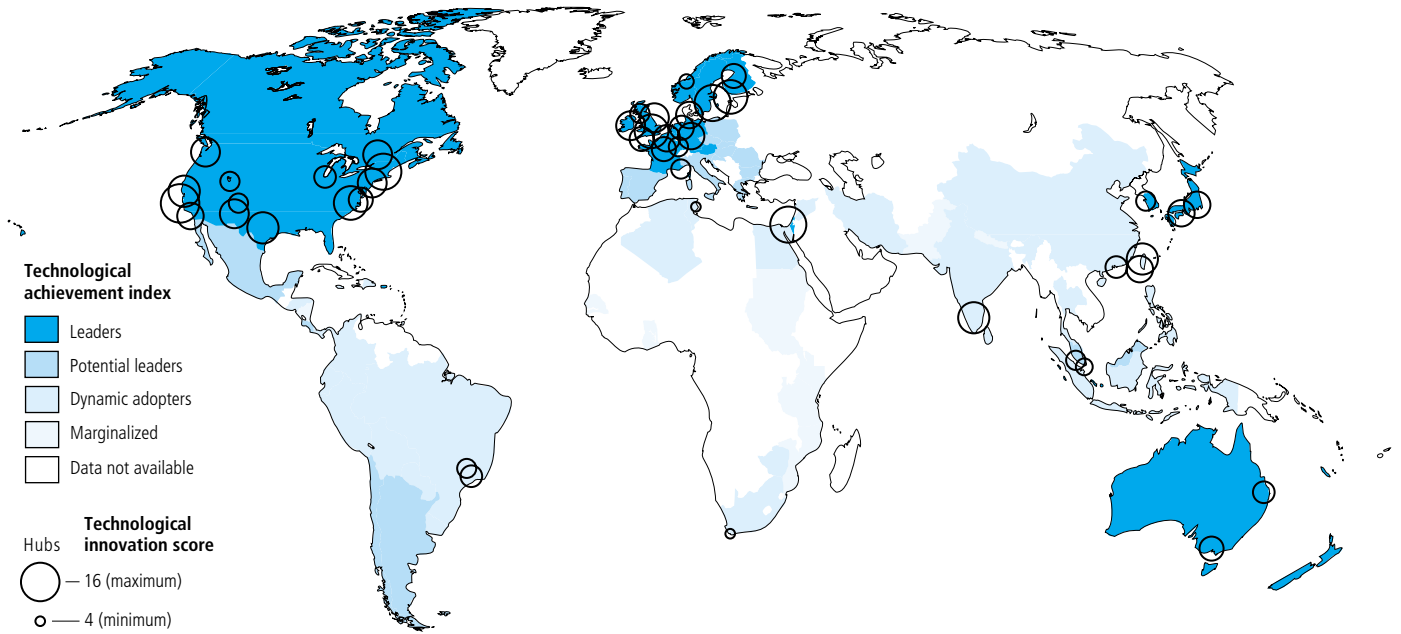


**THE GEOGRAPHY OF TECHNOLOGICAL INNOVATION AND ACHIEVEMENT**



**Global hubs of technological innovation** In 2000 *Wired* magazine consulted local sources in government, industry and the media to find the locations that matter most in the new digital geography. Each was rated from 1 to 4 in four areas: the ability of area universities and research facilities to train skilled workers or develop new technologies, the presence of established companies and multinational corporations to provide expertise and economic stability, the population’s entrepreneurial drive to start new ventures and the availability of venture capital to ensure that the ideas make it to market. Forty-six locations were identified as technology hubs, shown on the map as black circles

<b>Score</b>	13	Taipei, Taiwan (province of China)	11	Malmö, Sweden–Copenhagen, Denmark	10	Paris, France	8	Santa Fe, US	
16	Silicon Valley, US	13	Bangalore, India	11	Bavaria, Germany	10	Baden-Württemberg, Germany	8	Glasgow-Edinburgh, UK
15	Boston, US	12	New York City, US	11	Flanders, Belgium	10	Oulu, Finland	8	Saxony, Germany
15	Stockholm-Kista, Sweden	12	Albuquerque, US	11	Tokyo, Japan	10	Melbourne, Australia	8	Sophia Antipolis, France
15	Israel	12	Montreal, Canada	11	Kyoto, Japan	10	Chicago, US	8	Inchon, Rep. of Korea
14	Raleigh-Durham-Chapel Hill, US	12	Seattle, US	11	Hsinchu, Taiwan (province of China)	9	Hong Kong, China (SAR)	8	Kuala Lumpur, Malaysia
14	London, UK	12	Cambridge, UK	11	Virginia, US	9	Queensland, Australia	8	Campinas, Brazil
14	Helsinki, Finland	12	Dublin, Ireland	10	Thames Valley, UK	9	Sao Paulo, Brazil	7	Singapore
13	Austin, US	11	Los Angeles, US	10		8	Salt Lake City, US	6	Trondheim, Norway
13	San Francisco, US							4	El Ghazala, Tunisia
								4	Gauteng, South Africa

Source: Hillner 2000.

**Four categories of the technology achievement index** (see annex 2.1, p. 46; and annex table A2.1, p. 48)

LEADERS	POTENTIAL LEADERS	DYNAMIC ADOPTERS	MARGINALIZED
Finland (2 hubs)	Spain	Uruguay	Nicaragua
United States (13 hubs)	Italy	South Africa (1 hub)	Pakistan
Sweden (2 hubs)	Czech Republic	Thailand	Senegal
Japan (2 hubs)	Hungary	Trinidad and Tobago	Ghana
Korea, Rep. of (1 hub)	Slovenia	Panama	Kenya
Netherlands	Hong Kong, China (SAR)	Brazil (2 hubs)	Nepal
United Kingdom (4 hubs)	Slovakia	Philippines	Tanzania, U. Rep. of
Canada (1 hub)	Greece	China (3 hubs)	Sudan
Australia (2 hubs)	Portugal	Bolivia	Mozambique
Singapore (1 hub)	Bulgaria	Colombia	
Germany (3 hubs)	Poland	Peru	
Norway (1 hub)	Malaysia (1 hub)	Jamaica	
Ireland (1 hub)	Croatia	Iran, Islamic Rep. of	
Belgium (1 hub)	Mexico		
New Zealand	Cyprus		
Austria	Argentina		
France (2 hubs)	Romania		
Israel (1 hub)	Costa Rica		
	Chile		

This Report introduces the technology achievement index (TAI), which aims to capture how well a country is creating and diffusing technology and building a human skill base—reflecting capacity to participate in the technological innovations of the network age. This composite index measures achievements, not potential, effort or inputs. It 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.

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.

### Why a composite index?

The TAI is intended to help policy-makers define technology strategies. This Report argues that development strategies need to be redefined in the network age. It calls on policy-makers to take a new look at their current technology achievements as a first step. 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 design of the index reflects two particular concerns. First, to focus on indicators that reflect policy concerns for all countries, regardless of the level of technological development. Second, to be useful for developing countries. To accom-

plish this the index must be able to discriminate between countries at the lower end of the range.

### 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 commercialization 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.

- *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. Two indicators are used to reflect the human skills needed to create and absorb innovations: mean years of schooling and gross enrolment ratio of tertiary students enrolled in science, mathematics and engineering. Though it would be desirable to include indicators of vocational training, these data are not available.

### Data sources and limitations

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.

### Weighting and aggregation

The methodology for constructing the TAI is presented in detail in the technical note. Each of the four dimensions has equal weight. Each of the indicators that make up the dimensions also has equal weight.

### TAI values and rankings

TAI estimates have been prepared for 72 countries for which data are available and of acceptable quality. 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.

Dimension	Indicator	Source
Creation of technology	Patents granted per capita	World Intellectual Property Organization (WIPO 2001a)
	Receipts of royalty and license fees from abroad per capita	World Bank (World Bank 2001h)
Diffusion of recent innovations	Internet hosts per capita	International Telecommunication Union (ITU 2001a)
	High- and medium-technology exports as a share of all exports	United Nations Statistical Division (calculated based on data from Lall 2001 and UN 2001a)
Diffusion of old innovations	Logarithm of telephones per capita (mainline and cellular combined)	International Telecommunication Union (ITU 2001b)
	Logarithm of electricity consumption per capita	World Bank (World Bank 2001h)
Human skills	Mean years of schooling	Barro and Lee (Barro and Lee 2000)
	Gross enrolment ratio at tertiary level in science, mathematics and engineering	United Nations Educational, Scientific and Cultural Organization (calculated based on data from UNESCO 1998, 1999 and 2001a)

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 groups 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:

- *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 tenth 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.

### Technological achievement and human development

Although technological achievements are important for human development, the TAI measures only technological achievements. It does not indicate how well these achievements have been translated into human development. Still, the TAI shows a high correlation with the human development index (HDI), and it correlates better with the HDI than with income.

Source: Desai and others 2001.