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Education and Growth: Some Disaggregate Evidence from the Italian Regions.

Abstract

The relationship between education and growth is examined in a sample of Italian regions. The neoclassical and Schumpeterian approaches which emphasize education growth and stock respectively as determinants of output growth are tested against each other using disaggregate data on education and capital stock. The main results are that productivity growth is influenced by the stock of education rather than its rate of growth. Tertiary education which does not promote growth in the aggregate becomes a significant growth enhancing factor if its allocation among sectors with different TFP dynamics is taken into account. In general controlling for this allocation effect reinforces the effects of education on output growth.

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1. Introduction

The relationship between human capital and growth has been very thoroughly investigated in a long list of papers from the growth accounting exercises of the sixties to the recent offspring inspired by the endogenous growth literature. Although from a theoretical point of view the relevance of human capital in the growth process seems indisputable, the empirical evidence is more controversial and does not help to clarify whether human capital promotes economic growth or not and how its effects come about. This may be due to several reasons, from the unavailability of reliable cross-country and time series data to the dubious proxies commonly used in the empirical literature. The most common among the latter, namely education, has been criticised on the grounds that it does not take into account some crucial components of human capital dynamics such as learning on the job and experience, or differences in school quality. However the results of microeconomic studies along Mincerian lines about the effects of education on wages convincingly point to a strong positive correlation between education and individual income. This suggests that education is not such a bad proxy of human capital and that educational attainment increases should be positively related to output growth at the macro level. Unfortunately the macro evidence is far from univocal reflecting different views at the theoretical level.

In fact we still do not have a well defined theory about the mechanisms through which an increase in the educational attainment of the population should affect the growth performance of the economy. In the absence of a general agreement on this matter two main approaches can be distinguished: one emphasizes the role of education accumulation while the other focuses on its stock. In a very influential paper Mankiw, Romer and Weil (1992) proposed an explanation of growth differences in terms of an augmented Solow model in which human capital is just an input in a standard Cobb-Douglas production function as well as capital and raw labour. Solving the model for its steady state equilibrium they show that it fits fairly well growth data from a wide sample of countries. In their study the rate of accumulation of human capital affects the rate of growth of the economy and makes a strong contribution to reducing the unexplained residual of the Solow model[1].

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[1] In fact the measure proposed by MRW is a proxy of the rate of investment in education and, to be more precise, of the rate of accumulation of the secondary education since they use the enrolment rates to secondary school. The high R squared obtained in their estimates depends strongly on this proxy

The accumulation of human capital is a crucial engine of growth in Lucas (1988) model as well. In this case the mechanism is different since it relies on the externalities generated by the accumulation itself and by the learning process, thereby producing endogenous growth in the long run.

The MRW approach has been questioned by Benhabib and Spiegel (1994, from now on B&S) who, following a framework of analysis proposed by Nelson and Phelps (1966), claim that the stock of education instead of its rate of growth should be considered as the crucial factor in the growth process[2]. According to Nelson and Phelps the ability of an economy to innovate and to exploit the catch-up potential due to the technological gap relative to a leader country is strongly influenced by the availability of a well educated labour force. The underlying hypothesis, also common to the Schumpeterian models of endogenous growth, is that output growth depends on the rate of creation of new technologies as well as on their diffusion. Both require the existence of an adequate stock of research abilities and technical competencies in the labour force. This implies that differences in growth rates across countries are positively correlated with differences in their stocks of education.

The Nelson-Phelps-Benhabib-Spiegel hypothesis has several empirical implications. Some of them have been left untested for lack of suitable data. In particular if the effect of education on output growth acts mainly through innovation we should expect that: first some components of total education, such as upper secondary and higher education, exert a stronger influence since these levels of education provide the most relevant research and development abilities. This argument applies in particular to industrialized countries where sophisticated scientific and technical competencies make the difference rather than basic abilities. Second, the effect of education on total factor productivity should be stronger in those sectors of the economy where innovation is the most important engine of growth. This opens the possibility of allocation effects. The same educational stock need not produce equal effects on growth if it is differently allocated among sectors with different TFP dynamics.

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for human capital. They ignore primary education and this substantially affects the variability of the human capital stock measure. Secondary enrolment rates vary by more than primary ones increasing the disparity within the sample. Following this objection Klenow and Rodriguez-Clare (1997) reran the MRW regression obtaining a R squared value of 0.48 compared to the 0.78 of the original estimation.

[2] Barro (1997,1998) finds that the initial stock of education influences the subsequent growth of output.

The purpose of this paper is to test the accumulation and stock approaches as well as the aforementioned implications of the B&S hypothesis in a sample of Italian regions. The availability of data on regional capital stocks and the possibility to disaggregate both educational data according to the levels of education and output data among the sectors of the economy allows a more thorough test of the hypothesis advanced by Benhabib and Spiegel. The choice of regions of an industrialized country as units of analysis provides other advantages. First, figures are much more reliable than in the case of international comparisons involving developing countries, because of the better data quality and the homogeneous survey methodology. This is particularly true when educational variables are involved since the structure and the quality of educational systems are so different among countries that homogenisation is often a very hard task to accomplish. Second, the test may contribute to shed some light on the effects of education on economic growth in industrialized countries where these effects seem much more questionable according to the empirical evidence collected so far (See Wolff and Gittleman, 1992; Benhabib and Spiegel, 1994). Third, some biases which might be present in cross-country studies are less relevant in a regional context. For instance, a problem which may cause biased estimates of the coefficients of the educational variables is that governments which carry on active educational policies are likely to implement some measures which foster growth as well. This is less likely to happen in a regional context because educational policy is normally common to all regions within the same country.

There is of course the reverse side of the coin. A possible pitfall of a regional sample is the lower variability relative to international data sets. In the former case the educational attainment levels are very much influenced by national education policy, particularly as regards lower levels. Primary education figures, for instance, are mostly determined by compulsory education policies in the industrialized countries. As regards the higher levels the costs of education are common to all regions within a country and student facilities are much more similar than in the international context. These factors exert a homogenising influence on human capital investment decisions[3]. However in the Italian case the variability of development and educational levels is much higher than in other industrialized countries, the problem of weak signal in the data is therefore reduced.

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[3] Among the European regions common national patterns of education attainment are easily discernible in the data. See Lodde (1999)

Another problem regards the low number of observations in a one country cross-region sample. A pooling of the observations relative to two periods (1971-81 and 1981-91) had to be made to increase the statistical power of the estimates. A panel methodology would have been preferable, unfortunately data on educational attainment levels in Italy are available only from censuses.

The paper is organized as follows. The next section reports some descriptive evidence on education in the Italian regions. Section three examines what the evidence tells us about the accumulation/stock alternatives. Section four tests the implications of the B&S model. The paper ends with some conclusive remarks.

2. Some descriptive evidence.

The educational attainment levels of the labour force are very different among the Italian regions[4].The average years of total education were 6.16 in the North and 4.87 in the South in 1971. Twenty years later the labour force appears much more educated although the Italian regions still lag behind the average European standards. In 1991 the figures jump to 9.4 years for the northern regions and 8.74 for the southern ones. These values show that the gap between the two Italian macro regions narrowed substantially during the period under analysis. This is confirmed by the value of the coefficient of variation which declines significantly during the period changing from 0.16 to 0.05 (see table 1).

To test the null hypothesis of no convergence in the attainment levels we compute the statistics: (standard deviation of the log of the initial value/standard deviation of the log of the final value)^2 which follows an F distribution with n-1, n-1 degrees of freedom. As can be seen from table 1 the ratio of initial to final values is significantly greater than one at the 1% level for total and primary education and at the 5% level for secondary and tertiary. A rapid process of convergence was going on during the period, particularly in the seventies, as graph 1 shows very clearly. Nonetheless the mean levels of education in the northern regions were still higher in 1991. This convergence is mainly due to the government education policy and to the general increase in the per capita income of the poorer regions[5].

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[4] Italy shows the highest regional dispersion in educational attainment levels among the European countries during the period 1981-91. See Lodde (1999).

[5] A general process of convergence has been going on at the international level as well from the sixties

Table 1. Average years of education in the Italian regions. Total, primary, secondary, tertiary. 1971, 1991.

	1971				1991			
	tot	pri	sec	ter	tot	pri	sec	ter
Piemonte	6.18	4.53	1.18	0.48	9.15	4.42	3.58	1.15
Valle d'Aosta	5.90	4.50	0.96	0.44	9.21	4.51	3.64	1.05
Lombardia	6.45	4.64	1.24	0.57	9.44	4.34	3.80	1.31
Trentino	6.55	5.04	1.06	0.44	9.30	4.68	3.55	1.08
Veneto	6.09	4.65	0.97	0.48	9.12	4.61	3.43	1.08
Friuli	6.64	4.75	1.35	0.55	9.56	4.36	3.96	1.25
Liguria	6.71	4.45	1.52	0.75	9.78	3.95	4.21	1.62
Emilia Rom.	5.78	4.09	1.14	0.55	9.31	4.13	3.84	1.34
Toscana	5.92	4.22	1.12	0.58	9.11	4.27	3.55	1.28
Umbria	5.65	3.84	1.17	0.63	9.45	3.94	4.04	1.48
Marche	5.18	3.60	1.05	0.53	9.04	4.19	3.53	1.32
Lazio	6.90	3.93	1.79	1.18	10.08	3.61	4.43	2.03
Abruzzi	5.16	3.38	1.22	0.56	9.11	4.07	3.61	1.43
Molise	4.33	2.96	0.89	0.48	8.60	4.07	3.17	1.36
Campania	5.13	3.29	1.12	0.72	8.98	4.09	3.24	1.65
Puglia	4.61	3.14	0.91	0.56	8.46	4.33	2.90	1.23
Basilicata	4.04	2.76	0.88	0.41	8.30	4.09	3.06	1.14
Calabria	4.47	2.75	1.12	0.59	8.53	3.97	3.06	1.50
Sicilia	4.91	3.02	1.09	0.80	8.76	4.05	3.16	1.56
Sardegna	4.60	3.65	0.33	0.62	8.80	4.51	3.01	1.28
Italy	5.83	4.01	1.19	0.63	9.21	4.21	3.61	1.39
North	6.25	4.38	1.25	0.62	9.40	4.24	3.80	1.36
South[6]	4.87	3.15	1.07	0.66	8.74	4.15	3.13	1.46
Mean	5.56	3.86	1.16	0.6	9.1	5.21	3.54	1.36
St.dev	0.88	0.72	0.21	0.17	0.45	0.26	0.42	0.24
Coef.var.	0.16	0.19	0.18	0.29	0.05	0.06	0.12	0.17

Convergence F-test

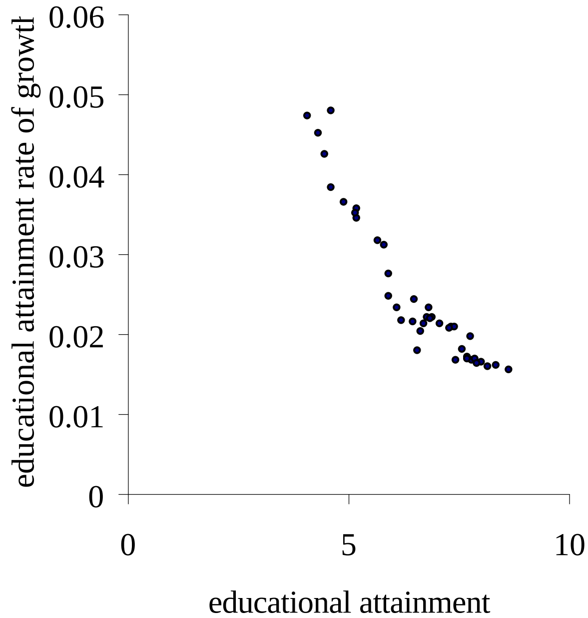
	tot	pri	sec	ter
F-stat.	10.94	9.41	2.12	2.17
Prob.	1.4E-06	4.7E-06	0.055	0.049

Source: ISTAT, Population Censuses 1971, 1991.

onwards. A high rate of convergence in the enrolment rates and (to a lesser extent) in the attainment levels has been detected in a large sample of countries. See Lichtenberg (1994).

[6] The South group includes Abruzzo, Molise,Campania, Puglia, Basilicata, Calabria, Sicilia and Sardegna.

Graph 1. Scattered diagram of the education rate of growth and initial levels in the Italian regions. Average years of total education. Pooled data 1971-81, 1981-91.



Secondary education behaves in a similar way, the dispersion declines (the coefficient of variation is 0.18 in 1971 and 0.12 in 1991) but the northern regions labour force remains on average more educated at the end of the period. The picture is quite different if we take a look at higher education. Although the coefficients of variation decline as in the former cases (from 0.29 to 0.17), there is no clear distributional pattern between the two groups of regions. Several southern regions show higher levels of tertiary education from the very beginning of the period. In particular, southern regions like Campania and Sicilia belong to the top five group, while the opposite is true for Veneto, Piemonte and Valle d'Aosta which rank very low in the list. While a high correlation can be found both in the beginning and at the end of the period between income per capita and total educational attainment there is no correlation at all with higher education. This might be due to the very low cost of tertiary education in Italy compared to other industrialized countries. The effect of this incentive was probably enhanced in the southern regions by the high unemployment rate of the workers with secondary education which pushed young people to enter university due to poor job prospects. This postponement choice was made possible by the strong family organisation which provided the necessary financial support, thanks also to the contemporaneous increase in family income. A very consistent number of graduates has been absorbed by the public sector in Italy but, contrary to a very widely held belief, this share declined both in the South and the North during the period under analysis. However it remained permanently larger in the southern regions relative to the northern ones.

Table 2. Share of the labour force occupied in the public sector per level of education.

	Tertiary education		Secondary education	
	1971	1991	1971	1991
North	0.72	0.52	0.41	0.31
South	0.81	0.65	0.56	0.46

Source: ISTAT, population censuses 1971, 1991.

3. Accumulation or stock? Some evidence

The relationship between education and output growth can be analysed in a cross-region growth accounting framework taking logs and differentiating a standard Cobb-Douglas production function to get the following expression:

$logGDP_t - logGDP_0 = logA_t - logA_0 + a_1(logK_t- logK_0) + a_2(logL_t-logL_0) + a_3(logE_t-logE_0) + loge_t-loge_0$.

Where E stands for the following educational variables:

EDU: average years of total education in the labour force;

TER: average years of tertiary education in the labour force;

SEC: average years of secondary education in the labour force;

PRI: average years of primary education in the labour force [7];

The period under analysis spans from 1971 to 1991. The data on education come from Italian population censuses while GDP, capital and labour figures are drawn from the CRENoS data bank on the Italian regions[8]. To increase the statistical power of the regressions, the data from the two periods of ten years (1971-81 and 1981-91) have been pooled together.

The estimation results, shown in table 3, suggest that education growth does not contribute positively to economic growth: the total years of schooling coefficient enters

[7] Total education is broken down according to the Unesco ISCED classification. Primary education includes 5 years of primary level (scuola elementare in Italy) and 3 years of lower secondary (scuola media). Secondary level corresponds to 5 years of upper secondary education (ginnasio and liceo). Finally the tertiary level includes university and post university degrees.

[8] Capital figures have been estimated with the perpetual inventory method by Paci and Pusceddu (1999).

with a negative sign and is not significant. Disaggregating education by levels does not change the picture: both tertiary and secondary education coefficients show the expected sign but are not significant, while the sign for primary education is negative[9].

Table 3. Cross-region growth accounting with education. Average years of total, primary, secondary and tertiary education. Pooled data 1971-81, 1981-91.
Dependent variable: annualized change in log GDP
Method of estimation: OLS
N. observations = 40

	1	2	3	4
C	0.016	0.011	0.007	0.016
	(3.09)[a]	(1.60)	(0.99)	(3.88)[a]
ΔK	0.221	0.198	0.201	0.238
	(2.31)[b]	(2.13)[b]	(2.28)[b]	(2.61)[b]
ΔL	0.764	0.822	0.801	0.747
	(5.40)[a]	(5.52)[a]	(6.12)[a]	(5.62)[a]
ΔEDU	-0.004			
	(-0.03)			
ΔTER		0.103		
		(0.79)		
ΔSEC			0.136	
			(1.41)	
ΔPRI				-0.074
				(-0.83)
DUMMY[10]	-0.005	-0.003	-0.002	-0.006
	(-2.01)[c]	(-1.35)	(-0.78)	(-2.42)[b]
R2	0.70	0.70	0.71	0.70
F	23.6	24.1	25.4	24.2

t- statistics in parentheses corrected for heteroschedasticity when detected[11]
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

These results resemble very much B&S findings. Their explanation is that in cross-country studies some poor countries start with very low levels of education, this implies that a small absolute increase becomes very big in relative terms. On the other hand many

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[9] We also included the log of initial labour productivity to account for catch-up effects but results do not change substantially.
[10] A temporal dummy has been introduced to allow for different intercept terms in the two periods.
[11] The White correction method has been used whenever the test is significant at the 1% or 5% level.

of these countries do not experience similar rates of output growth. They conclude that education cannot be treated as a standard input in a production function, instead it should be considered as a factor facilitating both domestic innovation and technology transfer from abroad. Therefore its stock rather than its rate of growth should be the crucial variable to consider. We shall go back to their model later on, for now let us examine the robustness of this result more closely.

Recently Krueger and Lindhal (1998) have criticised the results of macroeconomic studies on education and growth. They argue that microeconomic evidence, particularly Mincerian estimates of the effects of education on wages, strongly support the idea of a positive return to investment in education. At the macro level this should entail a positive correlation between education and output rates of growth. They question the reliability of B&S findings because of measurement error and the inclusion of capital in the estimates. Due to the fact that data on educational attainment levels are commonly estimated from flows rather than stocks[12] measurement errors are likely to be present. As is well known this causes the coefficients to be biased. The second line of criticism regards the inclusion of physical capital among the regressors. According to Krueger and Lindhal if capital or investment are included, education carries no signal due to the presence of collinearity[13]. Moreover since capital is measured from investment flows which - in turn - influence GDP, errors in investment measurement cause the capital coefficient to be biased upwards.

However these criticisms are less relevant in our case. First the measurement error is certainly much lower since the original data measure stocks instead of flows and are surveyed with the same methodology. As for the capital problem the Krueger and Lindhal argument relies very much on the high capital coefficient found by B&S. Its value is around .50 which probably implies a too large capital share for a competitive economy. Rerunning B&S regression and imposing a constraint on the capital coefficient they find that education change becomes statistically significant. This does not happen here since the estimated (unconstrained) capital share is around .20, a value quite compatible with other estimates[14]. Moreover the results do not change substantially if we use a more parsimonious specification which omits capital. In table 4 below some

[12] B&S relay on estimates by Kyriacou(1991) who makes use of the enrolment rates to estimate stocks by means of the perpetual inventory method.

[13] This problem has been suggested by Romer (1990a) and Wolff-Gittleman (1992) among others.

"Barro's style" regressions are reported.

Table 4. Education and output growth. Pooled data 1971-81, 1981-91.
Dependent variable: annualized change in log GDP per worker.
Method of estimation: OLS
Num. Observations = 40

	1	2	3	4	5
C	0.095	0.051	0.053	0.166	0.127
	(2.47)[b]	(1.94)[c]	(2.36)[b]	(5.15)[a]	(4.47)[a]
ΔEDU	-0.157				
	(-0.79)				
ΔTER		0.142			
		(1.11)			
ΔSEC			0.159		
			(1.63)		
ΔPRI				-0.479	
				(-3.59)[a]	
EDU_0					0.006
					(2.71)[a]
$LOGGDPL_0$	-0.019	-0.009	-0.001	-0.038	-0.038
	(-1.99)[c]	(-1.50)	(-0.43)	(-4.43)[a]	(-3.57)[a]
DUMMY	-0.0044	-0.0028	-0.0012	-0.0060	0.0088
	(-2.08)[b]	(-1.27)	(-0.44)	(-3.24)[a]	(-3.40)[a]
R2	0.37	0.38	0.40	0.53	0.47
F	8.6	8.9	9.7	15.5	12.4

t- statistics in parentheses corrected for heteroschedasticity when detected
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

Controlling for the initial labour productivity ($GDPL_0$) the coefficients of the educational variables behave nearly in the same way as before. Only the primary education coefficient is significant while the others are not[15]. However regression 5 shows that the initial value of the stock of education (EDU_0) significantly affects the

[14] See Gollin (1998).

[15] Another possible criticism refers to the use of a logarithmic specification for the educational variables. It implies that these variables enter linearly in the production function. However Mincerian estimates suggest that GDP is a non linear function of education. The linear versus non linear specifications can be explored introducing education and its square in the regression. The results are not reported for brevity however, contrary to Krueger and Lindhal findings, the squared term is not significant in our sample.

subsequent growth of output[16]. In the next section we extend further on this result.

4. Education stock and output growth

The evidence reported above suggests that total, tertiary and secondary education dynamics play no role in explaining the rate of growth of output in our sample of Italian regions. This result is not surprising and confirms other findings in existing empirical literature[17]. It has led some scholars to formulate an alternative hypothesis which emphasizes the role of the stock of education instead of its rate of growth. We can identify two formulations of this hypothesis. On one hand the positive influence of the initial stock on subsequent growth has been interpreted as evidence of the externalities generated by education. Another rationale for such effect has been suggested by Barro and Sala y Martin (1995). According to them a higher initial level of education is an indicator of imbalance between human and physical capital. Since physical capital adjusts more quickly the investment rate increases thereby enhancing growth along the transitional path[18].

The second formulation, along Schumpeterian lines, sees the stock of education as a crucial determinant of the capacity to create and to adopt technological innovations both domestic and acquired from abroad. The most influential supporters of this line of thought are Benhabib and Spiegel. In their model the growth of total factor productivity is a function of the stock of education. The effects of the latter on the former operate through two channels: first a better educated labour force implies higher research and development abilities and more efficient learning processes, therefore - ceteris paribus - a faster rate of endogenous innovation; second it also enhances the capacity to implement new technologies developed elsewhere and to adapt them to specific internal needs.

Formally they start from a standard Cobb-Douglas growth accounting equation which can be expressed as follows:

$$\log Y_t - \log Y_0 = [A_t(H_t) - A_0(H_t)] + a(\log K_t - \log K_0) + b(\log L_t - \log L_0) +$$

[16] We use a linear specification of EDU instead of a logaritmic one, but results do not vary. The correct specification of the educational variables is controversial since the micro evidence would suggest that education enters exponentially in the production function.

[17] See Benhabib and Spiegel (1994) and Barro (1997, 1998).

[18] This hypothesis can be tested by regressing the rate of investment of the subsequent period on initial education. A positive correlation would suggest a quick adjustment of the capital stock toward the steady state ratio with the human capital stock. Unfortunately Barro's regressions do not show a significant correlation (Barro, 1998). The same happens in the Italian sample (the results are not shown here).

$(\log e_t - \log e_0)$

A more structural specification makes total factor productivity growth depend on the stock of education which influences the domestic rate of innovation, and on an interactive term capturing the interaction between education and the catch-up potential, measured by the GDP gap between country i and the technological leader. This hypothesis is formalized in the equation below:

$$[\log A_t(H_t) - \log A_0(H_t)] = c + gH_i + mH_i\,[(GDP_{max} - GDP_i)/\,GDP_i]$$

Substituting the second in the first equation and rearranging they get the final expression to be estimated:

$$\log GDP_t - \log GDP_0 = c + (g\text{-}m)H_i + mH_i\,(GDP_{max}/GDP_i) + a(\log K_t - \log K_0) + b(\log L_t - \log L_0) + (\log e_t - \log e_0)$$

This approach has some interesting implications which we shall tray to test in the following analysis. First, if the level of education affects growth by facilitating innovation one would expect upper secondary and tertiary education to be the most growth enhancing components of the whole stock since they reflect the research and development potential in terms of number of researchers. Tertiary education, in particular, embeds most of the advanced knowledge and technical skills required for developing new technologies. Therefore a good stock of higher education should affect TFP chiefly through the rate of domestic innovation. On the other hand secondary education incorporates more practical technical skills which facilitate learning and can be better exploited in the process of adaptation and implementation of already invented technologies.

Second, innovation does not contribute in the same way to the growth of output in all the sectors of the economy. It is much more relevant in sectors like manufacturing industry than in the service or the public sectors where factor accumulation is the most important determinant of output growth. This implies that the allocation of human capital among the sectors of the economy does matter for growth[19]. According to the ruling structure of pay offs some skills may be allocated to rent seeking activities or to sectors with lower innovation rates. Although they can generate high individual earnings their

[19] Paul Romer emphasized this aspect in his model of endogenous technical change (Romer, 1990b). See also Baumol (1990), Murphy, Shleifer and Vishny (1991). For an empirical analysis of the allocation effects of education in the European regions see Lodde (1999).

effects on the growth performance of the economy can well be marginal or even negative. This allocation effect might be, at least in part, responsible for the conflicting micro and macro evidence on the returns to education, however we shall not pursue this line of analysis any further here. At the macro level it can be tested by controlling for the sectoral composition of the educated labour force and by comparing the effects of education on the growth rates of the whole economy and of the manufacturing industry where the role of innovation is supposed to be stronger. Let us first see how the B&S framework performs in the Italian case. Table 5 shows the results obtained estimating the B&S equation in the sample of the Italian regions.

Table 5. Estimates of B&S model. Pooled data 1971-81, 1981-91.
Dependent variable: annualized change in log GDP
Method of estimation: OLS
Num. Observations = 40

	1	2	3
C	-0.031	-0.089	-0.072
	(-2.17)[b]	(-2.53)[b]	(-3.39)[a]
ΔK	0.170	0.115	0.130
	(2.12)[b]	(1.37)	(1.64)
ΔL	0.663	0.759	0.725
	(5.58)[a]	(5.98)[a]	(6.47)[a]
EDU	0.003	0.011	0.008
	(2.19)[b]	(2.34)[b]	(3.95)[a]
EDU*CATCH	0.004	-0.002	
	(3.76)[a]	(-0.60)	
CATCH		0.045	0.031
		(1.79)[c]	(4.27)[a]
DUMMY	-0.018	-0.019	-0.019
	(-4.38)[a]	(-4.71)[a]	(-4.85)[a]
R2	0.78	0.79	0.80
F	29.0	26.3	32.1

t- statistics in parentheses corrected for heteroschedasticity when detected
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

The variable CATCH is a measure of the catch-up potential, namely the ratio between the GDP of the leader region and that of region i. EDU is an average value of the total years of education in each period[20]. Regression 1 is an estimate of the standard B&S model. At a first glance it seems to perform rather well: both the stock of education and the interactive term coefficients show the right sign and are significant at the 5% and 1% levels respectively. The explanatory power of the model is also rather good as the coefficient of determination shows. However the coefficient of the interactive term is not robust to the inclusion of the catch-up variable alone. The effect of the interactive term on TFP appears to be driven by the catch-up component which remains significant with a much higher coefficient when we drop the interactive term in the third regression. The coefficient of the variable EDU is positive and always significant at least at the 5% level. These results conflict with those obtained by B&S in their extended sample but confirm their findings when the sample is restricted to the industrial countries. In the world sample they find a robust effect of education on the absorption of external technologies together with an insignificant coefficient for the endogenous component. The opposite holds in their industrial countries sample and here. The stock of education seems to exert a positive influence on TFP conditional on catch-up, and this effect operates through the channel of endogenous innovation.

A possible interpretation of this result is that for education to matter in the transfer of technologies both the technological and the educational gap must be very wide. In a sample where the variability of these variables is high a country with a very low level of education is unable to exploit its catch-up potential because its labour force lacks some crucial basic skills. On the other hand for countries or regions beyond this threshold, differences in higher levels of education might be less relevant[21].

A more disaggregate analysis gives some empirical support to this hypothesis. In table 6 total education is broken down into its three components: primary, secondary and tertiary education. Here the B&S model performs rather worse than in the aggregate case. None of the three components exerts a significant effect if we consider the endogenous technology part of the story while both secondary and primary education seem to influence the speed of external technology adoption. However, as before, these results are not robust to the inclusion of the catch-up variable (regressions 4 and 5). The tertiary education negative coefficient (although not significant) is particularly

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[20] EDU enters linearly in the regressions, a logarithmic specification does not make any difference. Very similar results are also obtained using initial instead of average values of the educational variables.

[21] In the regional case migration boundaries are weaker thus it might be easier for a firm to import some

disconcerting since this component embeds most of the technological knowledge required for the creation of new technologies. Its contribution to catch-up is also statistically undetectable. Moreover, unlike the aggregate case, dropping the interactive term does not change the picture: again there is no significant partial correlation between tertiary education and output growth (see table 7). On the other hand the secondary and primary components affect positively GDP growth holding the catch-up effect constant.

Table 6. B&S regressions with primary, secondary and tertiary education. Pooled data 1971-81, 1981-91[22].
Dependent variable: annualized change in log GDP
Method of estimation: OLS
Num. Observations = 40

	1	2	3	4	5
TER	-0.008 (-1.32)				
TER*CATCH	0.004 (0.93)				
SEC		-0.004 (-0.17)		0.006 (0.75)	
SEC*CATCH		0.007 (2.40)[b]		0.001 (0.08)	
PRI			0.001 (0.14)		0.007 (0.41)
PRI*CATCH			0.003 (2.45)[b]		-0.002 (-0.15)
CATCH				0.014 (0.85)	0.021 (0.40)
R2	0.70	0.74	0.74	0.73	0.73
F	19.6	22.8	23.2	19.0	18.9

t- statistics in parentheses corrected for heteroschedasticity when detected
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

However, as we pointed out above, the effects of education on output growth could be masked by the sectoral distribution of the former. Thanks to the available data a test of this allocation effect can be carried out for the Italian regions. We explore first the hypothesis that public sector absorption of a consistent share of the educated labour

very specialised skills not available locally.

force influences the relationship between the stock of education and TFP growth. Then we look at the performance of the educational variables in the manufacturing sector where, according to the B&S hypothesis, their effects are supposed to be stronger.

Table 7. Effects of primary, secondary and tertiary education on output growth. Pooled data 1971-81, 1981-91.
Dependent variable: annualized change in log GDP
Method of estimation: OLS
Num. Observations = 40

	1	2	3
TER	-0.029		
	(-0.77)		
SEC		0.007	
		(2.16)[b]	
PRI			0.004
			(2.12)[b]
CATCH	0.062	0.015	0.013
	(1.33)	(2.58)[b]	(2.49)[b]
R2	0.71	0.74	0.74
F	20.3	23.5	23.4

t- statistics in parentheses corrected for heteroschedasticity when detected
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

In the absence of a strong industrial sector, public administration has absorbed an abnormally large share of highly educated labour force in the poorer regions of the South. This has influenced young people's job expectations and their choice of specialisation causing labour force competencies to be more administratively than technologically oriented. Consider a region with a higher level of tertiary education. It will not necessarily experience a faster productivity rate of growth for two reasons: a) because its graduates are less adept, on average, at developing new technologies and at exploiting existing ones; b) because they are occupied in a sector where innovation is less relevant for growth[23].

The public sector test is reported in table 8. TERPUB and SECPUB measure the

[22] For brevity only the results for the educational variables are reported.
[23] Engineers are an example. In the southern regions a larger share are occupied in the housing sector or in the public administration where their innovation potential is less exploited.

average years of education allocated to the public sector. Both coefficients are significant and have the expected negative sign. The inclusion of these variables does not improve the performance of the B&S model since the interactive term coefficients remain not significant. However, if they are dropped, the tertiary education coefficient becomes significant while the secondary education coefficient nearly doubles compared to the previous value[24]. In our opinion this result gives further support to the idea that in the Italian regions education plays a more relevant role in the creation of endogenous technology and that its effects on growth are influenced by sectoral allocation.

Table 8. B&S regressions with the public sector. Pooled data 1971-81, 1981-91.
Dependent variable: annualized change in log GDP
Method of estimation: OLS
Num. observations = 40

	1	2	3	4
TER	0.027	0.038		
	(1.48)	(3.46)[a]		
TER*CATCH	-0.004			
	(-0.20)			
TERPUB	-0.041	-0.062		
	(-2.11)[b]	(-3.88)[a]		
SEC			0.001	0.013
			(1.77)[b]	(4.43)[a]
SEC*CATCH			0.002	
			(0.34)	
SECPUB			-0.017	-0.019
			(-4.73)[a]	(-4.47)[a]
CATCH	0.019	0.027	0.024	0.028
	(1.17)	(4.06)[a]	(1.92)[b]	(5.08)[a]
R2	0.74	0.80	0.84	0.84
F	17.2	26.5	30.1	33.8

t- statistics in parentheses corrected for heteroschedasticity when detected
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

Let us turn to the industrial sector. No allocation effect is present here[25], moreover

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[24] This result confirms Di Liberto and Symons (1998) finding that controlling for the extension of the public sector makes the coefficient of total education significant in a panel analysis of the Italian regions. However, contrary to us, they find that tertiary education is negatively correlated to output growth and that this result is robust to changes in the model specification.

[25] This is not completely true since TFP growth might be different depending on the technology

innovation is a crucial determinant of the output rate of growth. According to these premises we should expect the influence of education on growth to be stronger. In particular tertiary education should perform much better here than in the general case for the reasons mentioned above. We can still adopt the B&S framework thanks to the availability of capital stock data for the manufacturing industry at the regional level[26]. Therefore the results are comparable with those obtained for the whole regional economy.

Table 9. B&S regressions for the manufacturing sector. Pooled data 1971-81, 1981-91.
Dependent variable: annualized change in log manufacturing industry V.A.
Method of estimation: OLS
Num. observations = 40

	1	2	3	4	5	6
EDUIND	0.019			0.015		
	(2.08)[b]			(4.41)[a]		
EDUIND*CATCHIND	-0.003					
	(-0.39)					
TERIND		0.029			0.029	
		(0.44)			(3.20)[a]	
TERIND*CATCHIND		0.001				
		(0.01)				
SECIND			0.012			0.009
			(0.77)			(2.34)[b]
SECIND*CATCHIND			-0.003			
			(0.20)			
CATCHIND	0.063	0.033	0.039	0.045	0.034	0.035
	(1.39)	(2.15)[b]	(1.81)[c]	(6.56)[a]	(4.97)[a]	(4.77)[a]
R2	0.95	0.94	0.93	0.95	0.94	0.93
F	107.5	87.3	77.3	128.7	105.0	92.9

t- statistics in parentheses corrected for heteroschedasticity when detected
a = significant at 1% level
b = significant at 5% level
c = significant at 10% level

The results of the regressions reported in table 9 partially support these

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dynamics of each branch. However it is reasonable to assume that the allocation effect is weaker than in the whole economy.

[26] As in the previuos case figures come from the CRENoS data bank on regional capital stock.

expectations[27]. In the manufacturing industry the B&S model does not fit the data satisfactorily either. Again the interactive term is never significant when the catch-up effect is controlled for. On the other hand total, tertiary and secondary education coefficients are strongly significant and much higher than in the whole economy regressions when the interactive term is dropped. They resemble very much those obtained in the public sector experiment confirming the presence of an allocation effect. The explanatory power of the model improves substantially relative to the whole economy case (the coefficient of determination increases from approximately 0.73-74 to 0.94-95) and also relative to the public sector regressions.

Concluding remarks

Although related to the specific Italian experience the evidence presented in this paper may help, in our opinion, to shed some light on some debated questions in the literature on human capital and growth, particularly with reference to the industrialized countries. The main results can be summarized as follows.

- The rate of growth of education does not significantly affect output growth. This is true for total education as well as for its three subcomponents. On the contrary the initial stock of education positively affects output growth for the subsequent ten years in a regression including initial GDP per worker.
- A more specific analysis using the B&S framework shows that the stock of education is positively correlated to output growth, but its influence acts by enhancing the creation of domestic innovation rather than the absorption of external technologies. Surprisingly although the evidence suggests that total education affects TFP growth by increasing the rate of innovation, the tertiary component (which incorporates most of the relevant scientific and technical knowledge) seems to exert no significant influence.
- To explain this apparent anomaly the hypothesis has been made that the coefficients of education, particularly the tertiary component, on growth could be distorted by an allocation effect due to the attraction of the educated labour force toward the public sector. Controlling for this effect the coefficients of the educational variables increase and tertiary education emerges as a significant predictor of output growth.

[27] A dummy variable for the region of Valle d'Aosta has been included in all the regressions since there is a clear measurement error in GDP figures.

- Focusing on the manufacturing sector, where innovation is presumably a crucial input to output growth, the role of education appears more important. In this case again TFP growth is mainly influenced by the endogenous innovation component rather than by the absorption of external technologies.

Summarizing this evidence gives some support to the Schumpeterian approach versus the neoclassical one. The stock of education rather than its rate of growth emerges as a more relevant factor in the growth process. Thus education behaves not as a factor of production but as an important requirement for enhancing the rate of technical progress and output growth together with it. In the specific Italian case its role appears more important in developing endogenous technology and much less clear as regards external technology absorption. Contrary to other studies the evidence shows that higher education promotes growth once allocation effects are taken into account.

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