A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo)

Daniele Archibugi and Alberto Coco*

Revised Version, 23 May 2003

Italian National Research Council

Via dei Taurini, 19 – 00185 Rome, Italy

Tel. +39-06-4993-7838 – Fax +39-06-4463836

Email: archibu@isrds.rm.cnr.it

albertococo@yahoo.it

ABSTRACT

This paper presents a new indicator (ArCo) of technological capabilities that has the ambition to account for both developed and developing countries. Following similar attempts by UN Agencies, including the Technology Achievement Index (TAI) of the UNDP Human Development Report and the UNIDO Industrial Performance Scoreboard, this index takes into account a variety of dimensions of technological change. Three main components are considered: the creation of technology, the technological infrastructures and the development of human skills. Eight sub-categories have been included. ArCo also allows comparing the performance of countries across time. A preliminary attempt to correlate ArCo to GDP is also presented.

Keywords - technology creation, infrastructures, human skills, development index

1. INTRODUCTION: SCOPE, RELEVANCE AND ASSUMPTIONS

Technological capabilities have always been a fundamental component of economic growth and welfare. One of their key characteristics is that they are far from being uniformly distributed across countries, regions and firms. The generation of knowledge is largely concentrated in a few highly industrialised countries. The access to new and old knowledge, in spite of international trade,

* Preliminary versions of this paper were presented at the Workshop on Economic Impact of Innovation and Globalisation, Turin, 13 June 2002, at the Master in Science, Technology and Society, University of Buenos Aires Quilmes, 8 October 2002, at the Doctoral Program on Economics and Management of Technological Change, University of Madrid Complutense, 28 January 2003, at the ECA Knowledge Economy Unit, the World Bank, Washington, D.C., 8 May 2003. We also wish to thank Kim Bizzarri, Liliana Herrera Enriquez, Francesco Lissoni, Richard Nelson, Mario Pianta, Carlo Pietrobelli, Giuseppe Zampaglione and two anonymous referees for detailed comments to previous versions. We also wish to thank a large number of national statistical experts who provided information, statistics, and comments to complete and/or corroborate the ArCo database.

communications, foreign direct investment, public policies promoting scientific co-operation and many other channels of technology transfer, is a long way away from being geographically homogenous. A few countries upgrade constantly their knowledge base while the majority of them are lagging behind and they have many difficulties to absorb capabilities that have already become obsolete in other parts of the world.

The determinants of the generation, transmission and diffusion of technological innovations have been studied both from the theoretical and empirical viewpoint by a large body of literature (Pietrobelli, 2000). But the current understanding on the devices of technology creation and transfer are still inadequate, also for the lack of detailed indicators of technological change. This paper presents a new index of technological capabilities, ArCo, for a vast number of countries. It builds up on many learnt lessons on the nature of technological change and on other previous attempts to measure it, including the latest Technology Achievement Index presented by the UN's Human Development Report (UNDP, 2001) and the UN Industrial Performance Scoreboard (UNIDO, 2002).

Among the learnt lessons on the measurement of technological capabilities, we wish to recall the following:

- The technological capabilities of a nation are composed by a variety of sources of knowledge and of innovation. A comprehensive measure should be able to account for the activities that are codified as well as for those that are tacit (Lundvall, 1992). Some of the capabilities are disembodied, such as new ideas and inventions. Others are embodied in equipment, machinery and infrastructures, while others are embodied in human skills (Pianta, 1995; Smith, 1997; Evangelista, 1999).
- Technological capabilities are composed by clusters of innovations associated to different waves of industrial development (Freeman and Louta, 2001).
- The integration of new technology systems requires the mastering of previous technologies, allowing economic agents to build up competencies cumulatively (Pavitt, 1988a; Bell and Pavitt, 1997). Often new systems make previous ones obsolete (Juma and Konde, 2002). As Schumpeter remarked, "add as many mail-coaches as you please, you will never get a railroad by doing so".
- The various sources of technological capabilities are more likely to be complementary rather than interchangeable. First rate infrastructures devoid of a sufficiently qualified labour force will be useless and vice versa (Abramovitz, 1989, Maddison, 1991). Moreover, a successful integration among the various waves of innovations multiplies their economic and social impact (Antonelli, 1999; Amable and Petit, 2001).
- The creation and improvement of technological capabilities involve a crucial element of technological "effort". Access to advanced technology is a necessary condition, but it needs to be accompanied by substantial and purposeful investments to be absorbed, adopted and learnt (Pietrobelli, 1994; Lall, 2001a).
- Since the differences across countries' technological capabilities are huge, a measure to account them meaningfully should consider the components that are specific to both developed and developing nations (Lall, 2001a).

Our work has been inspired by a variety of attempts to generate measures of technological capabilities. Even when we departed from previous statistical exercises, we benefited from their methodology. In particular, we wish to mention, besides the already cited Technology Achievement Index (UNDP, 2001) and the Industrial Development Scoreboard (UNIDO, 2002; Lall and Albaladejo, 2001), also the Technology Index of the World Economic Forum's *Global Competitiveness Report* (WEF, 2002), and the critical analysis by Sanjaya Lall (2001b). Throughout the paper, we will elucidate as to when we have followed these approaches and when and why we have preferred to follow alternative paths.

It should be remembered that statistics of technological activities for the restricted group of the 30 most developed countries could be much more sophisticated in terms of coverage and significance. For this group of leading countries, a much wider number of indicators are available (and the quality of the data is much more satisfactory than for other countries). If we were to limit our analysis to this restricted number of countries, we would have used different indicators and methodology (for a discussion of the various attempts to measure scientific and technological capabilities of advanced countries see Archibugi and Pianta, 1992; Patel and Pavitt, 1995). It is hardly surprising that data for the selected number of countries that concentrate the bulk of inventive and innovative activities are much richer. The attempt here made is to provide measures for a much larger number of countries. The largest number of the countries here considered has a limited level of technological capabilities. Monitoring the existing capabilities will allow identifying the nature and intensity of technology gap and the appropriate strategies to bridge it.

This analysis is based upon a number of assumptions. First, we assumed that a comparative analysis *across* countries is meaningful (Sirilli, 1997). In spite of the enormous difference across countries (how can one describe in a single number the technology gap between Switzerland and Somalia?), countries can be compared. But we also assumed that a battery of indicators would be able to provide a more comprehensive vision of the differences than a single indicator. The statistics provide more meaningful information for homogenous groups of countries and will hopefully allow comparing each country with others closer geographically, culturally and economically (such as, for example, Switzerland and Germany, Somalia and Ethiopia. For a discussion, see Pietrobelli, 1994).

Second, we assumed that an analysis at the country level is still useful in spite of the enormous differences *within* countries. Synthetic indicators for countries as huge as China or India inevitably overestimate the technological capabilities of some areas and underestimate those of others. The same happens for countries with much higher technological capabilities such as, for example, the United States and Japan. Recent research on technological agglomerations (Cantwell and Iammarino, 2003) also showed that technological activities tend to cluster in a few hubs even in the most advanced countries. Still, the notion of national systems of innovation (see Lundvall, 1992, Nelson, 1993, Freeman, 1997; Edquist, 1997; Andersen et al., 2002) indicates that it makes sense to analyse technological capabilities of territorial states since they provide one of the main institutional settings for the generation and transmission of know-how. The same analysis has already been successfully applied to developing countries (see Lall and Pietrobelli, 2002 for Africa; Hobday, 1995, for Asia; Sutz, 1997, and Cassiolato & Lastres, 1999, for Latin America).

Third, although we measured technological capabilities with a variety of indicators, we made an attempt to provide a synthetic indicator. Other exercises made an effort to estimate countries technological capabilities by aggregating data at the firm level. Unfortunately, this approach has not yet generated data for a large number of countries. Our measure is typically a macro-economic one, and it is composed by a selected number of indicators at the country level. In spite of the limitations of a synthetic indicator, we share with the UNDP, UNIDO and WEF the belief that the various components singled out could be added up in order to provide a more comprehensive measure of technological activities.

2. CHANGES COMPARED TO PREVIOUS ANALYSES

We built upon the TAI attempt developed by UNDP (Desai, Fukuda, Johansson and Sagasti, 2001; UNDP, 2003), and the Industrial Development Scoreboard developed by UNIDO (Lall and Albaladejo, 2001; UNIDO, 2003;). The TAI takes into account many indicators, by classifying them in four categories: the creation of technology, the diffusion of new technology, the diffusion of old technology, and human skills. We considered this a more effective starting point than the index suggested by the WEF (2002). The UNIDO Industrial Development Scoreboard divides a battery of indicators into two broad groups: the first deals with competitive industrial performance (including manufacturing value added per capita, manufactured exports per capita, share of medium and high tech industries in manufacturing value added and share of medium and high tech in manufactured exports); the second one regards industrial capabilities (including foreign direct investment per capita, foreign royalty payments per capita, tertiary technical enrolments and enterprise financed R&D per capita); besides, it also considers the infrastructure as measured by telephone main lines. The main modifications we introduced to these two indexes are the following:

Enlarge the number of countries examined. In order to enlarge the number of countries to be included, and at the same time to maintain the coherence of data and sources, we focused on indicators whose coverage was more satisfactory. We took into account both the availability of data and the dimension of population: we neglected countries with less than 500.000 inhabitants, except for those countries (Luxembourg, Malta, Cyprus, Suriname) for which we retained sufficient data. As regards more populated countries on which we did not possess all the data (most of them in Africa), we estimated the missing values on the basis of national sources, interviews with country experts, and performance in comparable countries and indicators. In extreme cases, we adopted the minimum value in a group of similar countries (very often this minimum value is 0, because we were dealing with very poor countries). Our pool comprises 162 countries in total.

Allowing comparisons over time. In addition to cross-country comparisons, we tried to make time-series comparisons possible. The TAI index was not built to allow comparisons in different time points for each country. This was due to the choice of the goalposts in the calculus of the index: the observed maximum and minimum values permitted to build indicators standardised from 0 to 1 for each country thanks to the following formula:

$$\frac{\text{Observed value - Minimum observed value}}{\text{Maximum observed value - Minimum observed value}}$$

In the building of the TAI all observed values referred to the same time period. Since the maximum and the minimum observed values can change over time, this makes the indexes incomparable across time. Besides, the Industrial Development Scoreboard presents a time series comparison between years 1985 and 1998.

In order to allow time-series comparisons, we fixed a maximum and a minimum value identical for both the time points considered (a current period which oscillates from 1997 to 2000 and a past period from 1987 to 1990). Since almost all countries experienced some progress in the decade, the minimum observed value is taken from the past period only, whilst the maximum observed value is taken from the current one. In this way, we were able to build homogeneous indicators for all time periods, being sure that no country in the past could overcome the maximum value observed in the recent time, in other words no index in the past could overcome the value of 1. The formula for this new indicator can be written as:

$$I_x = \frac{Obs_{present} - Min_{past}}{Max_{present} - Min_{past}}$$

Since one indicator, namely the literacy rate, is known to oscillate between 0 and 100 percent, we considered these percentages as the automatic minimum and maximum goalposts (so there was no need to recur to the minimum and maximum observed values for this indicator).

3. THE ARCO TECHNOLOGY INDEX

We took into account three main dimensions of technological capabilities:

a) the creation of technology;
b) the technological infrastructures;
c) the development of human skills.

This choice was based on the assumption that the three components play a comparative role in the making of the technological capabilities of a nation. Thus, the overall Technology Index (ArCo) is built upon the equal weighting of the three mentioned categories, each of them is indexed. The formula of the ArCo index can be written as:

$$TI = \sum_{i=1}^{k} \lambda_i I_i$$

where ?$_i$ are the constants of ? by which the different indexes I$_i$ of actual technology creation, actual technology diffusion and actual human skills are weighed.

The index of each category is calculated by the same procedure used for the overall index, that is through the simple mean of some sub-indicators. In total we considered eight basic indicators: two for the first category and three for the second and the third. The eight sub-indexes are the following:

a1) patents;
a2) scientific articles;
b1) Internet penetration;
b2) telephone penetration;
b3) electricity consumption;
c1) tertiary science & engineering enrolment;
c2) mean years of schooling;
c3) literacy rate.

Let see in detail what each indicator contains and how it is built:

a) Creation of technology

a1) *Patents*. Patents are one measure of the technological innovations generated for commercial purposes. They represent a form of codified knowledge generated by profit-seeking firms and organisations.

Among the various patent sources (for surveys on patents as internationally comparable indicators, see Pavitt, 1988b; Archibugi, 1992), we considered patents granted in the United States. Since the latter is the largest, and technologically more developed, market of the world, it is reasonable to assume that important inventions and innovations are legally protected also in the US market. The TAI takes in consideration the patents taken out by individuals in their home country. But we do not adopt these data since there exist significant legal differences across countries. For example, the very high number of patented inventions registered by Japanese and Korean inventors at their national patent offices is also associated to a legal practice that imposes inventors to file an application for each claim.

The patent index is based on the utility patents (that is, invention patents) registered at the US Patent and Trademark Office (USPTO, 2002). We took into account the patents taken out in the USA by country of residence of the inventor. The USPTO receives a greater number of foreign patent applications than any other patent office. We are well aware that many inventions are not patented, especially among those invented in developing countries. However, patents are a good proxy of commercially exploitable and proprietary technological inventions.

The propensity of American inventors to register inventions in their own national patent office is higher than that of foreign inventors. To eliminate the bias towards American domestic patents, we replaced the effective number of domestic patents with our own estimation. The latter is based through a comparison between the Japanese and the US patents registered at the European Patent Office (EPO), which represents a foreign institution both for Japanese and American inventors. We used the following estimation:

$$\text{Estimated US domestic patents} = (JAP_{USA} * USA_{EPO}) / JAP_{EPO}$$

where JAP_{USA} is the effective number of patents granted to Japanese in the USA, and USA_{EPO} and JAP_{EPO} are the effective number of patents granted to Japanese and American inventors at the European Patent Office. We also estimated a similar proportion for the patents granted to Europeans in Japan and the results were rather close.

The number of patents for each country was normalised by dividing them for the respective populations (we expressed the number of patents for a million people). To account for yearly fluctuations (which might affect the results in small and medium sized countries) we considered a four-year moving average for the 1987-1990 and 1997-2000 periods.

Then we fixed the goalposts as the maximum and the minimum observed value in 1997-2000 period (230 for the maximum - corresponding to Japanese patents for a million people - and 0 for the minimum value) and, by applying the general formula, we constructed the standardised patent activity index, whose values oscillate from 0 to 1. As said before, in order to make comparisons in time and not only in space, we kept the same goalposts also for the previous years, so that we were able to calculate a comparable index for the period 1987-1990 and to evaluate the growth rate for every country in the last decade.

a2) *Scientific articles*. Scientific literature is another important source of codified knowledge. It represents the knowledge generated in the public sector, and most notably in universities and other publicly funded research centres and universities, although researchers working in the business sector publish a significant and growing share of scientific articles.

There is no systematic information available about all the scientific literature published in the world. We were forced to rely on the available sources. Among them, the most comprehensive and validated is the Science Citation Index generated by the Institute for Scientific Information. It reports information on the scientific and technical articles published in a sample of about 8,000 journals selected among the most prestigious in the world. The fields covered are: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

It is often claimed that the journals included are biased towards the English language. Although this complaint has some ground, we do not think that this data source is heavily discriminating against developing countries. It is more correct to say that it reflects the most visible part of the scientific literature, while it ignores other important components in both developed and developing countries. It is certainly significant that also late industrialising countries have started to be active in both patenting and scientific publications (see Amsden and Mourshed, 1997).

The recent data available to us are an elaboration by the US National Science Foundations (NSF, 2000 and 2002). The data are also available in a World Bank database, which reports them with a greater coverage in terms of years and countries. Article counts are based on fractional assignments; for example, an article with two authors from different countries is counted as one-half article to each country. The maximum goalpost is the number of articles for Switzerland in the 1997-99 three-year period (977 annual articles for a million people), while the minimum is 0, for many countries with no published scientific articles at all.

Data on R&D would have nicely complemented the measure of national technological creation, especially since they document the learning effort to acquire scientific and technological expertise by developing countries. However, we did not employ this source because reliable data are available for a smaller number of countries (see UNESCO, 2002; World Bank, 2003, table 5.12). UNIDO (2002) reported these data for 87 countries only, and for 16 of them the values are considered even negligible. Moreover, some developing countries include in R&D activities that do not fit the standard OECD Frascati Manual definitions (OECD, 2002). The advantage of patents and scientific articles is that both the data sources are validated by external sources and not only by national ones (the US Patent Office in the first case, and the academic journals monitored by the Institute for Scientific Information in the second). This should guarantee that the individual observations are collected according to standard criteria. We calculated a rank correlation between the hierarchy of countries according to US patents per million population here and the enterprise financed R&D per capita (employed in UNIDO, 2002). The result for the 61 countries with available data is very high, 0.92 (Archibugi and Coco, 2003). Thus the combination of patents and scientific article provide a rather robust measure of national technological effort also comprehensive of the R&D inputs.

b) Technological infrastructures

We considered three different indicators of technological infrastructures: Internet, telephony and electricity. They correspond to three major industrial revolutions of the XX century (Freeman and Louta, 2001). They are basic infrastructures for economic and social life. Although they are not necessarily connected to industrial capabilities, production knowledge is strongly associated to their availability and diffusion.

b1) *Internet penetration*. Internet is a vital infrastructure not only for business purposes, but also for access to knowledge. Internet users access a worldwide network. They differ from Internet hosts, which are computers with active Internet Protocol (IP) addresses connected to the Internet. The data on users, when available, are preferable to those on hosts for two reasons: first, they give a more precise idea on the diffusion of Internet among the population; second, some hosts do not have a country code identification and in statistics are assumed to be located in the United States, by causing a bias towards this country. The source is the World Bank (see also World Bank, 2003, table 5.11), which extracted the data from ITU 2001 (the same data are employed in UNDP, 2001).

In order to compare the penetration of Internet among the different countries we divided the number of users by population. The maximum goalpost is 540 per 1,000 people, value belonging to Iceland, while the minimum is 0, observed both in the recent and in the past period for some very poor countries. Internet is a new technology that has quickly become the keystone of the Information and Communication Technology, but it still was not commercially available in 1989-1990. For this reason, we postponed the past period to 1994 so that the data refer to a time interval of five instead of ten years.

b2) *Telephone penetration*. Telephony, besides its civilian component, is also a fundamental infrastructure for business purposes, and it allows tracing populations with human skills and acquiring technical information. Telephone mainlines are telephone lines connecting a customer's equipment to the public switched telephone network. They are another fundamental infrastructure for economic and social life. Data are presented per 1,000 people for the entire country (for more information, see World Bank, 2003, table 5.10) both by World Bank database and UNDP (2001), which both collected the data from ITU (2001). To mainlines we added mobile phones per 1,000 people, which are the natural evolution of telecommunication. We chose to assign equal weights to the older and the newer telephonic component, because, although they incorporate different degrees of technology, they share the same function.

As telephony represents a definitively acquired form of technology for a large number of countries (the developed ones), we expressed the sums between fixed and mobile lines in natural logarithms. This ensures that as the level of telephony increases (therefore as we move towards the more developed countries), the difference between the new and the old (lower) value expressed in logarithms decreases, so reducing the gap among countries, except for those countries with very low initial values. In other words, the use of log corresponds to the idea that after a certain amount, no telephones enrich the technological capacity of a country anymore.

Furthermore, since many countries must be considered to have achieved the desired level of telephony penetration, the chosen goal value for the calculus of the index is not the maximum observed value, but the OECD average (960 telephones for 1000 people). This not only increases the index for all countries, but also allows to eliminate useless differences among all those countries whose telephony share is superior to the mean one (they all get the value 1). Therefore, as the minimum observed value is 0 (transformed to 1 due to the use of logarithms), the formula becomes:

$$\frac{\text{Ln (observed value)}}{\text{Ln (OECD average)}}$$

b3) *Electricity consumption*. Electric power consumption (kilowatt per hour per capita) measures the production of power plants and combined heat and power plants, less distribution losses, and own use by heat and power plants (for more information, see World Bank, 2003, table 5.10). This indicator accounts for the oldest technological infrastructure. Electricity consumption is also a proxy measure for the use of machinery and equipment since most of it is generated by electric power. Although we are aware that this is likely to be larger for capital intensive industries than for services, we believe that the use of logs provides values that respond to the real use of machinery and equipment. Other valuable measures of industrial capacity developed, for example, by Lall and his colleagues (see Lall and Albaladejo, 2001; UNIDO, 2002) are available for a smaller number of countries only.

The observations on the telephony index about the use of logarithms and the adoption of the OECD average as the maximum goalpost, apply *a fortiori* for the electricity consumption index. The OECD average is 8384 kwh per capita, and the minimum value is 17 kwh per capita, corresponding to Ethiopia in 1989-90 and applied to many other poor countries whose value was not available. For other less-developed countries a minimum estimate was calculated.

We did not include data on high technology production and trade. Although various sources provide this kind of data (UNDP 2001, UNIDO, 2002, World Bank, 2003), three problems emerge. First, data for many countries are missing, and this either would reduce the number of countries considered or imply arbitrary estimations. Second, available data are not always reliable, especially concerning production, because they come from national sources, which can have different criteria in defining high-tech sectors. Third, many indicators developed on the ground of these data are not clearly connected to the technological capabilities of a country: high tech production and trade are the result of technological capabilities as much as they are a component of it.

We also did not include a measure of capital equipment and machinery. This is a key component of embodied technological capacity that is vital in both developed and developing countries (Scott, 1989, Pianta, 1995, Evangelista, 1999). The closest indicator for it would be gross fixed capital formation, which is also available for a large number of countries in the World Bank data base (World Bank, 2003, Table 4.9). However, we preferred not to include this measure for two reasons: first, it is not possible to separate the component of gross capital formation devoted to investment in capital equipment and machinery from other forms of investment; second, the indicator is expressed in monetary values, and this would make it more difficult to link ArCo to other currency-based economic variables.

c) The development of human skills

Technological capabilities are strongly associated to human skills. Disembodied knowledge (as measured by patents and scientific literature) and technological infrastructures (as measured by Internet, telephony and electricity) have little value unless used by experienced people. To complement our index, we took into account three different measures of human skills.

c1) *Tertiary science and engineering enrolment*. The first indicator considered is the share of tertiary students in science and engineering in the population of that age group. It gives an idea of the human capital formation in science and technology, through the creation of a skilled human base. It is obtained by multiplying two percentages, which are gross tertiary enrolment ratio and percentage of tertiary students in science and engineering.

Gross tertiary enrolment ratio is the ratio of total enrolment at the tertiary level, regardless of age, to the population of the age group that officially corresponds to the level of education considered. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level (for more information, see World Bank, 2003, table 2.12). We used the World Bank data set, which is originated by UNESCO (2002).

Science and engineering students include students at the tertiary level in the following fields: engineering, natural science, mathematics and computers, and social and behavioral science. By multiplying the two percentages, we obtained the desired indicator. The maximum value is 32.6%, corresponding to Finland in 1998, while the minimum value is 0, belonging to more than one country.

This indicator rests on an implicit assumption, namely that the quality of education provided across countries is comparable. On the contrary, we are aware that the quality of education, and the successful completion of education, greatly vary across countries. We probably overestimated the capability of developing countries and, consequently, underestimated that of developed countries. The completion of courses affects less the results since we assume that enrolment in science and engineering contributes to the technological capability of a country even if the courses are not terminated.

c2) *Mean years of schooling*. They represent the average number of years of school completed in the population over 14. Although this indicator does not consider differences in the quality of schooling, it gives an indication of the human skill level (the "stock"). The sources are the UNDP (2001) which collected an elaboration by Barro and Lee (2001), and World Bank (2003, table 2.13). The maximum goalpost is 12 and corresponds to United States' mean years of schooling, while the minimum value – 0,7 – was observed in Mali (anyway a 0 index was extended to other poor countries without available data). Even for this indicator we had to implicitly assume the level of education to be comparable across countries.

c3) *Literacy rate*. It is the percentage of people over 14 who can, with understanding, read and write a short, simple statement on their everyday life. Data are collected from World Bank (2003) and UNDP (2001) (for more information, see World Bank, 2003, table 2.14). As much in the analysis of the human skills as for the diffusion of technology, our intention was to include indicators that allowed to better discriminate among the less-developed countries (telephony mainlines and electricity in the previous category and mean years of schooling and literacy rate for this category). We considered the literacy rate as a necessary condition for the development of human ability. In this case the index oscillates between 0 and 100%, which consequently represent the minimum and the maximum goalpost.

A final note about *population*, which is the base for the calculus of the pro capita indexes. It is based on the *de facto* definition of population, which counts all residents regardless of legal status or citizenship, except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin (for more information, see World Bank, 2003, tables 1.1 and 2.1).

An interesting feature of our indicator is that none of the eight individual components is based, directly or indirectly, on monetary values. This means that it could be matched to indicators expressed in monetary value without any risk of collinearity. For istance, it could be compared with indicators such as international trade (including trade in high tech products), value added per employee (which is often used as a measure for productivity), gross capital formation (a measure of investment, including investment in capital goods), and, of course, GDP and its growth.

4. THE RESULTS AT THE COUNTRY LEVEL

Our results do not differ in a revolutionary manner from other similar studies, but a number of fresh considerations can be drawn. First of all, we tried, like in the TAI case, to group the 162 examined countries in different blocks, by classifying them along with the level of the overall ArCo Technology Index (table 1). We identified four groups, according to the existence of a significant gap among the last country of a group and the first of the subsequent:

1) leaders (from 1 to 25 ranking);
2) potential leaders (from 26 to 50);
3) latecomers (from 51 to 111);
4) marginalized (from 112 to 162).

Leaders (from 1 to 25 ranking). The first group includes those countries able to create and sustain technological innovation. This is the group that concentrates the bulk of the creation of technology. Seven considerations can be made:

a) What immediately can be noted is the excellent performance of Nordic European countries: Sweden ranks first, Finland second, Norway seventh. They have extraordinary technological infrastructures, and highly qualified human resources. In addition to the static picture, it is noteworthy their trend: all but Denmark improved their ranking with respect to a decade ago, with rates of growth beyond 20%.

b) Still more pronounced is the growth of Newly Industrialised Countries, the so-called Asian tigers: Taiwan, South Korea, Hong Kong, Singapore. In a decade, their Index grew by 52% in Taiwan and 31% in Hong Kong. A huge growth occurred in the category of the creation of technology (1100% in South Korea and 200% in Singapore).

c) North American countries are more or less stable in the first positions: USA ranks fifth and Canada sixth losing some position. The USA has a more prominent position in the creation of technology than in the other two categories.

d) Japan is at the eighth place (gaining four positions in a decade), fruit of an excellent performance in technology creation, very good in technological infrastructures, and relatively poor in human skills.

e) Western Europe shows a slowdown: Germany, France, Belgium, Austria, and Italy fell behind in the decade, not so much due to a slow growth, as for better performance by other countries (this is particularly the case in technological infrastructures). Switzerland ranked first a decade ago and now is third. Germany is now twelfth, losing five positions. The United Kingdom is stable at the thirteenth position whilst Ireland (23^{rd}) lost two ranks. Only Spain gained a few positions, but it is placed on the borderline (25^{th} rank), between the first and the second grouping.

f) Australia and New Zealand almost exchanged places: the first upgraded (from fourteenth to tenth) while the second downgraded (from eleventh to sixteenth).

g) Finally, Israel ranks fourth, even ahead of the USA. This apparently surprising result is attributable to the high number of patents granted in the USA, accompanied by an excellent achievement in the formation of human capital.

Potential Leaders (from 26 to 50 ranking). Countries which have invested in the formation of human skills, have standard technological infrastructures but have so far innovated little, make up the second group, like in the TAI case.

h) The largest number of countries in this group comes from the former Socialist Eastern European countries. Predictions here are particularly risky, especially since the economic and social conditions of these countries have been particularly turbulent. Data and trends for the ex-Soviet or ex-Yugoslavian new states are not entirely reliable. In spite of turmoil, these countries show a good performance in human skills. Russia downgraded considerably in the last decade in all three categories as a consequence to the transition to a market economy. Bulgaria and Romania lost meaningful positions too, while Hungary and Poland slightly gained.

Greece and Portugal, lagged areas in the European Union, are slowly catching up. The latter, with a growth rate of 30%, climbed from the 53^{rd} up to the 35^{th} rank. Greece gained a few positions by reaching the 27^{th} place.

i) Some South American countries are gaining positions: Argentina, Uruguay and, especially, Chile. The latter grew at a rate of 26% in the last decade, by reaching Argentina at the 40^{th} place.

j) In the Arab world, the performance of United Arab Emirates is to notice: thanks to a good availability of infrastructures, it gained fourteen positions and almost reached Kuwait, which remains the leader of the Arabic countries at the 47^{th} place.

Latecomers (from 51 to 111 ranking). The third group, the widest, is composed by countries that in a sense or in another try to grow in their technology content as in their development degree, obviously by starting with the last two categories of the Index - the technological infrastructures and the formation of human skills.

k) A first comment regards Central and South American countries, because none of them, with the exception of Cuba, had shown a downgrading trend since a decade ago (Panama, Venezuela, Costa Rica, Mexico, Jamaica, Peru, Colombia, Brazil, Paraguay, Bolivia). They particularly evolved in technological infrastructures (growth rates around 20%), whilst the formation of human skills increased at a lower rate (not superior to 10%).

l) A similar trend applies to Asian countries, among which Malaysia and Thailand (both with a growth rate beyond 20%) are in the top positions, followed by the Philippines (growth rate of 16%). Although placed at the bottom part of this list (100^{th}), Indonesia shows the highest growth rate since the previous decade (40%).

m) In the Asian group, China and India deserve a separate comment: China shows an extraordinary growth rate of technological infrastructures (71%), while it is quite stable in the human skills ranking. Overall, it shows one of the highest growth rates in the last ten years (35%, second only to Indonesia), by gaining twelve positions (from 97^{th} to 85^{th}).

n) India closes our grouping by ranking at 111^{th}. It may seem a constraint that India closes the third bloc, because it is not distant from the following countries. But in this group - apart from some African countries and Vietnam, which do not have reliable data relating to the past – India is the country that shows the highest growth rate (33%), driven, like China, by the development of technological infrastructures.

o) In the Middle East, Lebanon climbed until the 57^{th} position (growth rate of 26%), by placing behind Qatar (54^{th}) and ahead of Jordan (69^{th}), while Saudi Arabia increased its rank until the 75^{th}.

p) Finally, a restricted set of African countries moved on, led by South Africa (56^{th}) and composed mainly by North African countries, like Tunisia (92nd), Algeria (97th) and Egypt (99th). They show a delay in the technology infrastructure, but are growing in terms of human skills.

Marginalized (from 112 to 162 ranking). The fourth and last group is composed by marginalized countries, which do not have large access even to the oldest technologies, like electricity and telephony. In this group, the relative position is not particularly meaningful, also for lack of adequate data. Even high growth rates can simply be due to the fact that these countries presented very low values in both periods. These countries are practically deprived of the first category – creation of technology – and have poor technological infrastructures and human skills. Many African countries belong to this grouping, where the low technological level is associated to very low-income levels.

5. SOME STATISTICS ON THE INDICATORS

After having commented the results at the country level, we wish to report some simple statistics about the indicators. In table 2 we calculated the correlation matrix across the eight indicators presented. As expected, all correlation coefficients are positive. However, the values are different, indicating that the various indicators taken into account highlight different aspects of technological capabilities.

As predictable, the correlation is greater across indicators belonging to the same category of technology (creation, infrastructures or human skills), but with some exception. For example, the correlation between Internet users and scientific publications is high. At the same time Internet is less correlated with the traditional infrastructures (telephony and electricity). The latter are more correlated with literacy rate and years of schooling. So it appears that more traditional forms of technology are closer each other. In regard to this, the indexes of the creation of technology (patents, scientific articles) are little correlated with literacy rate, telephony and electricity.

It is also interesting to see how much every indicator is correlated with the final ArCo Technology Index. Being the latter a mean of the eight components, it is natural to expect a high correlation for each of them. This is the case, although patents show the weakest correlation and schooling the strongest.

But different results emerge if we consider the correlation within each group. In particular, we must signal the findings emerged within the group of *potential leaders* (table 3): composed mainly by East-European countries, it shows a negative correlation (although very weak) between indicators of human skills and those of technological infrastructure. In this group of countries there is no correlation between education performance from a side, and infrastructures and patenting activity from the other side. Also, there is no connection between scientific articles and patents, confirming that the sources of codified knowledge creation from the business sector and the academic community are not necessarily complementary.

Table 4 reports the correlation matrix for the *latecomers*, what signals a practical independence between indicators of human skills and indicators of creation of technology. The former ones exhibit little correlation also with the various technological infrastructures. Otherwise, a positive correlation between indicators of creation and indicators of technology infrastructure exists. This could be interpreted as a stronger convergence in the form of human skills than in the other two. We did not report correlation either inside the *leaders* group or inside the *marginalised* one. Whilst for the latter group data are not considered sufficiently reliable, in the group of *leaders* the countries involved reached the maximum level for more than one indicator and therefore the linear correlation coefficients are less informative.

Table 5 reports the correlation matrix for the three category indexes. The category of technology creation is a little less correlated with the other two and with the final ArCo index. The intra-group analysis does not reveal any new information.

Finally, it is interesting to look at the coefficients of variation of the indicators (table 6), which signal the different level of polarisation of technological capabilities across the 162 countries. As expected, the most significant dispersion occurs in the case of the generation of technology, which is very highly concentrated in a small club of countries. Also Internet users and, to a lower level, the scientific tertiary formation, are concentrated in just a few countries. Concerning infrastructures, we note that the older is the technology, the less polarised is its utilisation. Literacy is the least dispersed indicator.

According to historians who have taken into account the geographical location of inventions for one thousand year, it is certainly not surprisingly that the generation of inventions and innovations is strongly concentrated in some parts of the world (see Smithsonian Visual Timeline of Inventions, 1994). In a distant past, inventions were concentrated in hubs like the Greek cities, the Italian Renaissance republics as it is now in the Silicon Valley. From such a long-term perspective, the novelty is represented by the fact that innovations are generated in so many different locations, not that they remain concentrated in a few countries only.

A comparison of the variation coefficients across the two periods allows also to test whether the 162 countries are somehow converging or diverging in their technological capabilities. All the indicators show a certain convergence from the past (that is, a reduction of the divergence signalled by the coefficients), especially with regard to Internet (many countries in the past did not possess it at all, while it was already a common infrastructure in others), telephony and literacy rate. It also emerges that the propensity towards convergence is much faster in infrastructure, including new ones such as Internet, than in the creation of technology.

Also for the coefficients of variation we decomposed the analysis at the group level, and we found clear evidence that within the groups it exists more homogeneity than for the overall 162 countries. The ratios inside the groups are lower for every indicator, and this is particularly true for the final ArCo Index, which shows not only a lower absolute value, but also a quicker rate of convergence at the group level with respect to the aggregate level.

6. TECHNOLOGICAL CAPABILITIES AND ECONOMIC PERFORMANCE

An important application of ArCo is to allow to investigate the role played by technological capabilities in economic growth (for a review of the literature, see Fagerberg, 1994). In future research we will use a wider battery of statistical and econometric methods to explore this relationship. Here we limit ourselves to a preliminary analysis by linking the ArCo index to the economic growth proxied by the GDP per capita. Table 7 reports two sets of regressions: first we considered the absolute levels, by regressing per capita actual GDP expressed in US dollars at Purchasing Power Parities on the actual ArCo index values; then we investigated the dynamics in the last decade, by regressing the variation of GDP from 1990 to 2000 on the variation of the ArCo values in the same period.

The first part of the table signals a high correlation between the two indicators for the whole set of countries. The differences across countries are so wide that it is not surprising that there is a very strong association between per capita technological capabilities and GDP. But this relationship becomes weaker when we look at more homogeneous groups: once we consider countries comparable in terms of technological capabilities, a larger variety of income levels emerges. The beta coefficients are all significant, although the square-R decreases as we focus on less developed countries.

The bottom part of the table considers the dynamics: how is the variation in technological capabilities over a decade related to GDP variations? In this case, the relationship is weak for the full set of countries and the coefficient is not meaningful. But it becomes significant for every sub-group, especially for potential leaders and latecomers: improved technological capabilities are strongly associated to GDP growth. Of course, none of the results so far reported provide a unique interpretation on the causality between the two variables. Nor we inform on the impact of each component of the technological index (each sub-index) on the GDP level and growth. The exploration of these links will be addressed in future research.

Elsewhere (see Archibugi and Coco, 2003) we carried a regression of ArCo index on gross capital formation to explore whether the evolution of investments affected the technological capabilities in the different countries. The results show a slightly negative correlation, because the countries which invested more in the last decade are the poorer ones, therefore the ones with a lesser dowry of scientific and technological capability.

7. CONCLUSIONS

It is generally assumed that technological capabilities are a fundamental component for achieving substantive goals such as a satisfactory quality of life or a higher income. But in order to understand properly the role of technological capabilities in social and economic development, this should be conceptualised and quantified. As Witold Kula (1986) showed, the conceptualisation is necessarily associated to the quantification, and vice versa.

This paper presents a fresh attempt to develop an index of technological capabilities for a large number of countries. It follows other similar attempts, although we somehow modified the methodology. Our aim was to include a larger number of countries, and to rely on dependable data sources. This led to the inclusion of some indicators and to the exclusion of others. In the case of technology creation, resources devoted to R&D represent perhaps a better indicator than the combination of patents and scientific papers, but data for the majority of developing countries are not reliable or available. Further, we reported data on three technological infrastructures such as Internet, telephony and electricity, but we did not provide information about the stock of capital goods such as machinery and equipment. A careful scrutiny of the data indicates that they are not available or reliable for the number of countries we considered: on the one hand, we hope that electricity consumption can be a good proxy for capital machinery and equipment; on the other hand, this allow us to keep ArCo entirely independent from any indicator expressed in monetary value. Finally, as regards human resources, an ideal indicator would have been the job qualifications, allowing to capture also learning by doing and learning by using in the working process (Archibugi and Lundvall, 2001). But, again, these data are available for a much more restricted number of countries and they are hardly comparable.

We are aware of the limitations of each of the indicators employed, but we believe that they provide a faithful picture of the capabilities of each country. Overall, the results achieved are rather conforming to expectations. A great deal can be done in order to improve the quality of the data and to refine the index. We hope that this attempt will be a further incentive to promote the production of statistics on science and technology, especially from those institutions, such as UNDP, UNCTAD, UNIDO, UNESCO, the World Bank and others, that pioneered and generated data in the field. In future research, we will test the similarities and differences between the measure here presented and other comparable technological indicators. The database will also allow mapping countries according to their technological characteristics (besides their aggregate technological level), and this will hopefully help science and technology policy analysis for development.

The creation of a database is a preliminary condition to study the determinants and the impact of technological change. We know that technological capabilities are multifarious, and that any aggregate and macro-economic measure will not provide a faithful account. But this database might help testing a few hypotheses often discussed in the literature.

First of all, it might contribute to the vast literature on how technological capabilities are associated to economic growth. A large number of hypotheses discussed in the literature (see the review by Fagerberg, 1994) can be tested, and here we just made a preliminary attempt. It is widely debated if the technological capabilities are a determinant or an effect of economic growth. As with the chicken and the egg, it is difficult to sort out with a single answer. We expect the various sources of technological capabilities to have a different impact on economic growth, and this will also depend on the income level achieved by each country. Certainly the same component will have different impact across countries with such a huge difference in income levels.

Second, it might be possible to relate this indicator to economic aspects such as production and employment. Again, there will be no overlap between the ArCo Technology Index and measures for these economic activities. The index could also permit to relate international trade to technological capabilities since no trade indicators is included in it. This should be understood in two ways: the first is to explore how economic and social openness helps the development of technological capabilities, the second is how technological capabilities can be seen as a determinant of international competitiveness.

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1 In a companion paper (Archibugi and Coco, 2003), we are exploring the similarities and differences between ArCo and these measures. In order to carry out these comparisons, we had to restrict the number of countries in the sample. While the overall ranking of nations is broadly comparable, a few significant differences emerge. This is associated to both the statistical method and indicators used and to the slightly different purposes of the various approaches.

2 In principle, this implies that the three categories can be perfect substitutes: a reduction in the level of technology creation, for example, independently from the starting level, can be perfectly compensated by an equal increase in the level of human skills. The arithmetic mean does not take into account the dispersion of the three subindexes. If we wanted to consider this aspect, we could use the geometric mean, which assumes as much higher values as closer the three subindexes are. Anyway we maintained the aggregation criteria of arithmetic mean used by other established indicators (including the Human Development Index), even because the geometric one results too sensible to code values, often caused by an incompleteness of data for some indicator and for the poorest countries.

3 See World Bank, 2003. Data are reported in greater detail in the World Bank web site. In this paper, we will refer to the World Bank Report, although some of the information used is reported in the web site only.

4 Former USSR is the combination of the former republics. In 1986-88 we assigned articles to the ex-Soviet Republics according to their shares of 1995-97 period; the same is true for Croatia, Slovenia, and Macedonia inside the ex-Yugoslavia and for Czech Republic and Slovakia inside the ex-Czechoslovakia. German data are combined for all years.

5 The data were obtained by multiplying in each country the proportion of the population over 14 who completed the primary, secundary and tertiary education by the duration of the respective education's levels. Not all the countries could be analysed due to a shortage of data; we proceeded to estimate the data for Russia, by using Unesco data and the data made available by Russian Centre for Science Research and Statistics (CSRS, 1996 a,b). In Russia 3 years of primary school, 7 years of secondary school and from 6 to 9 years of higher education are contemplated. We used the gross enrolment ratio to the secondary level (93%) as a proxy of the proportion of the population who completed the primary school, and the enrolment to the tertiary level (58%) as a proxy of the population who completed the secondary school; finally we calculated the average between the proportion of graduated over the population and the proportion of enrolled at University over the population (1,2%). With these data we estimated the mean years of schooling for Russia according to the following expression:

$$MS=3*0,93+7*0,58+9*0,012=6,96.$$

In a similar way, we estimated the other missing values, for some African, Asian and ex-USSR countries.

6 The classification of countries according to the ArCo values is, of course, arbitrary. But since this is the first presentation of our index, we show the ranking produced by this measure. In future research, we plan to take into account aggregations according to other criteria (regions, high, medium and low income, high, medium and low human development, etc.). We also plan to relate the technological position of countries, as measured by ArCo, with other measures of technological activity (Archibugi and Coco, 2003) as well as with other social and economic indicators.

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TABLE 1. A COMPOSITE INDEX OF TECHNOLOGICAL CAPABILITIES ACROSS COUNTRIES (ARCO), '90-'00.

Actual ranking		**Actual Technology Index**	Past Technology Index	Past ranking	Growth rate from the last decade
1	Sweden	**0.867**	0.681	2	27.2%
2	Finland	**0.831**	0.614	6	35.2%
3	Switzerland	**0.799**	0.735	1	8.7%
4	Israel	**0.751**	0.669	4	12.2%
5	United States	**0.747**	0.663	5	12.6%
6	Canada	**0.742**	0.678	3	9.4%
7	Norway	**0.724**	0.581	9	24.6%
8	Japan	**0.721**	0.569	12	26.8%
9	Denmark	**0.704**	0.584	8	20.6%
10	Australia	**0.684**	0.561	14	21.9%
11	Netherlands	**0.683**	0.571	10	19.7%
12	Germany	**0.682**	0.593	7	15.0%
13	United Kingdom	**0.673**	0.562	13	19.8%
14	Iceland	**0.666**	0.484	18	37.8%
15	Taiwan	**0.665**	0.436	22	52.6%
16	New Zealand	**0.645**	0.570	11	13.3%
17	Belgium	**0.642**	0.523	15	22.7%
18	Austria	**0.619**	0.502	16	23.4%
19	Korea, Rep.	**0.607**	0.415	31	46.3%
20	France	**0.604**	0.499	17	21.0%
21	Singapore	**0.573**	0.397	37	44.5%
22	Hong Kong, China	**0.569**	0.435	24	30.8%
23	Ireland	**0.567**	0.450	20	26.0%
24	Italy	**0.526**	0.444	21	18.5%
25	Spain	**0.516**	0.410	34	25.8%
26	Slovenia	**0.507**	0.412	33	23.1%
27	Greece	**0.489**	0.416	30	17.5%
28	Luxembourg	**0.486**	0.426	27	13.9%
29	Slovak Republic	**0.481**	0.428	26	12.3%
30	Russian Federation	**0.480**	0.464	19	3.4%
31	Czech Republic	**0.475**	0.432	25	9.9%
32	Estonia	**0.472**	0.413	32	14.4%
33	Hungary	**0.469**	0.402	36	16.8%
34	Poland	**0.465**	0.393	39	18.3%
35	Portugal	**0.450**	0.346	53	30.0%
36	Bulgaria	**0.449**	0.435	23	3.2%
37	Cyprus	**0.440**	0.384	41	14.4%
38	Latvia	**0.439**	0.423	29	3.7%

39	Belarus	**0.431**	0.403	35	6.8%
40	Argentina	**0.426**	0.379	45	12.5%
41	Chile	**0.424**	0.336	57	26.2%
42	Ukraine	**0.417**	0.426	28	-2.2%
43	Uruguay	**0.417**	0.348	52	19.9%
44	Croatia	**0.414**	0.376	46	10.3%
45	Bahrain	**0.410**	0.355	49	15.4%
46	Lithuania	**0.408**	0.380	43	7.4%
47	Kuwait	**0.405**	0.380	44	6.7%
48	Moldova	**0.395**	0.394	38	0.2%
49	United Arab Emirates	**0.394**	0.321	63	23.1%
50	Romania	**0.393**	0.383	42	2.5%
51	Panama	**0.382**	0.337	56	13.3%
52	Kazakhstan	**0.381**	0.393	40	-2.8%
53	Trinidad and Tobago	**0.380**	0.348	51	9.3%
54	Qatar	**0.380**	0.353	50	7.6%
55	Georgia	**0.379**	0.371	47	2.3%
56	South Africa	**0.372**	0.334	58	11.1%
57	Lebanon	**0.370**	0.292	72	26.5%
58	Malaysia	**0.369**	0.295	69	25.2%
59	Venezuela, RB	**0.369**	0.328	60	12.4%
60	Costa Rica	**0.361**	0.322	62	12.2%
61	Malta	**0.361**	0.325	61	10.9%
62	Yugoslavia, Fed. Rep.	**0.358**	0.334	59	7.2%
63	Mexico	**0.358**	0.320	64	11.8%
64	Tajikistan	**0.356**	0.369	48	-3.6%
65	Turkey	**0.347**	0.286	75	21.4%
66	Jamaica	**0.346**	0.264	85	30.8%
67	Peru	**0.345**	0.292	74	18.2%
68	Thailand	**0.342**	0.278	80	23.3%
69	Jordan	**0.341**	0.300	67	13.6%
70	Azerbaijan	**0.337**	0.342	54	-1.4%
71	Colombia	**0.331**	0.286	76	15.6%
72	Brazil	**0.330**	0.280	77	17.6%
73	Armenia	**0.326**	0.339	55	-3.6%
74	Puerto Rico	**0.326**	0.293	71	11.4%
75	Saudi Arabia	**0.326**	0.280	78	16.4%
76	Paraguay	**0.323**	0.269	84	20.0%
77	Philippines	**0.322**	0.277	81	16.4%
78	Cuba	**0.322**	0.313	65	2.8%
79	Ecuador	**0.319**	0.294	70	8.3%
80	Uzbekistan	**0.319**	0.313	66	1.9%
81	Iran, Islamic Rep.	**0.313**	0.241	90	29.9%
82	Libya	**0.312**	0.274	83	13.7%
83	El Salvador	**0.311**	0.236	93	31.9%

84	Dominican Republic	**0.308**	0.258	86	19.4%
85	China	**0.306**	0.227	97	34.7%
86	Kyrgyz Republic	**0.306**	0.300	68	1.9%
87	Bolivia	**0.305**	0.254	88	19.8%
88	Fiji	**0.304**	0.278	79	9.1%
89	Oman	**0.300**	0.238	91	26.0%
90	Macedonia, FYR	**0.300**	0.276	82	8.5%
91	Turkmenistan	**0.289**	0.292	73	-1.2%
92	Tunisia	**0.288**	0.227	98	26.8%
93	Mauritius	**0.285**	0.231	95	23.6%
94	Syrian Arab Republic	**0.282**	0.256	87	10.2%
95	Sri Lanka	**0.280**	0.227	96	23.0%
96	Zimbabwe	**0.279**	0.248	89	12.2%
97	Algeria	**0.277**	0.221	100	25.1%
98	Guyana	**0.271**	0.226	99	20.0%
99	Egypt, Arab Rep.	**0.269**	0.219	101	22.6%
100	Indonesia	**0.265**	0.190	108	39.7%
101	Suriname	**0.264**	0.219	102	20.1%
102	Honduras	**0.258**	0.218	103	18.3%
103	Botswana	**0.255**	0.189	109	34.8%
104	Albania	**0.251**	0.231	94	8.5%
105	Iraq	**0.246**	0.238	92	3.4%
106	Zambia	**0.240**	0.213	104	12.3%
107	Vietnam	**0.239**	0.164	118	45.5%
108	Nicaragua	**0.238**	0.202	106	17.8%
109	Guatemala	**0.234**	0.187	110	25.2%
110	Gabon	**0.231**	0.204	105	13.1%
111	India	**0.225**	0.169	116	32.9%
112	Swaziland	**0.222**	0.184	111	20.4%
113	Morocco	**0.217**	0.169	117	28.5%
114	Namibia	**0.217**	0.184	112	17.6%
115	Congo, Rep.	**0.207**	0.195	107	6.4%
116	Kenya	**0.204**	0.177	114	15.1%
117	Ghana	**0.203**	0.163	119	24.3%
118	Mongolia	**0.197**	0.176	115	11.6%
119	Cameroon	**0.192**	0.163	120	18.0%
120	Pakistan	**0.191**	0.158	121	20.9%
121	Korea, Dem. Rep.	**0.187**	0.179	113	4.9%
122	Myanmar	**0.179**	0.135	123	32.2%
123	Lesotho	**0.178**	0.154	122	15.4%
124	Tanzania	**0.155**	0.126	124	23.2%
125	Senegal	**0.151**	0.109	130	38.1%
126	Papua New Guinea	**0.146**	0.119	125	22.4%
127	Togo	**0.145**	0.097	133	48.8%
128	Nigeria	**0.141**	0.114	127	23.6%

129	Sudan	**0.140**	0.096	136	46.3%
130	Yemen, Rep.	**0.140**	0.112	128	24.2%
131	Cote d'Ivoire	**0.136**	0.080	141	69.8%
132	Malawi	**0.134**	0.106	131	26.4%
133	Uganda	**0.133**	0.097	134	37.6%
134	Haiti	**0.129**	0.117	126	10.4%
135	Congo, Dem. Rep.	**0.125**	0.110	129	13.6%
136	Gambia	**0.123**	0.070	146	76.1%
137	Bangladesh	**0.123**	0.086	138	43.2%
138	Djibouti	**0.122**	0.099	132	22.3%
139	Nepal	**0.121**	0.070	145	72.9%
140	Madagascar	**0.116**	0.096	135	20.8%
141	Benin	**0.114**	0.078	143	46.3%
142	Rwanda	**0.113**	0.081	140	39.5%
143	Mauritania	**0.111**	0.077	144	43.6%
144	Central African Republic	**0.110**	0.081	139	36.1%
145	Angola	**0.107**	0.088	137	21.7%
146	Bhutan	**0.103**	0.063	148	65.2%
147	Lao PDR	**0.098**	0.057	151	73.6%
148	Mozambique	**0.098**	0.069	147	41.6%
149	Cambodia	**0.096**	0.047	156	103.3%
150	Liberia	**0.095**	0.079	142	20.5%
151	Eritrea	**0.093**	0.048	154	92.8%
152	Guinea	**0.079**	0.045	158	73.9%
153	Burundi	**0.078**	0.057	152	38.2%
154	Guinea-Bissau	**0.076**	0.061	149	26.2%
155	Sierra Leone	**0.075**	0.060	150	24.4%
156	Chad	**0.071**	0.050	153	42.6%
157	Ethiopia	**0.067**	0.047	155	41.1%
158	Mali	**0.066**	0.032	159	108.2%
159	Afghanistan	**0.056**	0.046	157	20.5%
160	Burkina Faso	**0.050**	0.028	160	79.2%
161	Niger	**0.031**	0.017	162	84.0%
162	Somalia	**0.028**	0.024	161	13.9%

Sources: CSRS (1996a,b); EPO (2000); ITU (2001); NSF (2000, 2002); UNESCO (2002); USPTO (2002); World Bank (2003).

TABLE 2. CORRELATION COEFFICIENTS ACROSS THE VARIOUS INDEXES OF TECHNOLOGICAL CAPABILITIES *(ALL COUNTRIES)*.

	Patent index	Articles index	Internet index	Telephony index	Electricity index	Tertiary index	Schooling Index	Literacy Index	**ArCo Technology Index**
Patent index	1.000	0.791	0.692	0.446	0.445	0.537	0.530	0.320	**0.705**
Articles index	0.791	1.000	0.833	0.571	0.567	0.699	0.665	0.420	**0.828**
Internet index	0.692	0.833	1.000	0.607	0.594	0.618	0.659	0.431	**0.805**
Telephony index	0.446	0.571	0.607	1.000	0.843	0.713	0.819	0.818	**0.890**
Electricity index	0.445	0.567	0.594	0.843	1.000	0.674	0.744	0.712	**0.854**
Tertiary index	0.537	0.699	0.618	0.713	0.674	1.000	0.707	0.617	**0.837**
Schooling index	0.530	0.665	0.659	0.819	0.744	0.707	1.000	0.805	**0.903**
Literacy index	0.320	0.420	0.431	0.818	0.712	0.617	0.805	1.000	**0.788**

LEGEND:

- Patent index: patents granted at the USPTO by country per million people (annual average from 1997 to 2000).
- Articles index: scientific Articles by country per million people (annual average from 1997 to 1999).
- Internet index: Internet users by country per million people (1999).
- Telephony index: fixed and mobile telephone lines by country per million people (1999).
- Electricity index: electricity consumption by country per million people (annual average from 1997 to 1998).
- Tertiary index: gross tertiary science and engineering enrolment by country (annual average from 1996 to 1998).
- Schooling index: mean years of schooling by country (2000).
- Literacy index: adult literacy rate by country (2000).
- Technology index: weighted mean of the previous indexes.

Sources: As for Table 1.

TABLE 3. CORRELATION COEFFICIENTS ACROSS THE VARIOUS INDEXES OF TECHNOLOGICAL CAPABILITIES FOR THE *POTENTIAL LEADERS* *(COUNTRIES FROM 26 TO 50).*

	Patent index	Articles index	Internet index	Telephony index	Electricity index	Tertiary index	Schooling Index	Literacy Index	**ArCo Technology Index**
Patent index	1.000	-0.018	0.519	0.385	0.401	-0.318	-0.258	0.095	**0.325**
Articles index	-0.018	1.000	0.362	0.530	0.342	0.067	0.143	0.191	**0.798**
Internet index	0.519	0.362	1.000	0.768	0.580	-0.532	-0.194	-0.236	**0.447**
Telephony index	0.385	0.530	0.768	1.000	0.606	-0.435	-0.188	-0.207	**0.531**
Electricity index	0.401	0.342	0.580	0.606	1.000	-0.309	-0.475	-0.575	**0.325**
Tertiary index	-0.318	0.067	-0.532	-0.435	-0.309	1.000	-0.106	0.396	**0.220**
Schooling index	-0.258	0.143	-0.194	-0.188	-0.475	-0.106	1.000	0.489	**0.199**
Literacy index	0.095	0.191	-0.236	-0.207	-0.575	0.396	0.489	1.000	**0.438**

LEGEND: As for Table 2.

Sources: As for Table 1.

TABLE 4. CORRELATION COEFFICIENTS ACROSS THE VARIOUS INDEXES OF TECHNOLOGICAL CAPABILITIES FOR THE *LATECOMERS (COUNTRIES FROM 51 TO 111).*

	Patent index	Articles index	Internet index	Telephony index	Electricity index	Tertiary index	Schooling Index	Literacy Index	**ArCo Technology Index**
Patent index	1.000	0.508	0.631	0.476	0.374	-0.012	0.001	0.161	**0.431**
Articles index	0.508	1.000	0.437	0.511	0.447	0.159	-0.008	0.094	**0.501**
Internet index	0.631	0.437	1.000	0.723	0.236	0.035	0.097	0.141	**0.500**
Telephony index	0.476	0.511	0.723	1.000	0.244	0.311	0.087	0.332	**0.686**
Electricity index	0.374	0.447	0.236	0.244	1.000	0.169	0.079	0.022	**0.627**
Tertiary index	-0.012	0.159	0.035	0.311	0.169	1.000	0.114	0.189	**0.507**
Schooling index	0.001	-0.008	0.097	0.087	0.079	0.114	1.000	0.421	**0.528**
Literacy index	0.161	0.094	0.141	0.332	0.022	0.189	0.421	1.000	**0.586**

LEGEND: As for Table 2.

Sources: As for Table 1.

TABLE 5. CORRELATION COEFFICIENTS ACROSS THE CATEGORY INDEXES OF TECHNOLOGICAL CAPABILITIES.

	Technology creation index	Technology diffusion index	Human skills index	**ArCo Technology Index**
Technology creation index	1.000	0.667	0.627	**0.819**
Technology diffusion index	0.667	1.000	0.894	**0.956**
Human skills index	0.627	0.894	1.000	**0.937**

LEGEND:

- Technology creation index: simple mean of Patent index and Articles index.
- Technology diffusion index: simple mean of Internet index, Telephony index and Electricity index.
- Human skills index: simple mean of Tertiary index, Schooling index and Literacy index.
- Technology index: simple mean of the previous indexes.

Sources: As for Table 1.

TABLE 6. COEFFICIENTS OF VARIATION OF THE VARIOUS INDEXES OF TECHNOLOGICAL CAPABILITIES.

	Actual	Past	Growth rate
Patent index - *all countries*	2.787	3.087	-9.7%
leaders	*0.705*	*0.935*	*-24.6%*
potential leaders	*3.251*	*3.374*	*-3.6%*
latecomers	*1.822*	*2.684*	*-32.1%*
Articles index - *all countries*	1.999	2.172	-8.0%
leaders	*0.420*	*0.626*	*-33.0%*
potential leaders	*0.654*	*0.672*	*-2.6%*
latecomers	*1.004*	*1.227*	*-18.2%*
Internet index - *all countries*	1.831	2.642	-30.7%
leaders	*0.459*	*0.838*	*-45.3%*
potential leaders	*0.737*	*1.330*	*-44.6%*
latecomers	*1.158*	*4.108*	*-71.8%*
Telephony index - *all countries*	0.435	0.550	-20.9%
leaders	*0.010*	*0.039*	*-73.7%*
potential leaders	*0.082*	*0.100*	*-18.1%*
latecomers	*0.175*	*0.285*	*-38.6%*
Electricity index - *all countries*	0.497	0.536	-7.4%
leaders	*0.039*	*0.071*	*-44.2%*
potential leaders	*0.109*	*0.109*	*-0.2%*
latecomers	*0.286*	*0.338*	*-15.5%*
Tertiary index - *all countries*	1.018	1.034	-1.5%
leaders	*0.319*	*0.369*	*-13.4%*
potential leaders	*0.501*	*0.664*	*-24.6%*
latecomers	*0.665*	*0.765*	*-13.0%*
Schooling index - *all countries*	0.549	0.590	-7.0%
leaders	*0.161*	*0.187*	*-14.2%*
potential leaders	*0.209*	*0.245*	*-14.5%*
latecomers	*0.288*	*0.327*	*-11.8%*
Literacy index - *all countries*	0.279	0.352	-20.8%
leaders	*0.018*	*0.029*	*-38.1%*
potential leaders	*0.062*	*0.079*	*-22.2%*
latecomers	*0.132*	*0.183*	*-27.8%*
Technology creation index - *all countries*	2.151	2.289	-6.0%
leaders	*0.435*	*0.630*	*-31.0%*
potential leaders	*0.707*	*0.712*	*-0.8%*
latecomers	*1.006*	*1.249*	*-19.4%*
Technology diffusion index - *all countries*	0.561	0.586	-4.2%
leaders	*0.100*	*0.065*	*54.4%*
potential leaders	*0.119*	*0.091*	*31.0%*
latecomers	*0.190*	*0.268*	*-28.9%*

Human skills index - *all countries*	0.439	0.475	-7.5%
leaders	*0.097*	*0.108*	*-10.3%*
potential leaders	*0.130*	*0.154*	*-15.1%*
latecomers	*0.166*	*0.219*	*-24.2%*
ArCo Technology Index - *all countries*	**0.578**	**0.589**	**-1.9%**
leaders	***0.133***	***0.177***	***-24.6%***
potential leaders	***0.077***	***0.089***	***-13.1%***
latecomers	***0.144***	***0.196***	***-26.7%***

LEGEND:

- Patent index: patents granted at the USPTO by country per million people (annual average from 1997 to 2000 for the actual value and from 1987 to 1990 from the past one).
- Articles index: scientific Articles by country per million people (annual average from 1997 to 1999 for the actual value and from 1987 to 1989 for the past one).
- Internet index: Internet users by country per million people (year 1999 for the actual value and year 1994 for the past one).
- Telephony index: fixed and mobile telephone lines by country per million people (year 1999 for the actual value and year 1989 for the past one).
- Electricity index: electricity consumption by country per million people (annual average from 1997 to 1998 for the actual value and annual average from 1988 to 1989 for the past one).
- Tertiary index: gross tertiary science and engineering enrolment by country (annual average from 1996 to 1998 for the actual value and annual average from 1987 to 1989 for the past one).
- Schooling index: mean years of schooling by country (year 2000 for the actual value and year 1990 for the past one).
- Literacy index: adult literacy rate by country (year 2000 for the actual value and year 1990 for the past one).
- Technology creation index: simple mean of Patent and Articles indexes.
- Technology diffusion index: simple mean of Internet, Telephony and Electricity indexes.
- Human skills index: simple mean of Tertiary, Schooling and Literacy indexes.
- Technology index: simple mean of the three previous (category) indexes.
- Coeff. of variation: ratio between standard deviation and simple mean of the observations. It signals the internal variability of each index.

Sources: As for Table 1.

TABLE 7. LINK BETWEEN ARCO TECHNOLOGY INDEX AND GDP PER CAPITA.

Regression of actual GDP per capita in PPP $ (99-01) on actual ArCo Technology Index (2000):

	correlation coefficient	constant	regression coefficient	standard error	t-statistic	square R
All countries	0.83	-5007	40518	5162	7.85	0.69
Leaders	0.26	16764	11588	3971	2.92	0.07
Potential leaders	0.31	-25722	87105	9261	9.41	0.10
Latecomers	0.29	-2555	26117	3880	6.73	0.08

Regression of the variation of GDP per capita in PPP $ in the last decade (1990-2000) on the variation of ArCo Technology Index in the same period:

	correlation coefficient	constant	regression coefficient	standard error	t-statistic	square R
All countries	0.28	0.207	0.472	0.325	1.85 *	0.08
Leaders	0.46	0.207	1.082	0.213	5.08	0.21
Potential leaders	0.65	-0.097	3.044	0.297	10.25	0.43
Latecomers	0.63	-0.015	2.098	0.294	7.14	0.39

* The regression coefficient is not significant at a 5% confidence level.

Sources: As for Table 1.