Quality of Human and Physical Capital and Technological Gaps across Italian Regions

Scoppa, Vincenzo

Dipartimento di Economia e Statistica - Università della Calabria

2007

Quality of Human and Physical Capital and Technological Gaps across Italian Regions

Working Paper Version
Forthcoming in Regional Studies, vol. 41, n. 5, July 2007, pp. 585-599

Vincenzo Scoppa[*]
Dipartimento di Economia e Statistica – Università della Calabria

This paper evaluates the relative contribution of factor accumulation and technology in explaining output per worker differences across Italian regions in the period 2000-2004. 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 rates of return on human capital; c) public investments and public-subsidized investments are weighted differently from private investment in the determination of physical capital stock. We show that better measurement of factor inputs allows a reduction in the solowian "measure of our ignorance".

JEL: O470; E230; E130

1. Introduction

A hot controversy is raging among growth economists about the ultimate causes of cross-country differences in per worker (or pro 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[1]. This question is sometime refered to as the "A vs. K"[2] 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

---

[*] I would like to thank for helpful comments and suggestions two anonymous referees, Francesco Aiello, Maria De Paola and seminar participants at the XX AIEL conference (Rome; 22-23 September 2005). Usual disclaimers apply.

[1] More specifically, differences in TFP could be caused by the adoption of different technologies or could be due to the existence of production externalities, spillovers, complementarity among production factors, economies of scale etc.

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

factor accumulation (their findings have been dubbed "a neoclassical revival"), Hall and Jones (1999), Klenow and 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 neoclassical growth theory, which assumes that technology is a public good freely available to all countries and, as a consequence, concludes that cross-country differences in development levels are due to a different degree of factor 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, whilst if a crucial role is played by technology or efficiency then policy interventions should be aimed at stimulating transfers of knowledge and of technology and the adoption of the most efficient productive, organizational process.

The main aim of this paper is to apply the "development accounting"[3] methodology – used recently by Caselli (2005), Klenow and Rodriguez-Clare (1997) and Gundlach, Rudman, Woessmann (2002) in cross-country development analysis – to evaluate to what degrees the wide differences in output per worker existing across Italian regions, for the period 2000-2004, can be attributed to different levels of accumulation of physical and human capital or to different levels 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 labour productivity (Aiello and Scoppa, 2000; Marrocu, Paci and Pala, 2000; Di Liberto, Mura and Pigliaru, 2004), the decomposition of differences in output per worker into the contributions made by 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 the evaluation of the impact of different values of parameters, various functional forms and a variety of procedures for measuring output and inputs. In fact, since development accounting exercises tend to be very sensitive to assumptions about 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

---

[3] The definition of "development accounting" is increasingly used to refer to analysis focusing on level rather than on rates of growth (which is instead traditionally defined as "growth accounting").

schooling of the labour force, as is standard in literature, but also by taking into account the effective cognitive skills acquired by students at school, as measured in international test scores. Secondly, region specific rates of return on human capital are used instead of a common national rate. With 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 productivities might 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 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 considerably reduced (by up to around 30%). Physical and human capital appear more heterogeneous across regions and much more related to productivity. In practice, it emerges that mismeasurement of factors emphasised 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 at international level too, the estimated preponderance of TFP could be reduced and differences would be ascribed directly to the accumulation of input factors.

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

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:

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

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.

In our basic framework we assume Hicks-neutral productivity (instead of Harrod-neutral or labour-augmenting productivity) and hence, output per worker is written as a function of the capital-labour ratio (K/L) (as in Caselli, 2005).[4] Dividing the production function [1] by *L*:

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

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:

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

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, in the first place, 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:

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

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: $c_k=\frac{Cov(\ln(y),\ln(\tilde{k}))}{Var(\ln(y))}$; c_h as the contribution of human capital: $c_h=\frac{Cov(\ln(y),\ln(\tilde{h}))}{Var(\ln(y))}$; and $c_A=\frac{Cov(\ln(y),\ln(A))}{Var(\ln(y))}$ as the contribution of technology.

As is evident from definitions, 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:

---

[4] On the other hand, Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) assume labour-augmenting technical progress and express output per worker as a function of the ratio capital/output K/Y. As shown by Caselli (2005) and Gundlach, Rudman and Woessmann (2002), the substantial difference between the two approaches is that, with the assumption of Harrod-neutrality, more weight is given to technology, since any technological shock which also causes a variation of capital is attributed to productivity instead of capital (since K/Y tends to remain constant).

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

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

2.1. The alternative index used by Caselli (2005)

It is useful to compare Klenow-Rodriguez-Clare's (KRC) approach with the slightly different strategy adopted by Caselli (2005). Defining $\tilde{k}\tilde{h} = \left(\frac{K}{L}\right)^{\alpha} h^{1-\alpha}$ the composite of physical and human capital[5], Caselli starts from the identity:

$$Var(\ln(y)) = Var\left(\ln(A) + \ln\left(\tilde{k}\tilde{h}\right)\right) = Var(\ln(A)) + Var\left(\ln\left(\tilde{k}\tilde{h}\right)\right) + 2Cov\left(\ln(A), \ln\left(\tilde{k}\tilde{h}\right)\right)$$

Under the assumption of the neoclassical growth model that technology is uniform across countries, from which $Var(\ln(A)) = 0$ and $Cov\left(\ln(A), \ln\left(\tilde{k}\tilde{h}\right)\right) = 0$, the implication of this "factor-only" model is that $Var\left(\ln\left(\tilde{k}\tilde{h}\right)\right)/Var(\ln(y))$ should be 1.

Therefore, an indicator of how successful the neoclassical approach is – that is, how important factor accumulation is in development differences – is given by the variable defined *success* in Caselli (2005):

$$success = \frac{Var\left(\ln\left(\tilde{k}\tilde{h}\right)\right)}{Var(\ln(y))}$$

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 attributed to the adoption of different technologies.

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

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

Comparing [4] with the definition of *success*, note that the two measures are identical if the covariance between A and $\tilde{k}\tilde{h}$ is equal to zero. On the other hand, if $Cov\left(\ln\left(\tilde{k}\tilde{h}\right), \ln(A)\right) > 0$ (as in fact data show), a higher contribution is attributed to factor inputs in Klenow and

---

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

Rodriguez-Clare's approach because their variance decomposition imputes half of the co-movements between X and A to factor inputs (in other words, the covariance term is split between factor and technological contributions).

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

In order to check the robustness of our results, similarly to Hall and Jones (1999) and Caselli (2005), we use a third 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 the five least productive (their geometric average is indicated with *w*):

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

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:

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

Again, the first term can be interpreted 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.

For completeness, in the analysis below we usually report the three alternative measures of the contribution of capital accumulation and technology, even if in many cases they do not show appreciable differences.

3. Data, baseline results and robustness checks

We use a data set, which has recently been made available by the Italian National Statistical Institute (ISTAT), containing the main economic variables for Italian regions, which were 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 2000 to 2004. In addition, we use micro data from the Bank of Italy's "Survey on Household Income and Wealth" (SHIW); data from ISTAT "Investments and the capital stock"; ISTAT "Labour Force Survey" and "Public Sector Accounts at Regional level" provided by the Italian Ministry of Economics and Finance

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 (data on investments are available for the period 1980-2004), 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 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) by the existing capital stock of Italy. The capital share of income α=0,302 is calculated as the ratio of gross profits to the value added (at factor cost), taken as average over 2000-2004 period[6].

Human capital

As is 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 on 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 on human capital ϕ is assumed equal to 5.7%, the private rate of return (considering net wages) estimated by Brunello and Miniaci (1999) using SHIW data.

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

Table 1. Regional output, physical capital and years of schooling per worker (average 2000-2004)

Regions and macro-areas	Output per worker	Capital per worker	Years of schooling
Piemonte	45.025	149.485	10.547
Valle d'Aosta	47.604	195.576	10.830
Lombardia	47.636	135.497	11.311
Trentino-Alto Adige	44.774	168.382	10.977
Veneto	43.164	131.215	10.745
Friuli-Venezia Giulia	44.548	144.560	11.137
Liguria	46.416	138.498	11.923
Emilia-Romagna	44.649	131.628	11.099
Toscana	42.397	116.840	10.898
Umbria	40.434	134.203	11.015
Marche	40.320	122.737	10.834
Lazio	45.233	122.537	11.306

---

[6] "Quota dei profitti lordi sul valore aggiunto al costo dei fattori" from "Rapporto annuale 2002".

Abruzzo	39.936	142.224	11.510
Molise	39.922	159.983	9.744
Campania	37.866	143.432	10.509
Puglia	36.395	121.159	10.779
Basilicata	39.765	179.612	8.850
Calabria	36.086	144.397	10.510
Sicilia	40.481	151.833	10.440
Sardegna	38.483	162.200	9.650
Italy	42.586	129.875	10.900
North-West	46.524	154.378	11.165
North-East	43.460	137.619	10.947
Centre	42.770	123.801	11.097
South	37.535	143.136	10.427

Source: our computations on ISTAT data (1995 euro)

3.1. Baseline results

Considering the variables y, k and h determined in the previous section, in this section, we evaluate how important, factors of production and technological efficiency are, respectively in explaining differences in output for the period 2000-2004. All the assumptions on parameter 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 across regions much more homogenously than output. The correlation of y with k is also quite low (0.10) while the correlation between y and h (0.49) is more accentuated.

Table 2. Matrix of variances and covariances (variables are in logs)

	Y/L	K/L	h
Y/L	0.0069		
K/L	0.0003 (0.10)	0.0016	
h	0.0011(0.49)	-0.0005 (-0.50)	0.0007

Correlation coefficients are in parentheses

Using the methodology explained above, the definitions of c_k , c_h , c_A , *success* and the ratio b_5/w_5 , the following results are obtained:

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

Variability explained by:	c_i	b_5/w_5
Physical Capital	4.9%	0.9%
Human Capital	15.9%	18.2%
TFP	79.3%	80.9%
Success of factor-only model: 17.8		

From our first baseline estimates in Table 3, the results are noteworthy: factor inputs explain only a marginal share of the differences in output per worker. In particular, physical capital per worker appears to have almost no influence (4.9%), while a limited influence is exercised by human capital (15.9%). Since differences in physical and human capital across regions appear quite limited, they could not explain much about the disparities in development. Regional Total Factor Productivity is the preponderant determinant of output per worker (79.3%) 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 regions had the same level of TFP with the observed dispersion) shows that the joint contribution of human and physical capital is equal to a modest 17.8%, again leaving more than 80% to technological differences. Moreover, the third 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 (80.9%).

Comparing the results for Italian regions with cross-country analysis and 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 explains 49%, while technology accounts for only the remaining 22%., Our estimates, on the other hand, are in line with Klenow and Rodriguez-Clare (1997) (for whom physical capital explains 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).

However, the very low correlation between physical capital and output per worker is rather worrying and represents a first warning that these variables may be badly measured and might not taking effective differences existing across regions fully into account. We verify now whether the implausible results, particularly those regarding the role of physical capital, depend on the assumptions made, and on the particular values imputed, in the determination of this variable with regards to 1) the capital income share α; 2) the depreciation rate δ; or 3) the initial capital stock K_0. It will be shown that estimates of the contribution of physical capital do not change substantially when these key parameters are changed.

The contribution of physical capital is increased as α assumes higher values, but quantitatively remains rather low even when considering implausible high values of α (for example, when α is 0.50 the contribution of capital is only 8.3%). For more realistic values – estimates by Gollin (2002) and Bernanke and Gurkaynak (2001) show that the capital share for Italy[7] ranges between 0.29 to 0.35 – physical capital contribution remains between 5% and 6%.

Similarly, when depreciation rate is changed, for example up to the very high value of 15%, the contribution of physical capital is around 13%. Therefore, if we exclude unrealistic

---

[7] The figures change according to the methods used to attribute to labour some share of self-employed income.

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

Moreover, nothing relevant is changed when the initial capital stock is calculated differently. Instead of inserting K_0 as calculated by Paci and Pusceddu (1999), it can be determined following the standard approach in growth accounting, assuming that it is equal to its steady-state level, that is: $K_0 = I/(n + g + \delta)$, where I is the geometric average of the flow of investment (years 1980-82), n is the regional growth rate of employment, g is the rate of productivity growth and δ is the depreciation rate. These variables are taken as averages over the period 1980-2004 in order to determine capital stocks in recent years through the perpetual inventory method. Again, the results are not very different from our baseline estimations, since the contribution of physical capital is now around 3%. In section 5 we will deal with more radical changes in the way physical capital is measured.

3.2. Robustness checks on human capital determination

In this section we verify how robust previous results are with regards to human capital, that is, we check how the results on the relative contribution of factors and technology change when human capital is measured using reasonable alternative values.[8] The modifications aim to evaluate how results change using an alternative measure of average years of education and taking into account different rates of return on 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 Labor Force Survey",[9] (average 2000-2004) instead of employed workers from the Survey of Bank of Italy. Data are shown in Table 4. [10]

Table 4. Average years of schooling among labour force

Piemonte	10.412	Lazio	11.296
Valle d'Aosta	10.202	Abruzzi	10.668
Lombardia	10.703	Molise	10.457
Trentino-Alto Adige	10.342	Campania	10.375
Veneto	10.364	Puglia	10.080
Friuli-Venezia Giulia	10.777	Basilicata	10.002
Liguria	10.857	Calabria	10.420
Emilia-Romagna	10.612	Sicilia	10.341
Toscana	10.411	Sardegna	9.980
Umbria	11.013		
Marche	10.515	Italy	10.710

---

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

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

[10] Average education based on 2001 census data is very similar (correlation rate is 0.95).

These data are for some regions different from the average years of education calculated on the basis of SHIW data set, but the rate of correlation of the two series is 0.69.

Table 5. Technology and factor contributions considering human capital accumulation among labour force

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	4.9%	0.9%
Human Capital	6.4%	8.3%
TFP	88.7%	90.7%

Using this new variable to calculate regional years of education, Table 5 shows that the relative contribution of human capital is less relevant (only 6.4%) than previously estimated. Since we aim to explain output per worker it is perhaps more appropriate to use a measure of workers' education rather than a measure of labour force education. However, for completeness, in section 4, we take into account both these series and compare their respective results.

Considering alternative rates of return on human capital

In section 3, we have assumed that the rate of return on schooling is equal to 5.7%: $\phi(s) = 0.057s$. This is an estimate of the private rate of return, while we should ideally take into account the social rate of return, which is hard to determine. The social return might be higher if externalities tend to prevail, but could be even lower if the signalling function of education prevails (see, among others, Acemoglu and Angrist, 2000, and Pritchett, 2004).

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

Table 6. The contribution of factor accumulation and technology with different rates of return on schooling

Rate of return ϕ	**1%**	**3%**	**5%**	**6.8%**	**10.1%**	**12%**	**15%**	**20%**
Physical Capital	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%
Human Capital	2.8%	8.3%	13.9%	18.9%	28.1%	33.4%	41.7%	55.7%
TFP	92.4%	86.8%	81.2%	76.2%	67.0%	61.7%	53.4%	39.5%

As expected, since more developed regions have a greater level of education, the role of human capital is enhanced if the rate of return is increased (Table 6). 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 on schooling

Instead of a constant rate of return on schooling, one could consider, on the basis of evidence from many labour economics studies, a decreasing marginal return. With this aim, Bils and Klenow (2000) propose the function $h=[\theta/(1-\psi)]s^{1-\psi}$ for the determination of human capital (with $\theta=0.32$ and $\psi=0.58$).

Table 7. Technology and factor contributions with decreasing marginal return on schooling

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	4.9%	0.9%
Human Capital	11.1%	12.6%
TFP	84.1%	86.5%

Using this formulation (see Table 7), human capital is less important in explaining development (11.1%).[11] In fact, since human capital is relatively more abundant in rich regions, by considering decreasing marginal returns the role of human capital is attenuated. However, the data and analysis in section 4 will show that it is more likely that marginal returns increase with the level of human capital. Some possible explanations for this pattern is proposed in section 4.

Summing up this section, we can point out that the standard robustness checks carried out show that estimates of the high relative contribution of TFP, and a limited role for factor accumulation, are substantially confirmed assuming different values for a number of parameters and different functional forms.

4. Improvements in human capital measurement

In this section, some more radical attempts at improving the measurement of human capital are undertaken. The main aim is to consider not just quantity of human capital, but also its quality. Traditional growth studies at cross-country 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 the effective productivity of education or its 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 growth literature (see Woessmann, 2003; Lee and Barro, 2001):

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 on education, assuming that in the labour market

---

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

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. With regards to the third approach, a number of empirical analyses (especially 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 likely explanation to 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.

4.1. School quality and cognitive skills measured in test scores

As pointed out in cross-country analysis, 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 knowledge acquired by students.[12] Regional human capital is accumulated at different rates according to cognitive abilities effectively acquired by students. This acquisition depends on a number of factors: the quality and motivation of teachers, students' (and parents') 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, in many countries, standardized tests periodically in order to assess the knowledge acquired by students in Mathematics, Science and Reading Comprehension. The International Association for the Evaluation of Educational Achievement (IEA) in the programme "Trends in International Mathematics and Science Study" (TIMSS) and the OECD in the "Programme for International Student Assessment" (PISA) provide data on students' cognitive skills in many countries. Moreover, OECD measures the

---

[12] Substantial migrations of workers across regions could undermine this analysis, but migration rates have been rather low until recently.

literacy among the adult population in the "International Adult Literacy Survey" (IALS in the mid-90s).[13] These tests show that large differences exist between countries in the skills acquired by individuals.

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

The above mentioned international test scores contain results at macro-region level with regards to Italy.[14] Lacking reliable single regional data for each region, to 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 and 2003) and IALS (1998). Each test is re-parameterised on a scale 0-100 and combined together (through geometric average) into a single measure of quality, denoted with q.

The test scores show the existence of huge differences between Italian regions (Table 8): Lombardia and Trentino, for example, reach a level in mathematics and science tests comparable to the world's best performers (Finland, Korea, Hong Kong), whereas Southern regions attain a level in line with the worst performers, usually non-OECD countries (Mexico, Turkey).

Table 8. 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	*Centre*	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 made in the literature (see, for example, Hanushek and Kimko, 2002) we suppose that educational institutions and quality of education change only slowly with time and therefore the performance of present students also reflects the knowledge possessed by previous generations of students, that is, the present stock of workers. This is also

---

[13] The OECD is currently carrying out the Adult Literacy and Life Skills Survey (ALL).

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

confirmed by the strong correlation existing between students' achievement in tests and the results which emerged from the test on literacy conducted in the 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: $h_i = \Lambda_i e^{\phi s_i}$, where $\Lambda_i = e^{\pi q_i}$ represents the efficiency (or quality) of human capital, which is variable across regions. The parameter π represents the rate of return on 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 Umbrian performance (around the Italian average)) leads to an increase of 5% in wages (and hence of worker 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 on skills for each country, a rate of $\pi = 0.4\%$ for Italy can be inferred.[15]

Table 9. 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	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%
Human Capital	20.5%	25.2%	29.9%	34.5%	39.2%	.43.9%	48.5%	53.2%	57.9%	62.5%
TFP	74.6%	69.9%	65.3%	60.6%	55.9%	51.3%	46.6%	41.9%	37.3%	32.6%
"Success" of factor-only model	19.7%	22.2%	25.3%	29.0%	33.3%	38.2%	43.7%	49.8%	56.4%	63.7%

Table 9 clearly shows the importance of human capital when its quality is properly taken into account. While when capital is measured simply considering years of education, it explains a mere 15% in Italian regional development differentials, introducing a correction in its measurement to consider the effective quality of labour force skills greatly increases its weight as a factor of development. Human capital can explain almost half of the difference in the levels of development, becoming the most important production factor, even considering very low rates of return on quality. If we consider $\pi = 0.5\%$ (about the average among the different available estimates) as a benchmark, human capital explains about 40% of differences in development.

If we use the average years of education among the labour force (see section 3.2), we

---

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

have similar results, even though the contribution of human capital is attenuated: from Table 10, with $\pi = 0.5\%$ human capital is able to explain about 30%.

Table 10. The contribution of human capital when education among labour force is considered.

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	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%	4.9%
Human Capital	11.1%	15.7%	20.4%	25.1%	29.7%	34.4%	39.1%	43.7%	48.4%	53.1%
TFP	84.1%	79.4%	74.7%	70.1%	65.4%	60.7%	56.1%	51.4%	46.7%	42.1%

Gundlach, Rudman and Woessmann (2002) adopt an alternative method to introduce quality into 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.[16] We divide the test scores of each macro-region by the Italian average, then we average through different available measures. The results are reported in Table 11.

Table 11. Weight of human capital in development using the methodology of Gundlach et al. (2002)

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	4.9%	0.9%
Human Capital	47.8%	46.2%
TFP	47.3%	52.9%

Table 11 substantially confirms the results obtained following Caselli's approach, that is, when human capital is adjusted to include quality, it appears as the main determinant (48%) in explaining differences in development among Italian regions.

While regional differences in quantity of schooling are not very relevant, considering quality too, it emerges that about half of the disparities in development among Italian regions can be attributed to the different skills of the labour forces.

4.2. Region-specific rates of return on education

The second method to take into account qualitative differences in human capital is based on the

---

[16] 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 approximately equivalent to assuming $\pi = 0.62\%$ in Table 9.

econometric estimation of a rate of return on schooling for each single region.[17] In theory, a better quality of education should make workers more productive and in competitive labour markets this should lead to a higher return on schooling. Therefore, instead of using direct measurements of acquired skills, it is appropriate to consider regional specific rates of return on schooling (ϕ_i), to take into account different levels of quality across regions.

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

With this aim, we use the regional rates of returns on education calculated by Ciccone (2004), using the Bank of Italy's Survey (SHIW) aggregating a series of waves (since 1987 to 2000, totalling over 45000 individual observations).[18] The author estimates a different *mincerian* wage equation for each region and adjusts the returns for gross wages.[19] The results are reported in Table 12.

Table 12. Regional rates of return on schooling (gross wages)

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	Centre	6.62
Abruzzi	6.66	South	6.55

Source: Ciccone (2004).

The data in Table 12 show a clear pattern in which richer regions have higher returns on human capital (that is, Nothern regions have rates of return significantly higher than Southern regions). This non standard result could be determined because of differences in educational quality or in labour market conditions.

A first direct explanation is that these rates of returns capture differences in the quality of human capital (see Woessman, 2003; Gundlach, Rudman and Woessmann, 2002). Skills in developed regions may be paid for more simply because they incorporate higher quality. This is strongly confirmed by the data of school quality considered in the previous section (the

---

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

[18] See also the related work of Ciccone, Cingano and Cipollone (2005).

[19] In the last part of this paper, the author estimates the private return on schooling as equal to the discount rate that equalizes the present value of the private costs and benefits generated by an increase in educational attainment. In our analysis this rate is less appropriate since it includes, among individual benefits, the probability of finding employment, which is not related to the output per worker which we are interested to explain.

correlation between the regional rates of returns and the school quality index is 0.66).

An alternative explanation may be offered in a standard supply and demand framework, such as the one used by Katz and Murphy (1992) and by Juhn, Murphy and Pierce (1993) to explain the increasing wage inequality among skilled and unskilled workers (for a review see Katz and Autor, 1999). One could represent developed regions as characterized by a relatively higher demand for skills with respect to poorer regions (for example because of complementarity existing between skills and the type of capital employed or the sectorial specialisation), leading to a demand curve shifted to the right. With an increasing supply curve with no substantial differences across regions, this would lead to both a higher proportion of skilled workers in richer regions labour markets, and, at the same time, to a higher relative compensation for skills.

Using the rates of return of Table 12, we obtain the results shown in Table 13 (first two columns). Since estimations of regional rates of return might not be robust, due to a small number of observations in each region, in the last two columns only the returns estimated for macro-regions, which appear more robust, are taken into account,. According to Ciccone, Cingano, Cipollone (2005), differences across macro-regions are significant at 1% level.

Table 13. Human capital's contribution to development using regional rates of return on schooling

	Regional returns		**Returns at macro-region levels**	
Percentage variability explained by:	c_i	b_5/w_5	c_i	b_5/w_5
Physical Capital	4.9%	0.9%	4.9%	0.9%
Human Capital	52.6%	52.0%	45.1%	47.4%
TFP	42.5%	47.0%	50.1%	51.7%
Success of factory-only model	72.7%		45.4%	

The results of the relative contribution of human capital in explaining development differences change significantly with respect to the assumption of a homogenous rate of return across regions, but are in line with previous adjustments for quality: human capital is now able to explain a considerable share of regional differences in development (45-50%).[20] The evidence from section 4.1 and 4.2 implies that the failure to take into account labour quality tends to overestimate the contribution of technology.

---

[20] When education is calculated among the labour force, the contribution of human capital ranges from 32% to 40%.

5. Quality of physical capital: public investments and public-subsidized investments

The stock of physical capital calculated in previous sections through perpetual inventory method uses all private and public investment, simply summing all the expenditure made for investment. As sustained forcefully by Pritchett (2000) and other growth economists, it is not reasonable to suppose that all the expenditure in investment is transformed directly into productive capital, especially for the public sector.[21] Pritchett (2000) argues that agency problems plaguing government are more pervasive than in the private sector since public sector firms or organizations often operate in monopolistic markets, there is no market for the ownership of assets and many goods provided by government are public goods. These problems give rise to distorted behaviour by public actors, such as corruption, "patronage" (transfers to political supporters) or simply shirking (low 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, notwithstanding the fact that in empirical growth analysis researchers almost invariably assume a perfect efficacy. Moreover, public investment may be made in important but less dynamic sectors or led by welfare considerations rather than simply by productive efficiency.

Golden and Picci (2005) carry out a painstaking analysis of the Italian regional endowment of infrastructures, comparing an index calculated on the basis of effectively existing physical infrastructures with an index of public expenditure on infrastructures (the amount of money spent over the years by government with this aim). They demonstrate the existence of wide differences among these two indexes: several regions (especially Southern ones) show a level of infrastructures which is much lower than their expenditure on 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 14, as the ratio between the index of physical infrastructures and the expenditure index. This measure can be interpreted as the degree of effectiveness of public investment, i.e., it indicates to what extent each euro spent is transformed into productive capital.

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

---

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

considered equally productive[22]. More precisely, we suppose that all the expenditure made do not transform in productive capital due to bad decisions, corruption and other agency costs and to aims pursued by the public sector which are based on welfare and equity considerations and not only on productive efficiency. 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 2003), provided by the Italian Ministry of Economics and Finance,[23] in order to determine the share on total investment of public investment (expenditure for constructions, machinery and equipment)[24] and the share of public subsidized investment (subsidies to firms for investments)[25]. Results are reported in Table 14.

Table 14. Fraction of public and public-subsidised investment on total investments

Regions	Public investment (%)	Public-subsidised investment (%)	Golden-Picci measure of public investment efficacy
Piemonte	15.59	4.26	1.638
Valle d'Aosta	56.45	8.16	0.855
Lombardia	13.48	2.91	1.161
Trentino-Alto Adige	29.22	6.85	1.236
Veneto	13.52	3.34	1.220
Friuli-Venezia Giulia	22.80	5.56	1.077
Liguria	29.63	7.93	0.669
Emilia Romagna	17.32	2.52	1.611
Toscana	21.48	3.43	1.613
Umbria	20.81	7.20	1.783
Marche	19.69	3.91	1.312
Lazio	25.83	3.93	0.817
Abruzzo	24.15	12.34	0.956
Molise	25.23	19.76	0.583
Campania	23.82	14.22	0.362
Puglia	18.41	11.78	0.722
Basilicata	31.76	25.22	0.533
Calabria	28.44	13.51	0.409
Sicilia	25.44	9.83	0.607
Sardegna	32.66	14.10	0.838
ITALY	20.10	6.23	1.000
North-West	15.82	3.80	
North-East	17.83	3.73	
Centre	23.30	4.08	
South	24.98	13.16	

Table 14 shows that Italian regions have different shares of public investment (16-17% in the North, 25% in the South) and even more dishomogenous shares of public subsidies to investments (4% in the North, about 13% in the South).

We firstly deal only with public investments.[26] The regional stock of capital is calculated

---

[22] Jorgenson and Griliches (1967) have shown the importance in growth accounting analysis of disaggregating the inputs by quality classes.

[23] Source: "Conti pubblici territoriali del Dipartimento per le Politiche di Sviluppo e Coesione"

[24] The sum of the categories "Beni e opere immobiliari" and "Beni mobili, macchinari".

[25] The category "Trasferimenti in conto capitale a imprese private".

[26] In this analysis we exclude Valle d'Aosta because it clearly represents an outlier. Probably this is due to its geomorphology: Valle d'Aosta is an extremely mountainous region, which makes public works extremely expensive, in particular in comparison to the small size of its economy.

giving to public investment in each region a weight equal to the "measure of effectiveness" built by Golden and Picci (2005). This should give a stock of public capital in line with the existing stock of physical infrastructures.

Table 15. Physical capital contribution weighing public capital with the Golden-Picci measure

Percentage variability explained by:	c_i	b_5/w_5
Physical Capital	20.8%	15.8%
Human Capital	39.2%	38.8%
TFP	40.0%	45.3%
Success of factor-only model	55.1%	

The results of variance decomposition with this new measure of capital stock are shown in Table 15. It is evident that the role of physical capital is substantially increased (from 5% to 21%) when one considers the efficacy of each regions in transforming investment disbursement into effective public capital.[27]

We now consider investments subsidized by the State. These subsidies to firms could distort investment choice: firms may over-invest (considering that their capital cost is reduced) or invest in less efficient projects or sectors (public contributions are often conditional on investing in particular sectors or on using determined technologies), or the funds could be embezzled by entrepreneurs or simply wasted (on this topic see the recent books by Giavazzi, 2005, and Rossi, 2005)[28]. Moreover, the State often uses public subsidies as a welfare policy and to help declining sectors, leading to lower productivity for these investments.

Considering these possible inefficiencies, which might reduce the efficacy of subsidized investments in forming productive capital, we give different weights to the amount of investment financed through public funds. However, differently from the above analysis of public investments, we suppose that this weight is uniform across regions, since we do not have any reliable measure to differentiate regions in this respect (Table 16).

Table 16. The contribution of physical capital with different weights for public subsidized investments

Efficiency of public subsidized investments	0 %	25%	50%	75%	100%
Physical Capital	38.7%	33.8%	29.2%	24.9%	20.8%
Human Capital	39.2%	39.2%	39.2%	39.2%	39.2%
TFP	22.1%	27.0%	31.6%	35.9%	40.0%
Success of factor-only model	91.8%	79.6%	69.7%	61.7%	55.1%

---

[27] With regards to human capital in Table 15 and 16, we assume $\pi = 0.5\%$ and $\phi = 5.7\%$.

[28] See Scalera and Zazzaro (2000) for an analysis of many distortions that can be related to public aids to firms, 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).

Table 16 shows that, by weighting differently subsidized investments, physical capital becomes much more significant in explaining regional development differentials. Supposing that subsidized investment is only 50% productive with respect to fully private investment, we are able to explain about 30% of productivity differences thanks to variations 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 30% (from 80% in the benchmark case).

6. 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 the uneven development across Italian regions for the period 2000-2004. By measuring production factors in the standard quantitative way, we attribute most of the differences (about 80%) in output per worker to TFP differences, whereas the weights of human and physical capital are respectively 16% and 4%.

The identifying of TFP as the main determinant of development experiences is robust to traditional accounting exercises of the type usually conducted in cross-country analysis (Caselli, 2005; Klenow and Rodriguez-Clare, 1997), consisting of the evaluation of the influence of different values of crucial parameters such as capital-output elasticity, the depreciation rate, the initial capital stock and the rate of return on schooling. 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 factor accumulation are not robust to some new exercises allowed by a greater availability of data derived from a comparison of 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 of up to 40-50%, using reasonable parameterisation. Similar figures can be obtained through an alternative mode of measurement, that is, when human capital stock is computed using region-specific rates of return on schooling, which are used to capture different levels of human capital quality.

Finally, physical capital is re-estimated by disaggregating public from private investments 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 welfare considerations which could drive public intervention or to moral hazard problems, corruption, and so on, that are much more likely in the public sector. Using this new evaluation, results change again drastically, since the role of physical capital is increased up to about 30%.

Overall, the re-evaluation of human and physical capital to take quality into account 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. 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 as “a measure of our ignorance”) and analysis adopting crude estimations of factors place inside TFP the mismeasurement of the quality of human and physical capital. In practice, in the baseline case, we have attributed 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 money spent does not exist, in reality, because of moral hazard problems, or it is simply 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 turn out to be less homogenous and highly correlated with regional productivity.

Our analysis can also shed light on the interpretation of cross-country 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 particularly to poor availability of data, production factors are often estimated in a cruder way at cross-country level. It is likely that if human capital and physical capital are better measured, 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 measure of our ignorance.

References

ACEMOGLU, D. and ANGRIST, S. (2000) How Large are Human Capital Externalities: Evidence from Compulsory Schooling Laws, in B.S. BERNANKE, and K. ROGOFF, eds., *NBER Macroeconomics Annual*, (MIT Press, Cambridge), 9-59.

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., (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*, Dipartimento di Scienze Economiche, University of 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.

CASELLI, F., G. ESQUIVEL, and F. LEFORT (1996) Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics, *Journal of Economic Growth*, 1, 363-389.

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.

CURRIE, J., and THOMAS, D. (1999) Early Test Scores, Socioeconomic Status and Future Outcomes, *NBER Working Paper* No. 6943.

DENNY, K., HARMON, C., and O'SULLIVAN, V. (2004) Education, Earnings and Skills: A Multi-country Comparison, *Institute for Fiscal Study*, WP 04/08.

DI LIBERTO, A., MURA, R., and PIGLIARU, F. (2004) How to measure the unobservable: A panel technique for the analysis of TFP Convergence, *Contributi di Ricerca CRENOS*, University of Cagliari.

EASTERLY, W. and LEVINE, R. (2001) Is Not Factor Accumulation: Stylized Facts and Growth Models, *World Bank*.

GIAVAZZI, F., 2005, *Lobby d'Italia. L'Italia dei monopoli, delle corporazioni e dei privilegi*, Rizzoli, Milano.

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.

GUNDLACH, E., RUDMAN, D. and WOESSMANN, L. (2002) Second Thoughts on Development Accounting, *Applied Economic*, 34, 1359-69.

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.

HANUSHEK E. and KIMKO, D. (2000) Schooling, Labor-Force Quality, and the Growth of Nations, *American Economic Review*, 90, 1184-1208.

HANUSHEK, E. (1996) Measuring Investment in Education, *Journal of Economic Perspectives*, 10, 9-30.

ISLAM, N. (1995) Growth Empirics: A Panel Data Approach, *Quarterly Journal of Economics*, 110, 1127-70.

JORGENSON, D. and GRILICHES, Z. (1967) The Explanation of Productivity Change, *Review of Economic Studies*, 34, 249-83.

JUHN, C., MURPHY, K., and PIERCE, B., (1993) Wage Inequality and the Rise in Returns to Skills, *Journal of Political Economy*, 101, 410-442.

KATZ, L., and AUTOR, D., (1999) Changes in the Wage Structure and Earnings Inequality, in ASHENFELTER, O., CARD, D., eds., *Handbook of Labor Economics*, vol. 3A, Amsterdam, North-Holland.

KATZ, L., and MURPHY, M., (1992) Changes in Relative Wages, 1963-1987: Supply and Demand Factors, *Quarterly Journal of Economics*, 107, 35-78.

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

LEE, J. W. and BARRO, R. (2001) Schooling Quality in a Cross–Section of Countries, *Economica*, 68, 465-88.

MANKIW, G. (1997) Comment on Klenow and Rodriguez-Clare: The Neoclassical Revival in Growth Economics: Has It Gone Too Far?, *NBER Macroeconomics Annual*, 12, 103-8.

MANKIW, G., ROMER, D. and WEIL, D. (1992) A Contribution to the Empirics of Growth, *Quarterly Journal of Economics*, 107, 408-37.

MARROCU E., PACI R. and PALA, R. (2001) Estimation of Total Factor Productivity for Regions and Sectors in Italy: A Panel Cointegration Approach, *Rivista Internazionale di Scienze Economiche e Commerciali*, 48, 533-58.

MCGRATTAN, E. and SCHMITZ, J. (1998) Explaining cross-country Income Differences, *Federal Reserve Bank of Minneapolis Research Department*, Staff Report 250.

MURNANE, R., J. WILLETT, and LEVY, F. (1995) The Growing Importance of Cognitive Skills in Wage Determination, *Review of Economics and Statistics*, 77, 251-66.

NEAL, A., and JOHNSON, R. (1996) The Role of Premarket Factors in Black-White Wage Differences, *Journal of Political Economy*, 104, 869-95.

PACI, R. and PUSCEDDU, N. (1999) Stima dello stock di capitale nelle regioni italiane: 1970-1994, *Contributi di Ricerca CRENOS*, University of Cagliari.

PICCI, L. (1995) Lo stock di capitale nelle regioni italiane, *Working Paper n. 4,* Dipartimento di Scienze Economiche, University of Bologna.

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

PRITCHETT, L. (2004) Does learning to add up add up? The returns to schooling in aggregate data, in *Handbook of Education Economics*, Harvard University.

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

ROMER, P., (1993) Idea Gaps and Object Gaps in Economic Development, *Journal of Monetary Economics*, 32, 543-573.

ROSSI, N., (2005) *Mediterraneo del Nord. Un'altra idea del Mezzogiorno*, Laterza, Roma.

SCALERA, D. and ZAZZARO, A., (2000) Incentivi agli investimenti o rendite alle imprese? Una riflessione sulla procedura di allocazione dei sussidi prevista dalla legge 488/1992, *Rivista di Politica Economica*,, 69-100.

TEMPLE, J. (1999) The New Growth Evidence, *Journal of Economic Literature*, 1, 112-56.

WOESSMAN, L. (2003) Specifying Human Capital, *Journal of Economic Surveys*, 17, 239-70.

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