Innovation, growth and economic development: have the conditions for catch-up changed?

By

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Abstract: This paper shows that there have been important changes in how the global economic system works. A high growth regime has gradually been substituted by one of low growth. This change appears to be especially pronounced for small economies. Until the end of the 1980s the scope for technological imitation was a significant factor in generating growth in low-income countries, but this did not extend to the 1990s. The results reported in this paper suggest that, during the 1990s, whether low-income countries managed to catch up or fall behind depended mainly on their ability to develop their "innovation system".

Key words: innovation, growth, economic development, catch-up

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1. Introduction

Why do some countries succeed in catching up with the developed countries, while others fall behind? This is one of the classic questions in comparative growth research (Gerschenkron, 1962; Abramovitz, 1986; Shin, 1996). Moreover, it is a question that does not seem to resolve easily. In fact, it continues to attract the attention of a large number of researchers from different theoretical strands and traditions.

What is it with this issue that makes it so central on the research agenda today? Apart from the obvious importance of the issue from a developing country point of view, this has to do with two important changes that have occurred during the last decades. The first change has to do with how the "stylised facts" of global development are perceived by researchers. Until the late 1980s, it was commonly assumed that the global economy was on a converging path, with poor countries catching up with the rich ones, although at different speeds, reflecting differences in efforts, capabilities and initial conditions. From the 1990s onwards, however, it became increasingly clear that this tendency towards convergence was not a global phenomenon (De Long, 1988; Baumol et al., 1989). Although it seemed to hold for the developed economies, perhaps extending to some so-called "newly industrializing countries" (NICs) in the post-second-world-war period, it did not necessarily apply for longer time spans and a wider set of countries. This was, at the time, interpreted as inconsistent with the then dominating economic perspective on growth, the so-called "neoclassical growth theory" put forward by Solow (1956), for which he received the Nobel Prize in economics. A search for new ways of understanding growth followed, and out of this emerged new perspectives on economic growth, which put technology and innovation, rather than capital accumulation, at the front (Fagerberg 1987, Romer 1990, Aghion and Howitt 1992). Increasingly, the ability of a poor country to catch up with the rich was seen not only – or mainly – as a reflection of its ability to generate (or attract) sufficient investments, but also of its capacity to absorb existing and generate new technologies (e.g. innovate).

Although the link between catch-up and innovation-diffusion is well supported by contemporary theorizing in economics, historical analyses and case studies (for an overview see Fagerberg and Godinho, 2004), econometric work on the subject has been slow in catching up with the changes in the theoretical agenda. However, the econometric work that exists confirms the increasing importance of innovation for successful catch-up (Fagerberg and Verspagen, 2002). It also calls into doubts catch-up strategies that are based solely on imitating the more advanced technologies of the advanced world. The prospect for drawing general conclusions from these observations, however, is hampered by the fact that econometric studies in this area have either been confined to a relatively limited sample of countries, focusing mostly on already developed economies and relatively advanced "newly industrializing countries", or have totally ignored the role that innovation and diffusion may play (for overviews of empirical work in this area, see Fagerberg, 1994, 2000 and Temple, 1999).

This paper attempts to transcend these limitations of the existing literature by linking data on the growth processes in a broad sample of countries to data on factors deemed to be important for innovation and diffusion of technology and its economic and social exploitation. We start by reviewing some "stylised facts" of global economic growth from the early 1960s to date with particular emphasis on the degree of convergence and the possibility of a trend-break in the way the global economy works. Then we proceed to a cluster analysis that allows us to distinguish between groups of countries with different performance, capabilities and characteristics. Finally we explore the main factors explaining economic growth in our broad cross-country sample, aiming to provide insight into which factors determine whether a developing country belongs to those who catch up (or alternatively the laggards), and the extent to which these causal factors that determine the fate of countries' growth performance have changed through time. The final section discusses the possible lessons from this exercise and the implications for the future research agenda.

2. Growth dynamics in the post-war global economy

For the purpose of this study we have collected data for a large number of countries at different level of development from the early 1960s onwards. The source of all data (also the ones used in subsequent sections of the paper, except where indicated otherwise) is the World Bank's World Development Indicators on CD-rom (various editions).[1]On average, for the sample of 96 countries that will be used throughout this section, the level of GDP per capita tripled between 1960 and 2000. In 1960, the richest country (Switzerland) was 45 times as rich as the poorest one (Malawi). Forty years later, in 2000, the richest country was Luxemburg, the poorest Sierra Leone, and the ratio of their per capita GDP levels had increased to 67.

Figure 1. GDP per capita (level and dispersion) in the global post-war economy

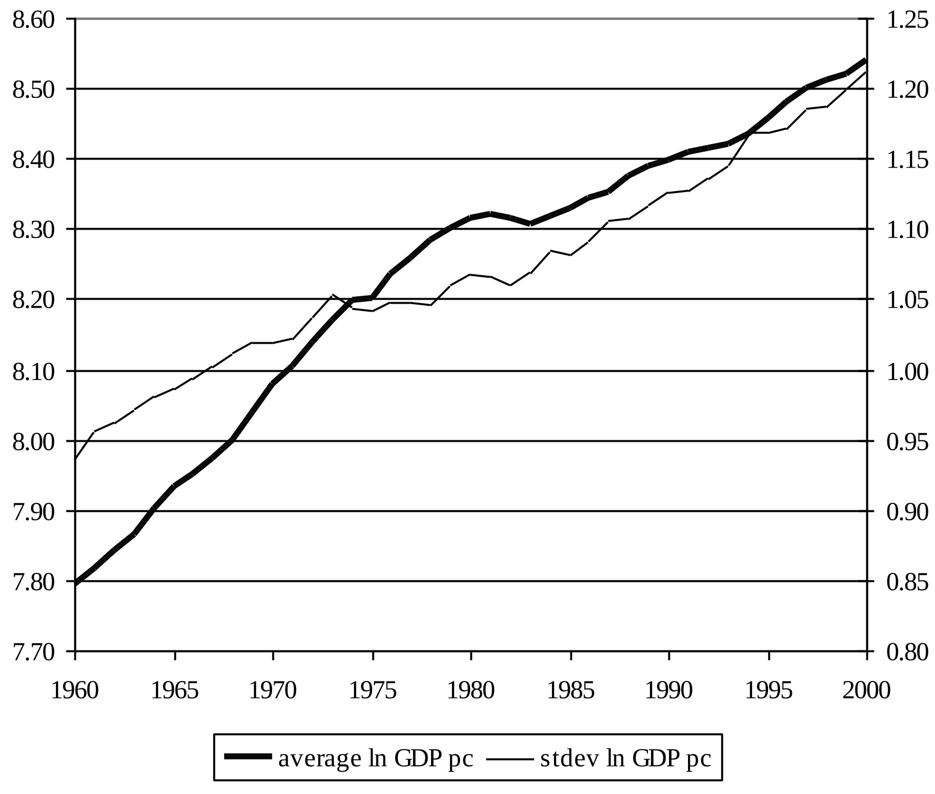
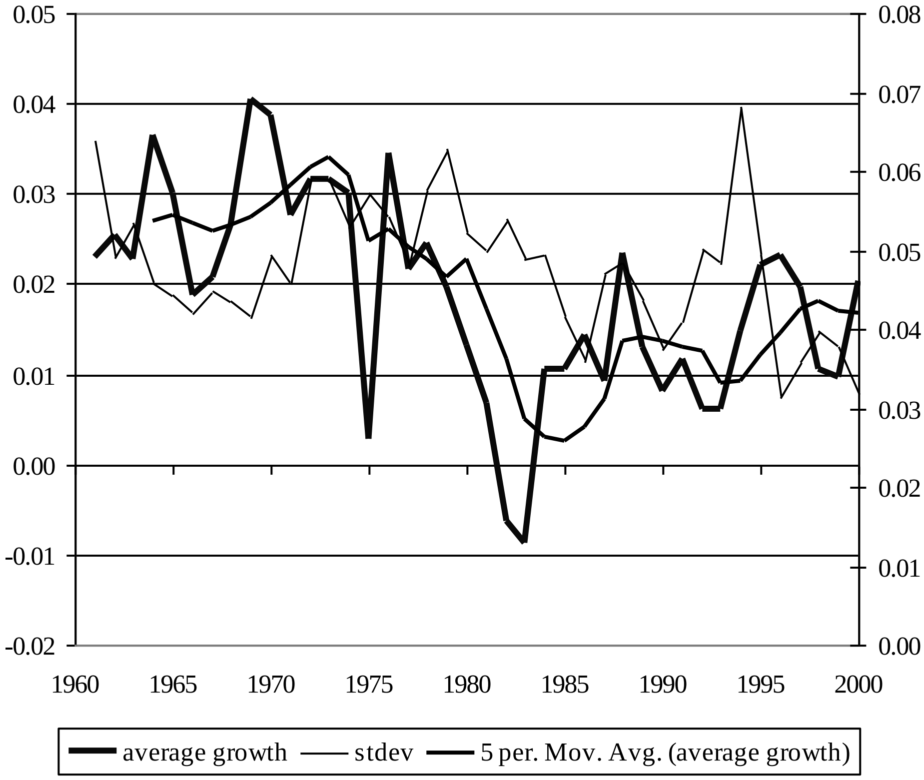


Figure 1 shows the increase in the (unweighted) average of the natural logarithm of GDP per capita (in 1995 international $ PPPs, as indicated before) for the 96 countries (thick line, left axis). A straight line would indicate a fixed growth rate. Over the total period, two separate regimes seem to emerge, each roughly corresponding to half of the period, i.e., 1960 – 1980 and 1980 – 2000. In the first period, growth is relatively rapid (a steep line), after 1980 the rate slows down.

The thin line in Figure 1 shows the standard deviation of the logarithm of GDP per capita in the sample (right axis), which is an indicator for the disparity of income levels. Over the whole period, we see a steady rise in this indicator, which means that per capita income differentials are growing over time.

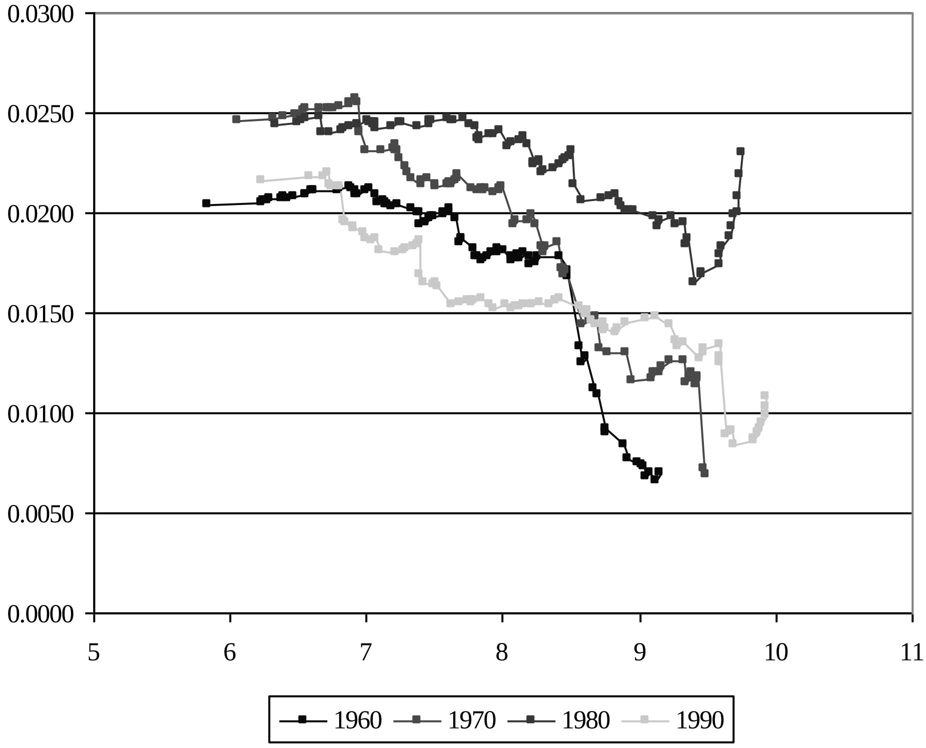
Figure 2. Growth rates in the post-war global economy



The slowdown in economic growth, which is also well documented elsewhere (e.g., Maddison 1995), is apparent from Figure 2 as well. The figure shows, for the same sample of countries, the average yearly growth rates of GDP per capita (the thick line). Until the early/mid 1970s, the average growth rate fluctuates around a constant level in the range of 2-3% per year. During the decade that follows the growth rate slows down markedly, and eventually settles at a level that is roughly half of what it was in the 1960s. The dispersion of the growth rates over countries (the thin line in Figure 2) also slows down (but less than the growth rate itself).

In Figure 3, we plot the dispersion of 10-year growth rates of GDP per capita for four different decades, against the level of GDP per capita. For each decade we start out with the dispersion of GDP per capita for the entire sample (observations to the far left in the graph). As we move from left (low levels of GDP per capita) to right (high levels of GDP per capita) along the dispersion curve, observations for the poorest countries are eliminated one by one, thus calculating the dispersion indicator for an ever smaller and comparatively richer subset of countries. However, we (arbitrarily) stop to calculate the level of dispersion when there are only 10 countries left. Hence, for each decade the point to the far right of the dispersion curve gives the level of dispersion for the 10 richest countries of the sample.

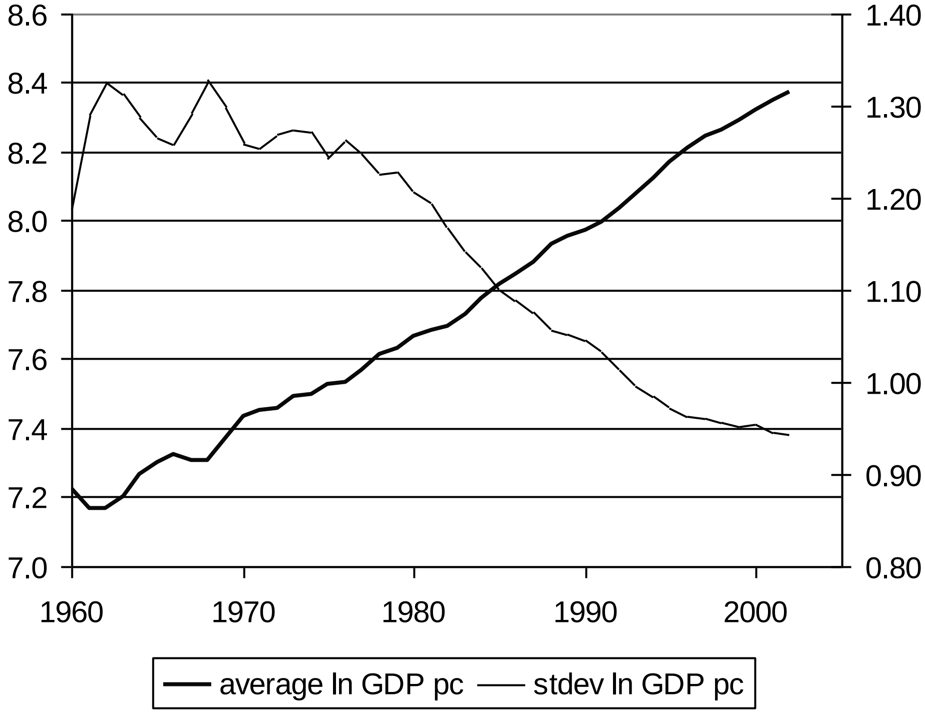
Figure 3. Changes in dispersion in the post-war global economy



The dispersion curves tend to be relatively flat to the left, indicating that the level of dispersion of GDP per capita growth is not much affected by the elimination a few poor countries. However, as more and more poor countries are eliminated, and the sample becomes increasingly homogenous, the dispersion of GDP per capita growth tends to decline (differences in growth becomes smaller). This tendency towards 'convergence' in GDP per capita growth rates as countries become richer, weakens over time, though, as is shown by the fact that the curves become flatter for later periods. For the most recent decades, there are clear signs of increasing differences in growth among the richest countries, with some countries forging ahead of others (this is reflected in the upward bending part of the curve to the far right in the graph). The latter finding is consistent with the results in Fagerberg and Verspagen (2002), who found that some countries, notably the USA and the UK, seemed to experience a change in trend growth in the positive direction. Hence there are clear signs of changes in the way global capitalism works. A high growth regime (before 1980) has been replaced by a low growth regime. Among the poorer economies, however, there continue to be marked differences in growth performance. Growth also tends to be less similar among the high-income countries, with some countries forging ahead of others.

It should be noted that the investigation so far have looked solely at the performance of countries. This is not the same as the performance of people since countries are very different in terms of population. The great majority of the countries of the world are small while a few are very large (with China and India as the most extreme examples). Hence it is theoretically possible that increasing differences in GDP per capita over time across countries, as has been shown to be the case here, could coincide with decreasing differences (or "convergence") in the income levels of people across the globe. This could happen if there is a general tendency for large countries to perform better economically than small countries. But it may also take place if one or a few very larger countries have a growth pattern different from the rest of the globe. One way to test for this is to give more emphasis to the evidence from populous countries when calculating the mean and dispersion of GDP per capita across the globe. This is done in Figure 4 which reports population-weighted mean and dispersion of GDP per capita from 1960 onwards.

Figure 4. Population-weighted GDP per capita (level and dispersion)



This clearly gives a different picture than the one presented in Figure 1. First of all there is no clear trend break in GDP per capita, indicating that the slow down in economic growth, found also by many other studies, may have been more apparent in small than in large economies. Second, and even more striking, the dispersion of GDP per capita is decreasing over time, e.g., not increasing as in Figure 1. In this case there is sign of a trend-break, though, since the calculated level of dispersion is essentially constant (although fluctuating) between the mid 1960s and late 1970s after which it starts to decrease.

What can we learn from this rather contradictory evidence? It is important to emphasize that the calculation presented in Figure 2 is no proof of global convergence at the level of regions, local communities or individuals. The reason for this is that changes over time in aggregated GDP per capita statistics for very populous countries such as China or India could mask very divergent patterns of development within these countries. Something like this was for instance shown to have taken place across regions within individual European Union member countries (Fagerberg and Verspagen, 1996). But the results clearly indicate that country size, as measured through population, may be an important factor in development, and that there may have been import changes in this respect in recent decades. This is something we will come back to later in this paper when analyse what the causal factors behind success (or lack of such) in growth and development are and the extent to which this has changed over time. However, to analyse this issue we need a framework that allows us to analyse a wide set of factors simultaneously, which is what we aim to develop in the next section.

3. Why growth differs

Why do some low-income countries succeed in catching up, while others fall behind? This is the question that we will try to explore in the following. Economic analyses of differences in growth across countries have mostly been based on one of two perspectives. The first, based on the traditional neo-classical theory of economic growth (Solow, 1956), starts from the assumption that technology is a public good (available free of charge). This perspective puts the emphasis on capital accumulation as the main vehicle for reducing differences in productivity across countries or regions. Moreover, this is normally assumed to happen more or less automatically, as long as markets are allowed to work freely.[2] The other, competing, perspective puts the main emphasis on innovation and diffusion of technology as the driving force behind differences in growth (Nelson and Phelps, 1966; Fagerberg 1987; Barro and Sala-i-Martin, 1995). The latter perspective is based on a totally different view on technology than the former, emphasizing its public as well as private character, and the complementarities with other factors that take part in the growth process. This leads to the hypothesis that without the ability to develop such complementary factors, countries or regions are likely to fall behind rather than catch up.

We have in previous work analyzed differences in growth performance with the help of a so-called "technology-gap approach", based on the second of the two perspectives outlined above (Fagerberg, 1987, 1988; Verspagen, 1991). In this approach economic growth is analysed as the outcome of three sets of factors:

- The potential for exploiting knowledge developed elsewhere (diffusion),
- Creation of new knowledge in the country (innovation), and
- Complementary factors affecting the ability to exploit the potential entailed by knowledge independently of where it is created.

The approach, based essentially on Schumpeterian thinking, is consistent with much existing knowledge on innovation and diffusion processes. Many of the assumptions and derived predictions can also be made consistent with "new growth theories" that focus on innovation-diffusion as the driving force of capitalist development (Romer, 1990; Grossman and Helpman, 1991). Empirical work on cross-country samples based on this perspective has confirmed the importance of national technological capabilities (and other supporting factors) for successful catch up (for overviews, see Fagerberg, 1994, 2002a).

3.1. Global "growth clubs"

As a first step in analysing high variability in growth performance that was illustrated in the previous section, we apply a cluster analysis on the data for growth over the 1960 – 2000 period, with two of the three factors mentioned above as variables.[3] One of the variables we use in the cluster analysis is the (initial) log of GDP per capita. This variable is commonly used as an indicator of the potential for catch-up based growth (the lower the initial income, the higher the catch-up potential is). In addition, as an indicator of the role of innovation in growth, we include the number of patents granted in the US to applicants from a specific country, divided by the country's population.[4] Because patents in the US market are subject to a (worldwide) novelty requirement, it seems reasonable to take this as an indicator of the country's contribution to the world technological frontier. The patenting data are taken from the US Patent and Trademark Office (population again from the World Bank). Finally, we include GDP per capita growth over a 10-year period, as a measure of economic performance.

In the analysis we divide the period 1960-2000 into four decades, beginning in 1960, 1970, 1980 and 1990, respectively. Growth is always measured over a 10-year period (1960-70, 1970-80, 1980-90, 1990-2000), the other two variables at the beginning of the period (except patenting in 1960, which is not available, and we substitute this with the value for 1963). We standardize all variables (i.e., subtract the mean and divide by the standard deviation) in order to make the clustering results invariant to differences in scales between the variables. The clustering method used is the so-called K-means clustering in SPSS (also known as 'quick clustering'). The number of clusters was initially (and arbitrarily) fixed to three, but with this fix we obtained always one or two very small clusters (one or two countries), something that, on inspection of the data, was obviously due to large outliers (e.g., a country having extremely low growth rates due to war or some other catastrophic event). Thus, we increased the number of clusters to accommodate these outliers, until we arrived at a result where there are three clusters that each contains a 'substantial' number of countries, plus one or two 'clusters' containing only a single country. We exclude these single-country clusters from the documentation and interpretation of the results.

Table 1 sum up the results of the cluster analysis. We obtained three relatively large clusters, with between 19 and 49 countries each, and, for the final period only, an additional small cluster with 5 countries. Over time we find the following invariant pattern. There is one, or in the last decade, two high-income cluster(s), for which patenting is high, and growth intermediate. There are two low-income clusters, both characterized by little (or almost zero) patenting, but with marked differences in growth performance between them. One of these low-income clusters displays high growth rates (in fact, higher than the high-income cluster), and one cluster that displays low growth rates (lower than the high-income cluster).

Table 1. Global growth-clubs

	Variable	Low income, low growth		Low income, high growth		High income, inter-mediate growth		Total sample		N Not classified	Front-runners (only 1990s)	
		Mean	N	Mean	N	Mean	N	Mean	N		Mean	N
1960s	Growth rate	0.013	43	0.059	19	0.031	32	0.028	96	2		
	Initial GDP	7.072		7.716		8.701		7.795				
	Patenting	0.068		0.570		8.011		6.082				
1970s	Growth rate	-0.001	30	0.047	33	0.023	40	0.023	105	2		
	Initial GDP	7.297		7.580		9.183		8.153				
	Patenting	0.195		0.178		12.110		8.601				
1980s	Growth rate	-0.011	49	0.032	22	0.023	32	0.009	105	2		
	Initial GDP	8.016		7.380		9.541		8.385				
	Patenting	0.196		0.037		22.242		10.352				
1990s	Growth rate	-0.011	31	0.028	33	0.020	35	0.012	105	1	0.012	5
	Initial GDP	7.652		7.776		9.605		8.473			10.067	
	Patenting	0.069		0.069		19.269		13.369			144.985	

We also examined the composition of the three clusters over time. The high-income, intermediate-growth cluster is clearly the most stable one, with 23 countries staying in this group in all four periods (and a number of others belonging to this group in three out of the four decades studied).[5] However, some Latin American and Arab countries that initially were in this cluster, did not manage to hold on, and slipped down into the low-growth clusters. On the other hand, the countries of the high-income cluster were joined by a number of other countries that at different points in time moved up from the low-income clusters. These were the countries that were most successful in catching up. The group includes, among others, European countries such as Greece, Portugal and Spain, and Asian countries such as Hong Kong, Japan, Korea and Singapore. There was considerably less stability among the poorer economies, with many shifting between the low and high growth clusters at least once. However, it was possible to identify a group of 12 persistent slow-growers, consisting mainly of African economies. These, evidently, are examples of countries falling behind.

The clustering analysis clearly brings out the roles of the potential for catch-up and innovation for economic growth. The low-income, high-growth cluster consists of countries that have been able to benefit from catching-up. For them, low initial income indeed points to a high catch-up potential. For the low-income, low-growth cluster, catch-up potential has not materialized, something that, in our interpretation, would be associated with a low capability to assimilate knowledge from the richer countries. Finally, the high-income, intermediate growth cluster is the group for which innovation-based growth is indeed taking place, and the results show is consistent with sustained growth, although at a lower rate than the countries that are catching-up. Arguably, the crucial question coming out of this (and the one to which we now turn) is what determines to which of the two low-income groups a less-developed country belongs, and how this can be influenced by policy.

3.2. Explaining differences in growth performance

What we will do in the following is to analyze the differences in growth performance between the countries in our sample with the help of regression analysis inspired by the technology gap perspective. For the potential to exploit knowledge developed elsewhere (diffusion) we use, as before in the cluster analysis, the initial level of GDP per capita in the region (log-form). The higher this level, the smaller the scope for imitating more advanced technologies developed elsewhere. Hence, the expected impact of this variable is negative. To this we add a number of other variables that reflect technological, economic and institutional factors deemed to be of relevance for the ability of a country to exploit existing and develop and implement new, economically valuable knowledge. Since many of the available indicators reflect aspects of more complex factors, these indicators are likely to be correlated. We therefore carried out a factor-analysis with the aim of reducing our many variables into a smaller number of dimensions.[6] The method used for extracting is the principal components method. The number of factors (components) is determined endogenously on the basis of eigenvalues.

The following variables were, for the 1970s, 1980s and 1990s, included in the factor analysis:

- The birth rate (number of births per 1000 people)
- CO_2 emissions (kg per 1995 US$ of GDP)
- Openness (exports and imports as a % of GDP)
- Population density (people per square km)
- Enrolment in primary education (gross, % of age group enrolled)
- Enrolment in secondary education (gross, % of age group enrolled)
- Share of agriculture in GDP (%)
- Share of industry in GDP (%)
- Share of services in GDP (%)
- Agriculture yield (kg cereal per hectare)
- Patenting per head of population (as measured before)

All variables are measured at the beginning of the decade, but sometimes we use different years when data are unavailable for the preferred year. In this way, we always identify three factors:[7]

The first factor, which we label “development”, has high (negative) loading on the birth rate, high (negative) loading on the share of agriculture in GDP, high (positive) loading on agricultural yield, high (positive) loading on primary and secondary education enrolment and high (positive) loading on patenting. A second factor, dubbed “industrialisation”, loads high (positive) on the share of industry in GDP and also on its consequence, CO_2 – emissions. The third factor, which is a mixture of various effects, loads high (positive) on population density and openness, hence we label this factor “openness/urbanization”.

Consistent with the technology gap approach, we include these three factors, together with initial GDP per capita, in a regression on GDP per capita growth.[8] To test for the possible impact of country size we also include the size of population (in log-form). Since it cannot be excluded that the impact of the latter depends on a few extremely large countries we also included dummy-variables for China and India, and we check for influential observations (outliers, in all variables) using the so-called hat-matrix. The results from the regression analysis are reported in Table 2. For each time period, we first present results for the complete sample and all variables included. We then identify influential observations (outliers), and exclude them from the sample. We then excluded the non-significant (10% cut-off) variables, one-by-one, starting with the least significant one. The end result of this procedure is presented as the second equation. We repeat this procedure for the low-income countries in each period.

Generally speaking, the factors that matter for growth do not change much between the 1970s and 1980s. In both periods the most significant factors behind growth and development were the scope for imitation of more developed countries, measured through (log of) GDP per capita, and “absorptive capacity” as reflected in the “development” and “openness/urbanization” variables. Among the latter, the “development” factor was clearly the most significant, particularly for the low-income countries. This is also reflected in a much higher numerical estimate for the “development” variable among low-income countries than for the sample as whole. These results conform to the expectations that can be derived from a “technology-gap approach”. There is also some indication of more populous countries doing somewhat better than their smaller counterparts, but the impact is more apparent for the sample as a whole than for low-income countries.

However, what clearly changes through time is the role of China and India in global growth. In the 1970s China’s estimated growth did not deviate significantly from what the predictions. India, on the other hand, was clearly a special case (unusually slow growth). But during the 1980s China starts to grow significantly faster than what the model would predict (around 5 % above expectations) while India’s performance becomes more in line with (slightly better than) the predictions. These tendencies continue in the 1990s, with both China and India growing significantly faster than expected (seven and two percent above expectations, respectively).

Hence, mega-countries such as China and India are clearly special cases, and this is also confirmed by the test for outliers. But the results for the 1990s are different from those of previous decades in other respects as well. The most important difference is that the scope for imitation, while very important in the 1970s and 1980s, totally fails to appear as a significant explanatory factor behind differences in growth in the 1990s. The same holds in fact for one of the other significant explanatory factor from the previous decades, the “openness/urbanization” variable. However, the “development” factor continues to be important. Population size is also a significant and positive factor behind economic growth in the 1990s, and the same holds for the “industrialization” factor (that previously was totally insignificant). Hence the results may be interpreted as lending support to the assertion that the conditions for catch up have changed.

Table 2: Why growth rates differ

	Initial GDP	Population	Factor 1: "Development"	Factor 2: "Industria-lization"	Factor 3: "Openness/ Urbanization"	DCHN	DIND	$\overline{R}^2$	N
1970s Total	0.015 (2.31) **	0.007 (2.96) ***	0.015 (2.57) **	0.004 (0.80)	0.014 (3.72) ***	-0.034 (1.24)	0.042 (4.59) ***	0.26	78
	0.012 (2.63) **	0.005 (2.35) **	0.015 (2.99) ***		0.009 (2.54) **	---	---	0.17	71
Low Income	0.015 (2.39) **	0.006 (1.68) *	0.031 (3.01) ***	0.000 (0.03)	0.013 (1.97) *	-0.007 (0.20)	0.036 (3.43) ***	0.34	51
	0.015 (2.40) **		0.042 (6.21) ***			---	---	0.32	48
1980s Total	0.016 (3.89) ***	0.005 (2.41) **	0.021 (5.43) ***	-0.004 (1.69) *	0.010 (5.63) ***	0.053 (3.27) ***	0.015 (1.67) *	0.38	83
	0.014 (2.92) ***	0.004 (1.93) *	0.020 (4.45) ***		0.009 (2.09) **	---	---	0.21	79
Low Income	0.018 (4.27) ***	0.005 (2.03) **	0.022 (3.70) ***	-0.005 (1.21)	0.010 (1.26)	0.049 (1.98) *	0.011 (0.95)	0.32	62
	0.021 (3.46) ***		0.027 (3.34) ***			---	---	0.13	59
1990s Total	0.004 (0.59)	0.001 (0.53)	0.013 (1.76) *	0.005 (1.09)	0.002 (0.91)	0.064 (5.75) ***	0.024 (3.96) ***	0.31	90
		0.004 (2.80) ***	0.009 (4.52) ***	0.015 (4.00) ***		---	---	0.28	86
Low Income	0.006 (0.73)	0.005 (2.44) **	0.008 (1.03)	0.018 (2.78) ***	-0.003 (1.18)	0.076 (7.18) ***	0.017 (2.56) **	0.40	59
		0.005 (2.29) **	0.012 (2.43) **	0.017 (2.62) **		---	---	0.26	56

Note: Absolute t-statistics (based on heteroskedasticity consistent standard errors) in brackets. One, two and three stars indicate significance at the 10, 5 and 1% level respectively. Estimated by OLS. "---" for a dummy variable indicates that the country is not in the sample.

These results, while suggestive, give rise to a number of new questions, which we will discuss in a bit more detail in the next section. However, before doing so it might be appropriate to ask how sensitive the above findings are with respect to how the variables included are defined. In order to test for the sensitivity of the above analysis for inclusion of other types of data/indicators, we exploit the fact hat more variables are available for the 1990s than for earlier decades. The additional variables that we were able to take into account were:

- Foreign Direct Investment (inward, % of GDP)
- Investment (gross fixed capital formation, % of GDP)
- Number of papers in scientific and technical journals, divided by population
- Enrollment in tertiary education (gross, % of age group enrolled)

We repeated the factor analysis for the 1990s including these variables (as well as all variables from the previous factor analysis). The factor analysis on this larger data-set (1990s) generated four factors (see appendix). The broad interpretations are in line with the results based on the smaller dataset considered previously (but with some modifications). The first factor ("development") had, as before, a high (negative) loading on the birth rate, a high (negative) loading on the share of agriculture in GDP, a high (positive) loading on the share of services in GDP, a high (positive) loading on agricultural yield, a high (positive) loading on all three levels of educational enrolment, a high (positive) loading on patenting, and a high (positive) loading on scientific and technical publications. The second factor ("industrialization") loads high and positive on CO_2 emissions, the investment rate, primary education and the share of manufacturing in GDP, and high and negative on the share of agriculture. Thus, this factor, although still related to "industrialization", takes on a somewhat broader meaning than previously. The third factor of the previous analysis is now split into two. The first of these ("openness") loads high (and positive) on openness in terms of trade as well as FDI, while the second of these ("urbanization") loads high (and positive) on population density. This allows us to test for the two different dimensions of the "openness/urbanization" factor separately. The results are reported in Table 3.

Table 3. A closer look at the 1990s

	Inititial GDP	Population	Factor 1: Development	Factor 2: Industrial -ization	Factor 3: Openness	Factor 4: Urban-ization	DCHN	DIND	$\overline{R^2}$	N
Total	-0.001 (0.09)	0.001 (0.66)	0.007 (1.20)	0.005 (1.34)	0.003 (1.39)	0.008 (4.37) ***	0.066 (6.36) ***	0.020 (3.88) ***	0.38	83
			0.006 (3.80) ***	0.006 (2.20) **		0.008 (3.66) ***	---	---	0.26	79
Low Income	0.003 (0.39)	0.002 (0.95)	0.014 (1.63)	0.003 (0.71)	0.004 (1.19)	0.010 (4.23) ***	0.072 (6.73) ***	0.016 (2.49) ***	0.44	55
		0.004 (2.07) **	0.019 (3.29) ***		0.010 (2.30) **	0.011 (2.06) **	---	---	0.27	50

Note: Absolute t-statistics (based on heteroskedasticity consistent standard errors) in brackets. One, two and three stars indicate significance at the 10, 5 and 1% level respectively. Estimated by OLS. "---" for a dummy variable indicates that the country is not in the sample.

Interestingly, when the regression analysis is repeated with these new factors included, the new, a clearer distinction emerges between the dynamics in the total sample and the sample consisting of low-income countries only. For the total sample there appears to be three significant factors behind growth: “development”, “industrialization” and “urbanization”. This is in line with the previous result with the exception that new “urbanization” variable (population density) replaces “population size” as a significant conducive factor for growth. In the case of low-income economies four significant variables were found: “population size”, “development”, “openness” and “urbanization”. Again there is broad resemblance with the previous results with the exception that this time both aspects of the previous “openness/urbanization” prove to be significant factors behind growth (at the expense of the “industrialization” factor). Hence, although there are some differences in results for individual variables/samples, the finding that the conditions for catch up have changed receive broad support. It is also noteworthy that (as in most of the previously reported regressions) the numerical impact of the “development” factor is much higher for developing countries than for the sample as a whole, emphasizing the importance of “absorptive capacity” for development.

4. Concluding remarks and issues for further research

This paper has shown that there have been important changes in how the global economic system works. Starting a quarter of a century ago, a high growth regime was gradually substituted by a regime characterized by relatively low growth (about one half of what was normal previously). This change appears to have been especially pronounced for small economies (which constitute the big majority of the countries in the world today). As shown in this paper this new growth regime gradually became characterized by much more stringent conditions for catch up. While, until the end of the 1980s, the scope for technological imitation was, conditional on other complementary factors, a significant factor in generating growth in countries below the technology frontier, this does not appear to be the case to the same extent in the 1990s.

The paper, albeit providing ample evidence of a change in the conditions for catch up, also raises new questions that deserve to be researched in more depth than what has been possible here. The probably most important one is why this shift has occurred. Is it caused by technological factors, for instance by the electronics revolution (Freeman and Louca, 2001), displacing earlier mechanical technologies (and reducing the value of capabilities associated with these older technologies)? Or does it primarily have to do with the mass investments in R&D infrastructure and education that have occurred in the rich part of the world in recent decades, and that many poor countries have found it hard to replicate (Fagerberg and Godinho, 2004)? Another possible explanation might be the increasing role played by global production networks organized by multinational enterprises and the ability of the latter to put their hands on most of the economic rents accruing from this division of labour (Shrolec, 2005)? Political and institutional changes that make it more difficult for developing countries to exploit foreign (and indigenous) technology to their own benefit may also play a role (Chang, 2002).

The results reported in this paper indicate that there are signs of divergence occurring among the developed economies, with some experiencing much higher growth than others. Moreover, such tendencies towards divergence are even more characteristic for the low-income countries. In the 1990s in particular, the scope for imitation does not appear to have any explanatory power whatsoever for how well a low-income country performs. The results reported in this paper strongly suggest that whether low-income country manages to catch up or – alternatively – falls behind to an increasing extent depends on its ability to develop its own “innovation system”. Other factors related to a country’s economic structure, integration in international markets and the size of character of the domestic market are almost certainly also relevant but the available evidence indicates that it is in many cases difficult to distinguish one effect (or chain of causation) from another. This relates, for instance, to the much-heralded issue of the role of “openness”, which is often pointed to as an important mechanism for small countries, but for which at least some recent research on the subject find little support.[9] The results reported in this paper also provide mixed evidence on the subject. However, may be what matters is not so much openness to trade or capital flows, but openness to ideas? Admittedly this is something for which paper has no good measure (and further research is clearly needed).

Another intriguing question that requires more theoretical and empirical research has to do with the role of population size (and density) in economic growth. As is well known some economic theoreticians have suggested that all other things being equal, more populous countries tend to do better than their smaller counterparts (see, for instance, Grossman and Helpman 1991). The argument has been that larger knowledge bases - and larger markets for new technologies based on such knowledge – give rise to favourable scale-effects in large economies. Such positive effects may arguably be enforced by higher population density (lower transaction costs). These suggestions rest, though, on very crude assumptions on how knowledge flows and country boarders interact, which need to be justified. The findings presented in this paper clearly illustrate the need for further research in this area. Is the rapid Chinese growth in recent decades a special case, or does it open up avenues for other large, developing countries? In the latter case, what are the options available for small, low-income countries (which after all constitute the bulk of developing countries)?

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Notes

[1] Specifically with regard to the data used in the current Section, we use the time series for GDP per capita in constant 1995 US$, which we convert to Purchasing Power Parities (PPP, in 1995 international $) using the 1995 observation from the series of GDP per capita in current PPP.

[2] Note, however, that a recent influential contribution by Sachs et al. (2004), which shares the Solowian emphasis on capital accumulation and neglect of knowledge, technology and innovation, holds that capital accumulation will only raise to the level necessary for catch up if massive intervention and support is allowed for (a low growth trap). Whatever the merits of this view, analysing development without taking knowledge, technology and innovation properly into account, provides in our view an extremely shaky ground for sweeping policy conclusions (of the type made by Sachs et al.). For a good assessment an overview of the role of factor accumulation in economic growth, see also Easterly, and Levine (2001).

[3] The “complementary factors” are a much too complex group of variables to introduce at this stage. We come back to this later.

[4] Of course, not all innovations are patented, so this a partial measure at best. Also there are big differences across sectors in the propensity to patent. However, at the aggregate (country) level, patent-based indicators of innovation correlate well with other available measures such as R&D (the availability of which is much more restricted, though, especially in a long run perspective). See Fagerberg (1987) and Smith (2004) for an extended discussion.

[5] In terms of this ’mobility analysis’ we considered the frontrunners group in the last period as belonging to the high-income, intermediate growth cluster.

[6] Our attempt to use factor analysis to measure capabilities important for development follows in the footsteps of the pioneering contributions by Adelman and Morris (1965, 1967). See also Temple and Johnson (1998) for a more recent application of the method.

[7] In the discussion of the factor loadings, ”high” indicates a high absolute value, i.e., ”high (negative)” points to a strongly negative value, and ”high (positive)” points to a strongly positive value.

[8] In recent years, a sizeable empirical literature has also emerged trying to expand the type of regression analysis presented here by pushing the search for explanatory factors far back in time (Acemoglu, Johnson and Robinson 2001,2002), or by taking into account other types of exogenous factors such as climate, geography, ethnic diversity etc. (Sachs et al. 2004, Masters and MacMillan 2001, Bloom et al. 2003, Alesina et al. 2003). However, it might be noted that in general there is conflicting evidence and interpretation about the impact of history, geography and nature on growth (Glaeser et al. (2004). One reason for this may be that variables reflecting different causes sometimes are so strongly correlated that little can be said with certainty apart from, perhaps, that there is a joint impact (Alesina et al. 2003, p. 183). Another possibility, pointed out already by Moses Abramovitz (1994), could be that the problems that such conditions give rise to, may also spur the creation of new knowledge and new social arrangements, which eventually may totally eliminate the problems (and even making society better off over a long-run). Without denying the possibility that some of the variables that we take into account in the analysis may have been influenced by long-run exogenous factors related to history, geography and nature, we are not going to push this line of inquiry further here.

[9] See for instance the evidence brought forward by Rodrik et al (2004) in a recent analysis of the role of institutions, geography, “openness” and other factors in economic development.

Appendix

Factor Analysis, 1970, 1980 and 1990: Rotated Component Matrix

	1970			1980			1990		
	1	2	3	1	2	3	1	2	3
CO2	-0.066	-0.085	**0.752**	-0.028	**0.732**	-0.114	-0.201	-0.044	**0.744**
BIRTH	**-0.888**	-0.232	-0.079	**-0.902**	0.017	-0.111	**-0.907**	-0.171	-0.095
OPEN	-0.050	**0.849**	0.078	0.101	0.044	**0.835**	0.079	**0.866**	0.096
POPDT	0.200	**0.660**	-0.050	0.051	-0.148	**0.760**	0.072	**0.849**	-0.133
PRIM	**0.607**	0.364	0.285	**0.600**	0.325	0.195	**0.556**	0.151	0.446
SECO	**0.892**	0.226	0.154	**0.915**	0.053	0.159	**0.917**	0.118	0.126
SHAGR	**-0.670**	-0.434	-0.384	**-0.767**	-0.214	-0.354	**-0.845**	-0.218	-0.203
SHIND	0.438	0.104	**0.759**	0.423	**0.773**	0.147	0.357	-0.009	**0.783**
SHSRV	0.487	**0.532**	-0.331	**0.521**	**-0.589**	0.295	**0.706**	0.268	-0.416
AGYLD	**0.806**	0.077	0.084	**0.835**	0.039	-0.018	**0.800**	-0.052	0.033
PAT	**0.793**	-0.107	-0.117	**0.724**	-0.285	-0.224	**0.684**	-0.220	-0.220

Factor Analysis 1990 (with additional variables): Rotated Component Matrix

	1990			
	1	2	3	4
CO2	-0.292	**0.595**	-0.271	-0.160
BIRTH	**-0.816**	-0.335	-0.104	-0.288
FDI	0.325	-0.006	**0.809**	-0.213
INV	0.208	**0.534**	0.191	0.441
OPEN	-0.084	0.238	**0.783**	0.381
POPDT	0.077	-0.056	0.002	**0.905**
PRIM	0.337	**0.625**	0.188	0.051
SECO	**0.851**	0.343	0.123	0.154
SHAGR	**-0.698**	**-0.502**	-0.222	-0.105
TERT	**0.881**	0.119	0.003	-0.063
SHIND	0.094	**0.853**	0.091	-0.003
SHSRV	**0.770**	-0.114	0.193	0.131
AGYLD	**0.735**	0.187	0.112	0.275
PAT	**0.764**	-0.041	-0.036	-0.014
SCIENCE	**0.858**	-0.062	0.155	-0.161

Note: Variables in bold have absolute value above 0.5

List of variables included in the factor analysis:

- BIRTH: The birth rate (number of births per 1000 people)
- CO2: CO_2 emissions (kg per 1995 US$ of GDP)
- OPEN: Openness (exports and imports as a % of GDP)
- POPDT: Population density (people per square km)

- PRIM: Enrollment in primary education (gross, % of age group enrolled)
- SECO: Enrollment in secondary education (gross, % of age group enrolled)
- SHAGR: Share of agriculture in GDP (%)
- SHIND: Share of industry in GDP (%)
- SHSRV: Share of services in GDP (%)
- AGYLD: Agriculture yield (kg cereal per hectare)
- PAT: Patenting per head of population (as measured before)
- FDI: Foreign Direct Investment (inward, % of GDP)
- INV: Investment (gross fixed capital formation, % of GDP)
- SCIENCE: Number of papers in scientific and technical journals, divided by population
- TERT: Enrollment in tertiary education (gross, % of age group enrolled)