INDUSTRIALIZATION AND GROWTH: THRESHOLD EFFECTS OF TECHNOLOGICAL INTEGRATION

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Abstract

Countries enjoy the benefits of industrialization in economic growth after surpassing a certain threshold of technological integration in the manufacturing sector. This feature of development is consistent with the observed gaps in long-run growth rates between rich and poor economies.

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1. Introduction

In spite of all the discussion on economic convergence, cross-country analyses of long-run economic growth reveal a divergent pattern. According to Madisson´s (1994) analysis over a sample of 21 countries, the ratio of the highest GDP per capita to the lowest increased from 3 to 17 between 1820 and 1989. And Pritchett (1997) estimates that from 1870 to 1990 the ratio of per capita income between the richest and the poorest countries increased by a factor of five.

This divergent pattern is also observed for more recent periods. Hall and Jones (1997) found that the ratio of GDP per worker of the fifth-richest countries to that of the fifth-poorest countries increased from 26 to 29 between 1960 and 1988. Easterly and Levine (2001) reported that divergence of per capita income has increased from 1960 to 1992. Their estimations in Table 1 show that the two higher fifths of countries grew faster than middle income countries, and these in turn grew faster than the two lower fifths.

Table 1
Rich Countries Grow Faster

Countries classified by income per person in 1960	Average growth of income per person 1960 -1992
Richest fifth	2.2%
Second richest fifth	2.6%
Middle fifth	1,8%
Second poorest fifth	1.2%
Poorest fifth	1.4%

Source: Easterly and Levine (2001).

Hence, the world division among these three "clubs" –rich countries, middle income countries and poor countries– is deepening. A recent World Bank research has confirmed this feature. Perry et al (2006) showed that the unimodal distribution of per capita real income across countries in 1960 has become a trimodal distribution in 1999. They showed as well that since 1960 there has been convergence within these "clubs" but divergence amongst them. It is thus unavoidable to conclude that the income gap between rich countries and the remainder has been widening over a long period.

The existence of persisting growth gaps across countries was discovered by Kaldor. In his classical paper on the patterns of development he wrote: "there are appreciable differences in the rate of growth of labour productivity and of total output in different societies" (Kaldor, 1961, p. 179). This was the sixth pattern; the first five were as follows: 1) output per worker shows continuing growth, with "no recorded tendency for a falling rate of growth of productivity", 2) capital per worker shows continuing growth, 3) the rate of return on capital is steady, 4) the capital-output ratio is steady over long periods, and 5) labour and capital receive constant shares of total income.

Kaldor´s patterns of development imply a world economic structure where convergence is not guaranteed. Historical experience of economic development supports this vision; even though a few previously underdeveloped economies have been able to take off, most underdeveloped economies have been unable to follow suit. Given this scenario, gaining an understanding of the underlying mechanisms of economic divergence is one of the most challenging tasks facing development analysts.

2. Industrialization and Economic Growth

It was also Kaldor who put forward the thesis that cross-country variations of economic performance were related to industrialization:

> "Fast rates of growth are almost invariably associated with the fast rate of growth of the secondary sector, mainly manufacturing, and… this is an attribute of an intermediate stage of development" (Kaldor, 1966, p. 7).

Following this line of research, Chenery, Robinson and Syrquin (1986) analyzed the relationship between industrialization and economic growth. Using data from a selected group of industrial and semi-industrial countries, and after identifying some unlikely exceptions – poverty traps, persistence of the Dutch disease phenomenon in the primary sector, and early development on export services, Chenery et al (1986) claimed to have found enough evidence to support Kaldor´s hypothesis:

> "Is industrialization necessary to continued growth? Our models of the transformation suggest that the answer is generally yes" (p. 350). "(…) We conclude that –on both empirical and theoretical grounds– a period in which the share of manufacturing rises substantially is a virtually universal feature of the structural transformation" (p. 350).

Murphy, Shleifer and Vishny (1989) also concurred to this viewpoint:

> "Virtually every country that experienced rapid growth of productivity and living standards over the last 200 years has done so by industrializing. Countries that have successfully industrialized –turned to production of manufactures taking advantage of scale economies– are the ones that grew rich, be they 18th-century Britain or 20th-century Korea and Japan" (p. 1003).

Some twentieth-century experiences of economic development are consistent with this pattern. Newly industrialized countries are among the highest growing economies over the period 1965-1990; they are, in order of performance, Singapore (1), Korea (2), Taiwan (5), Hong-Kong (6), China (7), Indonesia (8), Japan (10), Malaysia (11), Thailand (18), Brazil (19) and Yugoslavia (20). On the other hand, all the lowest growing economies in the same period are non-industrialized countries (see Barro and Sala-i-Martin, 1995, Tables 12.1 and 12.2). Besides, the most recent successful experiences of economic take offs, China and India, are also related to industrialization and economic diversification.

Thus, industrialization matters. That is why the advice of Leontief (1963) for developing countries was the following:

> "Given the country mix of resources and the available technologies, the essence of the process of development [is] to create an economic system as similar as possible to the system of the most developed economies" (p. 164).

Hence, if industrialization is the key to economic development, why do we observe so very few cases of successful economic take offs? Why cannot we the underdeveloped countries catch the train of progress? This paper attempts to provide an answer. According to a certain vision of economic development, a period of structural transformation is previously required in order to take advantage of the external effects of industrialization on productivity, competitiveness and economic growth. During that period, national institutions and economic agents have to commit themselves to industrialize (Hirschman, 1958; Amsden, 1989; Landes, 1998). Coordination problems related to this commitment are perhaps what make it so difficult to gain access to the exclusive “club” of developed economies (Hirschman, 1958; Murphy, Shleifer and Vishny, 1989). In summary, our main hypothesis is that the causal relationship from industrialization to economic growth is non-linear: each society should endeavour to achieve some minimum level of manufacturing technological integration before it can reap the benefits of industrialization in economic growth.

In this structuralist vision, each country is considered as some kind of living being that ought to transform itself into an adult before being able to survive and compete successfully in the world markets. The latter analogy is based on empirical analyses of economic development. Chenery, Robinson and Syrquin (1986) identified that along the process of industrialization some structural changes take place –economies grow up. The main features of this structural transformation are, according to these authors, the following: changes in final demands, changes in intermediate demands and changes in international trade. The first structural change is the well-known Engel´s law: income elasticity of food demand is lower than 1; thus, the agricultural sector expands slower than the economy as a whole. The second structural change is what these authors refer to as input-output deepening:

> “As countries industrialize, their productive structures become more “roundabout” in the sense that a higher proportion of output is sold to other producers rather than to final users. (…), this phenomenon can be broke down into two parts: first, a shift in output mix toward manufacturing and other sectors that use more intermediate inputs; and second, technological changes within a sector that lead to a greater use of intermediate inputs” (Chenery, Robinson and Syrquin, 1986, p. 57).

The third structural change is related to the evolution of international trade: comparative advantages change from the primary sector to the manufacturing sector. The following quotation is illustrative:

> “Through import substitution and the expansion of manufactured exports, developing countries shift away from the specialization in primary products that is characteristic of early stages of development. Underlying this shift are changes in supply conditions – accumulation of skills and physical capital plus the greater availability of intermediate inputs– as well as economies of scale based on a growing domestic market for manufactured goods” (Chenery, Robinson and Syrquin, p. 63).

Hence, according to the structuralist vision of economic development, it might be true that only when a country´s structural transformation is sufficiently advanced that it might open itself to world markets, become an exporter of manufactured goods and enjoy the benefits of industrialization –including higher growth rates.

Theoretical analyses that are consistent with this vision include growth and international trade models such as those of Lucas (1988), Young (1991), Matsuyama (1992) and Ortiz (2004, 2008). In these models, learning-by-doing is the engine of growth. Under an open economy regime, a country´s pattern of specialization is determined by its inherited advantages. Thus, advantages in high-learning economic activities, typically manufacturing, drive the economy along a superior path of economic development; whilst advantages in low-learning technological activities might lock the economy up in those activities and lead to sluggish economic growth.

Several reasons can be put forward in order to explain the strong economic externalities from the manufacturing sector. First, product diversification, and its important effects on productivity (Romer 1987, 1990), takes place typically in the manufacturing sector. Second, the continuous displacement of the technological frontier in the manufacturing sector allows the sector´s learning potential to remain high (Lucas, 1988; Young, 1993). Third, the manufacturing sector is characterized by intensive application of science and technology to transform intermediate goods and raw materials; moreover, the sector´s generation of new goods and new technologies induces the appropriation and diffusion of humanity's more important productive force: scientific knowledge (Romer, 1986). Fourth, the productivity of the manufacturing sector, as producer of intermediate and capital goods, impinges directly on the system profitability (Sraffa, 1960) and the rate of economic growth (Rebelo, 1991). Fifth, the manufacturing sector typically enjoys internal and external economies that enhance aggregate productivity (Caballero and Lyons, 1990).

Some words of caution are required at this point. It is convenient to emphasize that there is nothing magical about manufacturing; other economic activities requiring an intensive use of intelligence and technology –informatics, communications, biotechnology, scientific research, etc.– may also become leaders of economic growth (Landes, 1998, ch. 15; Rodrik, 2006).

3. Some Empirical Support

3.1. A Small Panel Data

According to the analysis of structural transformation (Chenery et al, 1986), economic diversification is directly related to production "roundaboutness". It is thus convenient to test the diversification effects on economic growth by using a measure of interindustrial dependence as a proxy. In order to do that, a small panel data set containing such a measure is used in this analysis.

Based on Kubo's work on cross-country comparisons of interindustrial linkages (Kubo, 1985), Kubo, de Melo, Robinson and Syrquin (1986) calculated comparable indices of aggregate interindustrial linkages using information from 30 input-output matrices of nine industrialized or semi-industrialized countries: Colombia, Mexico, Turkey, Yugoslavia, Japan, South Korea, Taiwan, Israel and Norway. Observations were taken for some years between 1950 and 1975. According to the authors, each country represented a different stage of structural change. To that extent, the sample may be thought of as being representative of the experience of economic development.

The procedure to calculate the mentioned indices was the following. First, the authors rearranged each matrix into 14 comparable economic sectors and calculated the matrix of technical coefficients $\mathbf{A} = [a_{ij}]$, where a_{ij} is the technical coefficient measuring the amount (in value terms) of input i which is consumed in the production process of one unit of good j. Subsequently, they calculated the Leontief matrix, $\mathbf{L} = \mathbf{I}\text{-}\mathbf{A}$, where $\mathbf{I}$ denotes the identity matrix of the same order as matrix $\mathbf{A}$. Finally they obtained an index of overall linkages as follows: $(OL) = \mathbf{f}'(\mathbf{L}')^{-1}\mathbf{i}$, where OL is a scalar, $\mathbf{f}$ is a 14x1 weight vector whose elements add up to 1, **i** is a 14x1 unit vector, the apostrophe (') denotes matrix transposition, and the power -1 denotes matrix inversion. Let us decompose this expression: $(\mathbf{L}')^{-1}\mathbf{i}$ is a 14x1 vector whose elements measure the degree of backward technological integration of the corresponding sectors, i.e. each element measures the proportion of gross output which is produced in the economy per unit value of final demand in the corresponding sector. The final expression (OL) is then a weighted average of these measures, where the weights are taken from the representative structure of the final demand vector for a semi-industrial country (see Chenery, Robinson and Syrquin, Chapter 4, 1986). These authors also obtain an index of domestic linkages (DL) by excluding imported intermediate inputs from the input-output matrix; the calculation is completely analogous to the previous one.

Appendix 1 exhibits the data on measures of interindustrial linkages, overall linkages (OL) and domestic linkages (DL), for the above panel of countries. It also includes the equivalent annual growth rates of per capita GDP during 10 years (G10), the real per capita GDP (RGDP), the average schooling years in the total population over age 25 (EDU), the average investment ratio in the next decade (I10), and the equivalent annual growth rate of population in the next decade (GN10).

3.2. Growth Regressions from the Panel Data

Appendix 1 is a small unbalanced panel. Using this information the growth regressions shown in Table 2 were run. Since cross-country regressions are usually subject to heteroscedasticity –this hypothesis cannot be rejected at the 1 percent level, OLS estimates are corrected using White´s consistent covariance matrix. The dependent variable is the average annual growth rate of GDP for the next 10 years (G10).

The first set of included independent variables (the basic set from now on), are the real per capita GDP (RGDP), the average annual growth rate of population in the following decade (GN10), the average investment ratio in the next decade (I10), and the initial level of educational attainment (EDU). These variables are thought to be robustly correlated with economic growth (Levine and Renelt, 1992). The RGDP coefficient is expected to be negative because of convergence effects; the EDU coefficient is expected to be positive because of human capital accumulation; the I10 coefficient is expected to be positive because of capital accumulation; and the GN10 coefficient is expected to be negative because population growth diminishes directly output per capita. The second set of independent variables contains the measures of interindustrial linkages (OL and DL), the dummy variable for the 70´s (D70), and the interactive dummies (OL*D70 and DL*D70). Because of the oil shocks of the 70´s, these interactive dummies are added in order to account for the downward jump of growth rates during this period; it is likely that the 70´s oil shocks diminished the positive externalities from interindustrial linkages because oil is the most important intermediate input for the current technology. The third set of independent variables contains the country dummies; notice that Colombia is taken as the reference country.

Table 2
Growth Regressions from Panel Data
(Sample = 30, t-statistics in parentheses)

Variable\Regression	(1)	(2)	(3)	(4)	(5)	(6)
CONSTANT	-0.14380 (-0.02512)	0.44619 (0.21906)	-4.50778 (-1.45470)	-4.88106 (-0.78800)	0.26691 (0.09231)	4.51025 (1.95658)
RGDP	-0.00102** (-2.87267)	-0.00056*** (-3.17038)	-0.00054*** (-2.94060)	-0.00059*** (-3.24556)	-0.00057** (-2.81040)	-0.00077*** (-4.09695)
GN10	-0.98734 (-0.91080)	-0.56345 (-1.64022)	-0.65040* (-1.98943)	-0.57784 (-1.65080)	-0.45755 (-1.12595)	-0.60034 (-1.48737)
I10	0.05116 (0.55827)	-0.04882 (-0.79414)	0.37445* (1.89191)	-0.06080 (-0.93833)	-0.04883 (-0.78782)	-0.09559 (-1.54282)
I10-SQ			-0.00797** (-2.29897)			
EDU	-0.10841 (-0.15431)	0.12286 (0.41848)	0.01416 (0.05004)	0.17634 (0.58099)	0.14251 (0.43950)	0.782443*** (3.24285)
OL	0.11350* (1.91701)	**0.10519*** (5.44688)**	**0.10917*** (5.15731)**	0.26410* (1.77816)	0.08314*** (3.43699)	
OL*D70	-0.01232 (-1.59489)	**-0.01821*** (-4.25776)**	**-0.01976*** (-4.63016)**			
D70				-1.22414*** (-3.15716)	-1.23085*** (-3.44334)	
OL-SQ				-0.00111 (-1.20040)		
DL					0.02734 (0.91989)	0.05205** (2.20207)
DL*D70						-0.01201 (-1.43523)
MEXICO	1.80144* (1.90385)					
TURKEY	0.66749 (0.55614)					
YUGOSLAVIA	-2.00966 (-1.56229)					
JAPAN	0.759815 (0.33805)					
SOUTH KOREA	-0.67507 (-0.41788)					
TAIWAN	0.20117 (0.12088)					
ISRAEL	2.05202 (0.59033)					
NORWAY	1.00252 (0.43667)					
R^2 adj.	0.72859	0.74007	0.75375	0.72004	0.72010	0.64091
S.E.	1.13750	1.11320	1.08349	1.15529	1.15516	1.30841

Significance level: * 10%, ** 5%, *** 1%.

The first regression uses as independent variables the basic set, the overall linkages measure (OL), the related interactive dummy (OL*D70), and the country dummies. These last set of variables is added in order to capture possible fixed-country effects. However, none of the country dummies is significant, and neither are they significant as a whole. Because the degrees of freedom are significantly reduced, this regression does not yield significant coefficients. Thus, the country dummies were dropped in order to run the second regression.

In this second regression, the initial level of per capita GDP (RGDP), the overall linkages measure (OL), and the corresponding interactive dummy (OL*D70) are significant at the 1% level and their respective coefficients exhibit the expected signs: negative for RGDP and OL*D70, and positive for OL. The basic regressors different to RGDP –GN10, I10 and EDU– are not significant. Moreover, the coefficient associated with the average investment rate (I10) is estimated as being negative.

Because of this odd feature, the third regression is run including as regressor the square of the average investment rate (I10-SQ). In this regression, estimated coefficients of all the basic independent variables obtain the expected signs: RGDP (-), GN10 (-), I10 (+) and EDU (+). Moreover, the RGDP coefficient is significant at the 1% level, the GN10 coefficient is significant at the 10% level, and the I10 coefficient is significant at the 10% level. The coefficient associated with the squared average investment rate (I10-SQ) is negative and significant at the 5% level; there is no easy explanation for this result, but it is clearly deduced that there are not accelerating effects on economic activity derived from investment. The coefficients associated with the overall linkages measure (OL) and the corresponding interactive dummy variable (OL*D70) preserve their signs and levels of statistical significance. This third regression is our preferred; it yields the regression with the highest adjusted R^2, 75.4%, and the coefficients of all standard variables get the expected signs. Therefore, according to the second and third regressions, data are not contrary to the hypothesis that technological integration impinges positively on economic growth in semi-industrial and industrialized economies.

The fourth regression was run in order to verify the possible existence of non linear effects from overall linkages; that is why the regression includes the square of the measure of overall linkages (OL-SQ). However, the associated coefficient is not statistically significant for this sample of countries.

The fifth regression was run in order to check which measure of interindustrial linkages was best related with economic growth. This exercise yields that when both measures are included, the overall linkages measure (OL) is significant whilst the domestic linkages measure (DL) is not. Since the difference between the measures of overall linkages and domestic linkages is accounted for imported intermediate inputs, the previous result suggests that commercial openness might favour economic growth if it leads to a greater economic diversification (Ortiz, 1994).

Although aggregate interindustrial linkages are better predictors of growth than domestic linkages, the sixth regression replaces the measure of overall linkages (OL) and the corresponding 70´s interactive dummy variable (OL*D70), both of them included in the second regression, by the measure of domestic linkages (DL) and the corresponding interactive variable (DL*D70). This regression yields that the measure of domestic linkages has a positive effect on growth, but it is only significant at the 5% level. Besides, the corresponding interactive dummy variable (DL*D70) is not significant. In this case, however, the measure of educational attainment (EDU) is significant at the 1% level. This last result is probably due to the high correlation of education (EDU) with the overall linkages measure (OL): the correlation coefficient between these two variables is 78%. Thus, it seems that EDU behaves in the sixth regression as a proxy for OL.

Why is education not significant in these regressions? A first explanation may be that this variable suffers from measurement problems; after all, educational attainment (EDU) is a quantitative index of years of education and, thus, it does not capture cross-country differences in education quality. A second possibility is that educational attainment is itself an endogenous variable: it may be determined by the maturity of the whole economic structure.

This second possibility would imply that structural transformation imposes some education requirements (Klees, 1989; Levin and Kelley, 1994; Bils and Klenow, 2000; Easterly, 2001, ch. 4). Data are not inconsistent with this hypothesis. In Appendix 2A, a regression was run for educational attainment (EDU) against the index of overall linkages (OL) and the set of country dummies (Colombia is the reference country). The coefficient associated with overall linkages is estimated positive and statistically significant at all levels; the coefficients associated with some industrialized country dummies –Yugoslavia, Japan, Israel and Norway– are estimated positive and significant. If educational attainment is run against the basic set of regressors and the overall linkages measure (Appendix 2B), the measure of overall linkages (OL) and the initial income level per capita (RGDP) exhibit the highest statistical significance level, in that order. Hence, education and economic growth might depend jointly on the measure of overall linkages.

3.3. A Cross-Country Data Set

The above considerations and estimations are based on a small but representative sample of nine semi-industrial and industrial countries. Since the data set is a non-balanced panel, the results might be subject to all sorts of potential problems of endogeneity. Instead of attempting to solve them, this research project focused on the analysis of a larger cross-country data set of fifty two (52) countries (Appendix 3). Since the project aims at estimating the impact of industrialization on economic growth, three industrialization indices were built: the 1980 share of the manufacturing sector in GDP (IND), the 1980 input-output coefficient for the whole economy (IO), and the input-output coefficient for the manufacturing sector (IOMAN). The data for these indices were collected from the United Nations´ *National Accounts Statistics*. The year 1980 was chosen mainly because information for many less developed countries and even for developed countries is not available for previous years; thus, a previous year analysis would reduce both the sample size and the representativeness of less developed economies.

It would have been useful to count with a direct measure of interindustrial linkages as in the panel data set. Since this information is not available, the project took advantage of the patterns of structural transformation that were examined before to postulate that the tightness of interindustrial linkages (and the degree of economic diversification) must be correlated with the manufacturing GDP share and the input-output coefficients for the whole economy and the manufacturing sector (IND, IO and IOMAN). Even though cross-country differences of product composition and relative prices may affect these coefficients (As Table 3 shows, some of these coefficients are too high for the corresponding level of development), the research project used them because there was no alternative. On the other hand, an ordering of these coefficients shows that in general highly developed economies tend to exhibit higher industrialization indices.

Taking into account the shift from panel data to cross-country analysis, the methodological approach is quite similar. The dependent variable is the average growth rate of per capita GDP between 1980 and 2000; in order to estimate this variable a semi-logarithmic regression of per capita GDP against time is run for each country over the period 1980-2000. The source of GDP data is the Penn–World Table (Heston, Summers and Aten, 2006). A basic set of independent variables is defined: the per capita real gross domestic product in 1980 (RGDP), the average rate of population over the period (GPOP), the average investment rate over the period (I), and the initial educational attainment (EDU). A second set of variables include the three industrialization measures and the dummy variable for oil exporting countries.

The educational attainment variable was taken from Barro and Lee (1993) statistical data base. As education data for Burkina Fasso, Cape Verde, Nigeria and Oman are not available for 1980, they were estimated taking advantage of the high correlation coefficient across countries between the log of education attainment and life expectancy at birth, 89%.

3.4 Cross-Country Growth Regressions

Appendix 3 is a cross-country data base. It contains information for 52 countries of different levels of development. Using this information the growth regressions shown in Table 3 were run. As in the panel data exercises, the hypothesis of heteroscedasticity cannot be rejected at the 1 percent level. Hence, OLS estimates are corrected using White´s consistent covariance matrix.

The first regresssion includes as independent variables the basic set. All the estimated coefficients yield the expected signs, and all of them, with the exception of the log of education, are significant at the 5% level. The second and third regressions add the manufacturing share (IND) as independent variable in a linear and a quadratic way, respectively; however, the associated coefficients are not significant. The fourth and fifth regressions use instead the aggregate input-output coefficient (IO) as independent variable; but the associated coefficients in these regressions are not significant either. The sixth and seventh regressions use the manufacturing input-output coefficient (IOMAN) as independent variable; in this case, the quadratic expression in IOMAN –seventh regression– does yield estimated coefficients which are significant at the 1% level.

Table 3
Cross-Country Growth Regressions
(t-statistics in parentheses)

Regression	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
Constant	0.05674	0.16875	0.26431	0.40812	2.21629	0.33856	10.00887***	9.84068***	10.63516***	10.2381***	10.0529***	-2.15333	-9.70280
	(0.16038)	(0.50797)	(0.6626)	(0.83261)	(1.43522)	(0.37354)	(3.34553)	(3.10788)	(3.24424)	(3.86846)	(3.68844)	(-1.64705)	(-0.79557)
RDGP	-3.16E-5**	-3.56E-5**	-3.60E-5**	-3.65E-5**	-4.32E-5***	-3.23E-5**	-3.45E-5***	-3.37E-5***	-3.73E-5***	-3.14E-5***	-3.35E-5***	-0.00013***	-0.00013***
	(-2.34797)	(-2.53900)	(-2.56567)	(-2.55349)	(-2.14349)	(-2.29009)	(-3.12373)	(-2.97735)	(-3.01506)	(-3.20147)	(-2.70446)	(-3.11367)	(-3.04099)
GPOP	-0.20333**	-0.21291**	-0.19966**	-0.20294**	-0.19222**	-0.20211**	-0.24791***	-0.23323*	-0.26631***	-0.27245***	-0.27049***	-0.54487***	-0.51465**
	(-2.27707)	(-2.39824)	(-2.19403)	(-2.20626)	(-2.14349)	(-2.20878)	(-2.84357)	(-1.71638)	(-3.08943)	(-3.40144)	(-3.26755)	(-3.16842)	(-2.72054)
I	0.057174**	0.06580**	0.06330**	0.06472**	0.06650**	0.05833**	0.05742**	0.05834**	0.12315*	0.06623***	0.06817***	-0.00161	4.47e-5
	(2.44650)	(2.47257)	(2.45208)	(2.33682)	(2.53642)	(2.39390)	(2.63578)	(2.60649)	(1.80317)	(3.22634)	(2.92324)	(-0.06640)	(0.00178)
I-SQ									-0.00180				
									(-0.96911)				
Log(EDU)	0.16992	0.26903*	0.29987**	0.25903	0.32350**	0.17173	0.15780	0.14230	0.09331			0.57148	0.52239
	(1.13509)	(1.68514)	(2.10728)	(1.57295)	(2.07390)	(1.13424)	(1.02852)	(0.67342)	(0.60898)			(1.42607)	(1.30726)
IND		-0.01928	-0.03848										
		(-1.23188)	(-0.96244)										
IND-SQ			0.00060										
			(0.56153)										
IO				-0.01276	-0.10360								
				(-0.84042)	(-1.39379)								
IO-SQ					0.00104								
					(1.22581)								
IOMAN						-0.00452	-0.30926***	-0.30780***	-0.34442***	-0.31446***	-0.30965***	0.06450***	0.29297
						(-0.31030)	(-3.14848)	(-3.06736)	(-3.27587)	(-3.56954)	(-3.46976)	(3.63052)	(0.80622)
IOMAN-SQ							0.00240***	0.00241***	0.00271***	0.00245***	0.00241***		-0.00173
							(2.89407)	(2.84086)	(3.09417)	(3.26143)	(3.17732)		(-0.63057)
PETROL											0.095153		
											(0.32082)		
R^2 Adj.	0.38592	0.39002	0.37871	0.38266	0.38236	0.373983	0.41163	0.39886	0.41667	0.41394	0.40177	0.50953	0.48258
S.E.	0.66303	0.66081	0.66691	0.66479	0.66495	0.66944	0.64900	0.66720	0.64622	0.64772	0.65441	0.35039	0.35989
No. Obs.	52	52	52	52	52	52	52	48	52	52	52	21	21
IOMAN min.							64.4	63.9	63.6	64.2	64.2		

Significance level: * 10%, ** 5%, *** 1%.

Taking into account that educational attainment is estimated for four countries, they are excluded from the sample and the eight regression is run for just 48 observations; this regression yields quite similar coefficients to the previous one, and the significance levels are practically equal. The ninth regression includes in the set of regressors the square of the average investment rate (I-SQ); the estimated coefficient is negative –as in the panel data exercises– but it is not significant. All not significant variables were dropped in the tenth regression; the result improves greatly: the estimated coefficients exhibit the expected sign: RGDP (-), GPOP (-), I (+), IOMAN (-), and IOMAN-SQ (+), and all of them are significant at the 1%. The eleventh regression is run in order to test whether the condition of oil exporter has some effect on economic growth, but the corresponding estimated coefficient is not significant. Our preferred estimation is regression 10, for it exhibits the highest significance levels. Regressions 12 and 13 are run for the 21 higher income countries of the sample excluding oil exporting countries (Norway, Denmark, Iceland, Canada, Sweden, Netherlands, Austria, Germany, France, Finland, Japan, New Zealand, Spain, Argentina, Portugal, Uruguay, Cyprus, Mexico, Costa Rica, Chile and Mauritius). The results confirmed that in this case the relationship between the manufacturing input-output coefficient and economic growth is linear, as in the panel data exercises.

Since the cross-country regressions 7 to 11 yield that economic growth is a significant convex function in the manufacturing input-output coefficient (IOMAN), the minimum IOMAN value is estimated as follows: $-\alpha/(2\beta)$, where α (< 0) is the estimated IOMAN coefficient, and β (> 0) is the estimated $IOMAN^2$ coefficient. The IOMAN threshold estimations fluctuate slightly around the value 64 (See Table 3).

Using the coefficients of regression 10, Table 4 shows the estimated effect on the long-run rate of growth (Δg) from a 1 point increase in the manufacturing input-output coefficient (ΔIOMAN = 1) according to the inherited level of IOMAN:

Table 4
Effect of a Point Increase of IOMAN on the Long-Run Rate of Economic Growth

IOMAN	60	64	70	76
Δg	-2.0	-0.1	2,9	5,8

Source: Own estimations.

A point increase of the manufacturing input-output coefficient –leaving everything else constant– would reduce the long-run rate of growth for a country with a low coefficient (IOMAN < 64); a country like Colombia ($IOMAN_{COL}$ = 64.2), whose IOMAN is close to the minimum, would not find too much effect on growth; but a country like Japan ($IOMAN_{JAP}$ = 70.4) would increase its long-run growth rate in around 3%; and Korea ($IOMAN_{KOR}$ = 76.4) in around 6%. This exercise shows, thus, how strong are the accelerating effects of manufacturing technological integration after surpassing the threshold of industrialization.[1]

As in the panel data econometric exercises, the cross-country regressions reveal that educational attainment [log(EDU)] does not seem to be a good predictor of economic growth once one controls for manufacturing interindustrial linkages (IOMAN). However, as shown by

[1] The exercise in Table 4 assumes that changes in IOMAN reflect changes in manufacturing technological integration; it would be absurd to claim that higher input-output coefficients due to relaxation of cost minimizing behaviour would lead to higher economic growth.

the cross-country regression in Appendix 4, education does seem to depend on some structural factors, like real GDP (RGDP: positive and significant correlation), population growth (GPOP: negative and significant correlation), average investment rate (I: positive and marginally significant correlation), and aggregate input-output coefficient (IO: positive and highly significant correlation). The exercises revealed that the manufacturing input-output coefficient (IOMAN) is not a better predictor of educational attainment than the aggregate input-output coefficient (IO). Thus, as in the panel data exercises, aggregate measures of industrialization –the measure of overall linkages (OL) in the panel data, and the aggregate input-output coefficient (IO) in the cross-country data base– does seem to impinge positively on educational attainment levels.

4. Some Concluding Comments

Regression analyses on a small panel data set and a larger cross-country data set are the basis for the following comments:

1) There exists a nonlinear –quadratic– relationship between industrialization and economic growth. This feature is consistent with the hypothesis that countries enjoy the benefits of industrialization in economic growth after surpassing some threshold of technological integration in the manufacturing sector.

2) The referred relationship becomes linear only for industrial and semi-industrial countries; in this case the econometric exercises capture mainly the dominant positive effect of industrialization on growth for sufficiently high indices of technological integration in the manufacturing sector.

3) The cross-country econometric analyses reveal that technological integration in the manufacturing sector is highly correlated with economic growth, whilst aggregate technological integration is not. This result might imply that the manufacturing sector behaves as a leading sector.

4) The previous features help to explain why rich (industrialized) countries tend to grow faster in the long-run than poorer countries. Corollary: the convergent effect related to initial GDP per capita is overcome by divergent effects related to investment and industrialization.

5) Economic growth is not significantly correlated with educational attainment when one controls for technological integration in the manufacturing sector. Two likely explanations may act together to explain this result: first, measurement error bias due to the exclusion of education quality levels (EDU is a quantitative measure of education in years); second, educational attainment might not be a determinant of economic growth, instead it might be determined by the degree of economic development.

6) The latter hypothesis is not rejected by the available data sets: this paper finds a strong positive correlation between education and the measures of overall linkages (OL in the panel data regressions, IO in the cross-country regressions). If this hypothesis is true, education is revealed as a necessary but not sufficient condition for economic growth. In whatever scenario, education cannot be neglected. It provides many more external benefits than just economic growth; for instance, as seen before, education and life expectancy at birth are highly correlated.

Further analyses are required in order to test the hypothesis of an industrialization threshold for enhancing long-run economic growth. The complex relationship between education and economic growth should also be reviewed. If our hypotheses are confirmed, some policy recommendations would be adequate. First, government economic policies aimed at increasing economic growth should enhance the process of economic diversification and structural transformation. Second, educational policies should go hand-in-hand with industrialization policies so that human capital supply matches human capital demand along the path of development.

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Appendix 1
Unbalanced Panel Data
Nine Countries, Thirty Observations

Country	Year	G10 (%)	OL (%)	DL (%)	RGDP (1985 US$)	EDU (Year)	I10 (%)	GN10 (%)
Colombia	1953	0.80	50.0	37.2	1,760	2.34	21.3	3.05
	1966	3.20	65.4	52.3	2,126	2.77	17.7	2.55
	1970	3.39	69.0	53.9	2,387	2.71	16.6	2.35
Mexico	1950	2.58	54.3	40.5	2,224	1.50	16.4	3.26
	1960	3.53	68.9	51.3	2,870	2.41	18.7	3.19
	1970	3.55	63.9	52.0	4,061	2.45	21.6	3.13
	1975	1.15	69.5	54.2	4,755	3.31	21.4	2.62
Turkey	1963	3.32	52.1	46.4	1,884	2.05	18.9	2.55
	1968	3.78	56.7	51.5	2,181	1.99	22.4	2.34
	1973	1.62	59.6	52.8	2,612	2.72	23.8	2.21
Yugoslavia	1962	5.71	82.2	67.9	1,815	5.06	37.2	0.89
	1966	4.97	79.5	61.9	2,324	4.83	35.4	0.96
	1972	3.78	87.3	59.4	3,126	5.28	36.5	0.97
Japan	1955	8.26	89.9	81.3	1,865	5.84	23.3	0.97
	1960	9.49	94.5	82.7	2,701	6.71	29.5	1.04
	1965	6.62	94.6**a**	82.4	4,125	7.07	33.5	1.27
	1970	3.70	106.3	88.7	6,688	6.80	34.2	1.19
South Korea	1963	7.44	89.9	60.9	1,041	3.23	22.4	2.21
	1970	5.82	89.8	58.7	1,722	4.76	29.3	1.69
	1973	5.22	92.8	54.6	2,133	5.77	29.6	1.58
Taiwan	1956	4.92	76.5	42.6	852	2.51	13.6	3.06
	1961	7.21	85.9	55.0	1,001	3.32	18.4	2.59
	1966	7.48	92.9	55.7	1,377	3.80	24.3	2.09
	1971	6.90	93.7	55.2	2,099	4.39	28.2	1.92
Israel	1958	4.68	83.7	53.8	3,575	6.99	30.3	3.62
	1965	4.73	78.6	50.5	5,280	6.76	28.9	3.03
	1972	1.17	101.5	48.1	7,643	7.65	26.1	2.50
Norway	1953	2.71	66.7	40.8	4,709	4.88	32.7	0.88
	1961	3.61	77.9	47.8	5,673	5.56	33.2	0.78
	1969	4.21	87.2	47.6	7,628	6.55	34.6	0.56

Note (**a**): Using Kubo's estimation (1985), this figure was corrected from Kubo, de Melo, Robinson and Syrquin (1986). **Sources**. **G10**: Equivalent annual growth rate of real gross domestic product per capita during the 10 following years (Summers and Heston, 1991). **RGDP**: Real gross domestic product per capita in 1985 constant prices (Summers and Heston, 1991). **EDU**: Educational Attainment (Barro and Lee, 1993, Data Set for a Panel of 138 Countries, HUMANxx: average schooling years in the total population over age 25). **OL**: Overall linkages, and **DL**: Domestic Linkages (Kubo, Y., J. de Melo, S. Robinson, and M. Syrquin, 1986). **I10**: Average Investment-to-GDP ratio during 10 years (calculated from Summers and Heston, 1991). **GN10**: Equivalent annual growth rate of population during 10 years (calculated from Summers and Heston, 1991).

Appendix 2A
Education Regression from Panel Data

Dependent Variable: **EDU**
Method: Least Squares
Sample: 30
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.212229	0.787968	-1.538425	0.1396
MEX	-0.355881	0.315780	-1.126990	0.2731
TUR	-0.021976	0.303870	-0.072320	0.9431
YUG	1.112144***	0.312100	3.563419	0.0019
JAP	1.832601***	0.492092	3.724102	0.0013
KOR	0.155462	0.778825	0.199611	0.8438
TAI	-0.703573*	0.383256	-1.835778	0.0813
ISR	2.882305***	0.360283	8.000110	0.0000
NOR	2.075020***	0.291506	7.118280	0.0000
OL	**0.062130*** **	**0.011542**	**5.383023**	**0.0000**

R-squared	0.948404	Mean dependent var	4.400333
Adjusted R-squared	0.925185	S.D. dependent var	1.861372
S.E. of regresión	0.509128	Akaike info criterion	1.748968
Sum squared resid.	5.184232	Schwarz criterion	2.216034
Log likelihood	-16.23452	F-statistic	40.84705
Durbin-Watson stat.	1.880405	Prob(F-statistic)	0.000000

Appendix 2B
Education Regression from Panel Data

Dependent Variable: EDU
Method: Least Squares
Sample: 30
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.256147	1.868856	-2.812495	0.0094
RGDP	0.000277***	7.15E-05	3.879813	0.0007
GN10	0.278613	0.378143	0.736791	0.4681
I10	0.123609**	0.045936	2.690877	0.0125
OL	**0.063592*** **	**0.009977**	**6.373753**	**0.0000**

R-squared	0.849559	Mean dependent var	4.400333
Adjusted R-squared	0.825489	S.D. dependent var	1.861372
S.E. of regression	0.777580	Akaike info criterion	2.485751
Sum squared resid	15.11577	Schwarz criterion	2.719284
Log likelihood	-32.28627	F-statistic	35.29457
Durbin-Watson stat	1.238821	Prob(F-statistic)	0.000000

Significance level: * 10%, ** 5%, *** 1%.

Appendix 3
Cross-Country Data Base
Fifty Two Countries

COUNTRY	G	RGDP	GPOP	I	EDU	LIFE	IND	IO	IOMAN
Algeria	0,123842284	5095,49	2,54738	15,57952	1,55	59,28	11,27436	36,12268	60,65188
Argentina	0,403566297	10920,88	1,40455	14,65048	6,62	69,59	25,27867	41,59721	58,39808
Austria	0,904394508	17907,14	0,35026	23,54857	8,42	72,65	29,2156	48,45707	62,95066
Bangladesh	0,741547445	1347,85	1,98161	8,88429	1,68	48,47	9,800526	31,3015	69,11469
Benin	0,141677916	1130,22	3,16948	8,67190	0,65	48,44	5,379944	30,58882	68,37335
Bolivia	0,052563822	3069,9	2,04218	9,10476	4,00	52,24	14,16872	36,43516	64,71951
Botswana	2,124176185	2768,72	2,76544	17,39524	2,29	58,09	6,118571	42,54439	72,81411
Burkina Faso	0,292859241	751,63	0,02867	10,50333	0,78**(a)**	44,01	11,86	34,72	64,13
Burundi	-0,405874666	893,95	1,62694	4,62333	1,23	46,71	12,85013	30,4	60,9
Cape Verde	1,682880276	1929,96	0,01533	15,40190	3,00**(a)**	61,00	4,80	33,33	58,73
Cameroon	-0,761918733	2370,16	2,66124	4,96571	1,73	49,96	10,07828	39,32529	67,81481
Canada	0,687546113	18634,75	1,12917	23,21381	10,23	74,72	19,47591	60,29626	67,80181
Chile	1,676242809	6675,13	1,57158	17,95762	5,96	69,30	21,51048	44,99377	63,51016
Colombia	0,655013924	4828,63	2,02383	12,38333	3,94	65,91	23,2868	41,26383	64,25256
Costa Rica	0,579764248	6990,17	2,422151	8,866190	4,70	72,70	18,59875	54,8545	68,3
Cyprus	2,01127172	8422,27	1,08616	18,15381	6,53	74,60	18,22155	45,02928	67,03731
Denmark	0,826336824	18970,29	0,20725	20,28762	9,16	74,29	19,73832	47,74991	67,52627
Ecuador	-0,242743444	5024,58	2,47682	18,95619	5,40	63,26	17,84806	45,43264	64,78324
El Salvador	0,597711021	3985,98	1,47727	7,37952	3,30	57,10	15,01626	33,29592	60,58287
Fiji	0,300053408	4549,24	1,36710	12,60762	6,01	68,25	11,58798	46,34994	74,70726
Finland	0,525264173	15898,38	0,39975	26,26762	8,33	73,19	27,35022	52,63348	69,25085
France	0,738793174	17437,78	0,47854	22,20857	6,77	74,25	25,47335	45,98747	64,43179
Gambia	-0,212459168	876,86	3,62624	10,30048	0,63	40,18	6,606752	31,21658	72,35856
Germany	0,85928764	17613,58	0,25286	23,48286	8,41	72,63	33,63514	63,5	64,5
Ghana	0,325422081	1141,61	2,89911	5,47238	2,35	53,21	7,7619	26,31165	53,09951
Iceland	0,524266339	18727,74	1,05183	22,28857	7,11	76,63	18,09704	49,49224	69,10832
Jamaica	0,624611576	3705,79	0,87435	14,11381	3,60	70,75	16,1111	55,11065	73,15779
Japan	1,077577808	15520,33	0,42053	31,05476	8,23	76,01	28,19996	51,9	70,4
Jordan	-0,632393996	4458,36	4,27767	16,98095	2,93	64,41	11,86719	38,42105	59,34685
South Korea	2,937687598	4496,54	1,02823	35,46429	6,81	66,84	29,59015	56,66561	76,44427
Kuwait	0,507645743	30059,83	1,84278	14,53095	4,29	70,78	5,559896	24,86793	74,91187
Mauritius	2,022589104	6246,1	1,01489	10,68381	4,50	65,98	19,85702	47,50226	67,83147
Mexico	0,117632851	7271,13	1,94802	17,23476	4,01	66,76	21,93448	36,41993	58,55291
Netherlands	0,887649421	18169,31	0,58401	21,66429	7,99	75,72	18,91155	48,61876	72,6519
New Zealand	0,477318553	15443,76	1,02635	20,27333	11,43	73,20	21,69477	53,64555	64,5888
Nigeria	0,199271033	1002,73	0,02917	5,79095	0,90**(a)**	45,86	1,86	29,82	57,70
Norway	1,183810729	19615,39	0,48661	25,15524	8,28	75,74	17,30906	50,6796	75,2964
Oman	0,996918125	9559,55	0,03917	10,82429	2,73**(a)**	59,81	0,75	26,40	59,79
Peru	-0,463870244	4986,19	2,25444	16,40857	5,44	60,38	20,351	48,03725	67,99704
Portugal	1,334593498	9979,1	0,22980	20,62333	3,27	71,39	30,02382	52,95856	68,41947
Rwanda	-1,042588661	1247,21	1,84295	2,98714	1,13	45,77	15,80967	34,67853	64,83141
Sierra Leona	-1,644439984	1343,22	2,26049	3,28000	0,83	35,34	3,540956	28,4	74
Spain	1,093273137	12048,61	0,40681	22,00571	5,15	75,53	25,67592	48,3	63,1
Sri Lanka	1,653870127	1872,15	1,28592	13,54905	5,18	68,20	18,98982	31,6	43,5
Sudan	0,194648816	1062,64	3,09608	9,93238	0,64	48,17	8,076962	33,22901	60,60697

COUNTRY	G	RGDP	GPOP	I	EDU	LIFE	IND	IO	IOMAN
Swaziland	1,019434926	5526,65	3,07351	10,01000	3,12	51,58	21,65173	55,16831	73,09251
Sweden	0,609630444	18192,37	0,33051	20,27143	9,47	75,86	23,02885	48,63635	66,07289
Syrian Arab Rep.	0,021915355	1900,05	3,14735	8,32286	2,86	61,56	3,559587	38,33954	80,50306
United Arab Emir.	-0,561881143	47628,18	4,40554	20,45952	2,88	68,22	9,121071	25,70338	48,63356
Uruguay	0,956779511	8620,82	0,66551	12,88619	5,75	70,43	24,11038	42,19928	62,56271
Venezuela	-0,240430451	8925,36	2,35919	13,70429	4,93	68,34	15,78816	42,7308	68,29229
Zimbabwe	-0,193177419	3227,86	2,68738	12,42381	2,82	54,89	24,06963	48,75522	63,67754

Sources. **G**: Equivalent annual growth rate of real gross domestic product per capita over 1980-2000 (calculated from Heston, Summers and Aten, 2006). **RGDP**: 1980 real gross domestic product per capita in constant prices; taken from the chain GDP series RGDPCH (Heston, Summers and Aten, 2006). **GPOP**: Average annual growth rate of population during 10 years; population data are taken from the *World Bank World Development Indicators 2001*. **I**: Average investment-to-GDP ratio during ten years; investment and GDP data are in 1996 prices (Heston, Summers and Aten, 2006). **EDU**: Educational Attainment (Barro and Lee, 1993, *Data Set for a Panel of 138 Countries*, variable HUMANxx: average schooling years in the total population over age 25); Note **(a)**: estimated value. **LIFE**: Life expectancy at birth in 1980 (the World Bank´s *Global Development Finance & World Development Indicators*). **IND**: manufacturing sector GDP share in 1980, calculated from the United *Nations´ National Accounts Statistics: Main Aggregates and Detailed Tables*. **IO**: Aggregate input-output coefficient. **IOMAN**: Manufacturing sector input-output coefficient. The last two variables are estimated at constant prices ─ whenever possible─ from the United Nations´ *National Accounts Statistics: Main Aggregates and Detailed Tables*.

Appendix 4
Cross-Country Education Regression

Dependent Variable: EDU
Method: Least Squares
Sample: 52
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.902154	1.103255	-1.724129	0.0913
RGDP	0.000101***	3.57E-05	2.822693	0.0070
GPOP	-0.553746***	0.205551	-2.693962	0.0098
I	0.081329**	0.035959	2.261753	0.0284
IO	**0.124880*** **	**0.029863**	**4.181810**	**0.0001**

R-squared	0.748446	Mean dependent var	4.614423
Adjusted R-squared	0.727037	S.D. dependent var	2.836534
S.E. of regresión	1.481972	Akaike info criterion	3.715836
Sum squared resid	103.2233	Schwarz criterion	3.903456
Log likelihood	-91.61174	F-statistic	34.95958
Durbin-Watson stat	2.020578	Prob(F-statistic)	0.000000

Significance level: * 10%, ** 5%, *** 1%.