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High-Tech Human Capital: Do the Richest Countries Invest the Most?

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Abstract

In this paper we show that the richest countries are investing proportionally less than middle income countries in engineering and technical human capital. We generalize this result, controlling for country-specific effects, cross-time error correlations, heteroskedasticity, the presence of outliers and the introduction of other explanatory variables. Thus, we establish an unexpected stylized fact (about human capital composition): the proportion of high-tech human capital in tertiary education presents an inverted U-shaped relationship with GDP per capita. This is interesting because Research and Development (R&D) endogenous growth models predict and most evidence show that investment in R&D increases with economic development.

KEYWORDS: human capital composition, high-tech human capital, R&D, development

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1 Introduction

The study of the effects of human capital composition on growth and development is a recent field in the economic literature. The idea that some classes of human capital contribute more to growth than others is intuitive, mainly if we think about R&D models in the spirit of Romer (1990) or Grossman and Helpman (1991), because only some types of human capital are engaged in R&D activities. The first paper in this class was the seminal work of Murphy, Shleifer and Vishny (1991), which supports the idea that the allocation of talent is important for growth and bases the argument on the choice between being entrepreneur or rent-seeker. These authors proxied rent-seeking by the proportion of Law students in colleges and entrepreneurship by the proportion of Engineering students in colleges and show some evidence that the latter contribute to growth while the former do not. Barro (1999) used data on students' scores on comparable international examinations on a growth regression and showed that scores on sciences and mathematics had a positive relationship with economic growth, but scores on the reading test were insignificantly related to growth. Also, Acemoglu (2001) shows microeconomic evidence on positive and negative relationships between some professions and the stream of wages.[1] This seems to be sufficient to conclude that the composition of human capital (regarding fields of knowledge) matters to economic growth.

The treatment of the relationship between human capital composition and development is even further from being exhausted in the economic literature in spite of the increasing attention by international organizations.[2] Recent reports from international organizations are concerned with the shortage of high-tech graduates in the developed countries. OECD (2001), for instance, presents *Eurostat* figures which show that the share of Scientists and Engineers in all HRST (Human resources in science and technology) was about 10% across European countries.[3] When the comparison is made between Scientists and Engineers in Science and Technology and HRST with tertiary education, the percentage only increases to 17%. The European Commission (1999) has also been concerned about the shortage of graduates in the scientific and natural specializations, stating that, "more than a quarter of the graduates of colleges and universities are from social sciences", recognizing that this is the largest graduation field in Europe.

However, there is a strong belief that richer countries invest more in R&D activities than do poor and middle-income countries. This belief has been recently theorized by Funke and Strulik (2000), who explain that richer countries invest more in R&D than poorer ones.

[1] Professions with a positive relationship with the stream of wages include Engineering and Computer Science. Professions with a negative relationship include Natural Science, Medicine and Law.

[2] In this paper, development is measured by GDP *per capita*. This is, of course, a restrictive measure, but it is commonly used in the cited literature.

[3] Scientists and Engineers are classified as Isco (International Standard Classification Occupations) 21 and isco 22.

Also Jones (1995) had shown time-series evidence that R&D personnel have grown a lot in the more developed countries in the last fifty years. As engineering and technical skills are intensively used in R&D activities, this allows for the prior that developed countries would invest more than other countries in these fields, which seems to be a contradiction with the numbers cited by the European Commission and OECD.

We address the relationship between some measures of Human Capital composition (high-tech proportion) and the level of development of a country and establish a stylized fact regarding this relationship. We will focus on the composition of Human Capital from tertiary education (Colleges and Universities).[4]

In Section 2, we describe the data and its sources. In Section 3, the stylized fact is documented. In Section 4 we address some tentative explanations for the fact and simultaneously test the robustness of the fact to the introduction of controls. Then, in Section 5, we conclude.

2 Overview of the data

We use data on enrollments and graduates (i.e. graduating students) by tertiary education from the UNESCO database between 1970 and 1997.[5] These programs include, according to the source, "education provided in universities, teacher's colleges, higher professional schools, which require, as a minimum condition of admission, the successful completion of secondary education or evidence of the attainment of an equivalent level of knowledge". According to the first International Standard Classification of Education (ISCED76), this includes levels 5, 6 and 7,[6] which include both undergraduate and graduate programs. Both enrollments and graduates are flow variables and may be interpreted as a *proxy* for investment in human capital. These two measures differ because the first counts the number of students enrolled in Colleges and Universities and the latter counts the number of students that complete their programs. In our benchmark analysis, we have classified the fields "Computer Science (programming and software development) and Mathematics" and "Engineering" as high-tech human capital.[7] With this, we are focusing on the programs di-

[4] This does not mean that human capital composition is important only at this level. Nevertheless, due to availability of data, we test human capital composition only at this level. See Bertochi and Spaggat (1998) for some evidence on the Secondary education level.

[5] Raw data are presented by year and the disaggregated data (by fields) we need in this paper were supplied by UNESCO, replying to our request. All the used data are found in various issues of the UNESCO yearbook from 1970 to 1997. However, enrollments and graduates by major fields of education could be downloaded from the UNESCO site at http://www.uis.unesco.org/pagesen/DBEnrolTerField.asp.

[6] This roughly corresponds to Levels 5 and 6 of the new ISCED 1997.

[7] The complete list of fields is the following: Education Science and Teacher training; Humanities, religion and theology; Fine and applied arts; Social and Behaviorial Sciences; Commercial and Business Administration; Law; Natural Science; Mathematics and Computer Science; Medical Science and health related,

rectly related to technical and technological progress, trying to eliminate teaching-oriented or health services' oriented fields. This deserves some discussion, because the typical measure of "science and engineering" also includes "Natural Sciences", "Medical Sciences and health related" and "Social and Behavioral sciences". The latter field was not considered because we are focusing on technological fields. In Medical Sciences and health fields, health services seems to dominate and in Natural Sciences, teaching seems to dominate.[8] In the appendix, we present some evidence on broader definitions of high-tech (which also include Natural and Medical Sciences) that we will also discuss. Our empirical results suggest that the main finding is common to all the considered definitions of high-tech human capital. However, it is stronger in the restricted definition and it can be said that results obtained in broader definitions are strongly influenced by the first parcel (which includes Engineering, Mathematics and Computer Sciences fields). We define High-tech human capital as H and total enrollment in tertiary education as P and the high-tech human capital ratio as $\frac{H}{P}$, which can be read as the proportion of high-tech in tertiary education. The possible definitions for High-tech are classified from the restricted definition - H_1/P - (that includes "Engineering" and "Mathematics and Computer Sciences") to broader or enlarged definitions H_2/P (which also includes "Natural Sciences") and H_3/P (which also includes "Medical Sciences and Health related").[9]

The next Table shows that correlations between possible definitions of high-tech are always high.

Table 1: Different measures and definitions of High-tech

	Enrollments				Graduates			
	H_1/P	H_2/P	H_3/P	C(H_i/P, GDP)	H_1/P	H_2/P	H_3/P	C(H_i/P, GDP)
H_1/P	1	0.78	0.69	0.08	1	0.87	0.75	0.09
H_2/P	–	1	0.85	0.02	–	1	0.79	0.11
H_3/P	–	–	1	0.04	–	–	1	0.14

Note: H_1/P includes "Engineering" and "Mathematics and Computer Sciences",
H_2/P also includes "Natural Sciences",
H_3/P also includes "Natural Sciences" and "Medical Sciences and Health related".

We will relate this variable with GDP *per capita,* which is measured in international constant prices, from Penn World Table 5.6.. In order to avoid business-cycle effects and

Trade crafts and industrial programs; Engineering, Service trades; Mass Communication and Documentation; Other programs.

[8] "Medical Sciences and Health related" includes medicine, medical services, nursing and dental services. "Natural Sciences" includes life sciences, such as botany, biology, zoology, genetics, biochemistry, ornithology, and physical sciences, such as physics, chemistry, geology, marine science, geography and meteorology.

[9] We may stress that all these possible measures for high-tech proportion are independent of differences in the fraction of the population in each country that is a college graduate.

measurement error, we treated these variables as five-year period averages. With this we analyze each cross-section of five-year period or a system of six (for enrollments) and five (for graduates) equations, which include nearly 100 countries in each five-year period.[10]

The following table summarizes statistics from the total sample collected, using the five-year average per country as the observation unit.

Table 2: Summary Statistics (all countries, 1970 to 1997)

	Obs.	Mean	Max.	Min.	St. Dev.
H_1/P_enr	664	0.14	0.58	0.001	0.09
H_1/P_grad	533	0.15	0.79	0.008	0.10
H_2/P_enr	695	0.21	0.60	0.019	0.09
H_2/P_grad	555	0.20	0.79	0.010	0.10
H_3/P_enr	695	0.30	0.70	0.025	0.11
H_3/P_grad	561	0.29	0.86	0.024	0.13

An inspection of the table shows that on average high-tech human capital H_1/P is about 15% of the total (rising to near 20%, when we add natural sciences - H_2/P - and to near 30%, when we finally add health sciences - H_3/P), and essentially there is a huge variation of these measures across countries. However, across periods, data are highly persistent: in the enrollments case, for instance, the average high-tech ratio (H_1/P) varies between 13.7% (in 1970-74) and 14.7% (in 1980-84). The combination of high-tech ratio and GDP *per capita* corresponds to a total number of observations of 621 for enrollments and 465 for graduates.

Definition 1 *We define high-tech human capital as the enrollment or graduates in "Engineering" and "Mathematics and computer science" fields in the tertiary education level. Thus we have adopted the H_1/P definition for the benchmark analysis.*

3 The Relationship between high-tech human capital and Development

An idea of how the high-tech ratio varies across countries is provided by the following figures and table, which use enrollments as inputs. Figure 1 plots the high-tech ratio against GDP *per capita* in the first period (1970-74) and in 1990-94. This makes it clear that the United States, Canada, Australia and France show lower values for the high-tech ratio (with values between 5 and 12% of tertiary enrollments in high-tech) than Cyprus, Colombia and Ireland (above 20%). Table 2 shows correlations between regional dummies and our measure of

[10]Due to few observations in the period 1970-74 in the graduates measure, we begin this analysis in 1975-79.

high-tech human capital across the complete period (1970-97) and allows for the conclusion that this general relationship between high-tech human capital and development arises clearly: the richest countries (situated mainly in North America and Western Europe) show lower high-tech ratios than middle income countries (in East Asia, East Europe and Latin America) and these countries show higher values than the poorest countries (in Africa and Asia).

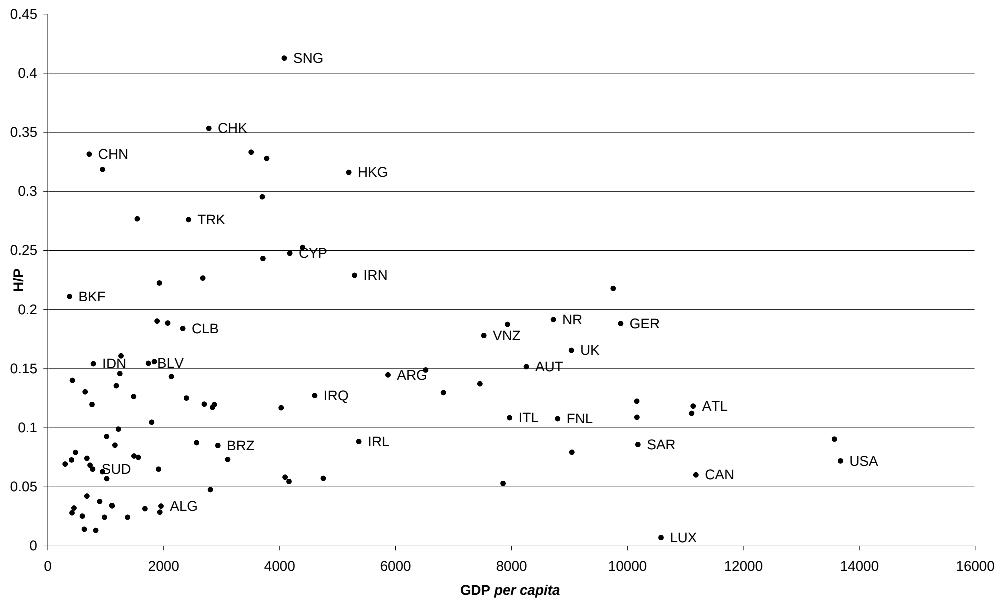

Figure 1.1. High-tech human capital and Development in 1970-74

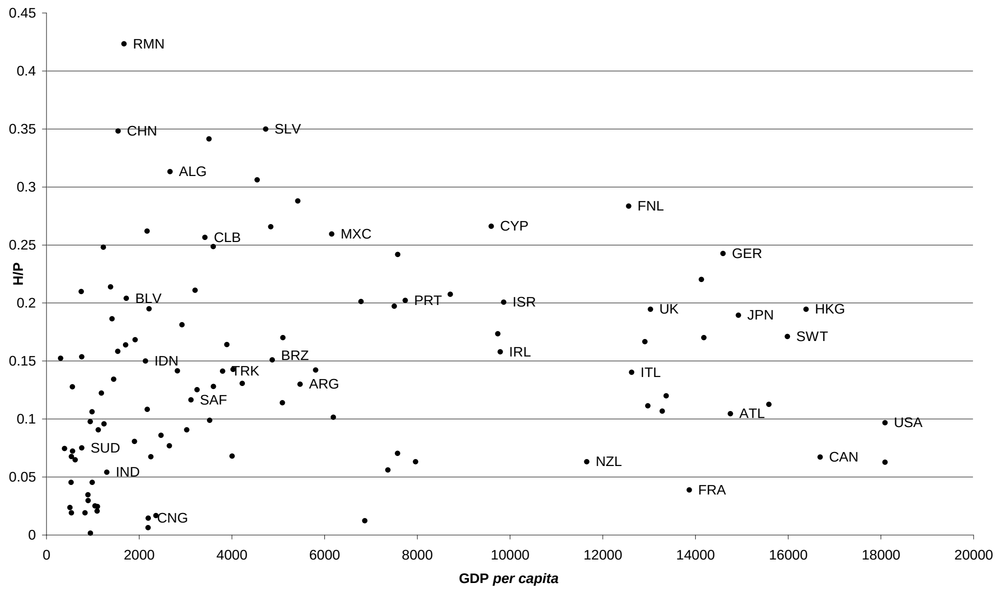

Figure 1.2. High-tech human capital and Development in 1990-94

Table 3: Human Capital Composition across the world

North America	-8%
West Europe	6%
East Asia/Pacific	12%
East Europe and Central Asia	38%
Latin America/Caribbean	8%
South Asia	-8%
Middle East and North Africa	-6%
Sub-Saharian Africa	-34%

Note: figures are correlations between a regional dummy and high-tech ratio and uses Enrollment.

Some of these observations in the high-tech ratio seem to be outliers because they show high values for the variables. We approach outliers in a very classical way.[11] This method

[11] We exclude observations which are greater than $q_{0.75}+1.5(q_{0.75}-q_{0.25})$ or below $q_{0.25}-1.5(q_{0.75}-q_{0.25})$, where q_i is the quantile of order i. The second rule is not effective in this case as it gives negative values. This leads to the exclusion of observations of H_1/P above 0.367 (as measured by enrollment) and above 0.369 (as measured by graduates). In H_2/P and H_3/P enrollment (graduates) case this leads to the exclusion of observations above 0.428 (0.416) and 0.596 (0.644), respectively. This procedure excluded 11 observations in the enrollment case and 14 in the graduates measure of the restricted definition (H_1/P), 12 observations in the case of enrollments and 11 in the case of graduates in the first broader definition (H_2/P). Finally, the same procedure excluded 7 and 4 observations in the enrollment and graduates measures of the H_3/P definition, respectively.

is complemented by the use of Least Absolute Deviations (LAD) median regression, which we show for comparison. There are also some few values for GDP *per capita* that seem to be severe outliers, but as LAD is only robust in the errors dimension, we have to be aware of this problem, when it arises: we will state differences from including or not these four observations (Kuwait and United Arab Emirates in 1975 and Qatar and United Arab Emirates in 1980).

We found an inverted U-shaped relationship between H/P and GDP *per capita* (see figure 2), which may be considered as a stylized fact because it is robust to different definitions of H/P (H_1/P, H_2/P, H_3/P), different measures (enrollment or graduates), different samples (total and excluding outliers) and all cross-section samples, consisting of each five-year period. This means that richer countries are investing less than middle income countries in high-tech human capital, which was not expected. First, we will document this relationship and then we test its robustness using panel data, multiple equation methods and introducing control variables. Next, we show figures with the sample including and excluding outliers and a polynomial adjustment.

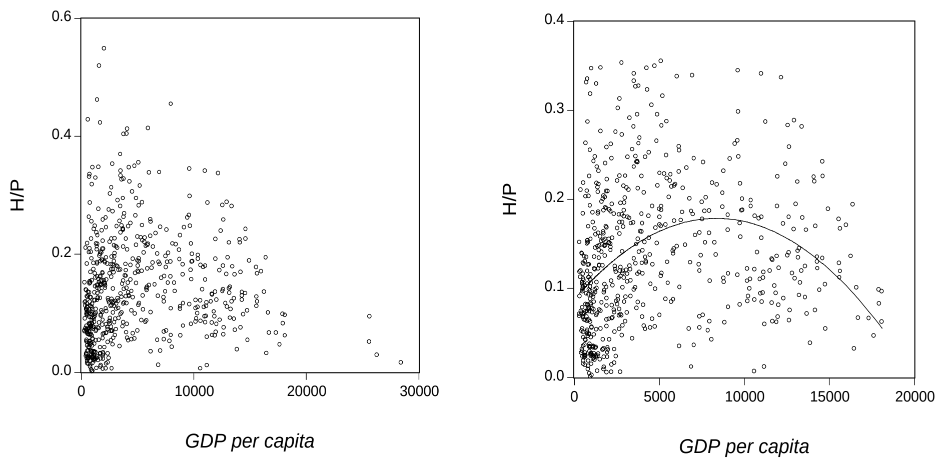

Figure 2 - Panel Sample: total sample (on the left) and total sample excluding outliers (on the right).

It is clear that as countries get richer the high-tech ratio increases in developing stages and slows down or decreases in the most developed stages. We can also observe robust linear relationships within groups of poor and rich countries. In Figure 3 we divide countries into poor and rich groups (using the USD$ 8000 GDP *per capita* as the threshold value above which a country is considered rich) and plot observations in both groups separately as well as linear relationships. Coefficients of linear regressions in the two groups are acceptable at 2% level (both in OLS and in LAD regressions).

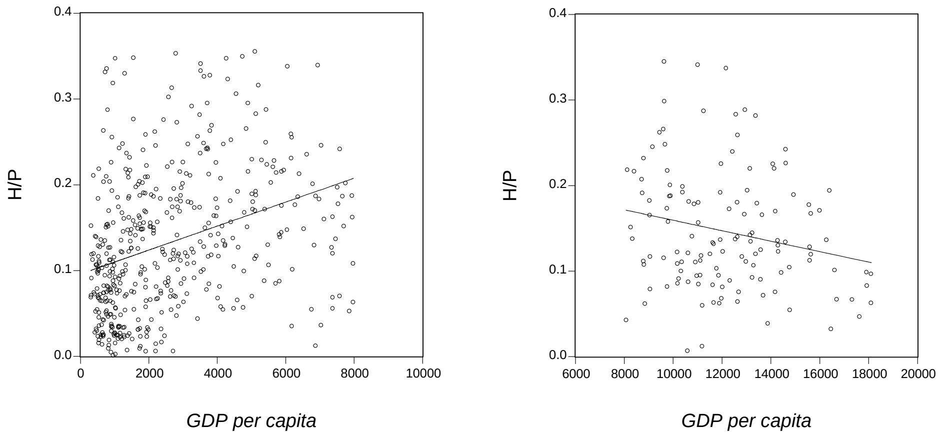

Figure 3 - Panel Sample: poor countries (on the left) and rich countries (on the right).

In Tables 4 and 5 we show results for OLS, LAD (Least absolute deviations) and SUR (Seemingly Unrelated Regressions) joint estimation of a polynomial relationship between the high-tech ratio and GDP *per capita* considering Enrollments and Graduates, respectively, as a measure of this ratio. SUR estimates allow the presence of a heteroscedastic error structure and cross-correlations of the error between equations. LAD estimates shows results' robustness to the presence of outliers and, in general, to non-normality in data. We also perform panel data analysis, showing Random (RE) and Fixed effects (FE) results.[12] In each period regression, we present the Wald statistic and p-value for testing the null of a zero coefficient of GDP *per capita* squared. High-values of this statistic show that the introduction of GDP squared in the regression improves its explanation power. When this Wald test suggests that the GDP squared coefficient is not significantly different from zero in the estimations for the total panel, we also present a linear specification. This will occur only in some Fixed-effects estimations. We also add information about significant Wald tests on similar coefficients along time in Tables 4.1. and 5.1. In Tables 4.2. and 5.2, respectively, we show changes that arise from the exclusion of the four high-income countries that are clear outliers.

[12] In order to avoid scientific notation in tables, we have multiplied the dependent variable by 10,000,000.

Table 4: The Polynomial Relationship between H_1/P and GDP (Enrollments)

	C	GDP	GDP^2	R^2 (N)	Wald (H_0: c_3=0)
Coefficients	c_1	c_2	c_3		
1970-74	793300***	304***	-0.0252***	0.12 (97)	13.91***
	(4.89)	(3.70)	(-3.73)		
1975-79	1051710***	116***	-0.00546***	0.11 (111)	22.99***
	(9.35)	(3.85)	(-4.79)		
1980-84	936460***	156***	-0.00727***	0.15 (113)	30.84***
	(7.91)	(4.61)	(-5.55)		
1985-89	779950***	248***	-0.0146***	0.17 (114)	22.71***
	(6.05)	(4.92)	(-4.77)		
1990-94	835830***	233***	-0.0130***	0.14 (107)	17.77***
	(5.82)	(4.38)	(-4.22)		
1995-97	1128770***	166**	-0.0100**	0.09 (68)	6.77**
	(6.17)	(2.39)	(-2.60)		
System (OLS)	1005110***	141***	-0.00729***	610	46.87***
	(18.60)	(7.75)	(-6.85)		
SUR	960120***	119***	-0.00519***	610	32.60***
	(15.09)	(6.21)	(-5.71)		
RE	1139610***	69***	-0.00274***	0.77 (610)	8.46***
	(11.92)	(3.13)	(-2.91)		
FE	–	40	-0.0014*	0.77 (610)	3.44*
		(1.36)	(-1.85)		
LAD	882881***	152***	-0.0082***	0.05 (621)	–
	(11.82)	(6.43)	(-6.20)		

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 4.1: Wald Tests

H_0:	All c_1 equal	
	4.49	
H_0:	All c_2 equal	
	8.58	
H_0:	$c_{3(7074)}=c_{3(8589)}=c_{3(9094)}=c_{3(9597)}$	$c_{3(7579)}=c_{3(8084)}$
	3.50	0.59

Table 4.2: The Polynomial Relationship between H_1/P and GDP (Enrollments) excluding GDP outliers

Coefficients	C c_1	GDP c_2	GDP^2 c_3	R^2 (N)	Wald (H_0: c_3=0)
1975-79	767890*** (5.66)	314*** (4.93)	-0.0224*** (-4.67)	0.17 (109)	21.79***
1980-84	738530*** (5.35)	285*** (4.80)	-0.00178*** (-4.28)	0.16 (111)	18.33***
System (OLS)	881800*** (15.39)	217*** (9.63)	-0.0130*** (-9.29)	606	86.37***
SUR	823840*** (11.45)	206*** (7.12)	-0.0115*** (-6.45)	606	41.55***
RE	1089350*** (10.38)	98*** (2.98)	-0.00437*** (-2.44)	0.77 (606)	5.95*
FE	–	26 (0.58)	-0.0006 (-0.28)	0.77 (606)	0.08
FE_1	–	18 (0.74)	–	0.77 (606)	–
LAD	721338*** (6.43)	234*** (5.18)	-0.0133*** (-4.36)	0.07 (617)	–

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 5: The Polynomial Relationship between H_1/P and GDP (Graduates)

Coefficients	C c_1	GDP c_2	GDP^2 c_3	R^2 (N)	Wald (H_0: c_3=0)
1975-79	1116190*** (8.80)	82** (2.26)	-0.00525** (-2.55)	0.06 (95)	6.49**
1980-84	899180*** (7.69)	141*** (3.76)	-0.00773*** (-3.68)	0.13 (102)	13.53***
1985-89	728960*** (5.13)	221*** (4.17)	-0.0123*** (-3.92)	0.15 (106)	15.37***
1990-94	873180*** (5.79)	198*** (3.88)	-0.0110*** (-3.75)	0.13 (91)	14.06***
1995-97	1140090*** (5.20)	135* (1.94)	-0.00802** (-2.22)	0.07 (57)	4.94**
System (OLS)	949540*** (14.87)	146*** (6.62)	-0.00806*** (-6.21)	451	38.48***
SUR	906070*** (12.70)	126*** (5.69)	-0.00622*** (-5.33)	451	28.37***
RE	1039930*** (10.04)	85*** (3.36)	-0.00368*** (-3.15)	0.77 (451)	9.92***
FE	–	83** (2.18)	-0.00290** (-2.45)	0.77 (451)	6.02**
LAD	715168*** (8.25)	224*** (7.93)	-0.0125*** (-7.68)	0.07 (465)	–

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 5.1: Wald Tests

H_0:	All c_1 equal	All c_2 equal	All c_3 equal
	5.17	5.56	4.04

Table 5.2: The Polynomial Relationship between H_1/P and GDP (Graduates) excluding GDP outliers

	C	GDP	GDP^2	R^2 (N)	Wald (H_0: c_3=0)
Coefficients	c_1	c_2	c_3		
1975-79	854630***	255***	-0.0199***	0.13 (94)	13.43***
	(5.74)	(3.78)	(-4.09)		
1980-84	700960***	266***	-0.0175***	0.16 (101)	19.74***
	(5.23)	(4.53)	(-4.44)		
System (OLS)	879090***	184***	-0.0108***	449	56.39***
	(13.41)	(7.69)	(-7.51)		
SUR	821540***	176***	-0.0098***	449	28.02***
	(10.45)	(5.87)	(-5.29)		
RE	1036230***	86**	-0.0038**	0.77 (449)	4.01**
	(9.19)	(2.55)	(-2.00)		
FE	–	34	-0.0003	0.78 (449)	0.01
		(0.64)	(-0.11)		
FE_1	–	29*	–	0.78 (449)	–
		(1.66)			
LAD	684018***	247***	-0.0141***	0.08 (463)	–
	(8.48)	(8.27)	(-7.58)		

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

The overall conclusion is that not only does this relationship seem to be qualitatively similar across time, it also presents quantitative regularities. Accounting for cross-period error-correlations and for heteroscedasticity in the error dimension (and also for non-normality and the presence of outliers) do not change the statistical significance of this polynomial relationship. With only six and five periods, respectively, we may expect imprecise country-specific effects. However, we implement panel data estimation and show that although the polynomial relationship is quantitatively weaker (we obtain lower significance levels), they remain quite significant, especially in the graduates case (Table 5). We point out that even in the enrollments case (Table 4) the coefficient on GDP^2 remains negative and marginally significant. This relationship is obtained essentially through the presence of four outlier observations in GDP *per capita*. In fact, the exclusion of the four GDP outliers strengthens the overall inverted U relationship, as can be observed in Tables 4.2 and 5.2. (lowering the value and significance of the constant in the regression and raising the values and significance of the coefficients of GDP and GDP squared), but had proven to be quite important in reaching the fixed-effects result. Thus, we may claim that this relationship is essentially driven by cross-country variation, because time-series effects (essentially country-specific effects correlated with GDP and GDP squared - fixed effects estimators) did lower the coefficients' magnitude and significance and became dependent on a small set of outlier observations. Accounting for fixed effects, a weak positive relationship between investment in high-tech human capital seems to appear in the graduates case (Table 5.2).

Now, we want to compare these results with those obtained with broader definitions of high-tech human capital, for which we present results from a sample that does not include the four severe GDP outliers (see Appendices A and B).[13] The same inverse U-shaped relationship is obtained with both of the broader definitions of high-tech proportion (H_2/P - Table 1.A and 1.B., H_3/P - Table 2.A and 2.B.), with some exceptions in regressions for the last period (1995-97). With the enrollments measure, we reach a robust negative relationship between the high-tech human capital proportion and GDP *per capita* squared with the fixed-effects estimator, which strengthens our stylized fact. This is even stronger because the richest countries are investing less than middle income countries in high-tech even if we consider as high-tech some services oriented human capital (such as Medical and health related).[14] However, in the H_2/P graduates definition (Table 1.B.), there is a significant positive relationship between high-tech proportion and development accounting for fixed-effects, which stresses the statistically weak positive relationship also obtained in Table 5.2. It seems that in accounting for country-specific effects that are correlated with GDP *per capita* there is a mild linear and positive relationship between high-tech graduates and development and a stronger linear and negative relationship between high-tech enrollments and development. If our sample sizes were equal, we could argue that, *ceteris paribus*, as a country becomes richer it also becomes more efficient in the production of high-tech human capital because with proportionally fewer inputs (enrollments), it produces proportionally more output (graduates), at least if H_1/P and H_2/P are considered. This is, of course, an assertion that deserves further evidence.

In all cases, Wald statistics (Tables 1.1.A., 2.1.A., 1.1.B. and 2.1.B) also show strong evidence of quantitative regularities in this relationship across time.

The presence of all observations in the sample (including outliers in the dependent variable) does not change the main result, considering either enrollments or graduates as a measure of the high-tech ratio. In fact, even similar coefficients across time may be accepted at high statistical significance. Even in each period, including all observations, this polynomial relationship is maintained under OLS or LAD estimations, in both the restricted and broader definitions and both in the enrollments and graduates measures of

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[13]However, in these cases (H_2/P and H_3/P), the inclusion of these GDP outliers does not influence the results as much as in the benchmark case (H_1/P).

[14]This does not mean that enrollments in "Natural Sciences" and in "Medical Sciences and health related" significantly decrease in the richest countries. In fact, taken alone, they do not have robust relationships with GDP *per capita*. Thus, this fact is mainly obtained from our restricted definition of high-tech.

high-tech.[15]

There is a robust inverted U-shaped relationship between high-tech human capital and economic development which accounts for nearly 10% of all variation in high-tech human capital. Jointly with country-specific effects it accounts for nearly 80% of the ratio variation. By now, we have made our main point: there is an unexpected decrease of the high-tech ratio in developed countries.

From here on, we will discuss some possible economic reasons that may be behind this fact, and if it can be still considered a puzzling fact. In testing for robustness of this relationship, we will use H_1/P definition and enrollments, as we have discovered that the main fact comes from this restricted definition and we have more observations on this measure. In fact, the two measures represent the same phenomenon: investment in high-tech human capital.

4 Discussion and Tentative explanations

The first comes from the observation that high values for the high-tech ratio are derived from certain east-European and German background countries, which could lead to the conclusion that certain institutional environments influence the choice of fields of education. For instance, in ex-communist countries a high-tech bias could arise due to links between low-tech professions and ideological thinking (e.g. marxist economics). The second is linked with countries' sectoral specialization. Industrial trade specialization, for instance, may be linked with high-tech specialization, and more services intensive countries may also be low-tech intensive. The last possible explanation is more closely linked with human capital supply than the previous ones: high-tech programs are often lengthier and are often considered to be more difficult than low-tech ones.[16] Also high-tech programs and graduates deal much more with new technologies than the low-tech ones, which can lead to a kind of adoption cost that lowers the proportion of high-tech production in the R&D-intensive countries, exactly those in which high-tech human capital seems to proportionally decrease.[17]

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[15] In LAD estimations there are, in fact, few exceptions for statistically significant coefficients in the broader definitions H_2/P and H_3/P. With the H_2/P definition, exceptions are: the periods 1975-79 and 1980-84 for enrollments, and the period 1995-97 for graduates. With the H_3/P definition, exceptions are: the periods 1980-84, 1990-94 and 1995-97 for the enrollment measure and the periods 1990-94 and 1995-97 for graduate measure. P-values for the coefficients on GDP and GDP^2 are always below or near 0.2 with the exceptions of the 1995-97 period in the H_3/P definition (either with enrolments or graduates), for which p-values are around 0.4.

[16] Engineering (and Medicine and some Natural Sciences) programs often last for five or six years but sociology or management take only three or four years to be completed.

[17] There are recent contributions on the influence of new technologies in human capital and on the technological-skill mismatch (see Katz and Murphy (1992) and Acemoglu and Zilibotti (2001), just as

For the first possible explanation, we will introduce dummies for the institutional background of the country as controls. Each country is classified into *British*, *French*, *German*, *Scandinavian* or *Socialist* institutional background. For the second explanation, we use dummies for sectoral specialization in exports. Thus if a country's exports are industry intensive, it is classified into *Manufactures*, if its exports are intensive in agriculture or mining products (non-fuel) it is classified into *Primary*, if external balance is dominated by services, it is classified as *Services*, if it is dominated by fuel products, it is classified as *Fuel,* and finally, if the country does not fall into any of the previous categories it is classified as *Diversified*. For the last possible explanation, we have used secondary education variables and life expectancy. Variables such as Pupil-teacher ratio, the Repetition rate, Expenditures per pupil and Enrollment in secondary education should be related with investment in quantity and quality of education. According to our assumption, more investment in the previous stage of education (essentially in its quality) may overcome some of the costs of a high-tech program. The repetition rate, for instance, is related with teaching and schooling quality and also with capacity for acquiring skills. We expect that the higher the quality in secondary schools will be, the more able will be students to engage in a high-tech program. Life expectancy is introduced as a proxy for preference for the future. With an assumption of costly high-tech programs, in societies where the life expectancy is low, returns for costly education are even less appropriate than from less expensive programs. We will test the sensivity to the introduction of life expectancy. Life expectancy is introduced in the first year of the period, GDP *per capita* is introduced as an average across the period, and all the other variables were introduced as the value in the first year of the previous period.[18] All the dummies introduced in the first two explanations are fixed across periods.

In this section we will try to separately deal with these possible explanations for the fact presented above, introducing available controls that could proxy each of these possible causes. In the estimations presented we consider the sample without outliers in the dependent variable and also excluding Kuwait and United Arab Emirates in 1975 and Qatar and United Arab Emirates in 1980. Prior to final specifications, we performed specification tests (Tables 1.C. to 3.C. in Appendix C.) that were used to select variables to show in final specifications. We excluded all the variables for which coefficients were not significantly different from zero at the 10% level. From this specification search we have excluded French and Scandinavian Institutional background, Fuel trade specialization, Teacher-pupil ratio and Expenditures per pupil. We will present LAD estimators that deal with the presence of outliers and possible non-normality in data. We also split the sample into poor and rich countries (using USD$ 6000 and USD$ 8000 as threshold values above which countries are considered rich), and show the estimates for a linear relationship in each of the groups.

examples).

[18]Variables on secondary education (from Barro and Lee (2001)) are available only for some years, corresponding to half decades (i.e. 1970 , 1975,...) until 1990.

Tables 6, 7 and 8 show the results.

Table 6: Determinants of high-tech ratio (H_1/P) - LAD - "institutional background"

	Total	Rich		Poor	
		8000	6000	8000	6000
GDP	161***	-38*	-52**	125***	180***
	(5.80)	(-1.71)	(-2.59)	(5.11)	(5.84)
GDP^2	-0.009***	-	-	-	-
	(-5.27)	-	-	-	-
German	318535*	402127**	365776*	1084495***	1128316***
	(1.73)	(2.42)	(1.81)	(2.75)	(2.78)
Socialist	854742***	NA	1726018***	809709***	648475***
	(6.12)	-	(13.52)	(4.65)	(4.06)
British	-183181**	-160480	-209677	-202947*	-128057
	(-2.40)	(-1.35)	(-1.57)	(-1.91)	(-1.26)
N	591	125	165	466	426
R^2	0.12	0.06	0.10	0.14	0.14

Notes: t-statistics are heteroscedastic-consistent. Models include an omitted constant. NA indicates that no observation of Socialist background in this sub-sample.

Table 7: Determinants of high-tech ratio (H_1/P) - LAD
"specialization"

	Total	Rich		Poor	
		8000	6000	8000	6000
GDP	180***	-55*	-47	100***	193***
	(5.69)	(-1.93)	(1.61)	(4.99)	(5.58)
GDP^2	-0.01***	-	-	-	-
	(-5.52)	-	-	-	-
Manufactures	405641***	88093	252533	613223***	684499***
	(2.08)	(0.41)	(0.97)	(3.74)	(2.81)
Services	-561003***	-6302	83351	-568322***	-714007***
	(-3.74)	(-0.02)	(0.24)	(-3.97)	(-3.52)
Primary	-387341***	-761305**	-412575	-311894**	-450147**
	(-2.75)	(-2.61)	(-1.14)	(-2.27)	(-2.36)
Diversified	-372755***	-450173	-168746	-281548**	-490589**
	(-2.86)	(-1.56)	(-0.66)	(-2.14)	(-2.62)
N	606	130	170	476	436
R^2	0.11	0.11	0.10	0.12	0.15

Notes: t-statistics are heteroscedastic-consistent. Models include an omitted constant.

Table 8: Determinants of high-tech ratio (H_1/P) - LAD - "higher high-tech costs"

	Total		Rich		Poor	
	(1)	(2)	(3) 8000	(4) 6000	(5) 8000	(6) 6000
GDP	205***	242***	-122***	-114***	131***	145***
	(2.88)	(4.47)	(-2.54)	(2.94)	(2.56)	(2.44)
GDP^2	-0.013***	-0.015***	-	-	-	-
	(-3.51)	(-5.20)	-	-	-	-
Enrollment	3155	5094	16575*	15509*	3040	163
	(0.72)	(1.65)	(1.72)	(1.90)	(0.65)	(0.03)
Repetition rate	-17257**	-13701*	-10668	-961	-16286*	-17202*
	(-2.11)	(-1.91)	(-0.75)	(-0.70)	(-1.95)	(-1.86)
Life Expectancy	14326	-	-96616*	-49879	18424	15573
	(0.98)	-	(1.66)	(-0.99)	(1.27)	(0.95)
N	267	270	78	98	189	169
R^2	0.18	0.18	0.13	0.17	0.20	0.21

Notes: t-statistics are heteroscedastic-consistent. Models include an omitted constant.

All of the three possible answers we suggested are quite reasonable in explaining the cross-country differences of high-tech proportion, but do not totally explain its relationship with GDP *per capita*. The institutional background "story" seems to give most importance to socialist institutions both in rich and poor countries, even after outliers exclusion. The specialization "story" stresses the importance of all the controls with a clear positive effect of the Manufactures dummy and clear negative effects of services and primary specializations and also of diversified economies. Thus high-tech proportion is clearly enhanced by the industry specialization of the economy. This is much more profound in poor countries than in richer ones. The last higher costs/supply "story" essentially stresses the role of the "repetition rate", which is particulary relevant in poor countries, and the enrollment rate is somewhat important in rich countries. It is worth noting that neither the polynomial relationship vanishes in the presence of these controls with the whole sample (including outliers) nor linear relationships with the divided samples.

All the main results can be also obtained when all the controls are introduced together, although results are omitted for reason of length and simplicity.[19] In this case, coefficients on GDP and GDP squared remained acceptable at high levels of significance, but some minor changes occur with the controls' significance. The services and the diversified dummies become more significant (with negative signs) and go along with a negative significant effect of British institutional background. Life expectancy becomes marginally significant. When Life expectancy is dropped, the enrollment rate becomes marginally significant.[20] The coefficient of Repetition rate kept its negative sign but turned out to be non-significant.

The inverted U-shaped relationship between H/P and GDP *per capita* is well robust to the introduction of a large set of controls and to deletion (or not) of outliers. This of course

[19] They are available upon request.

[20] This is not hard to imagine, as Life expectancy and Enrolment rates are closely related.

does not provide a definite answer to the unexpected relationship presented in the paper, but highlights some possible channels through which the high-tech human capital level is influenced. This could be the objective of future research, essentially for micro studies, as data on wages, for instance, become available.

5 Conclusion

In the data, the high-tech ratio has an inverted U-shaped relationship with the level of development, measured as GDP *per capita*. In fact, we find quite a robust non-positive relationship between the high-tech ratio and GDP, which indicates that rich countries invest proportionally less than lower-income countries in high-tech human capital. This is classified as a stylized fact because it can be seen using different samples (with and without outliers in both dimensions), different periods (each of the five-year periods between 1970 and 1997, which are all of the data available), different measures (enrollments and graduates) and different definitions (from a restricted definition to two broader definitions of high-tech human capital) for the *proxy* for the composition of human capital at universities and colleges. Some additional variables may contribute to explaining the high-tech human capital ratio. This ratio seems to be linked with the economies' institutional background, with structural transformation/income-effects or trade specialization and also with high lifetime costs of high-tech programs. Conditional on these controls, the puzzling relationship of a decreasing proportion of high-techs in richer countries remains.

There are interesting prospects for future research. First, as more data become available, it could be possible to test for productivity and wages micro relationships. Second, a natural research agenda includes fully explaining this relationship between GDP *per capita* and the proportion of high-techs in the economy with relation to structural transformation and increasing R&D activity, as the evidence shows a clear relationship between our measure of human capital composition and specialization dummies.

6 Appendices

A Broader definitions of High-Tech human capital (Enrollments)

Table 1.A: The Polynomial Relationship between H_2/P and GDP (Enrollments)

Coefficients	C c_1	GDP c_2	GDP^2 c_3	R^2 (N)	Wald (H_0: c_3=0)
1970-74	1771340*** (10.62)	240*** (2.97)	-0.0185*** (-2.73)	0.08 (96)	7.46***
1975-79	1823560*** (11.61)	190*** (2.66)	-0.0144*** (-2.74)	0.06 (110)	7.49***
1980-84	1679920*** (11.07)	174*** (2.67)	-0.0101** (-2.22)	0.08 (113)	4.91*
1985-89	1618660*** (12.16)	184*** (3.63)	-0.0109*** (-3.49)	0.09 (115)	12.17***
1990-94	1807160*** (11.63)	135*** (2.35)	-0.00831*** (-2.46)	0.05 (108)	6.04*
1995-97	1823880*** (9.27)	93 (1.22)	-0.00521 (-1.19)	0.03 (67)	1.43
System (OLS)	1779730*** (28.89)	150*** (6.26)	-0.00929*** (-6.12)	609	37.41***
SUR	1704800*** (22.83)	143*** (4.87)	-0.00847*** (-4.64)	609	21.50***
RE	1913420*** (17.59)	92*** (2.72)	-0.0059*** (-3.09)	0.70 (609)	9.53***
FE	–	50 (0.13)	-0.0023 (-1.25)	0.70 (609)	1.55
FE_1	–	-40*** (-3.07)	–	0.70 (609)	–
LAD	1776769*** (25.50)	142*** (5.07)	-0.00935*** (-5.02)	0.02 (622)	–

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 1.1.A: Wald Tests

H_0:	All c_1 equal	All c_2 equal	All c_3 equal
	1.65	2.40	3.67

Table 2.A: The Polynomial Relationship between H_3/P and GDP (Enrollments)

	C	GDP	GDP^2	R^2 (N)	Wald (H_0: c_3=0)
Coefficients	c_1	c_2	c_3		
1970-74	2569380***	353***	-0.0276***	0.10 (97)	7.05***
	(10.45)	(2.98)	(-2.66)		
1975-79	2544780***	323***	-0.0235***	0.10 (110)	12.59***
	(11.09)	(3.56)	(-3.55)		
1980-84	2434700***	248***	-0.0144**	0.09 (114)	6.64**
	(12.12)	(3.04)	(-2.58)		
1985-89	2317810***	252***	-0.0146***	0.09 (116)	9.60***
	(11.92)	(3.48)	(-3.10)		
1990-94	2733500***	129*	-0.0082*	0.03 (110)	3.59*
	(12.43)	(1.74)	(-1.90)		
1995-97	2351240***	155*	-0.00762	0.06 (68)	2.50
	(9.53)	(1.81)	(-1.58)		
System (OLS)	2547430***	212***	-0.0129***	615	44.35***
	(29.67)	(6.89)	(-6.66)		
SUR	2409940***	208***	-0.0122***	615	23.81***
	(24.13)	(5.21)	(-4.88)		
RE	2882830***	79*	-0.0060**	0.73 (615)	5.71**
	(19.37)	(1.76)	(-2.39)		
FE	–	-105**	0.0014	0.74 (615)	0.41
		(-2.19)	(0.64)		
FE_1	–	-78***	–	0.74 (615)	–
		(-5.21)			
LAD	2540849***	209***	-0.0124***	0.04 (622)	–
	(29.01)	(5.93)	(-5.34)		

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 2.1.A: Wald Tests

H_0:	All c_1 equal	All c_2 equal	All c_3 equal
	2.79	4.72	6.73

B Broader definitions of High-Tech human capital (Graduates)

Table 1.B: The Polynomial Relationship between H_2/P and GDP (Graduates)

	C	GDP	GDP^2	R^2 (N)	Wald (H_0: c_3=0)
Coefficients	c_1	c_2	c_3		
1975-79	1449100***	209***	-0.0157***	0.07 (100)	8.11***
	(9.13)	(2.76)	(-2.85)		
1980-84	1403500***	198***	-0.0121***	0.08 (106)	6.82***
	(8.44)	(2.79)	(-2.61)		
1985-89	1305600***	188***	-0.0096***	0.11 (112)	7.55***
	(8.74)	(3.21)	(-2.75)		
1990-94	1483360***	153***	-0.0081**	0.07 (95)	5.39**
	(8.94)	(2.64)	(-2.32)		
1995-97	1536850***	138*	-0.0076*	0.06 (57)	3.44*
	(6.59)	(1.76)	(-1.86)		
System (OLS)	1456700***	156***	-0.00857***	470	28.22***
	(20.24)	(5.76)	(-5.31)		
SUR	1432990***	140***	-0.0072***	470	15.55***
	(16.72)	(4.28)	(-3.54)		
RE	1544430***	94**	-0.00386*	0.73 (470)	3.30*
	(12.57)	(2.47)	(-1.82)		
FE	–	83	-0.0022	0.73 (470)	0.68
		(1.27)	(-0.82)		
FE_1	–	37*	–	0.73 (470)	–
		(1.90)			
LAD	1366561***	162***	-0.0090***	0.04 (482)	–
	(14.29)	(4.47)	(-3.96)		

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 1.1.B: Wald Tests

H_0:	All c_1 equal	All c_2 equal	All c_3 equal
	1.03	0.74	1.72

Table 2.B: The Polynomial Relationship between H_3/P and GDP (Graduates)

Coefficients	C c_1	GDP c_2	GDP^2 c_3	R^2 (N)	Wald (H_0: c_3=0)
1975-79	2103680*** (7.71)	431*** (3.96)	-0.0314*** (-3.82)	0.13 (103)	14.61***
1980-84	1984350*** (9.87)	409*** (4.76)	-0.0237** (-3.97)	0.18 (109)	15.78***
1985-89	1827200*** (9.24)	372*** (4.46)	-0.0192*** (-3.59)	0.18 (114)	12.91***
1990-94	2214170*** (8.34)	278*** (3.18)	-0.0146*** (-2.79)	0.10 (97)	8.74***
1995-97	2542180*** (8.06)	164 (1.60)	-0.0081 (-1.45)	0.05 (59)	2.10
System (OLS)	2149230*** (20.27)	299*** (7.94)	-0.0159*** (-6.84)	482	46.77***
SUR	2146760*** (17.50)	259*** (5.52)	-0.0137*** (-4.76)	482	22.70***
RE	2501340*** (13.80)	138** (2.56)	-0.00625** (-2.14)	0.78 (482)	4.57**
FE	–	-102 (-1.19)	0.0040 (1.10)	0.78 (482)	1.21
FE_1	–	-18 (-0.74)	–	0.78 (482)	–
LAD	1984482*** (18.27)	339*** (8.29)	-0.0187*** (-7.28)	0.08 (486)	–

Note: t-statistics based on heteroscedastic-consistent variance matrix are presented in parentheses. Acceptable statistics (rejection of the null) are signaled with * (10%), ** (5%) and *** (1%).

Table 2.1.B: Wald Tests

H_0:	All c_1 equal	All c_2 equal	All c_3 equal
	3.90	4.53	6.32

C Specification Search

Table 1.C: Determinants of high-tech ratio (H_1/P) - OLS - "institutional background"

	(1)	(2)	(3)	(4)	(5)
GDP	207***	202***	204***	195***	194***
	(9.27)	(8.99)	(9.05)	(9.09)	(8.35)
GDP^2	-0.013***	-0.012***	-0.013***	-0.01***	-0.01***
	(-9.04)	(-9.08)	(-9.04)	(-8.53)	(-8.05)
French	-74440***	-	-	-	-
	(-1.15)	-	-	-	-
German	-	339260***	-	-	-
	-	(2.74)	-	-	-
Scandinavian	-	-	246580	-	-
	-	-	(1.58)	-	-
Socialist	-	-	-	913140***	-
	-	-	-	(6.42)	-
Britain	-	-	-	-	-283390***
	-	-	-	-	(-4.63)
N	591	591	591	591	591
R^2	0.11	0.12	0.12	0.20	0.14
F	25.3	26.4	25.7	48.0	32.0

Notes: t-statistics are heteroscedastic-consistent. Models include an omitted constant.

Table 2.C: Determinants of high-tech ratio (H_1/P) - OLS
"specialization"

	(1)	(2)	(3)	(4)	(5)
GDP	187***	218***	202***	225***	216
	(8.25)	(9.75)	(8.02)	(9.68)	(9.61)
GDP^2	-0.01***	-0.013***	-0.012***	-0.013***	-0.013
	(-8.65)	(-9.53)	(-8.21)	(-9.31)	(-9.28)
Manufactures	711930***	-	-	-	-
	(6.80)	-	-	-	-
Services	-	-279830***	-	-	-
	-	(-3.45)	-	-	-
Primary (non-fuel)	-	-	-130840**	-	-
	-	-	(-1.78)	-	-
Diversified	-	-	-	-166580***	-
	-	-	-	(-2.67)	-
Fuel	-	-	-	-	18480
	-	-	-	-	(0.17)
N	606	606	606	606	606
R^2	0.20	0.13	0.12	0.13	0.12
F	50.2	31.0	28.1	29.4	26.9

Notes: t-statistics are heteroscedastic-consistent. Models include an omitted constant.

Table 3.C: Determinants of high-tech ratio (H_1/P) - OLS - "higher high-tech costs"

	(1)	(2)	(3)	(4)	(5)
GDP	132***	228***	260***	263***	63*
	(4.12)	(8.75)	(9.79)	(9.25)	(1.85)
GDP^2	-0.010***	-0.014***	-0.015***	-0.015***	-0.006***
	(-6.13)	(-9.00)	(-8.22)	(-9.22)	(-3.65)
enrollment	7950***	-	-	-	-
	(4.36)	-	-	-	-
Pupil/Teacher	-	-7010	-	-	-
	-	(-1.43)	-	-	-
Expenditure	-	-	14	-	-
	-	-	(0.18)	-	-
Repetition rate	-	-	-	-16660***	-
	-	-	-	(-3.00)	-
Life Expectancy	-	-	-	-	29880***
	-	-	-	-	(5.83)
N	472	455	328	287	596
R^2	0.17	0.16	0.19	0.26	0.18
F	31.9	28.1	25.8	33.7	42.7

Notes: t-statistics are heteroscedastic-consistent. Models include an omitted constant.

D Data description

There are three main databases from which we have collected data for this paper: (1) Easterly and Sewadeh, Global Development Network Growth Database, WORLD BANK (WB), from which we collect macroeconomics variables, (2) Barro and Lee (BL) database, from which we collect secondary education data and (3) UNESCO database, from which we collect data on enrollments and graduates in tertiary education level by field. The list of countries used in each estimation is available upon request. We present below the list of variables and their source.

		Direct Source
H_1/P	Ratio of the sum of Engineering, Mathematics and Computer Science Enrollment/Graduates (E/G) to the sum of all the fields in tertiary education. Average across each five-year period.	UNESCO
H_2/P	Ratio of the sum of Engineering, Mathematics and Computer Science and Natural Sciences E/G to the sum of all the fields in tertiary education. Average across each five-year period.	UNESCO
H_3/P	Ratio of the sum of Engineering, Mathematics and Computer Science, Natural Sciences and Medical and Health related sciences E/G to the sum of all the fields in tertiary education. Average across each five-year period.	UNESCO
GDP	real Gross Domestic Product *per capita*.(international prices, base year=1985) from Penn World Tables 5.6. Average across each five-year period.	WB
GDP^2	GDP *per capita* squared.	–
	Enrollment in Secondary Educational Level (in % of Population in the age group). First year of the period.	WB
	Real Government current expenditure in Secondary Schools per pupil. First year of the period.	BL
	Repetition rate at secondary schools. First year of the period.	BL
	Pupil/Teacher Ratio at Secondary Schools	BL
	Life Expectancy at birth. First year of the period.	WB
	Manufactures specialization in exports dummy.	WB
	Services specialization in exports dummy.	WB
	Primary specialization in exports dummy.	WB
	Primary specialization in exports.	WB
	Fuel (mainly oil) specialization in exports.	WB
	Country institutional background dummies	WB

In the GDP database we had information only on Yugoslavia, Federal Republic, Czech Republic, Slovakia and Yemen Republic. In periods from 1970 to 1980 (inclusive), the high-tech ratio in Former Democratic Yemen, Former Yugoslavia and Former Czechoslovakia in the UNESCO database corresponds to GDP *per capita* in Yemen Rep., Yugoslavia (Federal Republic) and Czech Republic, respectively, in the WB database. In the period 1985-89, the high-tech ratio in Former Yemen Arab Republic, Former Yugoslavia and Former Czechoslovakia in the UNESCO database corresponds to GDP per capita in Yemen Rep., Yugoslavia (Federal Republic) and Czech Republic, respectively, in the WB database. In 1990-94, the high-tech ratio in Yemen (The Republic of Yemen had been unified in May 1990), Former Yugoslavia, Czech Republic and Slovakia in the UNESCO database corresponds to GDP *per capita* in Yemen Rep., Yugoslavia (Federal Republic), Czech Republic and Slovakia, respectively, in the WB database. In the last 1995-97 period, the high-tech ratio in Yemen, Yugoslavia (Federal Republic), Czech Republic and Slovakia in the UNESCO database corresponds to GDP *per capita* in Yemen Rep. Yugoslavia (Federal Republic), Czech Republic and Slovakia, respectively, in the WB database.

References

[1] Acemoglu, D. (2001), Good jobs versus bad jobs, *Journal of Labor Economics*, 19(1), 1-21, Jan.

[2] Acemoglu, D. and F. Zilibotti (2001), Productivity Differences, *Quarterly Journal of Economics*, May, 116(2), 563-606.

[3] Barro, R. (1999), Human Capital and Growth in Cross Country Regression, *Swedish Economic Policy Review*, number 6.

[4] Barro, R. and J. Lee (2001), "Schooling Quality in a Cross Section of Countries", *Economica,* 68 (272), 465-488.

[5] Barro, R. and X. Sala-i-Martin (1995), *Economic Growth*, McGraw-Hill.

[6] Bertocchi, G. and M. Spagat (1998), *The evolution of modern educational systems: technical versus general education*, distributional conflict and growth, CEPR Discussion paper 1925.

[7] Easterly, W. and M. Sewadeh (2002), Global Development Network Database, World Bank, *http://www.worldbank.org/research/growth/GDNdata.htm.*

[8] European Commission (1999), *Key data on Education in Europe*, Office for Official publications of the European Communities.

[9] Funke, M. and H. Strulik (2000), On Endogenous growth with physical capital, human capital and product variety, *European Economic Review*, 44, 491-515.

[10] Grossman, G. and E. Helpman (1991), *Innovation and Growth in the global economy*, MIT press.

[11] Jones, C. (1995), "Time-series tests of endogenous growth models", *Quarterly Journal of Economics*, 100, 495-525.

[12] Katz, L. and K. Murphy (1992), "Changes in Relative Wages, 1963-1987: Supply and Demand Factors", *Quarterly Journal of Economics, 107(1), 35-78.*

[13] Murphy, K., A. Shleifer and R. Vishny (1991), "The Allocation of talent: implications for growth", *Quarterly Journal of Economics*, May, volume CVI, 2, 503-530.

[14] OECD (2002), *International mobility of highly skilled*, Paris.

[15] Romer, P. (1990), "Endogenous Technological change", *Journal of Political Economy*, vol. XCVIII, 71-102.