Measuring Technology Achievement of Nations and the Capacity to Participate in the Network Age[1]

M. Desai, S. Fukuda-Parr, C. Johansson, and F. Sagasti[2]

"development in the network age without the internet is like industrialization without electricity'. (Castells, 2000)

Disparities among countries in their capacity to create and use technology for development has persisted for a long time and are now huge. It is likely to become an increasingly significant factor in determining patterns of global development and poverty in the 21st century. The last decade's technological transformations and the emergence of the global marketplace have raised the stakes for all countries to be technologically connected – to be able to create, adapt and use global technological innovations. All countries face the challenges of participating and competing in the technology-based global marketplace and ensuring that technology is harnessed as a tool for human development. Yet the nature of those challenges is very different across countries, because countries vary hugely in their technological capacity and needs. This paper presents a measurement approach to assessing the technological achievements of a country as an aid to policy makers in identifying policy priorities. It develops a Technology Achievement Index (TAI), a composite measure of technological progress that ranks countries on a comparative global scale.

A new paradigm of technology and development

As we enter the network age, some 2 billion people still do not have access to electricity, the basic technology of the industrial age. Global technological innovation is highly concentrated in the high-income OECD countries. These countries, with 14% of world

---

[1] This index was developed for the Human Development Report 2001, Making New Technologies Work for Human Development published by OUP for UNDP.

1

population, accounted for 86% of the 836,000 patent applications filed globally in 1998, and 85% of 437,000 scientific articles published worldwide (World Bank 2001 and WIPO 2000). Of all royalties and license fees earned world wide in 1999, 54% went to the US and 12% to Japan (World Bank 2001). Despite rapid expansion of the internet in developing countries, the digital divide is still huge; internet users made up over half of the US population and nearly a third of the rest of OECD countries, but still 3% or less in Latin America and East Asia, and 1% or less in South Asia, Sub-Saharan Africa and the Arab States. (Nua 2001) Even old technologies that have been in existence for over a century have stalled – in Sub-saharan Africa, per capita electricity consumption has not risen for the last decade and since 1970, tractor use rate declined from 1.8 per 1000 hectares cultivated to 1.5. (FAO 2000). Telephones are similarly out of reach for much of the developing world – contrast the lines per capita: 594 per 1000 people in the high-income OECD countries, and 69 in developing countries on average (ITU 2001). Wireless phones have spread rapidly in poor countries but even more rapidly in the rich countries – widening the communications gap.

These gaps in technological advance can further widen developmental divides in the 21st century of rapid technological transformations that are driving the historic shift from the industrial to the network age in which the rewards and penalties of global technological advances are increasing. (Lee 2000)   The breakthroughs in biotechnology and ICT are extending the frontiers of advances in medicine, food production, communications, and

---

[2] The paper reflects the personal views of the authors and do not constitute policies of UNDP and other institutions to which they belong.

many other activities that make possible huge gains in human development. The technology sector is also the fastest growing sector of the global economy. (Lall 2000).

The challenge of rethinking development policies go beyond considering these incremental changes, but to a historic shift from the industrial to the network age. Recent breakthroughs in information communications technologies and biotechnologies have led to transformations - technological advances are more rapid (e.g. doubling of computing power every 18 months), more fundamental (e.g. breakthroughs in genetic engineering), and more dramatically shifting costs (e.g. decline in cost of transmitting trillion bits of information from US$150,000 to just 12 cents over the last 3 decades). The developments in biotechnology and information telecommunications technology codify, store, process and communicate information and knowledge. These advances have structural and not just incremental impacts because they are pervasive *inputs* into almost all human activities and so have have pervasive impacts throughout the society. These transformations are intertwined with economic globalization leading to a historic shift, from the industrial to the network age. Production, research, and many other activities are restructured into 'networks' of individuals and organizations specialized into niches of expertise, with the costs of communications driven down to zero and geographical boundaries falling.

The network age is changing the way – by whom and where – technological innovation is created and diffused. Global research and development activities are increasingly

privatized and globally networked. Corporations have resources and the ownership

(patents) to finance R & D and take products to market. They take cutting edge

innovations and carry them across the globe through direct foreign investments and

licenses. Entrepreneurs with start-up companies take to market higher risk technological

innovations, financed by venture capital. (Lall 2001)   Global markets and global rules of

intellectual property shape incentives and diffusion.

A new map of technology creation and diffusion is emerging. Centres of cutting edge

global technology innovation are the 'hubs' that spin in the synergy of four inputs needed

for technology development: knowledge, market opportunities, finance and incentives.

Top scientists from around the world congregate in these hubs. So do foreign direct

investment, technology stocks and venture capital. All in a global network, working

collaboratively, migrating from one global laboratory or incubator to the next – the hubs

and their actors circumnavigate the globe.

Developing technological capacity

Not all countries need to be on the cutting age of global technological advance. But

every country needs the capacity to understand and adapt global technologies for local

needs. It is often mistakenly assumed that technology transfer and diffusion are relatively

easy, that developing countries can simply import and apply knowledge from outside by

obtaining equipment, seeds and pills. But for firms or farms to use a new technology—to

identify its potential benefits, to learn it, adapt it and use it—requires new skills and the

ability to learn and develop new skills with ease (Lall, 2000). For example, a study from

Thailand shows that four years of education triples the chance that a farmer will use fertiliser effectively. (Lipton et at, 2001). Furthermore, with today's rapidity of technological advance, the skill and knowledge required is the adaptability to mastering new technology continuously.

Beyond the capacity to use of adopting new techniques, developing countries also need capacity to invent and adapt new technologies. Global markets will not develop cures for malaria, cheap wireless computers, or pest resistant cassava – products with huge gains for the well being of poor people but not much profit potential. Poor countries need to foster their own creativity to use both local and global knowledge and science to find technological solutions to their development problems. Centres of excellence in the 'South' can do much to produce technology tools for tackling poverty.

There is a long history of efforts to develop science and technology in developing countries. In the network age of global markets and technology networks, nurturing technological creativity and access to global technologies requires flexible, competitive, dynamic economic environments, institutions in private and public sectors, and a minimum of physical infrastructure. Three kinds of capacity are particularly critical in this new environment. First, technological change dramatically raises the premium every country should place on investing in the education and training of its people. And in the network age, primary education will not suffice – the advanced science and engineering skills developed in secondary and tertiary schools, as well as vocational and on-the-job training are increasingly important. Second, the capacity to develop policies that

5

manage technology such as intellectual property rights and risks of socioeconomic, environmental and health consequences. Third, the capacity to be connected to and participate in the global technology development networks.

A number of developing countries – or parts of them – are well connected to global networks. Concentrated in North America, Western Europe and Japan, global hubs of innovation are emerging in developing countries such as Bangalore (India), El Ghazala (Tunisia), Sao Paolo (Brazil), and Gauteng (South Africa). Among the 46 top global hubs ranked by the Wired magazine ranking, 9 are in Asia, 2 in South America, 2 in Africa (Hillner 2000) Developing countries are competitive in global markets for technology intensive products. Korea, Singapore, China, Mexico, Malaysia are among the top 15 exporters of high tech products and outpace Ireland, Canada, Sweden and other long industrialized countries. Private sector investments in research based technology sectors are increasing (Chako). Migration creates diaspora, which in turn creates business networks. Take the strong link between Silicon Valley and Bangalore, built on the Indian diaspora. A global labour market is in the making in skill-intensive professions, and the diasporas strengthen the social ties in economic networks as they invest at home, but also facilitate contacts for market access. (Kapur 2001)

And most significantly, public and private sector efforts are producing breakthroughs in adaptations that meet the needs of human development, from the public initiative to develop a low cost computer in Brazil to India's simputer, a $300 computer that is wireless and runs on batteries, to malaria treatment in Vietnam that combined traditional

herbal knowledge with modern science. (Simputer Trust 2000; Kirkman 2001, WHO 2000).

Assessing national capacity - Technology Achievement Index (TAI)

Concept and features

In reviewing its technology technology policies, a useful starting point is a realistic assessment of its current situation in technological progress and in monitoring its progress. This paper proposes a composite index of technological achievement (TAI) – reflecting the level of technological progress and capacity of a country to participate in the network age. A composite index helps a country situate itself relative to others, especially those farther ahead. Many elements make up a country's technological achievement, but an overall assessment is more easily made based on a single composite measure than on dozens of different measures. Like other composite indices in *Human Development Reports* such as the Human Development Index, the TAI is intended to be used as a starting point to make an overall assessment, to be followed by examining different indicators in greater detail.

The index aims to capture technological achievements of a country in four dimensions:
- creating new technology;
- diffusing the adoption of new technologies;
- diffusion of long existing technologies that are still basic inputs to the industrial and the network age;
- building a human skill base for technological creation and adoption.

The index focuses on outcomes and achievements rather than on effort or inputs such as numbers of scientists, R & D expenditures, or policy environments. This is because the causal relationship between these inputs and outcomes are not well known. For example, does a larger number of scientists lead to more output in technological advance? Do countries that spend more on R & D achieve more?

These approaches differ from some other indexes of technological advance that have been developed. The Technology Index published in the Harvard Competitiveness Reports focuses on the enabling policy environment for technological innovation and diffusion.[3] The Index of Technological Progress developed by Rodriguez and Wilson focuses only on information telecommunications technologies.[4]

The TAI is not a measure of which country is leading in global technology development, but focuses on how well the country as a whole is participating in creating and using technology. Take the United States—a global technology powerhouse—and Finland. The United States has far more inventions and Internet hosts in total than does Finland, but it does not rank as highly in the index because in Finland the Internet is more widely diffused and more is being done to develop a technological skill base throughout the population.

Two particular concerns influenced the design of this index:
first to be as relevant for the broad range of the world's countries, especially developing countries with low levels of technological advance, and to be able to discriminate among these countries. Large proportions of people in these countries still do not have access to 'older' technologies such as telephone, electricity, agricultural mechanisation, motorized transport. It was important to include a broad range of 'new' and 'old' technologies;

---

[3] *Warner[3] developed an Economic Creativity Index, of which one component is the Technology index, itself using either the Innovation Index or the Technology Transfer Index. The index is built in the context of competitiveness ranking countries by the 'economic creativity index'. The conceptual framework is stated as "nations can link themselves to the global technology engine by being centres of innovation themselves, or by facilitating technology transfer and rapid diffusion of innovation. ' But the index is focussed on the enabling environment than on the outcome, and on the environment that prevails in the country that make for technological vitality. There is a great deal of value judgement in the choice of indicators used – for example IPR is seen as an indicator of innovation. There is no indicator to show that aggressive use of compulsory licensing or parallel imports or generic drugs as an indicator of proactive policy to diffuse technology. It covers 61 countries. The innovation index is highly correlated with patents. Full documentation needs to be reviewed. The coverage is mostly OECD countries plus the transition economies and a handful of developing countries. It does not distinguish adequately among developing countries.*

[4] *Rodriguez and Wilson[4] developed an 'Index of Technological Progress'. It focuses on ICT because it is the leading technology and combines televisions, fax machines, personal computers, Internet hosts and mobile phones. Consumption of technologically advanced commodities is not necessarily a good measure for 'technological advance' of a country. Thus, for example, high income/low population countries like Kuwait and Qatar rank higher than Korea, Russia.*

second, to be directly policy relevant to the challenges of the wide range of countries.

Components of the index

The TAI focuses on four dimensions of technological capacity that are important for reaping the benefits of the network age. The indicators selected relate to important technology policy objectives for all countries, regardless of their level of development:

- *Creation of technology.* Not all countries need to be at the leading edge of global technological development, but the capacity to innovate is relevant for all countries and constitutes the highest level of technological capacity. The global economy gives big rewards to the leaders and owners of technological innovation. All countries need to have capacity to innovate because the ability to innovate in the use of technology cannot be fully developed without the capacity to create— especially to adapt products and processes to local conditions. Innovation occurs throughout society, in formal and informal settings, though the current trend is towards increasing commercialisation and formalization of the process of innovation. In the absence of perfect indicators and data series the TAI uses two indicators to capture the level of innovation in a society. The first is the number of patents granted per capita, to reflect the current level of invention activities. The second is receipts of royalty and license fees from abroad per capita, to reflect the stock of successful innovations of the past that are still useful and hence have market value.

- *Diffusion of recent innovations.* All countries must adopt innovations to benefit from the opportunities of the network age. This is measured by diffusion of the Internet— indispensable to participation—and by exports of high- and medium-technology products as a share of all exports.

  Higher-technology goods present important opportunities to developing countries. Many high-technology sectors are among the most dynamic in the global economy. Upgrading the technology content of the manufacturing sector diversifies the economy and creates opportunities in new markets.

  The Internet is far more than a tool for rich countries. By dramatically increasing the access to information while decreasing the cost, the Internet has vast potential to aid political participation, increase people's incomes, and in improving healthcare.

9

- *Diffusion of old innovations.* Participation in the network age requires diffusion of many old innovations. Although leapfrogging is sometimes possible, technological advance is a cumulative process, and widespread diffusion of older innovations is necessary for adoption of later innovations. Two indicators used here—telephones and electricity—are especially important because they are needed to use newer technologies and are also pervasive inputs to a multitude of human activities. Both indicators are expressed as logarithms and capped at the average OECD level, however, because they are important at the earlier stages of technological advance but not at the most advanced stages. Thus while it is important for India to focus on diffusing electricity and telephones so that all its people can participate in the technological revolution, Japan and Sweden have passed that stage. Expressing the measure in logarithms ensures that as the level increases, it contributes less to the index.

- *Human skills.* A critical mass of skills is indispensable to technological dynamism. Both creators and users of new technology need skills. Today's technology requires adaptability—skills to master the constant flow of new innovations. The foundations of such ability are basic education to develop cognitive skills and skills in science and mathematics. Cognitive skills are hard to define and measure. There have been some limited attempts of cross-country comparisons of skills, such as the International Adult Literacy Survey (IALS) and the Trends in Mathematics and Science Study (TIMSS). They are, however, very limited in their coverage, particularly when it comes to developing countries. Instead, mean years of schooling is used as a proxy. This measure gives a good indication of the overall level of basic educational skills in the population, notwithstanding the fact that education quality varies from country to country. The second indicator used to gauge human skills is the enrolment in tertiary education in science, mathematics and engineering. This measure gives an idea of the current effort in developing advanced skills in science and mathematics. Every country needs this skill base to be able to adapt and innovate new technologies. Though it would be desirable to include indicators of vocational training, these data are not available.

Weighting and aggregation

The methodology used to calculate the TAI is similar to the human development index: a simple average of the dimension of the index, which in turn are calculated based on the selected indicators. The TAI has eight indicators, two in each of the four dimensions:

- Technology creation, measured by the number of patents granted to residents per capita and by receipts of royalties and license fees from abroad per capita.
- Diffusion of recent innovations, measured by the number of Internet hosts per capita and the share of high- and medium-technology exports in total goods exports.
- Diffusion of old innovations, measured by telephones (mainline and cellular) per capita and electricity consumption per capita.
- Human skills, measured by mean years of schooling in the population aged 15 and above and the gross tertiary science enrolment ratio.

Two of the indicators, telephones per capita and electricity per capita, are also expressed as logarithms and capped at OECD average levels, as discussed above. Just as in the HDI, the value of the different indicators are normalised to a scale from 0 to 1 using goalposts, such that an indicator value that is equal to the upper goalpost will be normalised to 1 and a value equal to the lower goalpost will be normalised to 0, according to the following formula:

$$\text{Indicator index} = \frac{\text{actual value - observed minimum value}}{\text{observed maximum value - observed minimum value}}$$

However, in the HDI these goalposts are set to reflect a desirable standard. For example, the upper goalpost for life expectancy is set to 85 years – a society with this life expectancy can be said to have succeeded in providing a long and healthy life for its citizens.   In contrast, there are no such desirable levels for the indicators in the TAI: they have in common the property that higher levels are better, but it is impossible to set a "desirable" level of patenting activity or of high- and medium- technology exports. For this reason the goalposts used in calculating the index are simply the observed minima and maxima of the indicators: for each indicator, the best-performing country is assigned a value of 1 and the worst a value of 0 for the index calculation. The obvious drawback of

11

this approach is that it complicates trend analysis: when values change over time, goalposts also change, making the indices of two different time points incomparable. However, the TAI was not designed to measure change over time.

A second important issue is that of weighting of different indicators and dimensions. In the TAI, the four dimensions each contain two indicators. The index for each dimension is calculated as the simple average of the indicator indices in that dimension. The TAI, in turn, is the simple average of these four dimension indices. The indicators in each dimension are given equal weight, and the dimensions are given equal (one-fourth) weight in the final index. This means that diffusion of technology is, effectively, given more weight - two of the four dimensions deal with this. (For an example on how the index is calculated, appendix 1: Calculating the Technology Achievement Index.)

TAI values and rankings

TAI estimates have been prepared for 72 countries for which data are available and of acceptable quality and are shown in Table 1. For others, data were missing or unsatisfactory for one or more indicators, so the TAI could not be estimated. For a number of countries in the developing world, data on patents and royalties are missing. Because a lack of data generally indicates that little formal innovation is occurring, a value of zero for the missing indicator was used in these cases.

Global patterns

The results show three trends: a map of great disparities among countries, diversity and dynamism in technological progress among developing countries and a map of technology hubs superimposed on countries at different levels of development. The map of great disparities shows four group of countries (see map 2.1), with TAI values ranging from 0.744 for Finland to 0.066 for Mozambique. These countries can be considered leaders, potential leaders, dynamic adopters or marginalized:

12

- *Leaders (TAI above 0.5)*—topped by Finland, the United States, Sweden and Japan, this group is at the cutting edge of technological innovation. Technological innovation is self-sustaining, and these countries have high achievements in technology creation, diffusion and skills. Coming fifth is the Republic of Korea, and eighth is Singapore— two countries that have advanced rapidly in technology in recent decades. This group is set apart from the rest by its higher invention index, with a marked gap between Israel in this group and Spain in the next.

- *Potential leaders (0.35–0.49)*—most of these countries have invested in high levels of human skills and have diffused old technologies widely but innovate little. Each tends to rank low in one or two dimensions, such as diffusion of recent innovations or of old inventions. Most countries in this group have skill levels comparable to those in the top group.

- *Dynamic adopters (0.20–0.34)*—these countries are dynamic in the use of new technology. Most are developing countries with significantly higher human skills than the fourth group. Included are Brazil, China, India, Indonesia, South Africa and Tunisia, among others. Many of these countries have important high-technology industries and technology hubs, but the diffusion of old inventions is slow and incomplete.

- *Marginalized (below 0.20)*—technology diffusion and skill building have a long way to go in these countries. Large parts of the population have not benefited from the diffusion of old technology. These rankings do not shadow income rankings and show considerable dynamism in several countries with rising technological achievement— for example, Korea ranks above the United Kingdom, Canada and other established industrial economies. Ireland ranks above Austria and France. Large developing countries—Brazil, China, India—do less well than one might expect because this is not a ranking of "technological might" of a country. Finally, technology hubs have a limited effect on the index because of disparities within countries. If the TAI were estimated only for the hubs, such countries would undoubtedly rank as leaders or potential leaders.

These rankings do not shadow income rankings and show considerable dynamism in countries with rising technological achievements – for example, Korea ranks above the United Kingdom, Canada and other well established industrial countries. Ireland ranks above France.

Policy priorities for countries

A look at a country's TAI ranking and composition can reveal areas of strengths and weaknesses. This can be illustrated by cases of Brazil, Mexico and India.

BRAZIL - Brazil is one of the most dynamic countries in Latin America, having two world class technology hubs in Sao Paolo and Rio de Janeiro, being in the forefront of policy initiatives in global fora in areas such as the management of intellectual property. Yet the country ranks relatively poorly in the TAI at 43rd place, behind a number of other developing countries such as Malaysia, Mexico, Argentina, Costa Rica, Chile, Uruguay, Thailand, South Africa. Why?

First, the diffusion of old inventions – telephones and electricity – has been slow. Brazil lags far behind such countries as Malaysia, Argentina, and Chile. The likelihood is that these basic technologies that have been around for a century still have not reached rural communities and poorer families. And these two technologies are fundamental building blocks to being fully linked to the new technologies driving progress in the 21st century.

Second, Brazil lags behind in training people with skills. For example, enrolment of Brazilian students in science and mathematics in post secondary education is only 3.2% of the age group, far less than 13.2% in Chile, or 7.3 % in Uruguay. Developing countries that have made the most rapid progress in technological achievements – Korea and Singapore – have invested heavily in education. Gross enrolment rates are over 20%. Mean years of schooling in Brazil is 4.9 years compared with 6.8 years in Malaysia, 8.8 years in Argentina and 7.2 years in Mexico and 6.1 years in South Africa. The proportion of students in universities and other tertiary level institutions enrolled in

14

science and mathematics is only 3.2% of the age group in contrast to over 10% in Argentina, Chile, and the OECD average.

Technological advance is more rapid and more fundamental than it has been ever before in any historical era. Workers have to adapt to new technologies all the time, and that means that basic education is a necessity. *Does Brazil's education system need to be rethought to meeting the challenges of the network age?*

Third, Brazil is doing better than Argentina and Chile in entering the high tech export markets. But is this leading to linkages to dynamic development of the rest of the economy? Are the employers providing training for workers? Experience of leading countries that have successfully used technology for sustained economic growth and for equitable development show high levels of commitment to diffusion of technology widely through the population, and to the development of human skills.   Diverse countries such as Finland, Korea, Singapore all adopted very proactive policies for increasing quantity and quality of education in science and mathematics scoring not only high in enrolment levels but also in international performance tests, and provided many incentives for businesses to train their workers. They have also introduced invested heavily in the diffusion of technology.

While Brazil is leading the way in participating in the network age with its world-class hubs and pioneering policies for making new technologies work for human development, it still has a long way to go in spreading technological progress throughout the country, to all its people.

MEXICO - In contrast to Brazil, Mexico does well in the index, ranking number 32 out of 72 countries, higher than any other developing country except for the four Asian Tigers and cubs – Korea, Singapore, Hong Kong and Malaysia, and outranks Argentina, Costa Rica, Chile, Uruguay and Brazil.

While Mexico's high score is due first and foremost to its success in one measure - 66% of her export earnings come from high and medium tech products. This is one of the highest levels in the world. The only other countries that have over 60% of export earnings from high and medium technology products are the US, Japan, Korea, UK and Germany, Hungary and Malaysia. This clearly shows Mexico's extraordinary success in using new technologies. It shows that the country has responded very positively to the niche opportunities that are being created in the global market. High tech sector has been the most rapidly growing sector of the global economy in the last decade.

Yet other indicators show that Mexico has a long way to go in developing its technological capacity, and in translating that for the purposes of sustainable development for all its citizens.

First, the diffusion of old inventions – telephones and electricity – has been slow. Mexico lags far behind such countries as Malaysia, Argentina, and Chile. The likelihood is that these basic technologies that have been around for a century still have not reached rural communities and poorer families. And these two technologies are fundamental building blocks to being fully linked to the new technologies driving progress in the 21st century. *How bad is the technological divide within Mexico?*

Second, the development of human skills is another fundamental building block of technological capacity. Here again, Mexico can do much more, especially in science and maths training. Mexico has made significant progress in improving overall education, achieving 7.2 years of schooling, a level comparable to Chile, Uruguay, Italy and Malaysia. Yet the proportion of students in universities and other tertiary level institutions enrolled in science and mathematics is only 5% of the age group in contrast to over 10% in Argentina, Chile, and the OECD average. In an age of rapid technological advance, workers have to adapt to new technologies all the time, and that means that basic education is a necessity. *Is Mexico's education system adequate to meeting the challenges of the network age?*

Third, much of the exports are from foreign direct investment. Is this leading to linkages to dynamic development of the rest of the economy in Mexico? Are the employers providing training for workers? Is Mexico able to climb up the skill ladder and move into more skill intensive segments of the high and medium tech industries?

Mexico's high rank in the Technology Achievement Index (TAI) reflects the country's technological success in using advanced technology and the ability to compete successfully in the technology based global marketplace.   But there is a long way to go in diffusing technology – reaching poor people and empowering them to lift themselves out of poverty.   Experience of leading countries that have successfully used technology for sustained economic growth and for equitable development show high levels of commitment to diffusion of technology widely through the population, and to the development of human skills.   Diverse countries such as Finland, Korea, Singapore all adopted very proactive policies for increasing quantity and quality of education in science and mathematics scoring not only high in enrolment levels but also in international performance tests, and provided many incentives for businesses to train their workers. They have also introduced invested heavily in the diffusion of technology.

The Technology Achievement Index for Mexico is a starting point for debates on national technology policies – not for technology but for the use of technology in development that is dynamic and equitable.

INDIA – India has achieved showcase success in exploiting the opportunities of the network age. The ICT industry exports rose from $150 million to nearly $4 billion in 1999. Bangalore is a world - class hub, and other centres of technological innovation are emerging and developing.   Yet the country only 63 of 72 countries, at the bottom of the group of 'dynamic adopters'.   Why?

First, while the country has considerable capacity in state of the art technological innovation in new technologies, the TAI shows that these technological advances are not widespread. The country still only has 28 telephones per 1000 people, compared, for

17

example with 238 in Brazil, or 192 in Mexico. Mean years of schooling is only 5.1, whereas countries in the 'potential leaders' category have achieved more typically 8 or 9 years. It is also well known that rural electrification has a long way to go. The diffusion of technology has not been widespread, and the world class capacity to innovate has not been translated into patents or royalties and licence earnings to any significant level.

Second, India is a large country with a very large population. This has tended to dilute the strengths of the country in worldclass innovations.

Towards further developments

While this index provides interesting information for policy makers, further work is needed to develop a more complete measure of technological achievements. To do so requires overcoming the limitations of both concept and data.

In concept, this index measure only technological achievements, not those that are relevant for human development. Technological achievements measured could be used as much for destructive purposes as for human well being. The index does not indicate how well these achievements have been translated into human development. The index is also incomplete. A nation's technological achievements are larger and more complex than what this or any other index can capture. It is impossible to reflect the full range of technologies—from agriculture to medicine to manufacturing. Many aspects of technology creation, diffusion and human skills are hard to quantify. And even if they could be quantified, a lack of reliable data makes it impossible to fully reflect them. For example, important technological innovations occur in the informal sector and in indigenous knowledge systems. But these are not recorded and cannot be quantified. Thus the TAI is constructed using indicators, not direct measures, of a country's achievements in four dimensions. It provides a rough summary—not a comprehensive measure—of a society's technological achievements.

The index is also incomplete in country coverage - limited in coverage to 72 out of the nearly 200 countries of the world. While this is broader than that achieved by some of

the indexes, it is still far from idea, and is due to lack of data in international series. The data used to construct the TAI are from international series that are the most widely used in analyses of technology trends, and so are considered the most reliable of available sets, as shown below. The range of appropriate indicators is limited to those with reasonable coverage. Limitations in data series must be taken into account in interpreting TAI values and rankings. Some countries will have undervalued innovations because patent records and royalty payments are the only systematically collected data on technological innovation and leave out valuable but non-commercialized innovations such as those occurring in the informal sector and in indigenous knowledge systems. Moreover, national systems and traditions differ in scope and criteria. High numbers of patents may reflect liberal intellectual property systems. Diffusion of new technologies may be understated in many developing countries. Internet access is measured by Internet hosts because these data are more reliable and have better coverage than Internet user data at the country level.   (For detailed description of data sources, see appendix ss)

As technology policies gain prominence in development strategies, it is likely that progress would be made in overcoming both the data and conceptual limitations.

CALCULATING THE TECHNOLOGY ACHIEVEMENT INDEX

This illustration of the calculation of the TAI uses data for New Zealand for various years in 1997–2000.

1. Calculating the technology creation index

Patents and receipts of royalties and license fees are used to approximate the level of technology creation. Indices for the two indicators are calculated according to the general formula.

Patent index = (103 – 0) / (994 – 0) = 0.104

Royalty and license fee index = (13.0 – 0.0) / (272.6 – 0.0) = 0.048

The technology creation index is the simple average of these two indices:

Technology creation index = (0.103 + 0.048) / 2 = 0.076

2. Calculating the diffusion of recent innovations index

Using Internet hosts and the share of high- and medium-technology exports in total goods exports, the same formula is applied to calculate the diffusion of recent innovations index.

Internet host index = (146.7 – 0.0) / (232.4 – 0.0) = 0.631

High- and medium-technology export index = (15.4 – 0.0) / (80.8 – 0.0) = 0.191

Diffusion of recent innovations index = (0.631 + 0.190) / 2 = 0.411

3. Calculating the diffusion of old innovations index

The two indicators used to represent the diffusion of old innovations are telephones (mainline and cellular) and electricity consumption per capita. For these, the indices are calculated using the logarithm of the value, and the upper goalpost is the OECD average. For a detailed discussion see box 2.12 in chapter 2.

Telephony index = (log 720 – log 1) / (log 901 – log 1) = 0.967

For electricity consumption New Zealand's value is capped at 6,914, since it exceeds the goalpost.

Electricity index = (log 6,969 – log 22) / (log 6,969 – log 22) = 1.000

Diffusion of old innovations index = (0.966 + 1.000) / 2 = 0.984

4. Calculating the human skills index

The human skills index is calculated according to the general formula, using mean years of schooling and the gross tertiary science enrolment ratio.

Mean years of schooling index = (11.7 – 0.8) / (12.0 – 0.8) = 0.973

Gross tertiary science enrolment index = (13.1 – 0.1) / (27.3 – 0.1) = 0.474

Human skills index = (0.990 + 0.477) / 2 = 0.725

5. Calculating the technology achievement index

A simple average of the four dimension indices gives us the technology achievement index.

TAI = (0.076 + 0.411 + 0.984 + 0.725) / 4 = **0.549**

Appendix 2. Statistics on technology

Technology creation

The capacity for technology creation is a complex and dynamic system that cannot be fully captured by any particular indicator. And on a global scale, there is very little quantitative data on technology creation. For these reasons, it is impossible to give an accurate picture of technology creation capacity using only statistical evidence. Nonetheless, the data give a good indication of how technology creation capacity is distributed.

Patents

Patents are an often-used measure of innovation. Patents are clearly a very important indicator of innovative activity, as has been shown in numerous studies.

What complicates the use of patent data is that patent regulations vary widely from country to country. Some countries allow patents on e.g. plant varieties or business methods, others do not. Also, many developing countries have weak national patent offices, and so residents of these countries might choose to apply for patents in other countries directly. Business practices in some countries produce large number of patent applications that are not directly related to innovations. Also, industry structure has an impact: different industry sectors patent to varying degrees.

There are two main patent indicators used to measure innovation: first time patent applications filed by residents, and patents granted to residents. For the TAI, patents granted was chosen, in order not to count applications that were not awarded patents. However, the time between application and grant is about three years, introducing an extra time lag in the index.

Receipts of royalties and license fees

Royalties and license fees are, effectively, payments for the use of the intellectual property. As such, this data gives valuable information on the stock of innovations – which countries are and have been successful in building capacity for technology creation. But like all other indicators, these data are not perfect. Widely available data includes only payments received from abroad – not domestic payments. This penalizes large countries, who are less internationally oriented. The second problem is that the data

23

include payments not only for the use of innovations, but also other kinds of intellectual property, such as publishing rights.

Publications of scientific articles

The production of scientific articles is an established measure of scientific activity. There are however serious problems with this measure. Some of the most important:

- The selection of publications where articles are counted. Existing measures, such as ISI, suffer from a heavy Anglo-Saxon bias.
- Scientific articles are only one output of science. It does not directly measure such things as the quality of higher education or technical skills.
- The output of articles depends very much on the structure of R&D. In some disciplines, such as medicine, researchers publish many more articles per year than in others.

These reasons make this indicator unsuitable for the TAI.

Research and development expenditures (as % of GNP)

A country's expenditure on research and development, usually as a percentage of GNP, is a widely used measure of a country's efforts in technology creation. It is not an indicator of achievement.

Diffusion of technology

Manufacturing

Using technology in manufacturing is on important aspect of technology diffusion. There are two different approaches to measuring technology content in manufacturing: sectoral and product-based. The sectoral approach tries to classify different industries according to their technology intensity. Recent work by OECD in this field highlights some major problems with this approach. On the conceptual level, it is not clear if technology intensity means using technology or producing technology. Beyond this conceptual problem, there are several practical problems. The most serious one is of cross-country comparability. Any particular industry (e.g. textiles) could be low-technology in one country but high-technology in another. Especially when comparing developing countries with developed, this is highly problematic.

24

The product-based escapes these problems by measuring technology intensity of products, not sectors. Products in the same category by definition have the same technology content.

Because of the constraints of available data, exports were used as a proxy for manufacturing – the structure of exports is closely related to the structure of manufacturing for most countries.

There are different classification methods for exports by technology content. The OECD has proposed one, based on product categories in the export classification system known as Standard Industry and Trade Classification (SITC) revision 3. This is a very detailed classification system. However, the OECD proposal only studies high-technology exports. Many poor countries have very little or no high-technology exports. To distinguish between these it is important to also study take medium-technology exports. For this reason, a classification by Lall (2000) was used in the TAI. This classification is based on SITC revision 2, which is less detailed but enables trend analysis. The classification distuingishes between high-, medium- and low technology exports, as well as resource-based manufactures and primary products.

Internet / computing

There is a number of ways of measuring Internet diffusion. Of primary interest is how many people have the possibility to use the Internet should they have the need. However, as in many other cases the availability of data for developing countries is a major constraint. For many developing countries, Internet user surveys are of very poor quality or non-existent. User data are very often estimates with no basis in observations. Measuring Internet hosts instead of users is an attempt to escape these problems. A host is, in essence, a computer connected to the Internet. This is straightforward to count. While the number of Internet-connected computers does not directly tell us how many users there are, it gives a good indication, and data are available for practically all countries.

Electricity

Electricity is an old technology that is still not diffused to large parts of the world. It is crucial to almost all forms of technological development. Therefore, it is of great importance when measuring technology diffusion. The problem in measurement is that

no data is available on the national level on how many people have access to electricity. The closest proxy available is consumption – the more people have access to electricity, the higher consumption. Of course, other factors, such as geography, also influence consumption.

Telephony / Telefax

Telephones are another old technology where diffusion has stalled, and one that is important to many other aspects of technological development. Fortunately, telephony diffusion is also easy to measure. Data on the number of telephone subscribers, both of landlines and cellular telephones, are widely available.

Human skills

Human skills are vital to be able to adapt to new technological realities, and are thus included in the TAI. Two indicators are used: mean years of schooling and the gross tertiary science enrolment ratio.

Mean years of schooling

Mean years of schooling is the average number of years of school completed in the population of age 15 and above. While this measure does not take into account differences in the quality of schooling, it gives an indication of the level of human skills in the population.

To create these estimates, a combination of survey data on school attainment and time-series data on enrolment was used. The survey data gives information on proportions of the population that have completed primary, secondary and tertiary education. This data is available for about 40 percent of data points. Where this data is not available, trend data on gross enrolment, adjusted for repeaters, is used to estimate the proportions of the population having attained primary, secondary and tertiary education.

In the second step these attainment levels are multiplied by the duration of the respective level in different countries to produce an estimate on the average years of schooling. These estimates are produced for two different groups, the population age 15 and above and the population age 25 and above. For the TAI, the prior was chosen since it corresponds more closely to the age of the workforce, particularly in developing countries.

26

Enrolment data

Mean years of schooling is an indicator that moves very slowly. To reflect present efforts in building a technology skill base, it is useful to study enrolment data. While primary and secondary education are important, we identified tertiary science education is vital to have the capacity to adapt to new technologies. This indicator refers to the number of students enrolled in technical and scientific tertiary education, as a share of the population in the relevant age range (19-24 for most countries). The indicator used in the TAI is the gross tertiary science enrolment ratio, which refers to the number of students enrolled in technical and scientific tertiary education, as a share of the population in the relevant age range (19-24 for most countries).

Table 1 - Technology achievement index

TAI rank		Technology achievement index (TAI) value	Technology creation		Diffusion of recent innovations		Diffusion of old innovations		Human sk	
			Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000	s en 1
Leaders										
1	Finland	0.744	187	125.6	200.2	50.7	1,203 d	14,129 e	10.0	
2	United States	0.733	289	130.0	179.1	66.2	993 d	11,832 e	12.1	
3	Sweden	0.703	271	156.6	125.8	59.7	1,247 d	13,955 e	11.4	
4	Japan	0.698	994	64.6	49.0	80.8	1,007 d	7,322 e	9.5	
5	Korea, Rep. of	0.666	779	9.8	4.8	66.7	938 d	4,497	10.8	
6	Netherlands	0.630	189	151.2	136.0	50.9	1,042 d	5,908	9.4	
7	United Kingdom	0.606	82	134.0	57.4	61.9	1,037 d	5,327	9.4	
8	Singapore	0.591	8	14.6 h,i	72.3	74.9	901	6,771	7.1	
9	Canada	0.589	31	38.6	108.0	48.7	881	15,071 e	11.6	
10	Australia	0.587	75	18.2	125.9	16.2	862	8,717 e	10.9	
11	Germany	0.583	235	36.8	41.2	64.2	874	5,681	10.2	
12	Norway	0.579	103	20.2 i	193.6	19.0	1,329 d	24,607 e	11.9	
13	Ireland	0.566	106	110.3	48.6	53.6	924 d	4,760	9.4	
14	Belgium	0.553	72	73.9	58.9	47.6	817	7,249 e	9.3	
15	New Zealand	0.548	103	13.0	146.7	15.4	720	8,215 e	11.7	
16	Austria	0.544	165	14.8	84.2	50.3	987 d	6,175	8.4	
17	France	0.535	205	33.6	36.4	58.9	943 d	6,287	7.9	
18	Israel	0.514	74	43.6	43.2	45.0	918 d	5,475	9.6	
Potential leaders										
19	Spain	0.481	42	8.6	21.0	53.4	730	4,195	7.3	
20	Italy	0.471	13	9.8	30.4	51.0	991 d	4,431	7.2	
21	Czech Republic	0.465	28	4.2	25.0	51.7	560	4,748	9.5	
22	Hungary	0.464	26	6.2	21.6	63.5	533	2,888	9.1	
23	Slovenia	0.458	105	4.0	20.3	49.5	687	5,096	7.1	
24	Hong Kong, China (SAR)	0.455	6	..	33.6	33.6	1,212 d	5,244	9.4	
25	Slovakia	0.447	24	2.7	10.2	48.7	478	3,899	9.3	
26	Greece	0.437	(.)	0.0 j	16.4	17.9	839	3,739	8.7	
27	Portugal	0.419	6	2.7	17.7	40.7	892	3,396	5.9	
28	Bulgaria	0.411	23	..	3.7	30.0 i	397	3,166	9.5	
29	Poland	0.407	30	0.6	11.4	36.2	365	2,458	9.8	
30	Malaysia	0.396	..	0.0	2.4	67.4	340	2,554	6.8	
31	Croatia	0.391	9	..	6.7	41.7	431	2,463	6.3	
32	Mexico	0.389	1	0.4	9.2	66.3	192	1,513	7.2	
33	Cyprus	0.386	..	..	16.9	23.0	735	3,468	9.2	

28

TAI rank		Technology achievement index (TAI) value	Technology creation		Diffusion of recent innovations		Diffusion of old innovations		Human sk
			Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000
34	Argentina	0.381	8	0.5	8.7	19.0	322	1,891	8.8
35	Romania	0.371	71	0.2	2.7	25.3	227	1,626	9.5
36	Costa Rica	0.358	..	0.3	4.1	52.6	239	1,450	6.1
37	Chile	0.357	..	6.6	6.2	6.1	358	2,082	7.6
Dynamic adopters									
38	Uruguay	0.343	2	0.0 j	19.6	13.3	366	1,788	7.6
39	South Africa	0.340	..	1.7	8.4	30.2 k	270	3,832	6.1
40	Thailand	0.337	1	0.3	1.6	48.9	124	1,345	6.5
41	Trinidad and Tobago	0.328	..	0.0 i	7.7	14.2	246	3,478	7.8
42	Panama	0.321	..	0.0	1.9	5.1	251	1,211	8.6
43	Brazil	0.311	2	0.8	7.2	32.9	238	1,793	4.9
44	Philippines	0.300	(.)	0.1	0.4	32.8	77	451	8.2
45	China	0.299	1	0.1	0.1	39.0	120	746	6.4
46	Bolivia	0.277	..	0.2	0.3	26.0	113	409	5.6
47	Colombia	0.274	1	0.2	1.9	13.7	236	866	5.3
48	Peru	0.271	..	0.2	0.7	2.9	107	642	7.6
49	Jamaica	0.261	..	2.4	0.4	1.5 i	255	2,252	5.3
50	Iran, Islamic Rep. of	0.260	1	0.0 i	(.)	2.0	133	1,343	5.3
51	Tunisia	0.255	..	1.1	(.)	19.7	96	824	5.0
52	Paraguay	0.254	..	35.3	0.5	2.0	137	756	6.2
53	Ecuador	0.253	..	..	0.3	3.2	122	625	6.4
54	El Salvador	0.253	..	0.2	0.3	19.2	138	559	5.2
55	Dominican Republic	0.244	..	..	1.7	5.7 i	148	627	4.9
56	Syrian Arab Republic	0.240	..	..	0.0	1.2	102	838	5.8
57	Egypt	0.236	(.)	0.7	0.1	8.8	77	861	5.5
58	Algeria	0.221	..	..	(.)	1.0	54	563	5.4
59	Zimbabwe	0.220	(.)	..	0.5	12.0	36	896	5.4
60	Indonesia	0.211	..	..	0.2	17.9	40	320	5.0
61	Honduras	0.208	..	0.0	(.)	8.2	57	446	4.8
62	Sri Lanka	0.203	..	..	0.2	5.2	49	244	6.9
63	India	0.201	1	(.)	0.1	16.6 i	28	384	5.1
Marginalized									
64	Nicaragua	0.185	..	..	0.4	3.6	39	281	4.6
65	Pakistan	0.167	..	(.) j	0.1	7.9	24	337	3.9
66	Senegal	0.158	..	0.0 j	0.2	28.5	27	111	2.6
67	Ghana	0.139	(.)	..	(.)	4.1	12	289	3.9
68	Kenya	0.129	(.)	(.)	0.2	7.2	11	129	4.2
69	Nepal	0.081	..	0.0	0.1	1.9 i	12	47	2.4
70	Tanzania, U. Rep. of	0.080	..	(.)	(.)	6.7	6	54	2.7
71	Sudan	0.071	..	0.0	0.0	0.4 i	9	47	2.1
72	Mozambique	0.066	..	..	(.)	12.2 i	5	54	1.1

TAI rank		Technology achievement index (TAI) value	Technology creation		Diffusion of recent innovations		Diffusion of old innovations		Human sk
			Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000
Others									
	Afghanistan	.	..	..	0.0	..	1	..	1.7
	Albania	.	..	..	0.1	4.2 i	39	678	..
	American Samoa	.	..	..	..	..	248	..	..
	Andorra	.	..	..	23.2	..	722	..	..
	Angola	.	..	..	(.)	..	10	60	..
	Anguilla	.	..	..	..	..	..	..	..
	Antigua and Barbuda	.	..	..	6.6	..	602	..	..
	Armenia	.	8	..	0.9	11.7	158	930	..
	Aruba	.	..	..	5.0	53.5 i	494	..	..
	Azerbaijan	.	..	..	0.1	6.3	118	1,584	..
	Bahamas	.	..	..	..	..	422	..	..
	Bahrain	.	..	..	3.6	5.7 i	453	7,645	6.1
	Bangladesh	.	(.)	(.)	0.0	2.9 i	5	81	2.6
	Barbados	.	..	0.8	0.5	31.3	538	..	8.7
	Belarus	.	50	0.1	0.3	46.5	259	2,762	..
	Belize	.	..	0.0 i	2.2	0.2 l	182	..	..
	Benin	.	..	..	(.)	..	..	46	2.3
	Bermuda	.	..	..	95.8	..	..	..	..
	Bhutan	.	..	..	2.1	..	18	..	..
	Bosnia and Herzegovina	.	..	..	1.0	..	110	539	..
	Botswana	.	1	(.)	2.7	..	150	..	6.3
	British Virgin Islands	.	..	..	..	..	..	..	..
	Brunei Darussalam	.	..	..	8.0	..	451	7,676	..
	Burkina Faso	.	..	..	(.)	..	5	..	..
	Burundi	.	..	0.0	0.0	..	3	..	..
	Cambodia	.	..	..	(.)	..	11	..	..
	Cameroon	.	..	..	(.)	2.2 i	..	185	3.5
	Cape Verde	.	..	(.) i	0.1	..	131	..	..
	Cayman Islands	.	..	..	..	..	..	..	..
	Central African Republic	.	..	..	(.)	13.6 i	..	..	2.5
	Chad	.	..	..	(.)	..	..	..	..
	Comoros	.	..	..	0.1	..	10	..	..
	Congo	.	..	0.0 j	(.)	..	..	83	5.1
	Congo, Dem. Rep. of the	.	..	..	(.)	..	..	110	3.0
	Cook Islands	.	..	..	..	..	..	..	..
	Côte d'Ivoire	.	..	..	0.1	..	33	..	..
	Cuba	.	..	..	0.1	..	39	954	7.7
	Denmark	.	52	..	114.3	41.0	1,179	6,033	9.7
	Djibouti	.	..	..	0.1	..	14	..	..
	Dominica	.	..	0.0 i	4.1	50.7 l	..	..	..

30

TAI rank	Technology achievement index (TAI) value	Technology creation		Diffusion of recent innovations		Diffusion of old innovations		Human sk	
		Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000	s er 1
East Timor	.	..	..	..	..	..	..	..	
Equatorial Guinea	.	..	..	0.0	..	..	..	..	
Eritrea	.	..	..	(.)	..	7	..	..	
Estonia	.	1	1.2	43.1	31.9	624	3,531	..	
Ethiopia	.	..	..	(.)	..	3	22	..	
Faeroe Islands	.	..	..	52.5	3.9	798	..	..	
Falkland Islands (Malvinas)	.	..	..	..	..	..	..	..	
Fiji	.	..	..	0.9	..	130	..	8.3	
French Guiana	.	..	..	1.4	..	386	..	..	
French Polynesia	.	..	..	9.3	..	321	..	..	
Gabon	.	..	..	(.)	0.9 i	39	749	..	
Gambia	.	1	..	(.)	..	27	..	2.3	
Georgia	.	67	..	0.4	..	142	1,257	..	
Gibraltar	.	..	..	..	..	935 d	..	..	
Greenland	.	..	..	70.8	0.6	698	..	..	
Grenada	.	..	..	0.1	1.7 l	337	..	..	
Guadeloupe	.	..	..	2.3	..	643	..	..	
Guam	.	..	..	1.5	..	..	..	..	
Guatemala	.	(.)	..	0.5	16.0	86	322	3.5	
Guinea	.	..	..	(.)	..	9	..	..	
Guinea-Bissau	.	..	..	(.)	..	..	..	0.8	
Guyana	.	..	..	0.1	..	78	..	6.3	
Haiti	.	..	..	0.0	3.2 i	12	33	2.8	
Holy See	.	..	..	..	..	..	..	..	
Iceland	.	15	..	232.4	9.8	1,297	20,150	8.8	
Îles Turques et Caïques	.	..	..	..	..	..	..	..	
Îles Wallis et Futuna	.	..	..	..	..	..	..	..	
Iraq	.	..	..	0.0	..	30	1,359	4.0	
Isle of Man	.	..	..	..	..	..	..	..	
Jordan	.	..	..	0.2	..	105	1,205	6.9	
Kazakhstan	.	55	..	0.6	15.0	111	2,399	..	
Kiribati	.	..	..	1.0	..	45	..	..	
Korea, Dem. Rep.	.	..	..	..	..	46	..	..	
Kuwait	.	..	..	4.4	6.8	398	13,800	6.2	
Kyrgyzstan	.	14	..	1.1	10.9	77	1,431	..	
Lao People's Dem. Rep.	.	..	..	0.0	..	8	..	..	
Latvia	.	71	4.3	13.4	12.4	412	1,879	..	
Lebanon	.	..	..	2.3	..	..	1,820	..	
Lesotho	.	..	6.5	0.1	..	..	..	4.2	
Liberia	.	..	..	(.)	..	..	..	2.5	
Libyan Arab Jamahiriya	.	..	..	(.)	1.8 i	..	3,677	..	

31

| TAI rank | Technology achievement index (TAI) value | Technology creation | | Diffusion of recent innovations | | Diffusion of old innovations | | Human sk | |
		Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000	en 1
Liechtenstein	.	..	..	..	..	902 d	..	..	
Lithuania	.	27	(.)	7.5	29.2	401	1,909	..	
Luxembourg	.	202	272.6	49.5	34.0	1,211	12,400	..	
Macau	.	..	..	0.7	3.7	610	..	..	
Macedonia, TFYR	.	19	1.1	1.9	23.8 i	258	..	..	
Madagascar	.	..	(.) i	0.1	3.0	..	..	..	
Malawi	.	..	..	0.0	..	6	..	3.2	
Maldives	.	..	0.0 j	1.7	..	90	..	..	
Mali	.	..	..	(.)	..	..	..	0.9	
Malta	.	18	0.0	19.5	72.0	609	3,719	..	
Marshall Islands	.	..	..	0.1	..	..	..	..	
Martinique	.	..	..	1.6	..	698	..	..	
Mauritania	.	..	0.0 i	(.)	..	6	..	..	
Mauritius	.	..	0.0	5.2	4.3	312	..	6.0	
Micronesia, Fed. Sts.	.	..	..	6.2	..	..	..	..	
Moldova, Rep. of	.	42	(.)	0.7	6.2	131	689	..	
Monaco	.	641	..	..	..	..	..	..	
Mongolia	.	56	0.4	0.1	3.2 i	53	..	..	
Montserrat	.	..	..	..	..	..	..	..	
Morocco	.	3	0.2	0.1	12.4 i	66	443	..	
Myanmar	.	..	(.)	0.0	..	6	64	2.8	
Namibia	.	..	3.5 i	3.7	..	82	..	..	
Nauru	.	..	..	..	..	..	..	..	
Netherlands Antilles	.	..	..	0.9	..	..	4,118	..	
New Caledonia	.	..	..	2.3	..	362	..	..	
Niger	.	..	..	(.)	..	..	..	1.0	
Nigeria	.	..	..	(.)	0.4	..	85	..	
Niue	.	..	..	..	..	..	..	..	
Norfolk Island	.	..	..	..	..	..	..	..	
Northern Mariana Islands	.	..	..	0.5	..	526	..	..	
Occupied Palestinian Territory	.	..	..	..	..	..	..	..	
Oman	.	..	..	1.4	13.2	139	2,828	..	
Palau	.	..	..	..	..	..	..	..	
Papua New Guinea	.	..	..	0.1	..	14	..	2.9	
Pitcairn	.	..	..	..	..	..	..	..	
Puerto Rico	.	..	..	0.6	..	542	..	..	
Qatar	.	..	..	..	..	406	13,912	..	
Reunion	.	..	..	(.)	..	..	..	..	
Russian Federation	.	131	0.3	3.5	16.0	220	3,937	..	
Rwanda	.	..	0.0	0.1	..	3	..	2.6	
Saint Helena	.	..	..	..	..	..	..	..	

| TAI rank | Technology achievement index (TAI) value | Technology creation | | Diffusion of recent innovations | | Diffusion of old innovations | | Human sk |
		Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000
Saint Kitts and Nevis	.	..	..	0.2	30.6 i	536	..	..
Saint Lucia	.	..	..	0.2	5.4 i	..	..	..
Saint Pierre and Miquelon	.	..	..	..	1.2	..	..	..
Saint Vincent and the Grenadines	.	..	..	(.)	2.0 i	221	..	..
Samoa (Western)	.	..	..	5.3	..	..	..	..
San Marino	.	..	..	..	..	..	..	..
Sao Tome and Principe	.	..	..	8.6	..	31	..	..
Saudi Arabia	.	(.)	0.0	0.3	5.2 i	170	4,692	..
Seychelles	.	..	..	0.1	(.) i	..	..	..
Sierra Leone	.	..	..	0.1	..	..	..	2.4
Solomon Islands	.	..	0.1	1.4	..	21	..	..
Somalia	.	..	..	0.0	..	..	..	..
Suriname	.	..	0.0 i	0.0	1.0 i	213	..	..
Svalbard and Jan Mayen Islands	.	..	..	..	..	..	..	..
Swaziland	.	..	0.2	1.4	..	45	..	6.0
Switzerland	.	183	..	82.7	63.6	1,109	6,981	10.5
Taiwan Province of China	.	..	..	74.3	61.3 i	1,068 d	6,287	8.8
Tajikistan	.	2	..	0.1	..	35	2,046	..
Togo	.	..	..	0.1	0.4	12	..	3.3
Tokelau	.	..	..	..	..	..	..	..
Tonga	.	..	..	82.6	..	94	..	..
Turkey	.	(.)	..	2.5	26.7	384	1,353	5.3
Turkmenistan	.	10	..	0.3	..	83	859	..
Tuvalu	.	..	..	..	..	..	..	..
Uganda	.	..	0.0 j	(.)	2.2	5	..	3.5
Ukraine	.	84	..	1.2	..	203	2,350	..
United Arab Emirates	.	..	..	20.9	..	754	9,892	..
Uzbekistan	.	25	..	(.)	..	68	1,618	..
Vanuatu	.	..	..	1.6	..	..	..	..
Venezuela	.	..	0.0	1.2	6.2	253	2,566	6.6
Viet Nam	.	..	..	(.)	..	31	232	..
Virgin Islands (U.S.)	.	..	..	9.2	..	..	..	..
Western Sahara	.	..	..	..	..	..	..	..
Yemen	.	..	..	(.)	..	18	96	..
Yugoslavia	.	19	..	2.4	23.4 i	271	..	..
Zambia	.	(.)	..	0.2	..	12	539	5.5

a. For purposes of calculating the TAI a value of zero was used for countries for which no data were available.

33

TAI rank	Technology achievement index (TAI) value	Technology creation		Diffusion of recent innovations		Diffusion of old innovations		Human sk	
		Patents granted to residents (per million people) 1998[a]	Receipts of royalty and license fees (US$ per 1,000 people) 1999[b]	Internet hosts (per 1,000 people) 2000	High- and medium-technology exports (as % of total goods exports) 1999	Telephones (mainlines and cellular, per 1,000 people) 1999	Electricity consumption (kilowatt-hours per capita) 1998	Mean years of schooling (age 15 and above) 2000	t s er 1

b. For purposes of calculating the TAI a value of zero was used for non-OECD countries for which no data were available.

c. Data refer to the most recent year available during the period specified.

d. For purposes of calculating the TAI the weighted average value for OECD countries (901) was used.

e. For purposes of calculating the TAI the weighted average value for OECD countries (6,969) was used.

f. Data refer to the most recent year available during the period 1989-94.

g. Data are based on preliminary UNESCO estimates of the tertiary gross enrolment ratio.

h. Data from national sources.

i. Data refer to 1998.

j. Data refer to 1997.

k. Data refer to the South African Customs Union, which comprises Botswana, Lesotho, Namibia, South Africa and Swaziland.

l. Data refer to medium-technology exports only.

Source:

Column 1: calculated on the basis of data in columns 2-9; see technical note 2 for details

Column 2: WIPO 2001a

Column 3: unless otherwise noted, World Bank 2001h

Column 4: ITU 2001a

Column 5: calculated on the basis of data on exports from Lall 2001 and UN 2001a

Column 6: ITU 2001b

Column 7: World Bank 2001h

Column 8: Barro and Lee 2000

Column 9: calculated on the basis of data on gross tertiary enrolment ratios and tertiary science enrolment from UNESCO 1998, 1999 and 2001a.

References

Barré, Rémi. 2001. "Sense and nonsense of S&T productivity indicators"

World Economic Forum. 1999. *The Global Competitiveness Report 1999.* New York: Oxford University Press.

Castells, 2000, 'Information, Technology and Global Capitalism', in Hutton and Giddens, eds. *On the Edge, essays on a Runaway World,* London, Jonathan Cape

Fleischer, Manfred. 1999. "Innovation, Patenting, and Performance." *Economie Appliquée* 52 (2):95-119.

WIPO (World Intellectual Property Organization). 2000. *Industrial Property Statistics.* Publication A. Geneva.

Hatzichronoglou, Thomas. 1997. "Revision of the High-Technology Sector and Product Classification." STI Working Paper 1997/2. OECD Directorate for Science, Technology and Industry, Paris.

IMD (International Institute for Management Development). *The world competitiveness yearbook 2000.* Lausanne: IMD International.

Lall, 2000 xxx (background paper for HDR2001_

Lall, Sanjaya. 2000. "The Technological Structure and Performance of Developing Country Manufactured Exports, 1985-98." *Oxford Development Studies* 28 (3):337-69.

UNESCO (United Nations Educational, Scientific and Cultural Organization. 1998. *World Science Report 1998.* Paris.

Lee, Jong-Wha, 2001, "Education for Technology Readiness: Prospects for Developing countries", *Journal of Human Development, vol 2 number 1, January 2001*

Lipton. Blackman and .Sinha, xxxxx background paper for HDR2001

Rodriguez and Wilson, Are Poor Countries Losing the Information Revolution? University of Maryland at College Park, May 2000, INFODEV working paper, World Bank.

Francisco Sagasti, The Knowledge Explosion: 50 years of emerging divide. HDR

Background Paper, October 2000

Warner, Andrew, 'Economic Creativity' in World Competitiveness Report, 2000,

Harvard University

Wired Magazine, July 2000

World Economic Forum. 2000. *The Global Competitiveness Report 2000.* New York:

Oxford University Press.