

# The knowledge revolution

The engine of growth is knowledge, with profound implications for us all



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**W**e are on the threshold of a truly revolutionary era of discovery – ranging from the origins of the universe to new states of matter and microscopic machines, from a new understanding of the oceans and of the biological connections across the earth's species to the functioning of the human brain and the origins of consciousness. This 'golden age' of discovery, with frequent breakthroughs in every field, brings with it far-reaching social changes.

A social and economic revolution is taking place on the scale of the agricultural and industrial revolutions. It is a 'knowledge revolution' driven by knowledge and by the technologies for processing and communicating it. Knowledge is an intangible public good that is privately produced. It is becoming the primary factor of production just as land and machines were in the agricultural and industrial revolutions respectively. The terms of the debate between capitalism and socialism are changing and leading to a human-centred society with different types of markets as well as corporate and financial structures. In all this property rights to knowledge are key.

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Human capital – as defined by an individual's knowledge and skills – is the engine of development. Markets require a more egalitarian distribution of wealth to function efficiently. The golden age of industrial society, with its voracious and unequal use of the earth's resources, is reaching its logical limit. A new pattern of economic growth, knowledge-intensive growth, is replacing the resource-intensive patterns that have prevailed since the end of World War II. This leads to a vision of society that is innovative in the use of knowledge, a society centred on diversity and human capital and offering the prospect of substantial economic progress.

## The knowledge revolution

Radical advances in information technology are an obvious manifestation of this change. Underlying these are changes in the management of human knowledge, in its creation and distribution, and corresponding changes in the organisation of society. The dynamics in the world economy today are in computing and software, in telecommunications and biotechnology, in entertainment and financial markets.

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In a sense, knowledge has always been the driving force of change in human societies. Tens of thousands of years ago, the shift from a hunter-gatherer society to the agricultural society was driven by the knowledge of how to use seeds to sow and harvest food. In the agricultural society the main fuel was fertile land, but the knowledge of how to use it changed the way humans lived, moving from smaller nomadic societies to more stable, organized and larger settlements.

The next shift, from agricultural to industrial society, occurred in the 18th century when people learned how to use machines, particularly the internal combustion engine and the steam engine, to transform fossil fuels into controlled physical power. In the industrial society the fuel was fossil fuels such as coal and oil. The industrial revolution was driven by knowledge about how to use the new fuels.

Both the agricultural revolution and the industrial revolution had one thing in common: the adoption of new fuels and new knowledge about how to use them. In both cases, an increasing level of economic advancement was associated with the increasing use of specific fuels: land in the agricultural society, and fossil fuels in the industrial society.

In a similar way, the current revolution is driven by knowledge – knowledge about how to use a different fuel: information technology. This fuel is fundamentally different because it is not physical, unlike land and fossil fuels. Therefore economic progress no longer means using more physical resources in order to produce more. Instead, it means achieving more with less.

Changes in land use led to the agricultural society. Changes in the use of fossil fuels led to the industrial society. And changes in the use of information technology are leading to the knowledge society. The knowledge revo-

lution leads inevitably to the advent of the knowledge society, a society which is global in nature, deeply innovative in, and dependent on, the use of human knowledge.

Just as the most dynamic sectors in the industrial society were those that benefitted from the use of fossil fuels as an inexpensive and abundant input, and those in the agricultural society were the sectors using inexpensive and abundant land products, the new dynamic sectors are those which produce goods making use of information technology to expand the ability of the human brain to save, process, retrieve and communicate information. Examples are computers and software, telecommunications and biotechnology, entertainment and financial markets, design and animation, and all services based on human knowledge such as medical services and education. Today more Americans make semiconductors than work in the construction machinery, and the North American Telecommunications industry employs more than the automobile and the automobile-parts industries combined (Beck, 1992). The US health and medical industry is now larger than oil refining, aircraft, autos, auto parts, logging, steel and shipping put together. More Americans work in biotechnology than in the entire machine-tools industry.

These sectors will expand more quickly than others and therefore the resulting society will produce mostly goods which are knowledge-intensive, much as the agricultural society produced mostly agriculture-related goods, and the industrial society produced mostly industry-related goods. This is why this new society is the 'knowledge society'.

### What is knowledge?

As human knowledge becomes the main input of economic production, it is important to focus on some of its most striking properties from the point of view of society.

Knowledge is a 'public good' because, at the *physical* level, one can share it with others without losing it. Knowledge is not rival in

consumption as apples or oranges are. One can restrict access to knowledge to gain economic advantage, a point discussed below. However, I can share my knowledge with the reader without losing it myself. Land and machines, by contrast, are 'private goods' because if I use them they are not available to others.

This difference with knowledge leads to a completely new calculus, a new mathematical framework, for socio-economic thinking. In the case of knowledge,  $1+1$  is not 2, rather  $1-1=1$ . Because knowledge is a new type of input – a non-physical, public good – the knowledge revolution introduces a change in social and economic organization because markets for public goods behave fundamentally differently from the usual way we think of private goods.

The differences go further because knowledge is different from other public goods, such as law and order, which is non-rival in consumption. But law and order is provided by governments, like most public goods, whereas knowledge is provided privately. Individuals create knowledge. This does not exclude socially-created knowledge, emerging from educational systems and the cultural heritage of society. But it points out the fundamental difference that the knowledge society's key input of production is a public good that is privately produced.

All this is new. Sociology, political sciences and economics are still learning to explain a society based on such inputs. The economics of knowledge is in its infancy, and ready for growth. It has only recently been observed that in markets with privately produced public goods, efficiency and distribution are closely interlinked, in a distinctive way (Chichilnisky and Milgrom, 1996). For efficiency, the distribution of property rights must be relatively more egalitarian, assigning

more public goods to those who own fewer private goods. This is in stark contrast with conventional markets where efficiency and distribution are divorced from each other.

In the new society based on knowledge, markets may require a more equal distribution of wealth to function efficiently. The knowledge society could be more egalitarian than the industrial and the agricultural societies, although this is only a well-informed hope requiring further investigation.

Another argument in favour of this hope is that knowledge puts humans rather than land

or machines at the centre of economic growth. Knowledge is privately produced and, at the purely physical level, it is centred in the human brain from where the most interesting and innovative knowledge originates. Although much knowledge resides in physical and electronic media, such as books

and CD-ROMs, the ability to create new knowledge and adapt or cross-fertilize across different areas resides in humans.

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### Capitalism and corporate structure

An extraordinary tug of war between capitalism and socialism has dominated world politics and economic thinking for several decades. But the issue of ownership of capital, which is at the core of the distinction between capitalism and socialism, is becoming less important.

Capital and machines are crucial in the industrial society but knowledge and ideas are more important and more scarce than capital. Who owns the capital is no longer the main issue. Ownership of ideas is becoming more critical. The ownership of 'intellectual capital' is key and markets which trade property rights on knowledge, or 'intellectual capital' behave quite differently from classical markets.

Think of ideas in the technology and entertainment sectors, the most dynamic sectors in

the US economy today. If one has a great idea in these areas, capital will come to it. A corporation will realize it. This is the role of the modern financial markets and of the corporate structure. The extraordinarily successful development of these two creatures of capitalism, the corporation and the financial market, is transforming its foundations.

A recent study by the World Bank documents the importance of human capital. It ranks countries by their wealth, their human capital and their physical capital, which includes natural and manufactured capital. The World Bank data in the Chart shows that for many of the most industrially advanced countries, human capital explains wealth two or three times better than physical capital.

As already noted, knowledge is an intangible public good that is privately produced. The calculus of knowledge is therefore quite different from anything else. To a certain extent the more one gives, the more one has. To take advantage of this extraordinary feature, however, society needs appropriate institutions. Property rights play a very important role in inducing market efficiency. The importance of finding appropriate regimes for property rights on knowledge should not be underestimated. In Japan the lack of property rights on software has handicapped the development of the industry. We are in the process of moving to a version of capitalism in which markets for knowledge, or for the rights to use it, will be central components.

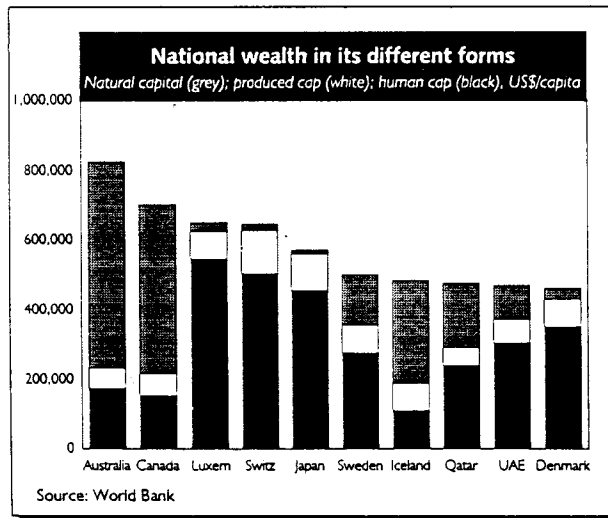
### Organisation of production

It is well known that knowledge leads to

economies of scale associated with 'learning by doing'.

The benefits from large-scale production are not new. Aircraft production is a classic example, arising from the need for large size plants and equipment, and leading to natural monopolies. However, recent research indicates that knowledge exhibits different economies of scale. Larger markets help achieve more efficiency, but large plants and equipment may be unnecessary. Some of the most productive knowledge-driven firms are small and labour intensive. Software production is an excellent example. Here increased productivity occurs through mobility of labour between firms in the same sector. As the sector expands we learn more and become more productive. Each firm may be small, and still reap these benefits.

This means that we may observe economies of scale with



firms small enough to be competitive. The loss of economic efficiency due to monopolistic behaviour is minimized. For example Microsoft and Compac are very large firms. But they are 'disciplined' in terms of prices by threats from small competitors, which do

not need large plants or equipment to operate. One can simultaneously have competitive markets and economies of scale. This could not happen in traditional sectors in which economies of scale require large size and lead to monopolies.

### Social diversity

Social diversity is another important factor in the knowledge society. In many cases the more diverse the society, the more it can

innovate by cross-fertilization of ideas from different sources. Innovation is not always welcome in the agricultural or industrial society because it can disrupt the established order. Order and organization are the foundations of productivity in those societies. But this is not necessarily so in the knowledge society. Change, even chaos, can be productive. The knowledge society can change more rapidly and can absorb innovation with less trauma.

Societies can leap directly from agrarian to knowledge societies without going through a period of heavy industrialization. An interesting example in the Midwest of the US is the area in the great lakes surrounding Chicago, an area where agricultural markets have led to financial markets, and another is Tuscany in Italy, a wine and olives economy which is modernizing without going through heavy industrialization. In the developing world Barbados, India and the Philippines are following similar roads.

But social diversity is costly in a world in which work is organized around the old fashioned principles of the industrial society. Recent research has shown that traditional markets can only operate within a limited amount of social diversity (Chichilnisky, 1994 and forthcoming).

Social diversity has an obvious manifestation through unemployment. Much unemployment is caused by lack of educational access, and this access is often connected with differences in the endowments and the preferences of the traders in a market economy. Today's excess demand for technical services is matched by the excess supply of workers with old fashioned skills. Labour mobility distributes knowledge around and, by doing so, generates positive externalities. Society gains, but individuals often lose. The US worker is driven today by fears of losing a job and their place in society. One reason is that most jobs are in skilled sectors to which an older population of workers may not have ready access. Without proper institutions, individuals are justifiably insecure. Welfare systems are out-

dated. Everyone agrees that they must change.

### Human capital accumulation

It is no secret that for a young American worker the most important determinant of access to gainful employment is education. After many years of questioning the issue, social scientists have finally accepted the fact that education means higher income, and more education, in the right sectors, means much higher income.

This verdict has changed. About 20 years ago it was fashionable for labour economists to question the value of education. Today it is widely accepted that skills determine employment and better skills lead to higher income, although there are quibbles about what these skills should be. It is also no secret that better human capital means better productivity and therefore, in a market economy, better wages. The value of education used to be regarded with deep suspicion and scepticism but it is now clear that the right education opens doors to employment and social participation.

The challenge is how to make the knowledge revolution accessible to the underclass in industrial countries and to the large mass of people who live today in developing countries below their minimal basic needs.

The challenge of using knowledge to fight poverty is enormous, but it is of overriding importance. There are no acceptable alternatives. We know that unemployment means poverty, and lack of education means unemployment. In the developing world, standard resource-intensive development policies have left a legacy of failure, disappointment and often anger. India, the Philippines, and even Barbados are at the forefront of a new wave of economic development which is updating the South East Asian model to the world of the knowledge revolution (Chichilnisky, forthcoming). India is one of the world's most successful software exporters. Properly harnessed by updated institutions, knowledge may be the key to successful economic development across the world ●