Chapter 1

The Power and Reach of Knowledge

Knowledge is critical for development, because everything we do depends on knowledge. Simply to live, we must transform the resources we have into the things we need, and that takes knowledge. And if we want to live better tomorrow than today, if we want to raise our living standards as a household or as a country—and improve our health, better educate our children, and preserve our common environment—we must do more than simply transform *more* resources, for resources are scarce. We must use those resources in ways that generate ever-higher returns to our efforts and investments. That, too, takes knowledge, and in ever-greater proportion to our resources.

For countries in the vanguard of the world economy, the balance between knowledge and resources has shifted so far toward the former that knowledge has become perhaps the most important factor determining the standard of living—more than land, than tools, than labor. Today's most technologically advanced economies are truly knowledge-based. And as they generate new wealth from their innovations, they are creating millions of knowledge-related jobs in an array of disciplines that have emerged overnight: knowledge engineers, knowledge managers, knowledge coordinators.

The need for developing countries to increase their capacity to use knowledge cannot be overstated. Some are catching on, developing national knowledge strategies, and catching up. But most need to do much more, much faster, to increase their knowledge base, to invest in educating their people, and to take advantage of the new technologies for acquiring and disseminating knowledge. Countries that postpone these tasks will fall behind those that move faster, and the unhappy consequences for their development prospects will be hard to remedy.

The quest for knowledge begins with the recognition that knowledge cannot easily be bought off the shelf, like cabbages or computers. The marketability of knowledge is limited by two features that distinguish it from more traditional commodities. The first is that one person's use of this or that bit of knowledge does not preclude the use of that same bit by others—it is, as economists say, *nonrivalrous*. This morning's weather forecast is as useful to me if I pass it on as if I keep it to myself. Not so this morning's cup of coffee. Thomas Jefferson understood this well. As he put it, "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me."

Second, when a piece of knowledge is already in the public domain, it is difficult for the creator of that knowledge to prevent others from using it—knowledge is *nonexcludable*. A new mathematical theorem or a new understanding of surface physics, once published, is at large, out there to be used by anyone, to improve a piece of software, for example, or to launch a new line of detergent. Ideas that resonate in the marketplace, from Venetian woolens and glassware in the 17th century to fast food and telemarketing today, can be quickly imitated.

These two properties of knowledge, the main characteristics of public goods, often make it possible for people to use knowledge without paying for it. This reduces the gains to innovators from creating knowledge—and in no small measure. The inability to appropriate all the returns to knowledge is the disincentive to its private supply. If anyone can use an innovation, the returns are diluted, and innovators have no incentive to invest in the costly research and development (R&D) to generate it in the first place. There will thus be too little investment in the creation of knowledge.

Precisely because knowledge is underprovided, governments often set up institutions to restore the incentives to create it. These take the form of patents, copyright, and other forms of intellectual property rights (IPRs), all of which are designed to provide innovators an opportunity to recoup the costs of creating knowledge and to earn a fair return. As knowledge becomes a critical asset for firms and individuals in the new, knowledge-based economy, the need to protect their rights with respect to those assets increases. At the same time, efforts to encourage the creation of knowledge must be balanced against the need to disseminate knowledge, especially to developing countries, and especially where the social returns exceed private returns.

There are many examples in health and environmental matters, to mention just two areas, where patents are not a solution because the social returns to an innovation (to all those benefiting from it) far exceed the private returns (to just those investing in it). Think of an innovation that might lead to a cure for such life-threatening diseases as AIDS and malaria, or reduce the threat of global warming. When the social returns exceed the private, investors, driven by the latter, invest too little from a social perspective in knowledge creation. And because of the large gaps between private returns and social returns, many governments have assumed responsibility—or provided financial incentives to the private sector—for creating some types of knowledge.

Given the special characteristics of knowledge, public action is sometimes required to provide the right incentives for its creation and dissemination by the private sector, as well as to directly create and disseminate knowledge when the market fails to provide enough. The payoffs to such public action have often been huge, as the following section will show for public health.

Knowledge and well-being

Over the past few decades, infant mortality has fallen dramatically worldwide. Higher incomes are a major factor behind the drop but do not account for all of it. Even parents earning the same real income as their parents or grandparents a few decades ago have better reason to expect that their children will live to see their first birthday. A country with an income per capita of $8,000 (adjusted for international purchasing power parity) in 1950 would have had, on average, an infant mortality rate of 45 per 1,000 live births. A country at that same real income in 1970 would have had an infant mortality rate of only 30 per 1,000, and in 1995 only 15 per 1,000 (Figure 1.1).

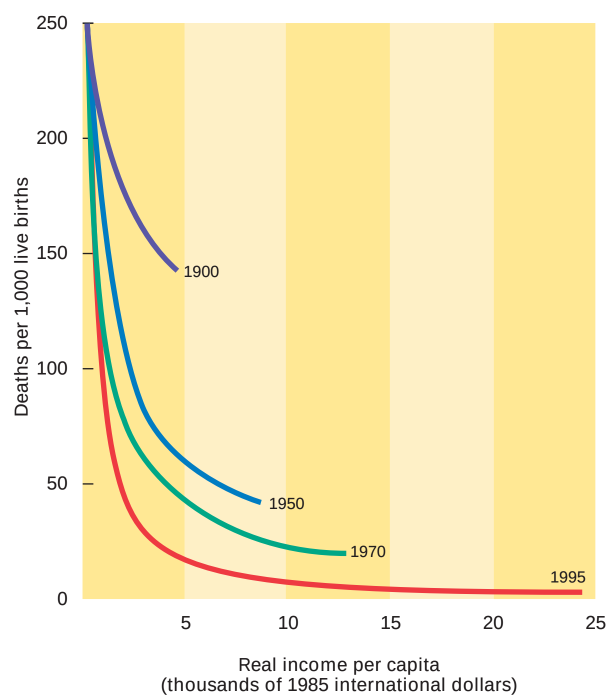
What explains this shifting relationship between infant mortality and real income? The growing power and reach of practical know-how goes a long way:

- The *invention* of antibacterial drugs and vaccines in the 1930s—and continuing progress in drugs, vaccines, and epidemiological knowledge—have helped tame most communicable diseases.
- *Education*, vital to the adoption and effective use of health knowledge, has expanded in almost every country. Many studies reveal that the amount of education attained by girls and women is an important determinant of children's health. A study of 45 developing countries found that the average mortality rate for children under 5 was 144 per 1,000 live births when their mothers had no education, 106 per 1,000 when they had primary education only, and 68 per 1,000 when they had some secondary education.

Figure 1.1

Infant mortality and real income per capita

As knowledge spreads, infant mortality falls—for rich and poor countries alike.



Note: Data are for 10 countries (1900), 59 countries (1950), 125 countries (1970), and 144 countries (1995) worldwide. Trendlines are calculated logarithmically. Source: Maddison 1995, Mitchell 1992, Summers and Heston 1994, World Bank 1997g.

- Progress in information technologies has accelerated the *dissemination* of medical knowledge and sanitary information, spreading medical advice faster. The information revolution has expanded—and in some cases reinforced—traditional ways of disseminating health knowledge. More people can now reach a doctor or other medical practitioner by telephone. And telemedicine, which allows some surgical procedures to be performed electronically, at a distance, is reaching more and more countries.

Traditions and other social factors influence a community's absorption of medical knowledge. People will not accept modern medical knowledge unless those offering it show an understanding of local knowledge and a sensitivity to cultural norms. Thus efforts to integrate modern and traditional practices may help improve public health by increasing the social acceptability of modern knowledge and harnessing the curative power of traditional knowledge. Moreover, knowledge does not automatically find its way to all people and places that need it. Appropriate institutions, whether public or private, are often required to facilitate its acquisition and adoption, as in Costa Rica (Box 1.1).

Box 1.1

Institutional innovations to diffuse health knowledge in Costa Rica

With less than one-tenth the income per capita of the United States, Costa Rica boasts health indicators that compare favorably with those of many industrial countries. Costa Ricans live nine years longer than their income per capita would predict, and infant mortality rates have fallen to industrial-country levels.

These impressive results are no accident. Since the 1960s, Costa Rican governments have given high priority to the general dissemination of health and sanitation information. They have decentralized institutions to promote information about health and dispatched community health teams to disseminate preventive information. When cholera broke out in South and Central America in 1991, Costa Rica rapidly deployed education, sanitation, and information programs that kept the disease at bay.

Today, more than 400 integrated care teams are reinforcing the government's messages of prevention and health promotion. Schools are also helping get these messages to the public—an easier task than in other countries, because 93 percent of the country's school-age children attend elementary school, 54 percent of adolescents attend high school, and 60 percent of all Costa Ricans are registered in at least one educational program.

Table 1.1

Household spending per capita by level of education in Peru

(1991 new soles per year)

Highest level attained by head of household	Average expenditure per capita
None/initial	430
Completed primary	543
Some secondary	633
Completed secondary	808
Nonuniversity tertiary	969
Some university	1,160
Completed university	1,429
Average for all households	874

Note: Data are from a survey of 2,200 households. "Initial" means some preprimary or primary education.
Source: World Bank 1991.

Knowledge is important for individuals and households to raise children and to allocate time between home production and outside jobs. Knowledge of oral rehydration therapy reduces infant mortality. Knowledge of energy-efficient, less hazardous stoves reduces environmental degradation and improves safety. Household smoke contributes to acute respiratory infections, which, according to estimates, kill more than 4 million infants and children a year. Recurrent episodes of such infections show up in adults (mainly women) as chronic bronchitis and emphysema, often leading to heart failure. Better stoves with better exhaust systems can thus lead to significant health benefits for millions of women and children.

The knowledge of a parent can also raise the living standard of all family members. In Peru the education of the head of the household is strongly associated with household spending, which reflects household earning (Table 1.1). In Vietnam, people living in households headed by someone with no education have a poverty rate of 68 percent. Primary education for the household head brings the rate down to 54 percent, secondary education to 41 percent, and university education to 12 percent.

Knowledge and economic growth

Starting as low-income economies in the 1960s, a few economies in East Asia managed, in a few decades, to bridge all or nearly all of the income gap that separated them from the high-income economies of the Organisation for Economic Co-operation and Development (OECD). Meanwhile many other developing economies stagnated.

What made the difference? One way to grow is by developing hitherto unexploited land. Another is to accumulate physical capital: roads, factories, telephone networks. A third is to expand the labor force and increase its education and training. But Hong Kong (China) and Singapore had almost no land. They did invest heavily in physical capital and in educating their populations, but so did many other economies. During the 1960s through the 1980s the Soviet Union accumulated more capital as a share of its gross domestic product (GDP) than did Hong Kong (China), the Republic of Korea, Singapore, or Taiwan (China). And it increased the education of its population in no trivial measure. Yet the Soviets generated far smaller increases in living standards during that period than did these four East Asian economies.

Perhaps the difference was that the East Asian economies did not build, work, and grow harder so much as they built, worked, and grew smarter. Could knowledge, then, have been behind East Asia's surge? If so, the implications are enormous, for that would mean that knowledge is the key to development—that knowledge *is* development.

How important was knowledge for East Asia's growth spurt? This turned out not to be an easy question to answer. The many varieties of knowledge combine with its limited marketability to present a formidable challenge to anyone seeking to evaluate the effect of knowledge on economic growth.

How, after all, does one put a price tag on and add up the various types of knowledge? What common denominator lets us sum the knowledge that firms use in their production processes; the knowledge that policymaking institutions use to formulate, monitor, and evaluate policies; the knowledge that people use in their economic transactions and social interactions? What is the contribution of books and journals, of R&D spending, of the stock of information and communications equipment, of the learning and know-how of scientists, engineers, and students? Compounding the difficulty is the fact that many types of knowledge are accumulated and exchanged almost exclusively within networks, traditional groups, and professional associations. That makes it virtually impossible to put a value on such knowledge.

Reflecting these difficulties in quantifying knowledge, efforts to evaluate the aggregate impact of knowledge on growth have often proceeded indirectly, by postulating that knowledge explains the part of growth that cannot be explained by the accumulation of tangible and identifiable factors, such as labor or capital. The growth not accounted for by these factors of production—the residual in the calculation—is attributed to *growth in their productivity*, that is, using the other factors smarter, through knowledge. This residual is sometimes called the Solow residual, after the economist Robert M. Solow, who spearheaded the approach in the 1950s, and what it purports to measure is conventionally called total factor productivity (TFP) growth. Some also call the Solow residual a measure of our ignorance, because it represents what we cannot account for. Indeed, we must be careful not to attribute all of TFP growth to knowledge, for there may be other factors lurking in the Solow residual. Many other things do contribute to growth—institutions are an example—but are not reflected in the contributions of the more measurable factors. Their effect is (so far) inextricably woven into TFP growth.

In early TFP analyses, *physical capital* was modeled as the only country-specific factor that could be accumulated to better people's lives. Technical progress and other intangible factors were said to be universal, equally available to all people in all countries, and thus could not explain growth differences between countries. Their contributions to growth were lumped with the TFP growth numbers. Although this assumption was convenient, it quickly became obvious that physical capital was not the only factor whose accumulation drove economic growth. A study that analyzed variations in growth rates across a large number of countries showed that the accumulation of physical capital explained less than 30 percent of those variations. The rest—70 percent or more—was attributed directly or indirectly to the intangible factors that make up TFP growth (Table 1.2).

Table 1.2

Decomposition of cross-country variance in growth rates

(percent)

Source of variance	Nehru and Dhareshwar, 1960–88	King and Levine, 1960–85	King and Levine, 1980s
Growth in capital per capita	24	25	29
Unexplained by factor accumulation	76	75	71
Of which:			
TFP growth	60	57	79
Covariance of TFP growth and capital accumulation	16	18	–8

Source: Easterly, Levine, and Pritchett forthcoming. See the Technical Note.

Later attempts introduced *human capital* to better explain the causes of economic growth. A higher level of education in the population means that more people can learn to use better technology. Education was surely a key ingredient in the success of four of the fastest-growing East Asian economies: Hong Kong (China), the Republic of Korea, Singapore, and Taiwan (China). Before their transformation from developing into industrializing economies, their school enrollment rates had been much higher than those of other developing countries (Table 1.3). They had also emphasized advanced scientific and technical studies—as measured by their higher ratios of students in technical fields than in even some industrial countries—thus enhancing their capacity to import sophisticated technologies. Moreover, the importance of education for economic growth had long been recognized and established empirically. One study had found that growth in years of schooling explained about 25 percent of the increase in GDP per capita in the United States between 1929 and 1982.

Adding education reduced the part of growth that could not be explained, thus shrinking the haystack in which TFP growth (and knowledge) remained hidden. Some analysts even concluded, perhaps too quickly, that physical and human capital, properly accounted for, explained all or virtually all of the East Asian economies' rapid growth, leaving knowledge as a separate factor out of the picture (Box 1.2). One reason these analysts came up with low values for TFP growth is that they incorporated improvements in labor and equipment into their measurement of factor accumulation. So even their evidence of low TFP growth in East Asia does not refute the importance of closing knowledge gaps. Indeed, it shows that the fast-growing East Asian economies had a successful strategy to close knowledge gaps: by investing in the knowledge embodied in physical capital, and by investing in people and institutions to enhance the capability to absorb and use knowledge.

Table 1.3

Gross enrollment rates in primary school in selected economies

(percent)

Economy	1970	1980	1990
Hong Kong, China	117	107	102
Korea, Rep. of	103	110	105
Singapore	105	108	104
Ghana	64	79	77
India	73	83	97

Note: Data are total primary enrollments divided by the number of children of official primary school age in the population. Rates can exceed 100 percent when persons younger or older than the official age are enrolled.
Source: World Bank 1998d.

Looking beyond East Asia, other growth accounting studies have examined larger samples of countries. Even when human capital is accounted for, the unexplained part of growth remains high. One such study, of 98 countries with an unweighted average growth rate of output per worker of 2.24 percent, found that 34 percent (0.76 percentage point) of that growth came from physical capital accumulation, 20 percent (0.45 percentage point) from human capital accumulation, and as much as 46 percent (just over 1 percentage point) from TFP growth. Even more remains to be explained in *variations* in growth rates across countries. The same study found the combined role of human and physical capital to be as low as 9 percent, leaving the TFP residual at a staggering 91 percent. To take another example: Korea and Ghana had similarly low incomes per capita in the 1950s, but by 1991 Korea's income per capita was more than seven times Ghana's. Much of that gap remains unexplained even when human capital is taken into account (Figure 1.2).

All these results are subject to measurement problems. For example, the measured stock of human capital may overstate the actual quantity used in producing goods and services. High rates of school enrollment or attainment (years completed) may not translate into higher rates of economic growth if the quality of education is poor, or if educated people are not employed at their potential because of distortions in the labor market.

Moreover, it is now evident that education without openness to innovation and knowledge will not lead to economic development. The people of the former Soviet Union, like the people of the OECD countries and East Asia, were highly educated, with nearly 100 percent literacy. And for an educated population it is possible, through foreign direct investment and other means, to acquire and use information about the latest production and management innovations in other countries. But the Soviet Union placed severe restrictions on foreign investment, foreign collaboration, and innovation. Its work force did not adapt and change as new information became available elsewhere in the world, and consequently its economy suffered a decline.

Beyond growth accounting

Does our limited ability to fully account for knowledge in growth diminish its importance for development? Certainly not. Many would agree with the British economist Alfred Marshall that "While nature . . . shows a tendency to diminishing return, man . . . shows a tendency to increasing return. . . . Knowledge is our most powerful engine of production; it enables us to subdue nature and . . .

Box 1.2

Knowledge in the East Asian miracle—an ongoing debate

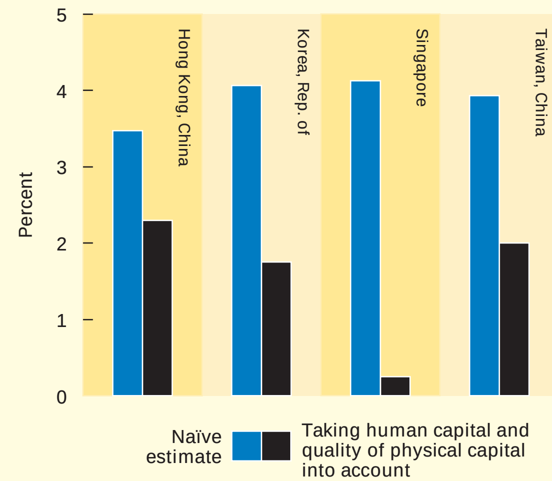
Despite the financial crisis that continues to wreak havoc in much of Asia, the four original miracle economies—Hong Kong (China), Korea, Singapore, and Taiwan (China)—illustrate the possibilities for rapid growth. A key question is whether they achieved their high growth rates by intensively using large quantities of productive factors—physical capital and labor—or by using knowledge.

Several economists have suggested that the growth of most of the East Asian countries can be "fully accounted" for by the increases in their inputs. A high rate of saving in these economies led to high rates of capital accumulation. And their high levels of investment in education led to high rates of increase in human capital. In this view, there is no miracle.

This perspective is open to several criticisms, however:

- True, these economies did maintain high saving rates, but they also invested those savings efficiently. Some other countries—the centrally planned economies, for example—saved aggressively yet did not grow at East Asian rates, because they invested that saving inefficiently.
- The approach incorporates the improvements in knowledge embodied in human and physical capital in its measures of these factors. In other words, if firms invested in closing the knowledge gap by investing in worker training and new equipment, or by purchasing technology licenses, this would not show up, at least in the short run, as an increase in TFP growth (see figure).
- Improvements in knowledge may have sustained the high levels of investment. Without a shift in knowledge, diminishing returns would have set in, and the high rates of investment and saving would have flagged. Indeed, other researchers have found that when the effect of TFP growth on capital accumulation is taken into account, the contribution of TFP growth is significantly greater.
- Equally important, the TFP calculations are highly sensitive to how one measures increases in physical and human capital and to the weights assigned to increases in those factors. Under certain idealized conditions (such as perfect competition), the observed shares of factors in GDP are the correct weights. But under imperfect competition the observed shares of capital and labor in GDP may not reflect the appropriate weights. For example, if wages were suppressed by direct government intervention in the labor market (as may have happened in Singapore), the observed share of labor in GDP may be too small and that of capital much too large. This, combined with faster accumulation of capital than of labor (as observed in East Asia), would understate the role of TFP growth.

Alternative calculations of TFP growth in four East Asian economies



Note: Data are for 1966–90. Source: Young 1995.

satisfy our wants." If anything, recognition of the importance of knowledge has gained momentum, and there is a renewed impetus to integrate knowledge into countries' development strategies.

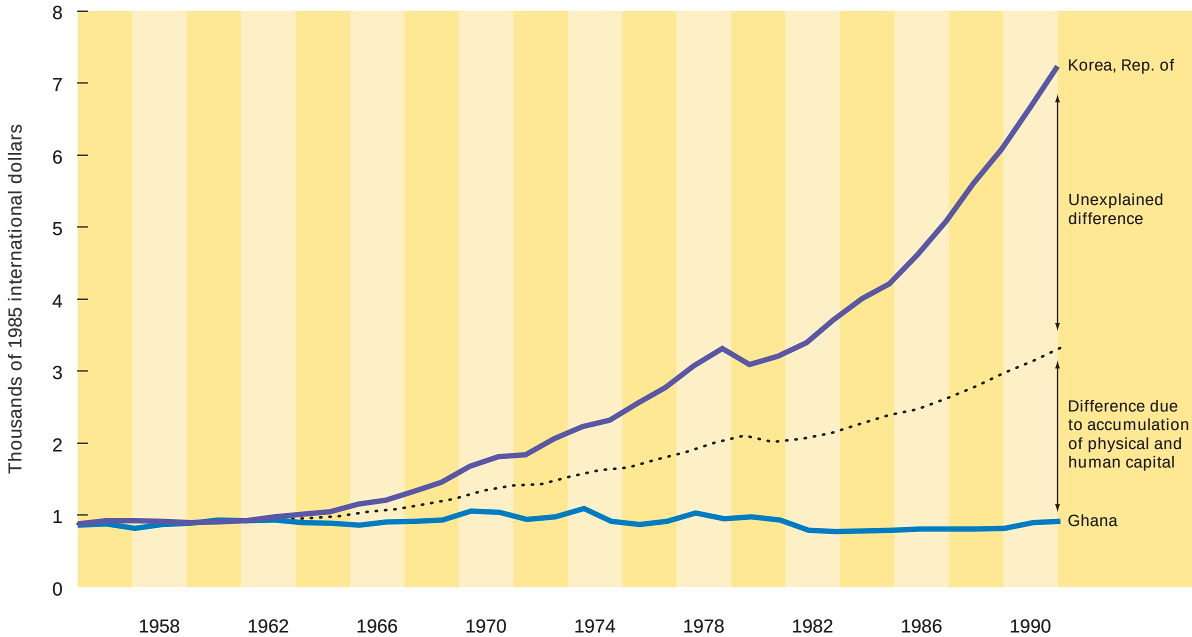
A key feature of growth in the 20th century has been the role of innovation and invention, as represented by the development of industrial research laboratories to promote innovation, and research universities to advance basic and applied science. Firms, and societies generally, have deliberately decided to allocate resources to improve productivity. Those decisions are much like those for other forms of investment: they are adversely affected by increases in the cost of capital. But because investments in R&D are typically not collateralized, and because they often require a large upfront outlay, they may depend more on the investing firm's cash flow than, say, investment in real estate. That is why small firms, and firms in developing countries in particular, tend to invest less in R&D.

Firms have also become more sophisticated in their thinking about the adoption and adaptation of new technologies. Many know, for instance, that costs associated with new technologies follow a learning curve, decreasing with experience. This may make them willing to enter new areas of business, even when current costs might make it unprofitable, because they recognize the value of learning. The same considerations affect investment in the transfer of technology by developing countries, both at the firm level and economy-wide. The East Asian econ-

Figure 1.2

Trends in real GDP per capita in Ghana and the Republic of Korea

Differences in capital accumulation alone do not explain the wide divergence in growth.



Source: Summers and Heston 1994 and World Bank staff calculations.

omies consciously made decisions to invest to close their knowledge gaps.

Some economists have incorporated in their growth models this purposeful investment in education, innovation, and adaptation of knowledge by people and firms as the main source of productivity growth, and thus as a key factor in economic growth. They see the world as a fertile field of nearly unbounded opportunity, where new ideas beget new products, new markets, and new possibilities for creating wealth. Although conceptually appealing, the approach stops short of providing a deeper empirical insight into explaining cross-country differences in economic growth. It, too, faces the challenge of usefully quantifying knowledge. But some studies have found that some knowledge-related factors affect countries' growth rates. In addition to human capital, they include investment in R&D, openness to trade, and the presence of infrastructure to disseminate information (Box 1.3).

Still other factors, not immediately associated with knowledge, probably add to growth as well. For instance, recent studies conclude that the quality of institutions and economic policies explains a significant part of economic growth. These institutions and policies foster the creation of knowledge. Without protection of the ownership of physical capital and knowledge capital, little investment or research would take place, because investors would not expect to earn appropriate returns from their efforts. And good institutions and policies facilitate the transfer of knowledge and enhance the likelihood that it will be used effectively. Moreover, the relationship between knowledge and institutions goes two ways: supportive institutions facilitate the production and dissemination of knowledge, and knowledge, especially about the consequences of alternative institutional arrangements, can lead to more supportive institutions. These interactions make it all the more important for countries to develop institutions that complement markets in creating a climate for producing and supporting the free flow of knowledge and information.

Threats and opportunities in a fast-moving global economy

Three considerations argue for a deeper understanding of the interaction between knowledge and development. First, the world economy is becoming ever more integrated—more global—and countries have little leverage on global trends, nor can they isolate themselves from them for long. Between 1960 and 1995, international trade (exports plus imports) grew steadily from 24 percent of world GDP to 42 percent. Multinational corporations today dominate the global economic landscape: a third of world trade is now between multinationals and their affiliates. Improvements in international communications have made distance largely irrelevant.

Second, the share of high-technology industries in total manufacturing value added and exports has grown in almost all the OECD countries (Table 1.4). And it is estimated that more than half of GDP in the major OECD countries is based on the production and distribution of knowledge. This has obvious implications for the composition of the work force: in the United States, more workers are engaged in producing and distributing knowledge than in making physical goods. These indicators are available mainly for the OECD countries and may not apply to developing countries. But they provide useful insights about the importance of knowledge for firms and countries competing in the global economy.

The creation of technical knowledge—as measured by patents issued, although not all technical knowledge is patented—is expanding rapidly. The number of patent applications worldwide increased from 1.4 million in 1989 to 2 million in 1993. Continuous innovation, automation, and competition in the creation and use of knowledge have shortened product cycles in many industries. One study predicted that, between 1993 and 2000, the average product cycle in the automobile industry would drop from eight years to four in the United States, and from six years to four in Japan.

Third, information technologies are advancing at a tremendous rate. It has been said that if the aircraft industry had evolved as spectacularly as the computer industry since the mid-1960s, by the mid-1980s a Boeing 767 would have cost $500 and could have circled the globe in 20 minutes on 20 liters of fuel. Such technical advances reflect progress in technical knowledge. The information revolution spurs the creation of new knowledge by giving inventors and innovators quick access to knowledge, for them a critical input. It also facilitates the production of an increasing number of other goods and services. For example, the microchip content of GDP in the United States has skyrocketed (Figure 1.3). But more important,

Box 1.3

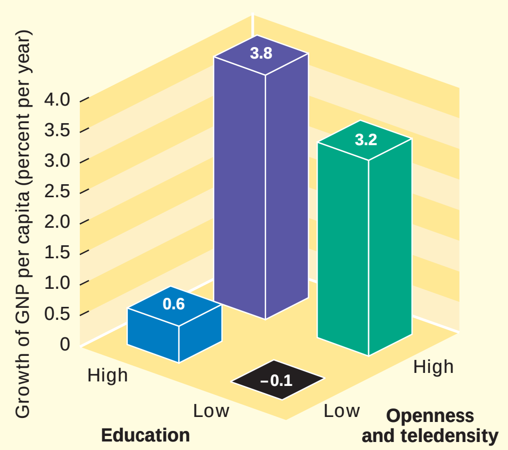
Growing faster with knowledge

Three indicators related to knowledge correlate significantly with growth rates: education, openness to trade, and the availability of communications infrastructure (as measured by telephone density, the ratio of telephone main lines to population). These three partial proxies for knowledge are by no means all there is to gauging access to knowledge or the ability to use it, but they do provide a rough approximation. They show that a country can add substantially to its growth rate by increasing the education of its people, its openness to international trade, and its supply of telecommunications infrastructure. The impact on growth can perhaps be as much as 4 percentage points for a country that moves from significantly below the average to significantly above the average on all these indicators (see figure).

These findings can be plausibly explained for each of the three factors:

- Openness to trade relates to the opportunity to tap foreign knowledge embodied in traded goods and services. Trade also allows people to learn about business practices in other societies. These knowledge-related benefits of trade come in addition to the traditional, well-established gains from international trade.
- The educational attainment of a population relates to people's capacity to use knowledge.
- Telephone density relates to people's ability to access useful information when needed.

Impact of education, openness to trade, and telephone density on economic growth



Note: Each bar represents the average growth rate for a group of countries over the period 1965–95. Education is average years of education in the population. Openness is the sum of exports and imports divided by GDP. Teledensity is the number of main lines per 100 people. Countries with "high" or "low" values on these variables are those with values at least one standard deviation above or below the sample average, respectively. See the Technical Note for details of the calculation. Source: World Bank staff calculations.

Table 1.4

Share of high-technology goods in manufacturing value added and exports in high-income economies

(percent)

Economy	Value added 1970	Value added 1994	Exports 1970	Exports 1993
Australia	8.9	12.2	2.8	10.3
Austria	—	—	11.4	18.4
Belgium	—	—	7.2	10.9
Canada	10.2	12.6	9.0	13.4
Denmark	9.3	13.4	11.9	18.1
Finland	5.9	14.3	3.2	16.4
France	12.8	18.7	14.0	24.2
Germany	15.3	20.1	15.8	21.4
Greece	—	—	2.4	5.6
Ireland	—	—	11.7	43.6
Italy	13.3	12.9	12.7	15.3
Japan	16.4	22.2	20.2	36.7
Netherlands	15.1	16.8	16.0	22.9
New Zealand	—	5.4	0.7	4.6
Norway	6.6	9.4	4.7	10.7
Spain	—	13.7	6.1	14.3
Sweden	12.8	17.7	12.0	21.9
United Kingdom	16.6	22.2	17.1	32.6
United States	18.2	24.2	25.9	37.3

— Not available.
Source: OECD 1996b.

the information revolution provides untold opportunities for knowledge to be broadly disseminated. The volume of international telephone traffic rose on average by 15 percent a year between 1975 and 1995, thanks to higher-quality, more affordable telecommunications.

Even if more developing countries commit to boosting their investment in knowledge, they may have to run fast to stay in place. As more industrial countries develop artificial (and cheaper) substitutes for many of their traditional exports, the prices of these goods is likely to fall. Just as El Salvador suffered when the invention of chemical dyes made indigo, its principal export crop, obsolete, so many countries today face similar challenges. Copper cables are being replaced by fiber optics, cocoa by artificial cocoa flavorings, and so on. Unless developing countries improve their productivity and shift into the production of new goods—both of which involve acquiring new knowledge—they will face declining standards of living relative to the rest of the world.

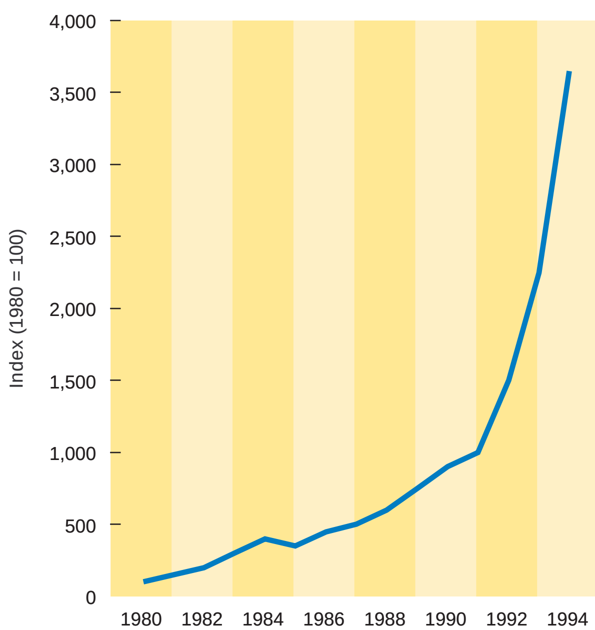
Developing countries striving not just to stand pat but to improve their standards of living must do even more. They must move up the value-added chain to produce goods that typically require and embody higher levels of technology, and to do that they must close the knowledge gap.

Today one country's advantage over others in certain lines of production and trade can no longer be viewed statically, in terms of such relatively unchanging tangible factors as relative supplies of labor, land, and natural resources. Once knowledge, and the potential to improve one's knowledge, are taken into account, *dynamic comparative advantage*—the relative advantage that countries can create for themselves—is what matters. Even dynamic comparative advantage suggests that developing countries will remain importers rather than principal producers of technical knowledge for some time. But the speed with which they do this—based on capacities and incentives—will have a major effect on living standards. Technological change has reduced the relative returns to unskilled labor, and countries that rely on unskilled labor and natural resource–based goods may thus face declining living standards. Countries that succeed in closing the knowl-

Figure 1.3

Real semiconductor content of the U.S. economy

The microchip's economic contribution is growing exponentially.



Note: This index is calculated by dividing real semiconductor output, as deflated by a semiconductor price index, by real GDP, and setting that value for 1980 equal to 100. It thus indicates real semiconductor content at 1980 prices per unit of real GDP. Source: Adapted from Flamm, background paper (b).

edge gap may, by contrast, seize a larger part of the returns to knowledge that account for much of the well-being of industrial countries.

Developing countries have tremendous opportunities to grow faster and possibly to catch up with the industrial countries. To take advantage of these opportunities in a fast-moving global economy, developing countries cannot afford to limit themselves to accumulating physical capital and educating their people. They must also be open to new ideas and capture the benefits of technological progress. They must therefore extend the power and reach of knowledge to close the gap in living standards. Some of the East Asian economies showed that the knowledge gap *can* be closed in a relatively short time, perhaps far less time than it takes to close the gap in physical capital. But there are strong complementarities between capital gaps and knowledge gaps, and the East Asian countries typically worked to close both gaps simultaneously.

Countries that fail to encourage investment in the effective use of global and local knowledge are likely to fall behind those that succeed in encouraging it. Some countries have recognized the potential of the global economy and have defined clear strategies to take advantage of it. Others will have to accept the reality of globalization more quickly than they might wish.

What it takes to close knowledge gaps

Successful development thus entails more than investing in physical capital, or closing the gap in capital. It also entails acquiring and using knowledge—closing the gaps in knowledge. The next three chapters address ways to close these gaps, arguing that developing countries have to position themselves to take advantage of the opportunities and to minimize the risks through effective strategies for acquiring and using knowledge. The main tasks are the following:

- Acquiring and adapting global knowledge—and creating knowledge locally (the topic of Chapter 2)
- Investing in human capital to increase the ability to absorb and use knowledge (Chapter 3), and
- Investing in technologies to facilitate both the acquisition and the absorption of knowledge (Chapter 4).

Strategies for addressing these three tasks are complementary. Countries cannot access new technology unless they also invest in education. New technology spurs demand for education and makes it easier to obtain knowledge. Thus, effective policies for acquiring, absorbing, and communicating knowledge are mutually reinforcing components of an overall strategy for narrowing knowledge gaps.