especially for the public sector.[18] Pritchett (2000) argues that agency problems plaguing government are more pervasive than in private sector since the public sector often operates in monopolistic markets, there is no market for the ownership of assets and many goods provided by government are public good. These problems give rise to distorted behaviour by public actors, such as corruption, "patronage" (transfers to political supporters) or simply shirking (no provision of effort to reduce costs), which create a wedge between the actual cost of investment and its minimum economic cost. The ratio between the minimum economic cost and the actual cost of investment is defined by Pritchett as the "efficacy of investment" and, in general, it is less than one, even if researchers assumes invariably that the efficacy is equal to one in empirical growth analysis.

Golden and Picci (2005) carry out a painstaking analysis of Italian regional endowment of infrastructure, comparing an infrastructure index calculated on the basis of effectively existing physical buildings with an index of expenditure in infrastructure (the amount of money spent over the years by government to this aim). They demonstrate the existence of wide differences among these two indexes: several regions (especially Southern regions) present a level of infrastructure much lower than their expenditure for public works ("missing infrastructure"). According to the authors, these differences can be attributed mainly to the existence of embezzlement, fraud and widespread corruption among politicians and public actors and also to waste and bad management. Golden and Picci (2005) elaborate a "corruption measure" (their Table 1, p. 46), reported in Table 15, as the ratio between the index of physical infrastructure and the expenditure index. This measure can be interpreted as the degree of effectiveness of public investment, that is, it indicates to what extent each euro spent is transformed in productive capital.

On the basis of these analyses we proceed disaggregating public investment and public-subsidised investment from private investment, since they cannot be realistically considered

[18] Caselli (2005) discusses, in line with Pritchett (2000), the opportunity of disaggregating public investments from private investments. However, he could not carry out the analysis due to a lack of reliable data at cross-countries level.

equally productive. More precisely, we suppose that the expenditures made do not transform in productive capital due to bad decisions, corruption, embezzlement and other agency costs. In the calculation of the regional stock of capital we give a different weight to these two categories of investments.

We use "Public Sector Accounts at regional level" (from 1996 to 2002) provided by the Italian Minister of Economics and Finance[19] in order to determine the share of public investment[20] and the share of public subsidized investment[21] on total investment. Results are reported in Table 15.

Table 15. Fraction of public and public-subsidised investment on total investments

Regions	Public investment (%)	Public-subsidised investment (%)	Golden-Picci measure of public investment efficacy
Piemonte	13,38	4,41	1,638
Valle d'Aosta	47,34	8,31	0,855
Lombardia	10,86	3,03	1,161
Trentino-Alto Adige	25,34	7,87	1,236
Veneto	11,60	3,41	1,220
Friuli-Venezia Giulia	18,10	6,68	1,077
Liguria	24,37	8,41	0,669
Emilia Romagna	12,87	3,01	1,611
Toscana	16,89	3,87	1,613
Umbria	17,82	7,67	1,783
Marche	17,83	4,31	1,312
Lazio	20,83	4,22	0,817
Abruzzo	17,37	12,69	0,956
Molise	22,69	20,58	0,583
Campania	19,16	14,30	0,362
Puglia	17,16	12,23	0,722
Basilicata	29,47	26,53	0,533
Calabria	26,89	13,58	0,409
Sicilia	22,64	10,42	0,607
Sardegna	28,40	15,44	0,838
ITALY	16,75	6,58	1,000
North-West	13,04	3,96	
North-East	14,46	4,17	
Center	19,02	4,44	
South	21,66	13,65	

Table 15 shows that Italian regions have different shares of public investment (13-14% in the North, 22% in the South) and even more dishomogenous shares of public subsidies to investments (4% in the North, about 14% in the South)

We firstly deal only with public investment.[22] The regional stock of capital is calculated giving to public investment of each region a weight equal to the "measure of effectiveness" build by Golden and Picci (2005). This should give a stock of public capital in line with the existing stock of physical infrastructures.

[19] Source: "Conti pubblici territoriali del Dipartimento per le Politiche di Sviluppo e Coesione. Distribuzione della Spesa Totale consolidata per categoria economica – Anni 1996-2002 (Milioni di euro correnti)"
[20] The sum of the categories "Beni e opere immobiliari" and "Beni mobili, macchinari" for "Settore Pubblico Allargato".
[21] The category "Trasferimenti in conto capitale a imprese private" for "Settore Pubblico Allargato".
[22] In this analysis we exclude Valle d'Aosta because it clearly represents an outlier.

Table 16. Physical capital contribution weighting public capital with Golden-Picci measure

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	18,0%	13,9%
Human Capital	38,5%	37,6%
TFP	43,4%	48,6%
Success of factor-only model	48.9%	

The results of variance decomposition with this new measure of the capital stock are shown in Table 16. It is evident that the role of physical capital is substantially increased (from 3% to 18%) when one considers the efficacy of each regions in transforming investment cost in effective public capital.[23]

We now consider the investments subsidized by the State. These subsidies to firms could distort firm's investment choice: firms could over-invest (considering that their investment cost is reduced) or invest in less efficient projects or sectors (contributions are often conditional on investing in particular sectors or using determined technologies), or the funds could be embezzled by entrepreneurs or simply wasted[24]. Considering these risks which reduce the efficacy of subsidized investment in forming productive capital, we give different weights to the amount of investment financed through public funds. However, differently from public investment, we suppose that this weight is uniform across regions, since we do not have any reliable measure to differentiate regions in this respect (Table 17).

Table 17. The contribution of physical capital with different weights for public subsidized investments

Efficiency of public subsidized investments	0 %	25%	50%	75%	100%
Physical Capital	35,9%	30,9%	26,4%	22,1%	18,0%
Human Capital	38,5%	38,5%	38,5%	38,5%	38,5%
TFP	25,6%	30,5%	35,1%	39,4%	43,4%
Success of factor-only model	82,9%	71.4%	62.2%	54.8%	48.9%

Table 17 shows that, by weighting differently subsidized investment, physical capital becomes much more significant in explaining regional development differentials. Supposing that subsidized investment are only 50% productive respect to fully private investment, we are able to explain more than 25% of productivity differences through differences in the stock of physical capital. As a consequence, considering also that human capital can explain almost 40%, the role of TFP is substantially reduced to 35% (from 80% in the benchmark case).

[23] As regards to human capital, we assume $\pi = 0.5\%$ and $\phi = 5.7\%$.

[24] See Scalera and Zazzaro (2000) for an analysis of many distortions that can be related to public aids to firms. See also Francesco Giavazzi ("Meno incentive, meno tasse", *Corriere della Sera*, 19-5-2004) and Roberto Perotti ("Patti territoriali, Un freno per il Sud", *Il Sole 24 Ore*, 2-12-2000; "E' meglio che lo Stato non investa", *La Repubblica*, 5-7-1999).

7. Concluding remarks

Using the variance decomposition methodology we have determined the role of accumulation of physical and human capital and the role of technology in explaining differentials in development across Italian regions. By measuring production factors in the standard quantitative way, we attribute most of the differences (about 80%) in development to TFP differences, whereas the weights of human and physical capital are respectively 16% and 4%.

The individuation of TFP as the main determinant of development experiences is robust to traditional accounting exercises of the type usually conducted at cross-countries level (Caselli, 2005; Klenow and Rodriguez-Clare, 1997), consisting in the evaluation of the influence of different values of decisive parameters such as the capital-output elasticity, the depreciation rate, the initial capital stock and the rate of return to school. In other words, the critique raised by Mankiw (1997) of excess sensitivity to parameter values does not appear compelling in our setting.

However, the estimates of the role of technology and factors accumulation are not robust to some new exercises allowed by a greater availability of data when comparing regions within the same country.

Instead of measuring human capital simply with the average years of education among labour force, following Hanushek and Kimko (2002) we take into account the effective skills acquired by students or by the adult population using the results of international test scores on cognitive abilities. This new measurement produces a noteworthy increase in the role of human capital up to 40-50%, using reasonable parameterization. Similar figures can be obtained through an alternative way of measurement, that is, when human capital stock is computed using region-specific rate of return to school, which are used to capture different quality of human capital.

Finally, physical capital is re-estimated by disaggregating public from private investment in order to take account – following the analysis of Pritchett (2000) and Golden and Picci (2005) – of different productivities of these two categories of investments, due to moral hazard problems, corruption, embezzlement and fraud that are much more likely in the public sector. Again, using this new evaluation, results change drastically, since the role of physical capital is increased up to about 30%.

Together, the re-evaluation of human and physical capital to take into account quality lead us to think that the accumulation of factors is an important source of development and that it can explain much more than previously estimated and that, on the other hand, the role of TFP is much smaller (about 30% instead of 80%). TFP is somehow a black box (Solow defined it "a measure of our ignorance") and analysis adopting crude estimations push inside it the mismeasurement of the quality of human and physical capital.

In practice, in the baseline case we were attributing to the residual TFP differences in the quality of human capital (workers possess heterogeneous skills which are not captured by differences in the years of education) and in the quality of physical capital (a part of physical capital as measured by the money spent is in reality not existing because fraud, embezzlement, etc. or it is less productive). Human and physical capital are not so similar across regions as it could appear from a superficial analysis: from a comprehensive evaluation, both human and physical capital result very different and to be highly correlated with productivity.

Our analysis can shed light also on the interpretation of cross-countries development accounting analysis. A number of studies argues that technological gaps have a dominant role in explaining output per worker levels across countries. However, due especially to a poor availability of data, production factors are often estimated in a cruder way at cross-countries level. It is likely that if human capital and physical capital are better measured (see the analysis of Gundlach, Rudman and Woessmann, 2002), as we have done in this paper thanks to more accurate regional data, then physical and human capital can emerge as fundamental factors of development and reduce the area of our ignorance.

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