# Four

# TECHNOLOGICAL CHANGE: 'GALES OF CREATIVE DESTRUCTION'

## CHAPTER OUTLINE

## TECHNOLOGY AND ECONOMIC TRANSFORMATION

Technological change is unquestionably one of the most important processes underlying the globalization of economic activity.[1] In Joseph Schumpeter's words, 'the fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forces of industrial organization that capitalist enterprise creates.[2] Schumpeter set technological change, specifically *innovation* – the creation and diffusion of new ways of doing things – at the very heart of the processes of economic growth and development. Technological change is unquestionably one of the most important processes underlying the globalization of economic activity. But a word of warning: technology, in itself, is *not* deterministic.

Technology is, essentially, an *enabling* or *facilitating* agent. It makes possible new structures, new organizational and geographical arrangements of economic activities, new products and new processes, while not making particular outcomes inevitable. Most importantly, technological change is a *socially and institutionally embedded process*:

> Specific choices within the frontier of technological possibilities are not the product of technological change; they are, rather, the product of those who make the choices within the frontier of possibilities. *Technology does not drive choice; choice drives technology*.[3]

The ways in which technologies are used – even their very creation – are conditioned by their social and their economic context. In the contemporary world this means primarily the values and motivations of capitalist business enterprises, operating within an intensely competitive system. Choices and uses of technologies are influenced by the drive for profit, capital accumulation and investment, increased market share, and so on.

## PROCESSES OF TECHNOLOGICAL CHANGE: AN EVOLUTIONARY PERSPECTIVE

Technological change is a form of *learning* – by observing, by doing, by using – of how to solve specific problems in highly differentiated and volatile environments.

But it is much more than a narrowly 'technical' process. It is also about much more than just 'the new'; older technologies persist and often remain useful.[4] Technological change not only involves the *invention* of new things, or new ways of doing things, but also – more importantly – depends upon the transformation of inventions into usable *innovations*, and their subsequent *adoption and diffusion*. In the economic sphere, this is essentially an entrepreneurial process. In the long run, it is, essentially, an *evolutionary* process.[5]

## Types of technological change

There are four broad types of technological change,[6] each of which is progressively more significant and far-reaching in its impact:

- *Incremental innovations*: small-scale, progressive modifications of existing products and processes, created through 'learning by doing' and 'learning by using'. Although individually small – and, therefore, often unnoticed – they accumulate, often over a very long period of time, to create highly significant changes.
- *Radical innovations*: discontinuous events that drastically change existing products or processes. A single radical innovation will not, on its own, have a widespread effect on the economic system; what is needed is a 'cluster' of such innovations.
- *Changes of technology system*: extensive changes in technology that impact upon several existing parts of the economy, as well as creating entirely new sectors. These are based on a combination of radical and incremental technological innovations, along with appropriate organizational innovations. Changes of technology system tend to be associated with the emergence of key generic technologies[7] (e.g. information technology, biotechnology, materials technology, energy technology, space technology, nanotechnology).
- *Changes in the techno-economic paradigm*: truly large-scale revolutionary changes embodied in new technology systems. These

> have such pervasive effects on the economy as a whole that *they change the 'style' of production and management throughout the system*. The introduction of electric power or steam power or the electronic computer are examples of such deep-going transformations. A change of this kind carries with it many clusters of radical and incremental innovations, and may eventually embody several new technology systems. *Not only does this fourth type of technological change lead to the emergence of a new range of products, services, systems and industries in its own right – it also affects directly or indirectly almost every other branch of the economy … the changes involved go beyond specific product or process technologies and affect the input cost structure and conditions of production and distribution throughout the system*.[8]

## Trajectories of technological change

Large-scale technological changes take time. They do not occur overnight, not least because they require a suitable combination of social, organizational as well as technical conditions:[9]

> Radical individual innovations are usually introduced in a relatively primitive version and, once market acceptance is achieved, they are subjected to a series of incremental innovations following the changing rhythm of a logistic curve … Changes generally occur slowly at first, while producers, designers, distributors and consumers engage in feedback learning processes; rapidly and intensively once a *dominant design* … has become established in the market and slowly once again when maturity is reached and … [the] … law of diminishing returns to investment in innovation sets in.[10]

Figure 4.1 maps such an idealized trajectory.

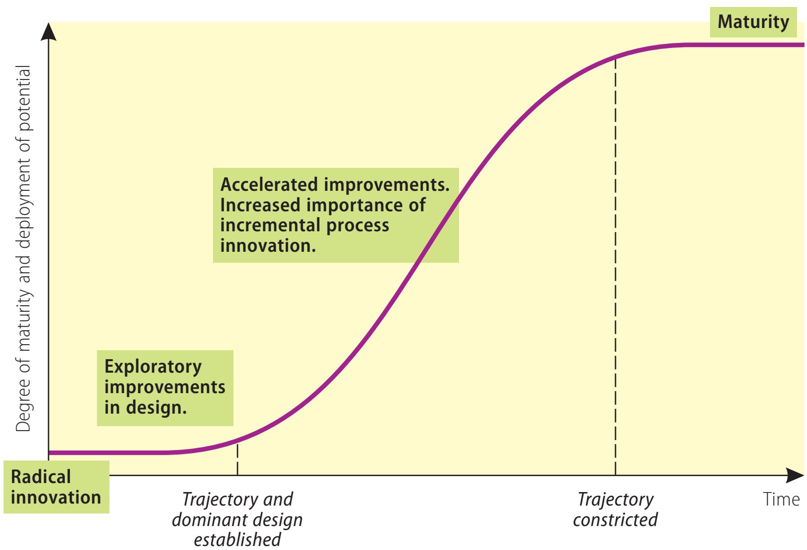



**Figure 4.1 Technological innovation: an idealized developmental trajectory**

*Source:* based on Perez, 2010: Figure 1

### *Technological revolutions and long waves*

Central to such an evolutionary perspective is the idea that economic growth occurs in a series of cycles or 'waves'. The best-known version of this idea is the Kondratiev wave (K-wave), a long wave of roughly 50 years' duration.[11] In Figure 4.2, beginning in the late 1700s, four complete K-waves are identified. We are now well into

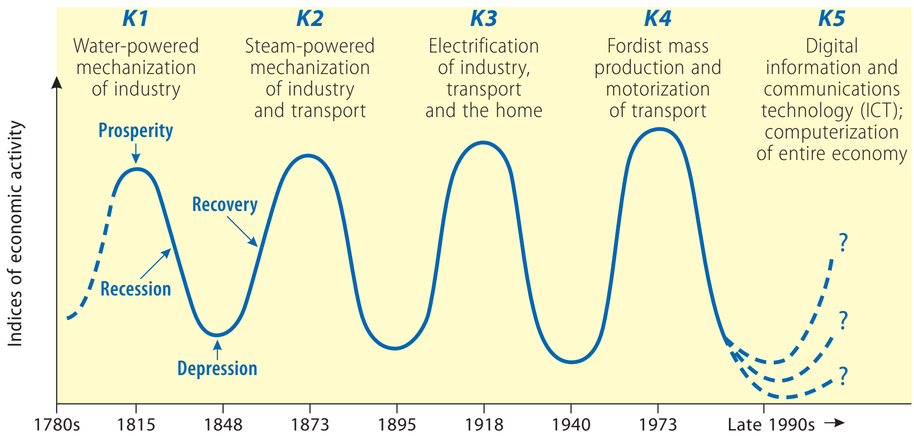



**Figure 4.2 Kondratiev long waves**

*Source:* based, in part, on Freeman and Louçã, 2001: Table II.1

a fifth, though precisely how far in, and what its precise trajectory will be, is not yet clear. Each wave can be divided into four phases: prosperity, recession, depression and recovery. Each wave tends to be associated with particularly significant technological changes around which other innovations – in production, distribution and organization – swarm or cluster and ultimately spread through the economy.

Although such diffusion of technology stimulates economic growth and employment, demographic, social, industrial, financial and demand conditions also have to be appropriate. In other words, it is the 'total package' that counts. At some point, however, growth slackens: demand becomes saturated or firms' profits become squeezed through intensified competition. As a result, the level of new investment falls, firms strive to rationalize and restructure their operations, and unemployment rises. Eventually the trough of the wave will be reached and economic activity will turn up again. A new sequence will be initiated on the basis of key technologies – some of which may be based on innovations that emerged during recession itself – and of new investment opportunities. Although there is disagreement over the precise mechanisms and timing involved, each of the waves is generally associated with changes in the techno-economic paradigm, as one set of techno-economic practices is displaced by a new set. This is not a sudden process but one that occurs gradually and involves the ultimate 'crystallization' of a new paradigm.

As Figure 4.3 shows, the process involves much more than just technical change. Each phase is also associated with characteristic forms of economic organization, cooperation and competition. Each successive K-wave also has a *specific geography*, as technological leadership shifts over time, both in terms of lead nations (as the bottom row of Figure 4.3 makes clear) and at the micro-geographical scale. In effect, 'the locus of the leading-edge innovative industries has switched from region to region,

| | K1 | K2 | K3 | K4 | K5 |
|---|---|---|---|---|---|
| **Main 'carrier' branches** | Textiles; Textile chemicals; Textile machinery; Iron working/castings; Water power; Potteries. | Steam engines; Steamships; Machine tools; Iron and steel; Railway equipment. | Electrical engineering; Electrical machinery; Cable and wire; Heavy engineering/ armaments; Steel ships; Heavy chemicals; Synthetic dyestuffs. | Automobiles; Trucks; Tractors; Tanks; Aircraft; Consumer durables; Process plant; Synthetic materials; Petrochemicals. | Computers; Digital information technology; Internet; Software; Telecommunications; Optical fibres; Robotics; Ceramics; Nanotechnology; Biotechnology. |
| **Core input and other key inputs** | Iron; Raw cotton; Coal. | Iron; Coal. | Steel; Copper; Metal alloys. | Oil; Gas; Synthetic materials. | 'Chips' (integrated circuits). |
| **Transport and communications infrastructure** | Trunk canals; Turnpike roads; Sailing ships. | Railways; Shipping. | Electricity supply and distribution. | Highways; Airports/airlines. | Digital networks; Satellites. |
| **Organization of firms and forms of cooperation and competition** | Factory systems. Individual entrepreneurs and small firms (<100 employees) competition. Partnership structure facilitates cooperation of technical innovators and financial managers. Local capital and individual wealth. | High-noon of small-firm competition, but larger firms now employing thousands rather than hundreds. As firms and markets grow, limited liability and joint stock company permit new pattern of investment, risk-taking and ownership. | Emergence of giant firms, cartels, trusts, mergers. Monopoly and oligopoly becomes typical. Regulation or state ownership of 'natural' monopolies and public utilities. Concentration of banking and 'finance-capital'. Emergence of specialized 'middle management' in large firms. | Mass production and consumption. 'Fordism'. Oligopolistic competition. Transnational corporations based on direct foreign investment and multi-plant locations. Competitive subcontracting on 'arm's length' basis or vertical integration. Increasing concentration, divisional-ization and hierarchical control. 'Techno-structure' in large corporations. | 'Networks' of large and small firms based increasingly on computer networks and close co-operation in technology, quality control, training, investment planning and production planning ('just-in-time') etc. |
| **Geographical focus: core country or countries** | Britain. | Britain (spreading into Europe and USA). | USA and Germany forging ahead and overtaking Britain. | USA (with Germany at first competing for world leadership), later spreading to Europe. | USA (spreading to Europe and Asia). |

**Figure 4.3 Key characteristics of successive K-waves**

*Source:* based, in part, on Freeman and Perez, 1988: Table 3.1; Freeman and Louçã, 2001: Table II.1; Perez, 2010: Table 1

from city to city'.[12] For example, 'Manchester was as much the cradle and the symbol of the Age of Steam as Silicon Valley has been for the microelectronics revolution'.[13]

## Information and communications technologies: the digital world

> Information is what our world runs on: the blood and the fuel, the vital principle.[14]

K5 is associated primarily with *information and communications technology* (ICT) and, especially, with *digital* technologies:

> For the first time in history, information generation, processing and transmission have become the main commodities and sources of

> productivity and power and not only a means of achieving better ways of doing things in the production process. New information technologies are not simply tools to be applied but processes to be developed.[15]

The 'new' telecommunications technologies are, in effect, 'the electronic highways of the informational age, equivalent to the role played by railway systems in the process of industrialization'.[16]

The current generation of information technologies has one very special characteristic, as Figure 4.4 shows. It is based upon the *convergence* of two initially distinct technologies: *communications technologies* (concerned with the transmission of information) and *computer technologies* (concerned with the processing of information). Both are now based on digital, rather than analogue, technologies. Digitization is, without doubt, the most pervasive and influential technological development of recent years. All kinds of information can now be stored in numerical (binary) form as electronic 'digits'. This means they can then be

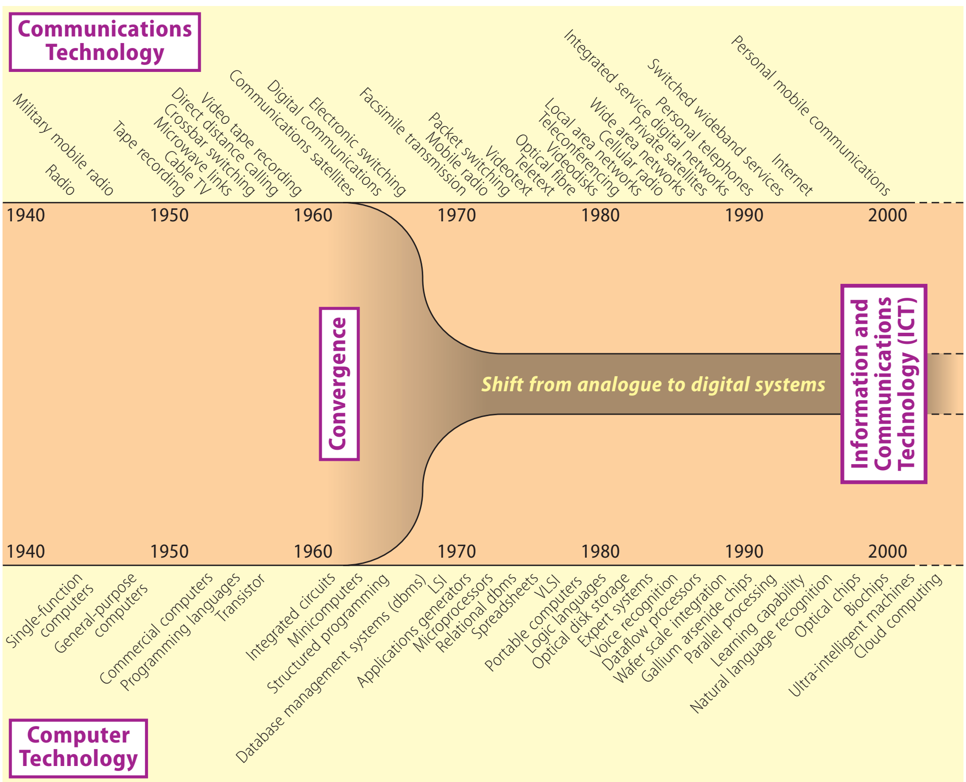



**Figure 4.4 Information and communications technologies: a process of convergence**

*Source:* based, in part, on Freeman, 1987: Figure 2

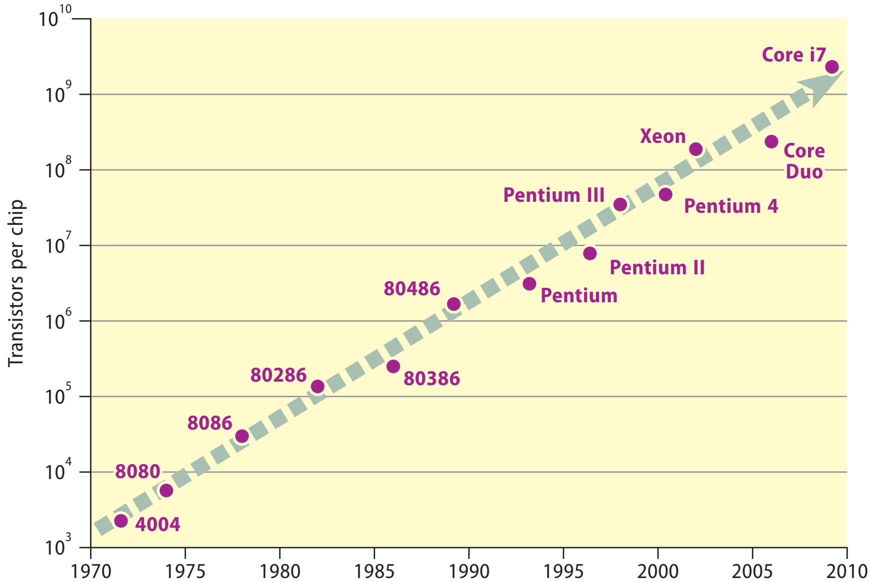



**Figure 4.5** Exponential increase in the capacity of microprocessors

processed, manipulated and stored by computers, and transmitted anywhere in the world almost instantly. In particular, the remarkable, and very recent, growth of the Internet, of mobile telephony, together with big changes in electronic mass media and the rapid emergence of 'social media', are generating major global effects at all levels, including individuals, households, local communities, nation-states and, of course, business organizations, especially TNCs.

Each successive K-wave has been driven by a 'key input'. In the case of K5, as Figure 4.3 shows, this was the 'chip', the *integrated circuit (IC)* or *microprocessor*, which emerged in the USA in the late 1940s and early 1950s. Most important has been the process of *miniaturization*: the development of increasingly complex ICs of progressively smaller and smaller sizes. Figure 4.5 illustrates this stunning process of miniaturization. It reflects the so-called 'Moore's Law': the prediction by Gordon Moore (the co-founder of Intel) in 1965 that the number of transistors per chip would double every 18 months. In 1964, there were a mere 30 transistors on a chip. Intel's first commercial microprocessor produced in 1971 contained 3500 transistors; its Pentium 4 of the late 1990s contained 42 million. Today, Intel's Core i7 chip for the newest Mac and Windows PCs has 1.4 billion transistors on a surface area of 160 square millimetres. Such developments have made possible not only increasingly powerful computers, but also vast reductions in their cost and, therefore, in their increasingly ubiquitous use in all kinds of products and processes.

Perez summarizes the complex interconnected nature of the ICT revolution particularly well:

> The current information technology revolution … opened up an initial technology system around microprocessors (and other integrated semiconductors), their specialized suppliers and their early uses in calculators, games and in the miniaturizing and digitizing of control and other instruments for civil and military uses. This system was followed by an overlapping series of other radical innovations, minicomputers and personal computers, software, telecoms and the internet, each of which opened up new system trajectories, while being strongly inter-related and inter-dependent. As they appeared, these systems interconnected and continued expanding together with intense feedback loops in both technologies and markets.[17]

As the power and sophistication of computer technology has increased, and as it has become increasingly widely available through networked systems, it is taking on the characteristics of a utility. Computing is becoming analogous to the electricity generating industry of the nineteenth century,[18] when businesses abandoned their own individual electricity generators to take advantage of the new electric grid system. Today they are beginning to move away from individual computer systems to networked systems provided through the Internet. An example of such new computers-as-utility systems is Google's global network of 'server farms':

> Designed to house tens of thousands of PCs, all wired together to work as a single supercomputer [these are] … the information-processing equivalent of a nuclear power station, able to pump data and software into millions of homes and businesses … No corporate computing system, not even those operated by big companies, can match the efficiency, speed and flexibility of plants such as Google's. One analyst estimates that Google can carry out a computing task for one-tenth of what it costs a typical company … *Cheap and plentiful electricity shaped the world we live in today … The transformation in the supply of computing promises to have equally sweeping consequences.*[19]

This development has become known as 'cloud computing': clusters of servers 'in the sky', as it were. However,

> its physical aspect could not be less cloudlike. Server farms proliferate in unmarked brick buildings and steel complexes, with smoked windows or no windows, miles of hollow floors, diesel generators, cooling towers, seven-foot intake fans, and aluminum chimney stacks. This hidden infrastructure grows in a symbiotic relationship with the electrical infrastructure it increasingly resembles. There are information switchers, control centers and substations. They are clustered and distributed. These are the wheel-works; the cloud is their avatar.[20]

# TIME–SPACE SHRINKING TECHNOLOGIES

As Figure 3.3 shows, *processes of circulation* are fundamental to the operation of production circuits and networks; indeed, to the operation of society as a whole. Circulation technologies – transportation and communications technologies – overcome the frictions of space and time.[21] Although these certainly cannot be regarded as the cause of globalization, without them today's complex global economic system simply could not exist. Transportation and communications technologies perform two distinct, though closely related and complementary, roles:

- *Transportation systems* are the means by which materials, products and other tangible entities (including people) are transferred from place to place.
- *Communications systems* are the means by which information is transmitted from place to place in the form of ideas, instructions, images, and so on.

For most of human history, transportation and communications were effectively one and the same. Before the invention of electric technology in the nineteenth century, information had to be physically carried. It could move only at the same speed, and over the same distance, as the prevailing transportation system allowed. Electric technology broke that link, making it increasingly necessary to treat transportation and communications as distinct, though intimately related, technologies. Such developments have transformed societies in all kinds of ways. From a specifically economic and business perspective, they strongly influence how – and where – business organizations are able to operate. As a consequence, these technologies have helped progressively to transform the economic–geographical landscape, at increasing geographical scales and over shorter periods of time. Figure 4.6 summarizes this process. We will focus on how such transformations in firms' activities and their geographies are actually being worked out later in this chapter and in Chapter 5. Before that, we need to identify some of the major innovations in transportation and communications, which have been so important in helping to transform the economic landscape.

## Accelerating geographical mobility

### *A shrinking world*

In terms of the time it takes to get from one part of the world to another there is no doubt that the world has 'shrunk' dramatically (Figure 4.7). Throughout most of human history, the speed and efficiency of transportation were staggeringly low and the costs of overcoming the friction of distance prohibitively high. Movement over land was especially slow and difficult before the development of the railways. Indeed, even as late as the early nineteenth century, the means of transportation were not really very different from those prevailing almost 2000 years earlier.

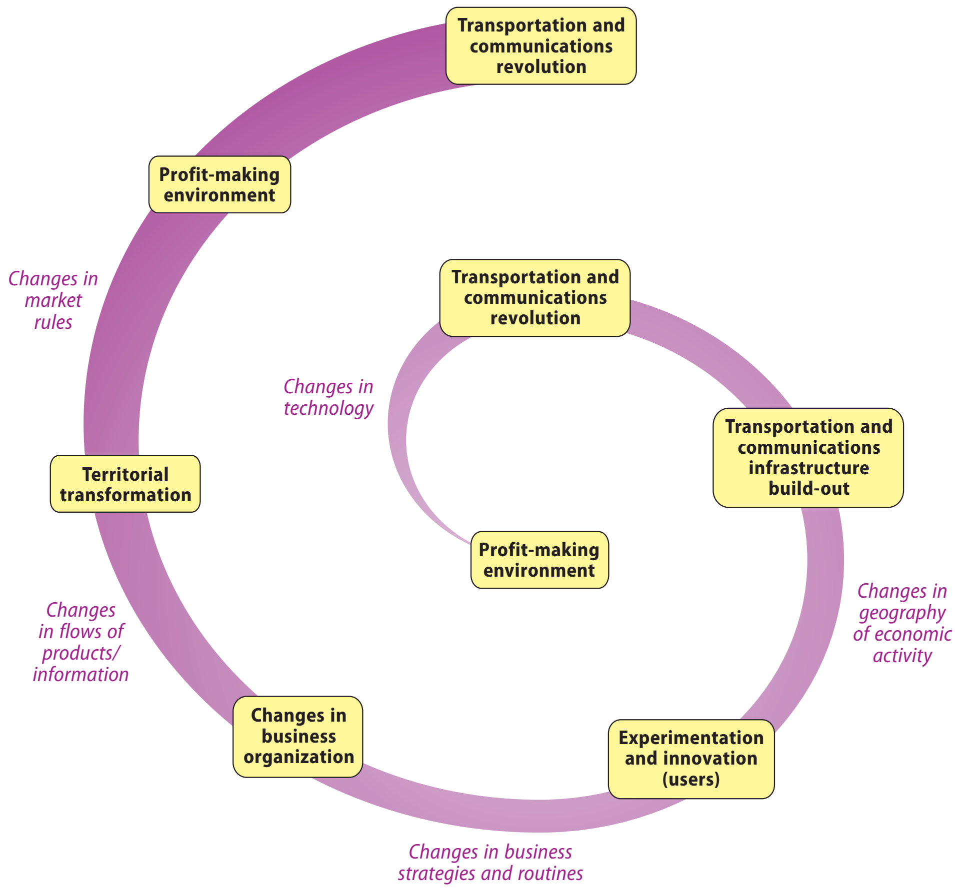



**Figure 4.6** **Transportation/communications revolutions and economic transformation**

*Source:* based on Fields, 2004: Figure 2.1



The major breakthrough came with two closely associated innovations in K2 (Figure 4.3): steam power as a means of propulsion and the use of iron and steel for trains, railway tracks and ocean-going vessels. These, coupled with the linking together of overland and oceanic transportation (e.g. with the cutting of the canals at Suez and Panama), greatly telescoped geographical distance at a global scale. The railway and the steamship introduced a new, and much enlarged, scale of human activity. The decline in global transportation cost was truly amazing.[22] Flows of materials and products were enormously enhanced and the possibilities for geographical specialization greatly stimulated. Such innovations were a major factor in the massive expansion in the global economic system during the nineteenth century.

The past few decades have seen an acceleration of this process of global shrinkage. For example, transportation costs fell 'from an average of 8 per cent of total

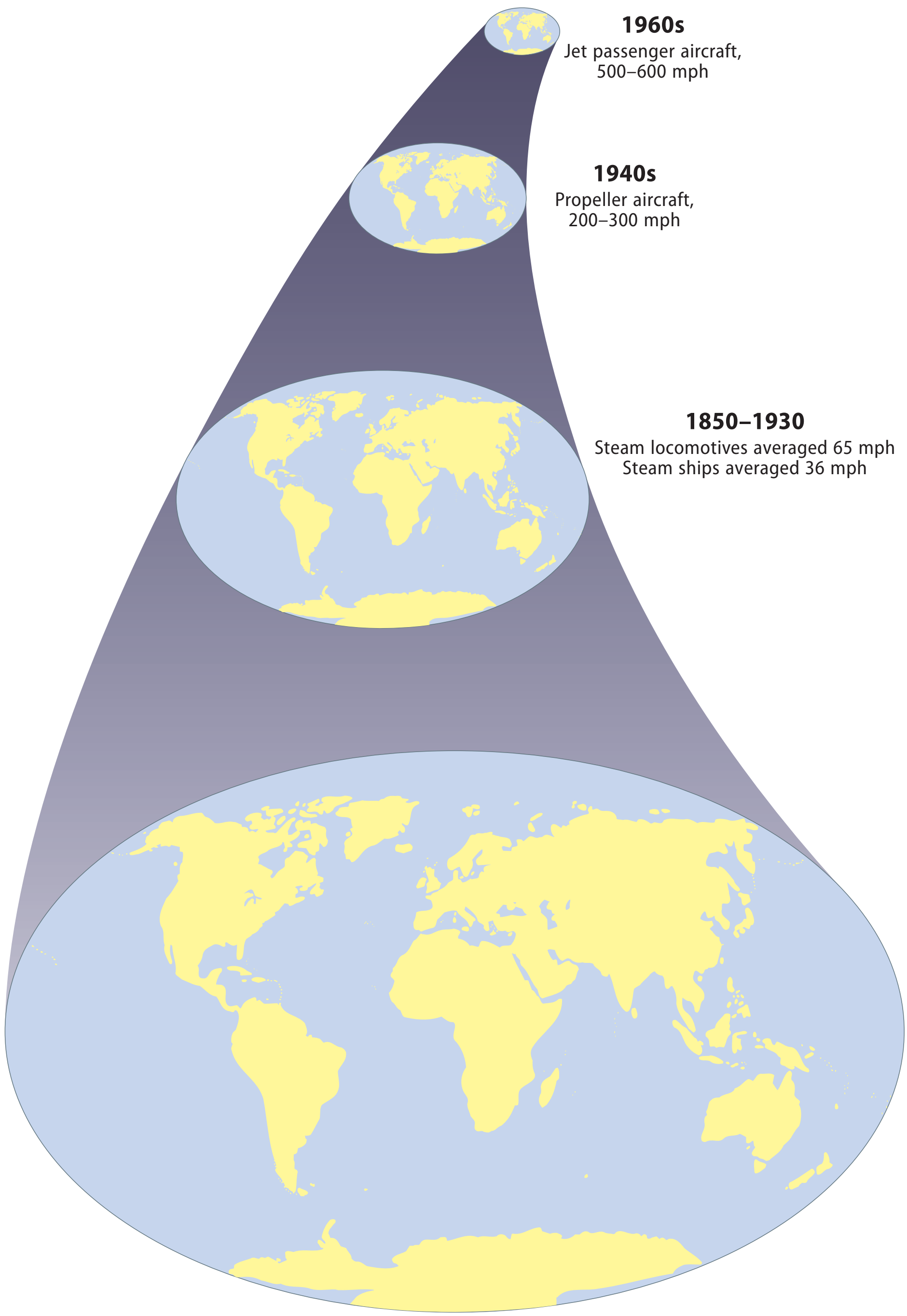



**Figure 4.7** **Global shrinkage: the effects of transportation innovations on 'real' distance**

*Source:* based on McHale, 1969: Figure 1 import costs in 1970 to about 3 per cent in 2002'.[23] Two developments have been particularly important, both of them appearing for the first time during the 1950s.

### *Take-off: the introduction of jet aircraft*

One was the introduction of *commercial jet aircraft*. This had two major effects. First, it enabled unprecedentedly rapid individual travel over vast distances, allowing face-to-face meetings at times and in places hitherto unrealistic. For TNCs, in particular, jet transport made possible the coordination and control of geographically dispersed operations. Direct control at a distance became a reality. It is no coincidence that the take-off of TNC growth and the (more literal) take-off of commercial jets both occurred during the 1950s. One estimate is that '320 million people meet annually at professional and corporate events after travelling by air'.[24]

The second significant effect of jet transport was on the movement of certain kinds of freight. Most heavy and bulky freight moves by sea, but for certain kinds of good and certain kinds of activity faster air transport is crucial:

> Between 1950 and 2004, air freight prices fell from \$3.87 per ton-kilometer to less than \$0.30, in 2000 US dollars … Of the world's \$12 trillion of merchandise trade, 35 per cent by value was shipped by air in 2006 … [for example] … air transport fills an important niche in just-in-time production systems. While shipments by sea are routine, firms use air cargo to fine-tune intermediate input flows and to ship goods with high value-to-weight ratios … [air transport] … also enabl[es] exports of perishable goods over long distances.[25]

### *Moving in bulk: containerization*

The other major development was the introduction of *containerization* for the movement of heavy and bulky ocean and land freight, an innovation that vastly simplified transhipment of freight from one mode of transportation to another, increased the security of shipments, and greatly reduced the cost and time involved in moving freight over long distances.[26] The first container ship, launched in 1956 to move goods from Newark, New Jersey, to Houston, Texas, through the Gulf of Mexico, was merely a conventional oil tanker strengthened to take 58 boxes each 9 metres long. Today, around 90 per cent of all non-bulk cargo is moved in containers:

> Container shipping certainly is the great hidden wonder of the world, a vastly underrated business … It has shrunk the planet and brought about a revolution because the cost of shipping boxes is so cheap. People talk about the contribution made by the likes of Microsoft. But container shipping has got to be among the 10 most influential industries over the past 30 years.[27]

However, the very success of containerization, in a world in which trade has grown very rapidly, especially on certain routes such as those from China to North America and to Europe, has created immense problems, notably port congestion. In 2004, a new generation of container ships, more than 300 metres long, more than 40 metres wide and capable of carrying 8000 containers each 6 metres long, entered service. In 2013, the new Triple-E container ships appeared, each able to accommodate 18,000 containers each 6 metres long. Relatively few ports have the capacity to take such huge vessels and this will, inevitably, enhance their dominance over smaller ports. In any case, there are already massive problems of delays at most major world ports because of the sheer volume of freight traffic and the physical and human problems of handling it quickly. Although the shrinkage of world trade created by the 2008 financial crisis created huge over-capacity in the container shipping industry, there is clearly a drive to introduce bigger and more efficient container ships. There is already talk of ships capable of carrying 25,000 containers.[28]

### *The unevenness of time–space convergence*

Although the world has indeed shrunk in relative terms, such shrinkage has been, and continues to be, highly uneven. This is contrary to the impression given by Figure 4.7. In fact, technological developments in transportation have a very strong tendency to be geographically highly concentrated. The big investments needed to build transportation infrastructures tend to go where demand is greatest and financial returns are highest. Consequently, *time–space convergence* affects some places more than others. While the world's leading national economies and the world's major cities are being pulled closer together in relative time or cost terms, others – less developed countries or smaller towns and rural areas – are, in effect, being left behind. The time–space surface, then, is highly plastic; some parts shrink while other parts become, in effect, extended. By no means everywhere benefits from technological innovations in transportation.

## 'Everywhere is at the same place': innovations in communications technologies

> We know that telecommunication tends to push the meaning of space towards zero, nevertheless, the earth still has simultaneous night and day, and depending on one's location an inconsiderate phone call can still get people out of bed.[29]

Developments in transportation technologies would have been impossible without parallel developments in communications technologies: *the* key technologies transforming relationships at the global scale. As Figure 4.4 shows, global communications systems have been transformed radically during the past 20 or 30 years through a whole cluster of significant innovations in information technologies.

In terms of communications infrastructure – the transmission channels through which information flows – two innovations have been especially significant: satellite communications and optical fibre technologies.

### *Transmission channels: satellites and optical fibre cables*

Satellite technology began to revolutionize global communications from the mid-1960s when the Early Bird or Intelsat I satellite was launched.[30] This was capable of carrying 240 telephone conversations or two television channels simultaneously. Since then, the carrying capacity of communications satellites has grown exponentially. Satellite technology made possible remarkable levels of global communication of both conventional messages and the transmission of data. A message could be transmitted in one location and received in another on the other side of the world almost simultaneously. Today, there are more than 100 geostationary satellites in orbit.

However, for most parts of the world, satellite communications have been increasingly challenged by *optical fibre* technology carried within submarine cables:

> Satellites were ideal for broadcasting … as well as providing a larger number of telephone circuits than the combined capacity of all submarine cables. The life of satellites, however, is much shorter than that of cables and the number of 'parking spots' available in geosynchronous orbit is limited … Satellites also forced a shift from analogue to digital transmission and digital signals are optimally carried by fibre-optic cables, which appeared in the 1980s, making both old telephone cables and even most satellites themselves obsolete.[31]

The first commercially viable optical fibre system was developed in the USA in the early 1970s. Since then, the speed, carrying capacity and cost of optical fibre transmission cables have changed dramatically. Optical fibre systems have a huge carrying capacity, and transmit information at very high speed and, most importantly, with a high signal strength. By the end of the 1990s, for example,

> a single pair of optical fibres, each the thickness of a human hair … [could] … carry North America's entire long-distance communications traffic. Gemini, a transatlantic undersea cable … completed … [in 1998] … ha[d] more capacity than all existing transatlantic cables combined.[32]

Since then, optical fibre technology has continued to accelerate, vastly increasing the speed and capacity of communications networks. At the same time, the geographical spread of optical fibre systems has increased dramatically (Figures 4.8 and 4.9). Today, more than 90 per cent of all international telecommunications are transmitted using optical fibre cables. The system continues to expand as a response to rapidly increasing demands, especially from the growth of Internet

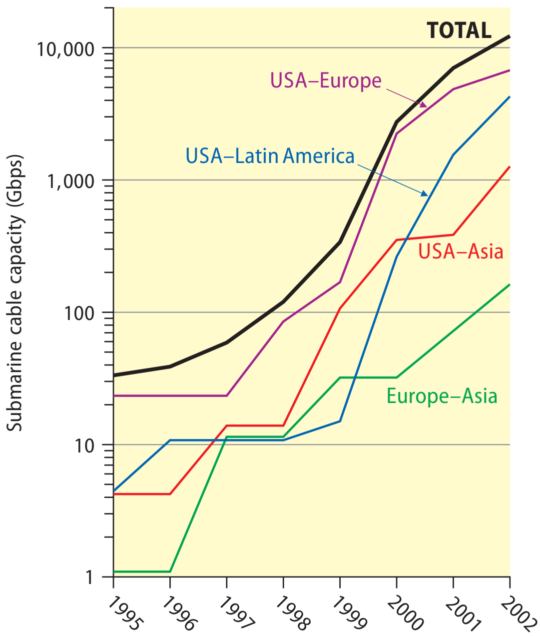



**Figure 4.8** **Growth in the information carrying capacity of submarine cable systems**

*Source:* based on material in the *Financial Times*, 15 November 2000

traffic. In particular, video and data transmissions require much higher bandwidth than speech. There is also a need to build in extra capacity to cope with cable failure (as happened in mid-2008 when three submarine cables serving the Middle East and South Asia were damaged).

## *The Internet: the 'skeleton of cyberspace'*

> The Internet is the decisive technology of the Information Age, as the electrical engine was the vector of technological transformation of the Industrial Age.[33]

The phenomenally rapid spread of the Internet has been one of the most remarkable developments of recent decades.[34] Its origins go back to the early 1970s and are to be found within the US Department of Defense. It spread initially through the linking of more specialized academic computer networks and, for some time, it seemed that it would remain a niche technology. Not so. As Figures 4.10 and 4.11 show, the growth of the Internet has been dramatic. Most important of all have been the development of the World Wide

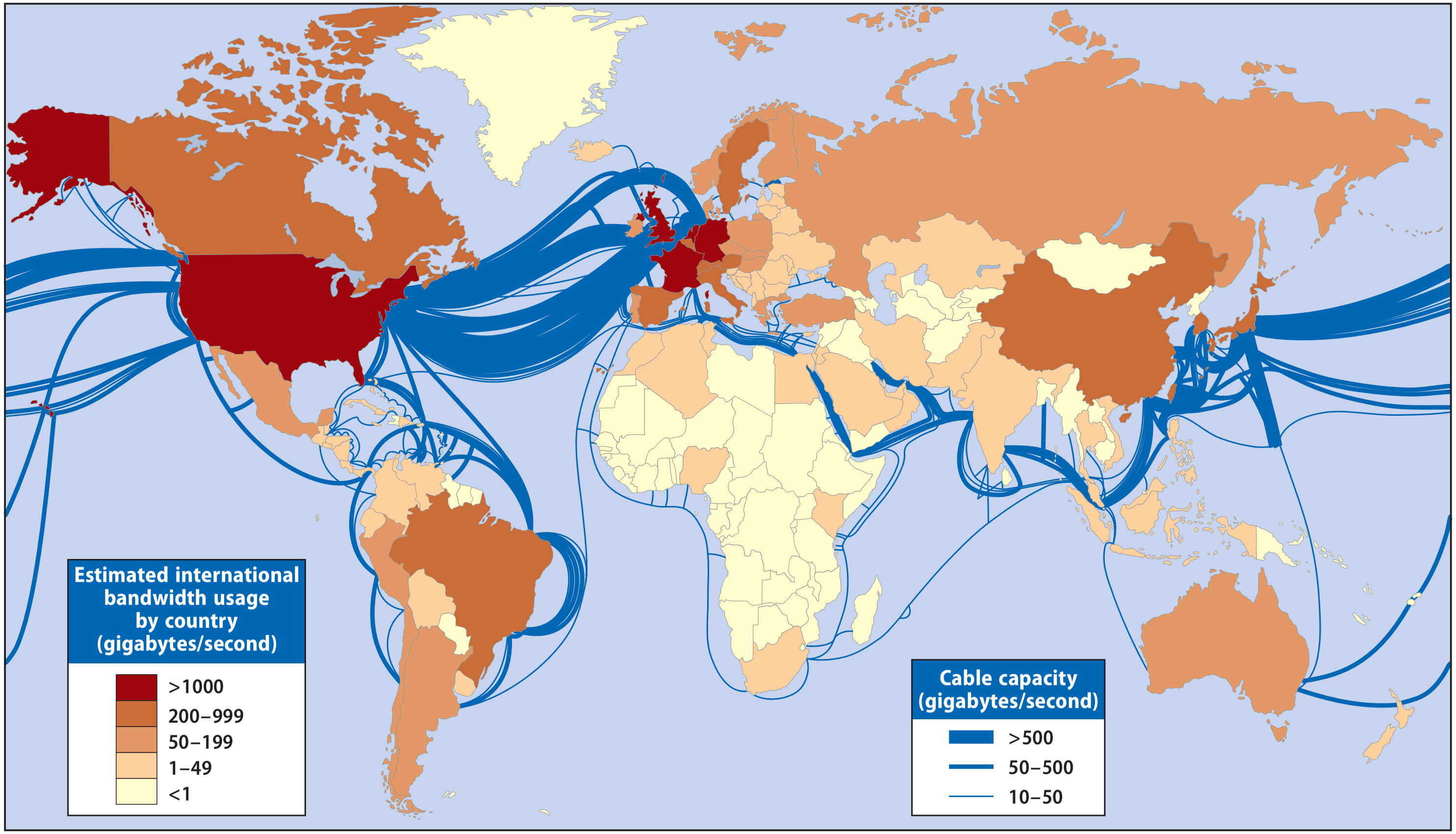



**Figure 4.9** **The world's submarine cable system**

*Source*: based on material in the *Guardian* (1 February 2008; 18 August 2008)

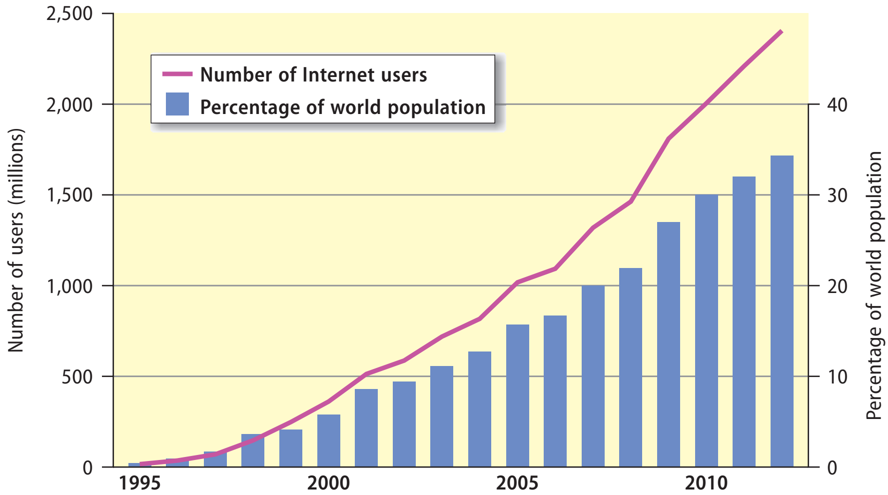



**Figure 4.10** **Exponential growth of the Internet**

*Source:* based on material in www.internetworldstats.com

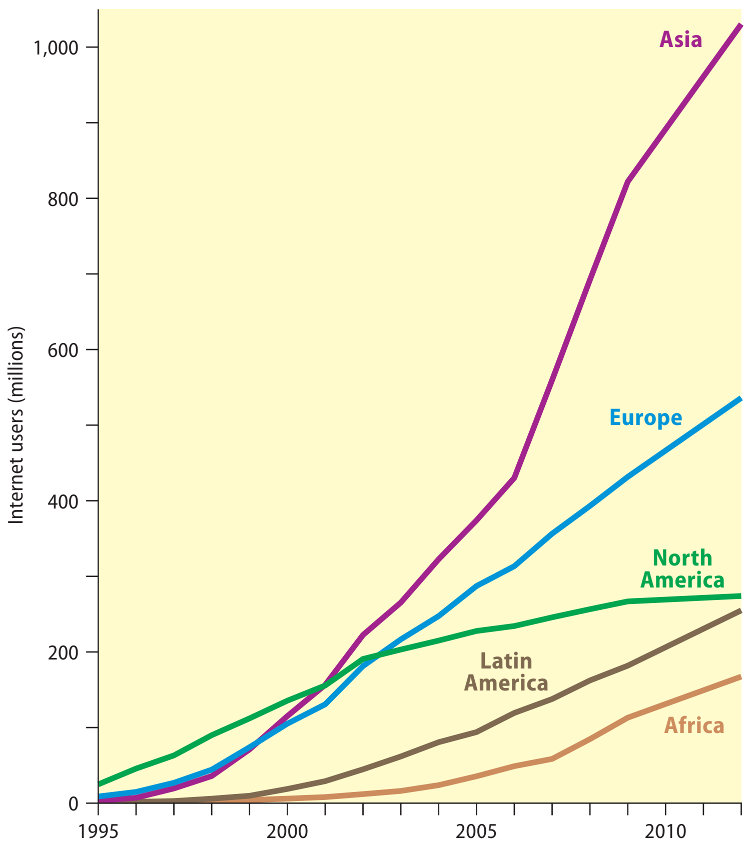



**Figure 4.11** **Growth of the Internet by region**

*Source:* based on material in www.internetworldstats.com

Web (invented by Tim Berners-Lee in the mid-1990s) and the rapid increase in access to broadband and wireless transmission.

Internet communication has replaced (in whole or in part) a huge swathe of conventional communications methods. A large proportion of business communication is now conducted through the Internet. Similarly for millions of individuals, email and, more recently, the 'new' social media such as Facebook and Twitter have become the preferred means of communication. At the same time, the Internet gives access to a phenomenal amount of information on virtually everything under the sun through the World Wide Web. Without doubt, the Internet is changing the world and how we perceive and understand it – at least for those with access to it (see below).

## *The electronic mass media*

The development of electronic mass media (radio, TV) during the twentieth century revolutionized the ways in which people living in one part of the world learn about what is happening in other parts of the world. Such media are especially powerful and influential not only because of their apparent immediacy, but also because they do not require the high level of literacy of books or newspapers. This is, of course, very important both commercially and politically. For example, large business firms require large markets to sustain them; global firms aspire to global markets. The existence of such markets obviously depends on income levels, but it depends, too, on potential customers becoming *aware* of a firm's offerings and being persuaded to purchase them. Even where consumer incomes are low, the ground may be prepared for possible future ability to purchase by creating an aspirational image.

Today, TV is the mass medium that has the most dramatic impact on people's awareness and perception of worlds beyond their own direct experience. Although the electronic media transmit messages of all kinds, a very large proportion of these messages (either explicitly or implicitly) are *commercial* messages aimed at the consumer. Because commercial advertising is a feature of most mass media networks throughout the world, the communications media open the doors of national markets to the heavily advertised, branded products of the transnational producers.

However, during the past three decades there has been a major 'phase shift' in the mass media with the appearance of cable and satellite broadcasting and, most recently, with the increasing interconnection with the Internet as well as a widespread deregulation of the media. As a result, the number of TV channels has grown dramatically, from a small number in each country to, potentially, many hundreds of channels. This has had major effects on the ways in which TV is used. Prior to the media diversification wave of the 1980s, there was a high level of standardization in the kinds of TV programme available. It was this kind of 'mutual experience' that led Marshall McLuhan to coin the metaphor of the *global village* in which certain images are shared and in which events take on the immediacy of participation.

But the increasing segmentation of TV messages means that the global village idea is no longer an accurate picture of reality:

> the fact that not everybody watches the same thing at the same time, and that each culture and social group has a specific relationship to the media system, does make a fundamental difference vis-à-vis the old system of standardized mass media … While the media have become indeed globally interconnected, and programs and messages circulate in the global network, *we are not living in a global village, but in customized cottages globally produced and locally distributed*.[35]

These trends are intensified through increasingly diverse ways of viewing TV programmes (e.g. on a variety of devices) and also at different times (through the use of on-demand TV services). Many of these trends, of course, are related to the development of wireless technologies and the rapid growth of smartphones and tablets.

### *Communications on the move: towards a wireless world*

Telecommunications depend traditionally on a massive physical infrastructure. But within that infrastructure, one of the most significant developments of recent years has been the phenomenal growth of *mobile* communications, especially the mobile telephone or cellular phone. One of the first patents for a 'radio-telephone' system linked to base stations was taken out by Motorola in 1973. But development was slow. In the early 1980s, what was then still a relatively rare, and very prestigious, instrument – the mobile phone – was the size of a brick, weighed around 800 grams and cost almost $4000. Today, the weight is down to 90 grams and the typical cost of a basic handset is well below $100. At the same time, the geographical range and sophistication of mobile phones and their operating systems have increased dramatically. Hence, there has been an explosion in mobile phone ownership throughout the world. In the early 1990s, there were only a few hundred thousand subscribers to mobile systems; now there are more than 6 billion.[36] Mobile phone subscriptions now vastly exceed fixed telephone lines and at an increasing rate. In 2008, mobile subscriptions were a little over three times those of fixed subscriptions; by the end of 2011 they were five times greater. The fastest growth in mobile phone subscriptions is in developing countries: these made up more than four-fifths of new world mobile subscriptions in 2011.[37]

Much of this increase is being driven by the development of faster 3G and super-fast 4G systems, which enable a huge increase in the speed and quality of mobile Internet services. The spectacular recent development of the 'smartphone', a multi-purpose, integrated communications device, has been revolutionary. Indeed, smartphones (and tablets) have become the means by which increasing numbers of people access the Internet. The ITU estimate is that there were more than 1 billion mobile broadband subscriptions by the end of 2011 and that this has become the fastest-growing ICT service, increasing by 40 per cent in that year.

Such developments are revolutionary in many ways, especially in terms of their impact on conventional telecommunications and on social behaviour:

> The growth of mobile broadband services is erasing the boundaries between telephony and the Internet altogether … As telephony has become increasingly digitized, the boundaries between traditional data and communications markets have become blurred … texting has come to rival or surpass voice messages on many world telecommunications networks … Instant messaging services such as Twitter and interactive Web pages such as Facebook, which permit online chat … greatly enhanced the popularity of texting, which often bypasses the format of conventional email …
>
> A clear sign of the mutually transformative impacts of the Internet and the world's telephony system is Voice Over Internet Protocol (VOIP), that is, telephone traffic conducted entirely through cyberspace, allowing users to bypass the toll charges ubiquitous among public switched networks … The world's most popular VOIP application by far is Skype … now the world's largest international provider of telephone services … One half of Skype calls are between countries, and account for one-fourth of all calls that cross national borders.[38]

What we are experiencing, therefore, is a very rapid transition from a fixed to an increasingly wireless world of telecommunications in which the technological *convergence* between computing and communications, shown in Figure 4.4, has entered a new phase. Such developments have the potential to generate enormous social and economic changes as they free users (whether they be businesses or individuals) from the physical tie to fixed communications infrastructure.

## *Digital divides: an uneven world of communications*

Although technological developments in communications have transformed space–time relationships between virtually all parts of the world, the outcomes – as in the case of physical movement – are immensely uneven. Not all places are equally connected in 'communications space'. The time–space surface is highly plastic; some parts shrink while other parts become, in effect, extended in relative, though not, of course, in absolute terms. By no means everywhere benefits equally from technological innovations in communications. As in the case of transportation facilities, the places that benefit most tend to be the already 'important' places. New investments in technology are market related; they go to where the returns are likely to be highest. The cumulative effect is both to

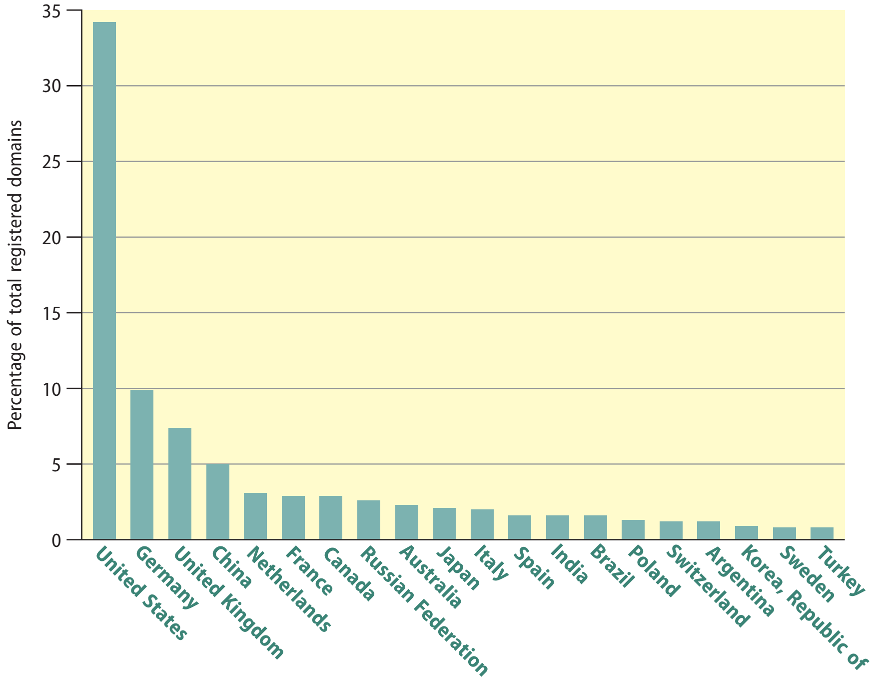



**Figure 4.12** **The uneven geography of Internet domain names**

*Source:* based on data provided by Matthew Zook

reinforce certain communications routes at the global scale and to enhance the significance of the nodes (cities/countries) on those routes.

Even the Internet is far from being the placeless/spaceless phenomenon so often envisaged. For example, Figure 4.12 shows the highly uneven geography of registered Internet domain names at the end of 2012. Although there has been some spreading out, the pattern remains highly concentrated. North America and Europe have over 77 per cent of world domain names. The USA alone has one-third of the world total.

The seemingly spaceless 'cloud computing' also has a geography, and it, too, is very uneven. Its basic infrastructure (including the server farms referred to earlier on p. 82) is overwhelmingly an urban – especially a big city – phenomenon:

> This is partly an historical accident … the Internet's fibre-optic cables often piggyback on old infrastructure where a right-of-way has already been established: they are laid alongside railways and roads or inside sewers … Building the Internet on top of existing infrastructure in this way merely reinforces real-world geography. Just as cities are often railway and shipping hubs, they are also the logical places to put network hubs and servers, the powerful computers that store and distribute data.[39]

For example, the network of Google server farms is located as close as possible to the largest concentrations of potential customers because

> as fast as electrons travel, physical distance still affects [online] response speed … Reducing [it] by even a fraction of a second mattered to users as Google discovered when it ran experiments to see if users noticed a difference between [a wait of] 0.9 seconds and [one of] 0.4 seconds … Users were conspicuously more likely to grow bored and leave the Google site after waiting that interminable 0.9 seconds.[40]

To a considerable extent, therefore, the map of the Internet mirrors the network of global cities. At the same time, however, the particular energy and other environmental requirements of server farms are leading to their location in smaller, more remote, places. For example, in the USA, towns like Quincy in Washington state (Microsoft, Yahoo, Dell), Maiden in North Carolina (Apple), Dalles in Oregon (Google) and Prineville in Oregon (Facebook) have become important server farm clusters.

But it is at the *global* scale that the uneven geography of communications access is most serious. There is a real, and serious, *digital divide* between those places and people with access to communications technologies and those without.[41] Because such access is the key to so much information and knowledge, this poses severe developmental problems. Figure 4.13 summarizes some of these global inequalities in access to the communications media.

One of the biggest obstacles to communications growth and access in poor countries is the lack of fixed line infrastructures and the immense cost of providing them in poor and, especially, in rural areas. Wireless communications have the potential to overcome this:

> Mobile phones do not rely on a permanent electricity supply and can be used by people who cannot read or write. Phones are widely shared and rented out by the call, for example by the 'telephone ladies' found in Bangladeshi villages. Farmers and fishermen use mobile phones to call several markets and work out where they can get the best price for their produce. Mobile phones are used to make cashless payments in Zambia and several other African countries …
>
> The digital divide that really matters, then, is between those with access to a mobile network and those without.[42]

Figure 4.13 shows that there has, indeed, been a huge change in the percentage of the population in developing countries having direct access to mobile telephones and the Internet. In the case of mobile phones, only 22.9 per cent had mobile subscriptions in 2005; by 2011 this had grown to 77.8 per cent. In the case of the Internet, only 7.7 per cent of the population in developing countries had access in 2005; by 2011 this had grown to 24.4 per cent. However, these figures are greatly distorted by developments in China, in particular, and in a small number of other

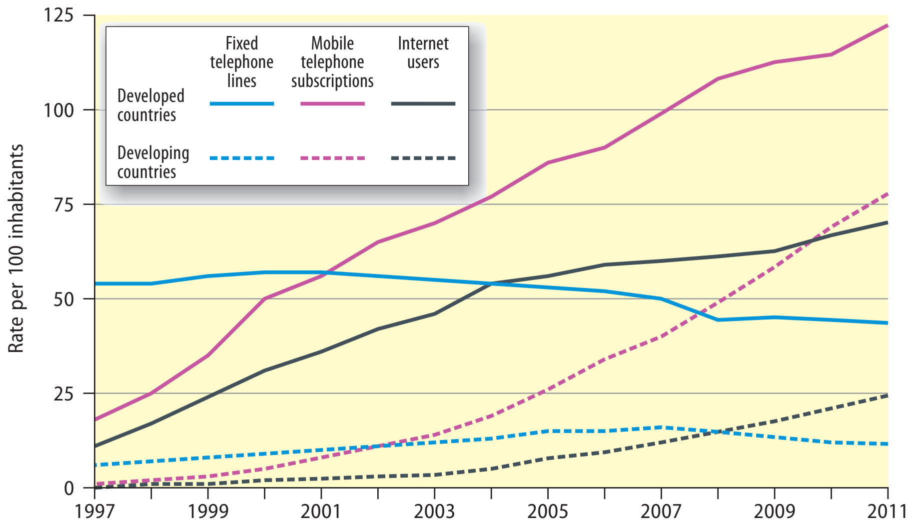



**Figure 4.13 Digital divides: uneven access to communications facilities**

*Source:* based on material in www.itu.int/ITU-D/ict/statistics

developing countries. For the majority, the digital divide remains alarmingly wide. Figure 4.14 demonstrates this very clearly.[43]

The digital divide between the 'global north' and the 'global south' is reflected in many ways, not least in the immense unevenness in geographical coverage in Wikipedia, as an analysis of geotagged articles has shown:

> There is clearly a highly uneven geography of information in Wikipedia. The US has the most articles about places or events (almost 100,000), while some smaller countries such as Tonga have fewer than 10 … But it's not just size that is correlated with extremely low levels of wiki representation. Almost the entire continent of Africa is geographically poorly represented in Wikipedia. Remarkably, there are more Wikipedia articles written about Antarctica than all but one of the 53 countries in Africa.[44]

As Mark Graham argues,

> these highly uneven geographies of information matter. They shape what is known and what can be known, which in turn influences the myriad ways in which knowledge is produced, reproduced, enacted, and re-enacted … The stickiness of information cores and peripheries, even in an age of supposed friction-free communications, is concerning because … spatial configurations of information both have power and reproduce power … Knowledge clusters that are reinforced by repeated rounds of spatial fixes thus result in, and reinforce, a landscape of uneven geographic development.[45]

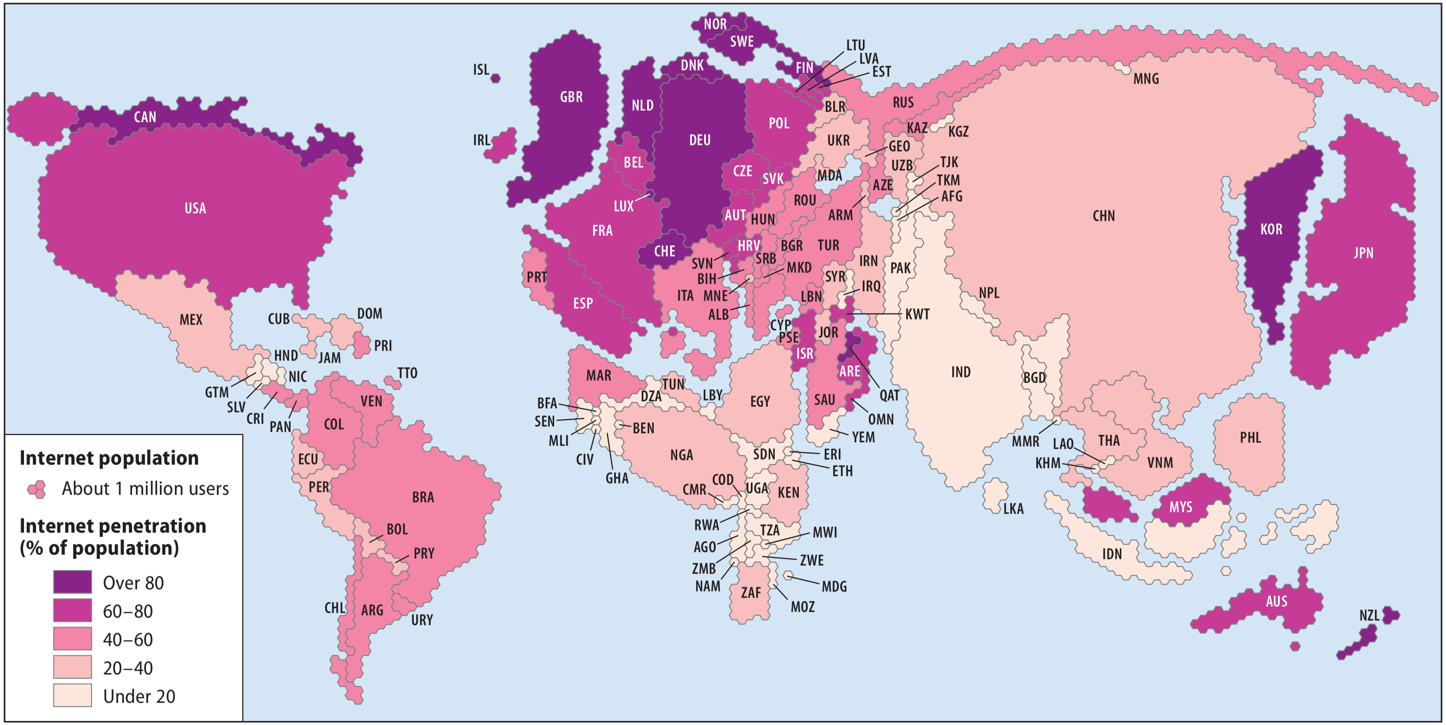



**Figure 4.14** **Digital divide: Internet population and penetration**

*Source:* Mark Graham and Stefano de Sabbata, geography.oii.ox.ac.uk

The world is certainly not 'flat' – even in the supposedly spaceless 'information world' of the popular imagination.

# TECHNOLOGICAL INNOVATIONS IN PRODUCTS, PRODUCTION SYSTEMS AND ORGANIZATIONAL FORMS

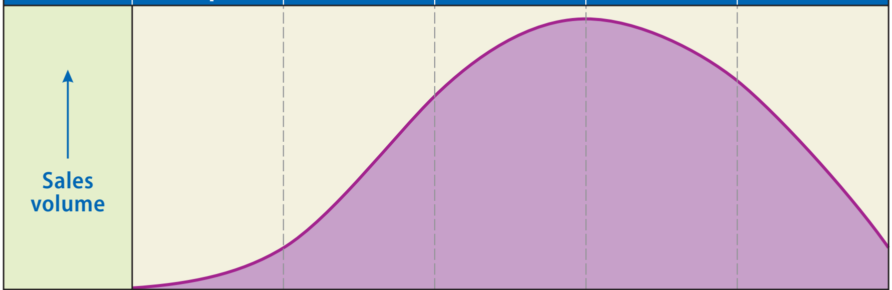
## Product life cycles

Although a firm's profitability can be enhanced through increased penetration of existing markets or expansion into new geographical markets, there are limits. In an intensely competitive environment the introduction of a continuous stream of new products becomes essential to a firm's profitability and, indeed, to its very survival. However, all products have a limited life span: what is generally referred to as the *product life cycle* (PLC). Figure 4.15 shows the major characteristics of an idealized PLC: the growth of sales follows a systematic path from initial innovation through a series of stages. There are clear similarities with the innovation trajectory shown in Figure 4.1.

This kind of development path has very important implications for the growth of firms and for their profit levels. Of course, the rate at which the cycle proceeds will vary from one product to another. In some highly ephemeral products the cycle may run its course within a single year or even less. In others the cycle may be very long. However, in general, product cycles have become shorter, increasing the pressure on firms to develop new products or to acquire them from other firms. There are three major ways in which a product's sales may be maintained or increased:

- to introduce a new product as the existing one becomes obsolete so that 'overlapping' cycles occur;
- to extend the cycle for the existing product, either by making minor modifications in the product itself to 'update' it or by finding new uses;
- to make changes to the production technology itself to make the product more competitive.

However, product innovation alone is inadequate as a basis for a firm's survival and profitability. Firms must strive to produce their products as efficiently as possible. Recent developments in *process* technology – and, especially, in ICT – are having profound effects upon production processes in all economic sectors (see the next section). There is a close relationship between a product's trajectory through its life cycle and the way it is made, as Figure 4.15 shows. Each stage tends to have




| | Initial development | Growth | Maturity | Decline | Obsolescence |
|---|---|---|---|---|---|
| *Demand conditions* | Very few buyers. | Growing number of buyers. | Peak demand. | Declining demand. | Steep fall-off in demand. |
| *Technology* | Short production runs. Rapidly changing techniques. | Introduction of mass production methods. Some variation in techniques but less rapid change. | Long production runs and stable technology. Few innovations of importance. | | |
| *Capital intensity* | Low. | High because of high rate of obsolescence. | | High because of large quantity of specialized equipment. | |
| *Industry structure* | Entry is 'know-how' determined. Numerous firms supply specialist services. Few competitors. | Growing number of competing firms. Increasing vertical integration. | Financial resources critical for entry. Number of firms starts to decline. | General stability at first, followed by exit of some firms. | |
| *Critical production factors* | Scientific and engineering skills. External economies (access to specialist firms). | Management, capital. | Semi-skilled and unskilled labour, capital. | | |

**Figure 4.15 The product life cycle**

particular production characteristics. In general, as the cycle proceeds, the emphasis shifts from product-related technologies to process technologies and, in particular, to ways of minimizing production costs. In this respect, the relative importance of labour costs – especially of semi-skilled and unskilled labour – increases. More generally, different types of geographical location are relevant to different stages of the product cycle.

This view of systematic changes in the production process as a product matures is appealing and has some validity. There undoubtedly are important differences in the nature of the production process between a product in its very early stages of development and the same product in its maturity. But this linear, sequential notion of change is overly simplistic and deterministic. At any stage, the production process may be 'rejuvenated' by technological innovation. There may not necessarily be a simple sequence leading from small-scale production to standardized mass production.

## Changes in production systems: towards greater flexibility and leanness

Most technological developments in production processes are, as we observed earlier, gradual and incremental: the result of 'learning by doing' and 'learning by using'. But periods of radical transformation of the production process have occurred throughout history. Over the long timescale of industrialization, the production process has developed through a series of stages, each of which represents increasing efforts to mechanize and to control more closely the nature and speed of work.

Five stages are generally identified:

- *Manufacture*: the collecting together of labour into workshops and the division of the labour process into specific tasks.
- *Machinofacture*: the application of mechanical processes and power through machinery in factories together with further division of labour.
- *Scientific management* ('Taylorism'): the subjection of the work process to scientific study in the late nineteenth century. This enhanced the fineness of the division of labour into specific tasks together with increased control and supervision.
- *Mass production* ('Fordism'): the development of assembly-line processes that controlled the pace of production and permitted the mass production of large volumes of standardized products.
- *Flexible and lean production*: the development of new production systems based upon the deep application of ICT.

These stages map closely onto the long-wave sequence shown earlier in Figure 4.3. The first K-wave was associated with the transition from manufacture to machinofacture. The application of scientific management principles to the production process emerged in the late phase of K2 and developed more fully in K3. The bases of mass production were established during K3, but reached their fullest development during K4. The key to production flexibility in K5 lies in the deep and extensive use of ICT, which provides more sophisticated control over production. Two particularly important processes are those of *flexible specialization* and *flexible mass production*. The potential of such flexible technologies is immense, and their implications are enormous. They involve three major tendencies:[46]

- A trend towards information intensity, rather than energy or materials intensity, in production.
- A much enhanced flexibility of production that challenges the old best-practice concept of mass production in three central respects:
    - A high volume of output is no longer necessary for high productivity; this can be achieved through a diversified set of low-volume products.

- Because rapid technological change becomes less costly and less risky, the 'minimum change' strategy in product development is less necessary for cost effectiveness.
- The new technologies allow a profitable focus on segmented rather than mass markets; products can be tailored to specific local conditions and needs.

- A major change in labour requirements in terms of both volume and type of labour. This involves a shift towards multitasking, rather than narrow labour specialization; a greater emphasis on teamworking; and individualized payments systems.

Largely because of the accelerating pace of development of ICT in production, the frontier of production process technology is changing very rapidly. One of the latest examples is 3D printing (sometimes known as 'additive manufacturing'):

> Machines based on advances in electronics, laser technology and chemistry can now 'print' complex three-dimensional objects, building them up layer-by-layer from granules of plastic or metal.
>
> The flexibility of 3D printing means that things can be made in much smaller numbers and much greater variety than was previously economically viable.[47]

However, 3D printing is still in its infancy: 'production equipment is expensive; technical experience with 3D printing is poorly established; making load-bearing or structural parts from 3D printing using metal is fairly difficult – most 3D printing so far has been used for plastic parts or non-structural metal objects'.[48] But its use is growing rapidly, especially for the production of prototypes. For example, Nike and Adidas are using 3D printing to increase the speed with which they can make multiple prototypes of their shoes,[49] and auto manufacturers to produce design samples and prototypes. More radically, Siemens is using 3D printing to manufacture spare parts and components for gas turbines: 'Siemens believes 3D printing could "revolutionise" the supply of spare parts … Soon they will be able to be printed exactly where they are needed – close to the customer.'[50]

The current position, therefore, is that of a *diversity* of production systems (Figure 4.16), but where the relative importance of specific processes is changing. In fact, no single production system is ever completely dominant. Even during the heyday of Fordist mass production there were firms and sectors in which smaller-scale, more craft-based, production persisted. Today, when all the emphasis is on flexible production, there is still a good deal of mass production and, indeed, of craft production. Figure 4.17 summarizes some of the contrasts between the three systems of production.

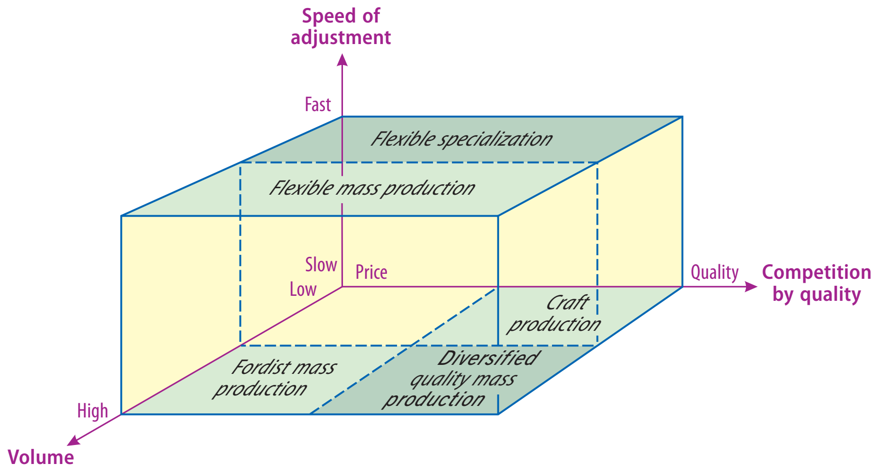



**Figure 4.16 Ideal types of production system**

*Source:* based on Hollingsworth and Boyer, 1997: Figure 1.3

| *Characteristic* | Craft production | Mass production | Flexible/lean production |
|---|---|---|---|
| *Technology* | Simple but flexible tools and equipment using non-standardized components. | Complex but rigid single-purpose machinery using standardized components. Heavy time and cost penalties in switching to new products. | Highly flexible production methods using modular component systems. Relatively easy to switch to new products. |
| *Labour force* | Highly skilled in most aspects of professional production. | Very narrowly skilled workers design products but production itself performed by unskilled/semi-skilled 'interchangeable' workers. Each performs a relatively simple task repetitively and in predefined time sequence. | Multi-skilled, polyvalent workers operate in teams. Responsible for several manufacturing operations plus simple maintenance and repair. |
| *Supplier relationships* | Very close contact between customer and supplier. Most suppliers located within single city. | Distant relationships with suppliers, both functionally and geographically. Large inventories held at assembly plant 'just in case' of supply disruption. | Very close relationships with functionally-tiered system of suppliers. Use of 'just-in-time' delivery systems encourages geographical proximity between customers and suppliers. |
| *Production volume* | Relatively low. | Extremely high. | Extremely high. |
| *Product variety* | Extremely wide: each product customized to specific requirements. | Narrow range of standardized designs with only minor product modifications. | Increasingly wide range of differentiated products. |

**Figure 4.17 The major characteristics of craft production, mass production and flexible/lean production**

*Source*: based, in part, on material in Womack et al., 1990

Thus, we can see a trend towards:

- *increasingly fine degrees of specialization* in many production processes, enabling their fragmentation into a number of individual operations;

- *increasing standardization and routinization* of these individual operations, enabling the use of semi-skilled and unskilled labour (this is especially apparent during the mature stage of a PLC);
- *increasing flexibility* in the production process that is altering the relationship between the scale and the cost of production, permitting smaller production runs, increasing product variety, and changing the way production and the labour process are organized;
- *increasing modularity* of production (see next section).

## Changing organizational forms: towards the network organization

Just as changes in production processes and systems can be broadly mapped onto the long-wave sequence shown in Figure 4.3, so, too, can changes in organizational form. In broad-brush terms, organizational change has followed a path from an early focus on individual entrepreneurs in K1, through small firms, but of larger average size, in K2, to the monopolistic, oligopolistic and cartel structures of K3, the centralized, hierarchical TNCs of K4 and the 'network' and alliance organizational forms of K5. I will have much more to say about such business networks in Chapter 5. Here I focus briefly on two aspects most closely related to recent ICT-led changes in production.

The first one is the *modular production network*, what Suzanne Berger calls the 'Lego' model of production involving networks of firms:

> For many industries, the changes of the past twenty years mean that *organizing production has become more like playing with a set of Legos* than building a model airplane or a car. In other words, it's now possible to create many different models using the same pieces. New components can be added on to old foundations; elements from old structures can be reused in new configurations; parts can be shared by many players with different construction plans in mind … *the myriad possibilities of organizing a company have grown out of new digital technologies that create countless opportunities for using resources, organizations, and customers all over the world to build businesses that did not even exist ten years ago*.[51]

The development of modular production networks[52] depends largely on the fact that some modern production circuits have 'natural' breakpoints, where there is a transition from dependence on tacit knowledge to one where information can be codified through standard, agreed protocols. Figure 4.18 shows how such modular production networks differ from that of a traditionally vertically integrated firm.

A second type of new network organization, again heavily dependent on ICT, is the *virtual firm* or the *cellular network* organization[53] (Figure 4.19). Organizationally,

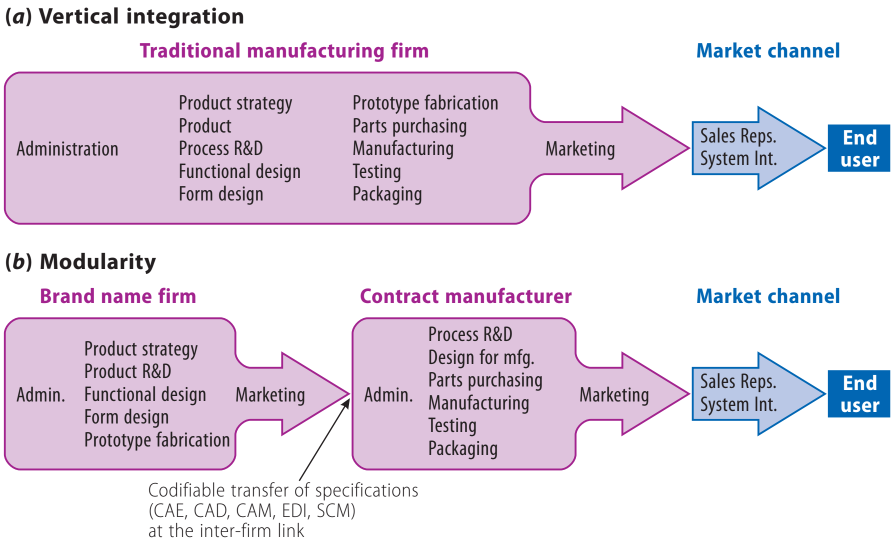



**Figure 4.18** From vertical integration to a modular production network

*Source:* based on Sturgeon, 2002: Figure 1

the entire network structure is relatively 'flat' and non-hierarchical. Its essence is that the participants are all separate firms with no common ownership. Network forms of this broad type are rapidly emerging in such 'knowledge businesses' as advanced electronics, computer software design, biotechnology, design and engineering services, health care, and the like.

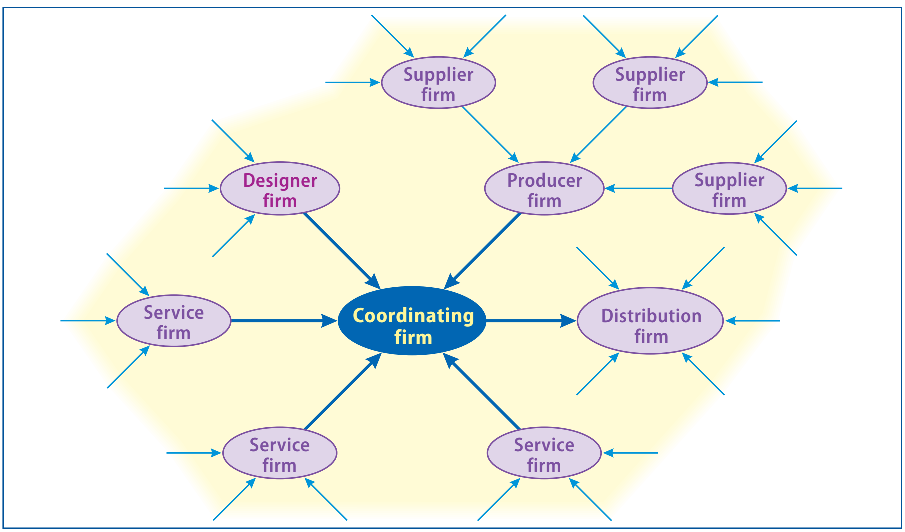



**Figure 4.19** A cellular network organization

*Source:* based, in part, on Miles and Snow, 1986: Figure 1

# GEOGRAPHIES OF INNOVATION

Innovation – the heart of technological change – is fundamentally a *learning* process. Such learning – by doing, by using, by observing and sharing with others – depends upon the accumulation and development of relevant knowledge. These processes have a very distinctive geography. Despite the fact that the development of highly sophisticated communications systems has facilitated the diffusion of knowledge at unparalleled speed and over unprecedented distances, 'conditions of knowledge accumulation are highly localized'.[54] Knowledge is *produced in specific places* and often used, and enhanced most intensively, in those same places. Hence,

> to understand technological change, it is crucial to identify the economic, social, political and geographical context in which innovation is generated and disseminated. This space may be local, national or global. Or, more likely, it will involve a complex and evolving integration, at different levels, of local, national and global factors.[55]

## National innovation systems

The idea underlying the notion of national innovation systems is that the specific combination of social, cultural, political, legal, educational and economic institutions and practices varies systematically between national contexts.[56] Such nationally differentiated characteristics help to influence the kind of technology system that develops there. These underlying forces help to explain the gradual shifts in national technological leadership evident in successive K-waves (see Figure 4.3). Despite the claims of the hyper-globalists that national distinctiveness is declining, the evidence strongly suggests that national variations in technology systems – and therefore in technological competence – persist. Certainly there is a lot of evidence to show that the volume and characteristics of technological innovation vary greatly by country.

One indicator is the number of patents granted by country. Patents are the mechanism by which an individual or a company can protect an invention for a period of years. As Figure 4.20 shows, the patent map is highly uneven. Patent grants are concentrated in a small number of countries: almost 50 per cent of patent grants went to the USA and Japan. However, rates of growth in patent grants have been fastest in some East Asian countries, notably China and South Korea. For example:

> Between 2000 and 2006, the number of patents granted to applicants from China and the Republic of Korea grew by 26.5% and 23.2% a year, respectively (average annual growth rate).[57]

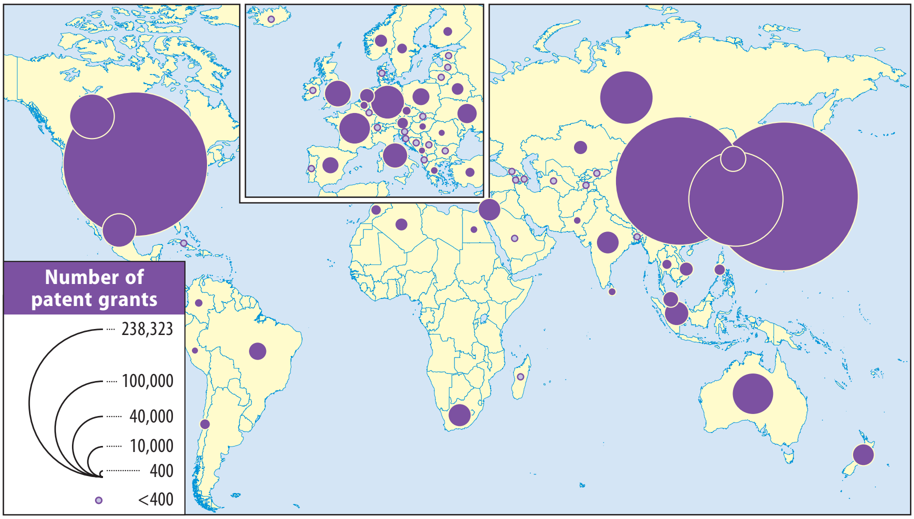



**Figure 4.20 Number of patents granted by country**

*Source:* based on data in WIPO-INSEAD, 2012: Table P2

The rapid growth of Chinese patents is matched by the 'awe-inspiring expansion of Chinese science' and its emergence as 'the second largest producer of scientific knowledge' as revealed by an analysis of 10,500 scientific journals worldwide for the period 1981–2008.[58]

Patents are one way of measuring innovative activity but there are many other ways. One is the *Global Innovation Index* (GII), a composite measure based upon 84 indicators encompassing both innovation inputs (institutions, human capital and research, infrastructure, market sophistication, business sophistication) and innovation outputs (knowledge and technology outputs and creative outputs). On this measure, as Figure 4.21 shows, smaller countries head the rankings. But, of course, in both the patent grant data and the GII, it is wealthier countries that figure most strongly. The map of the geography of innovation closely corresponds to the map of overall development.

## Localized knowledge clusters

National systems of innovation are not homogeneous entities. They consist of aggregations of *localized* knowledge clusters.[59] One reason for the significance of 'localness' in the creation and diffusion of knowledge lies in a basic distinction in the nature of knowledge itself, which is broadly of two kinds:[60]

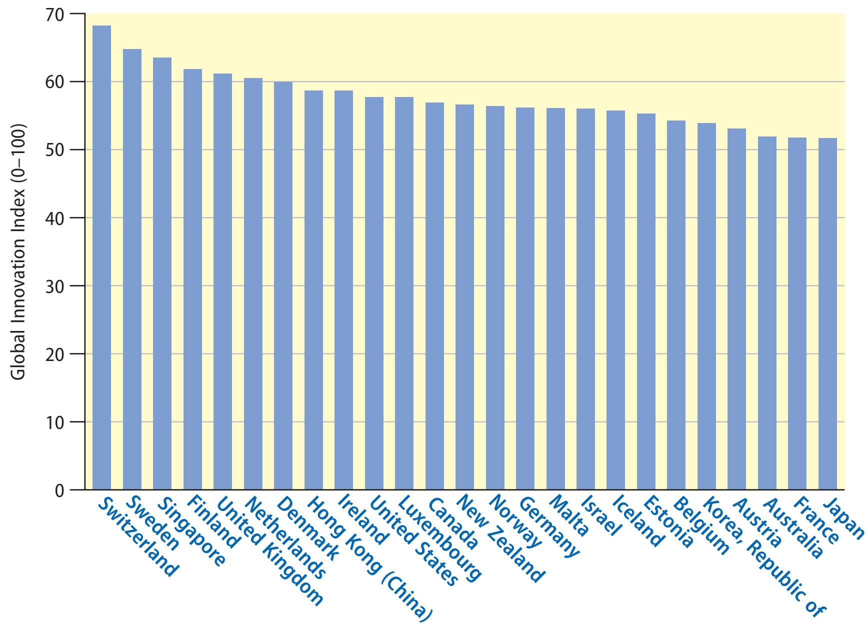



**Figure 4.21 Global Innovation Index rankings**

*Source:* based on data in WIPO-INSEAD, 2012: p. xviii

- *codified (or explicit) knowledge*: the kinds of knowledge that can be expressed formally in documents, blueprints, software, hardware, etc.;
- *tacit knowledge*: the deeply personalized knowledge possessed by individuals that is virtually impossible to make explicit and to communicate to others through formal mechanisms.

Although knowledge creation is more complex than this tacit/codified distinction implies it does help us to understand the role of space and place in technological diffusion. Codified knowledge can be transmitted relatively easily across distance. It is through such means that, throughout history, political, religious and economic organizations, for example, have been able to 'act at a distance'; to exert control over geographically dispersed activities.[61] Developments in transportation and communications technologies have enabled such 'acting' or 'controlling' to take place over greater and greater distances. Tacit knowledge, on the other hand, has a very steep 'distance-decay' curve. It generally requires direct experience and interaction; it depends to a considerable extent – though not completely by any means – on geographical proximity. It is much more 'sticky'. However, it is a mistake to take the 'tacit = local', 'codified = global' contrast too far because 'both tacit and codified knowledge can be exchanged locally and globally'.[62]

The specific socio-technological context within which innovative activity is embedded – what is sometimes called the *innovative milieu* – is a key factor in knowledge creation. This context consists of a mixture of both tangible and intangible elements:

- economic, social and political institutions;
- knowledge and know-how which evolve over time in a specific context (the 'something in the air' notion identified many decades ago by Alfred Marshall);
- 'conventions, which are taken-for-granted rules and routines between the partners in different kinds of relations defined by uncertainty'. [63]

The basis of localized knowledge clusters, therefore, lies in several characteristics of the innovation process that are highly sensitive to geographical distance and proximity:[64]

- *Localized patterns of communication*: geographical distance greatly influences the likelihood of individuals within and between organizations sharing knowledge and information links.
- *Localized innovation search and scanning patterns*: geographical proximity influences the nature of a firm's search process for technological inputs or possible collaborators. Small firms, in particular, often have a geographically narrower 'scanning field' than larger firms.
- *Localized invention and learning patterns*: innovation often occurs in response to specific local problems. Processes of 'learning by doing' and 'learning by using' tend to be closely related to physical proximity in the production process.
- *Localized knowledge sharing*: because the acquisition and communication of tacit knowledge is strongly localized geographically, there is a tendency for localized 'knowledge pools' to develop around specific activities.
- *Localized patterns of innovation capabilities and performance*: geographical proximity, in enriching the depth of particular knowledge and its use, can reduce the risk and uncertainty of innovation.

Local innovative milieux, therefore, consist primarily of a *nexus of untraded interdependencies* set within a temporal context of *path-dependent* processes of technological change. We outlined the major elements of such processes in general terms in Chapter 3. The point of emphasizing the 'untraded' nature of the interdependencies within such milieux is to distinguish the social 'cement' (especially face-to-face contact) which binds this kind of localized agglomeration from that which may be associated with the minimization of transaction costs (e.g. of materials and components transfers) through geographical proximity. The 'buzz' derived from 'being there' is at the heart of these social processes.[65]

But that is not the entire story. Localized knowledge clusters cannot be sustained and developed entirely through such incestuous relationships. A key additional process involves the connections between some of the actors in a given locality with outsiders (e.g. firms with suppliers, customers or sources of specific information and knowledge). In other words, as well as 'local buzz' there also have to be 'pipelines': channels of communication to other actors in other places. The processes of knowledge creation and innovation, therefore, consist of a complex set of networks and processes operating *within and across* various spatial scales, from the global, through the national, the regional and the local.

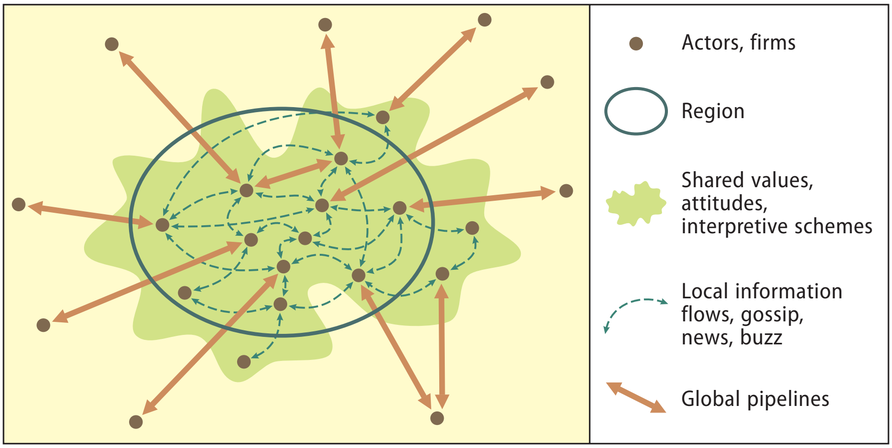



**Figure 4.22 Localized knowledge clusters in a wider context: local buzz and global pipelines**

*Source:* based on Bathelt et al., 2004: Figure 1

Figure 4.22 provides an idealized picture of this very complex process. It is based on the argument that

> the existence of local buzz of high quality and relevance leads to a more dynamic cluster … These actors and their buzz are, however, of little relevance if firms are not 'tuned in' … It is likely that a milieu, where many actors with related yet complementary and heterogeneous knowledge, skill and information reside, provides a great potential for dynamic interaction …
>
> A well-developed system of pipelines connecting the local cluster to the rest of the world is beneficial for the cluster in two ways. First, each individual firm can benefit from establishing knowledge-enhancing relations to actors outside the local cluster. Even world-class clusters cannot be permanently self-sufficient in terms of state-of-the-art knowledge creation. New and valuable knowledge will always be created in other parts of the world and firms who can build pipelines to such sites of global excellence gain competitive advantage. Second, it

> seems reasonable to assume that the information that one cluster firm can acquire through its pipelines will spill over to other firms in the cluster through local buzz … That is why a firm will learn more if its neighbouring firms in the cluster are globally well connected rather than being more inward-looking and insular in their orientation.[66]

The importance of localized knowledge/technology clusters to potential economic development has put them at the heart of economic policy in most countries. Who would not want to have a Silicon Valley as the driver of economic transformation? Everybody wants one, it seems, judging by the number of projects with the label 'silicon' in their title (a few examples: Silicon Alley, Silicon Fen, Silicon Glen, Silicon Gulf, Silicon Beach, even Silicon Roundabout in East London – the list is almost endless). Scores of places throughout the world have been labelled as the 'new' Silicon Valley.[67] Too often, however, such policies are driven by a desire to make a quick fix without much understanding of the complexity of the processes involved in the creation of such clusters. It is not difficult to recognize a successful cluster when one sees one; it is far more difficult (although not necessarily impossible) to be able to create or to replicate one as a matter of policy. Most are the outcome of the historical process of cumulative, path-dependent growth processes (see Chapter 3).

## NOTES

1 The term 'creative gales of destruction' is borrowed from Schumpeter (1943).
2 Schumpeter (1943: 83).
3 Borrus, quoted in Cohen and Zysman (1987: 183; emphasis added).
4 Edgerton (2007).
5 This approach is essentially 'neo-Schumpeterian'. See Dosi et al. (1988), Freeman (1982, 1987, 1988), Freeman and Louçã (2001), Metcalfe and Dilisio (1996), Perez (1983, 1985, 2010).
6 Freeman and Perez (1988), Perez (2010).
7 Lipsey et al. (2005) use the term 'General Purpose Technologies (GPTs)'.
8 Freeman (1987: 130; emphasis added).
9 Perez (1983).
10 Perez (2010: 186).
11 See Freeman et al. (1982), Freeman and Louçã (2001), Freeman and Perez (1988), Hall and Preston (1988), Perez (2010), Rennstich (2002).
12 Hall and Preston (1988: 6).
13 Perez (2010: 189).
14 Gleick (2012: 8). Gleick provides a highly readable account of the development of what he calls *The Information*. See also Castells (1996), Hall and Preston (1988).
15 Rennstich (2002: 174).
16 Henderson and Castells (1987: 6).
17 Perez (2010: 189).

18 Carr (2008b).
19 Carr (2008a: 2; emphasis added).
20 Gleick (2012: 396).
21 For broad-ranging discussions of these technologies see Brunn and Leinbach (1991), Castells (1996), Graham and Marvin (1996), Hall and Preston (1988), World Bank (2009b: chapter 6).
22 See O'Rourke and Williamson (1999: chapter 3) for a detailed discussion of these developments.
23 Dean and Sebastia-Barriel (2004: 314).
24 World Bank (2009b: 177).
25 World Bank (2009b: 177).
26 Levinson (2006) provides a comprehensive and highly readable account of the development of containerization. See also Cudahy (2010: 73–86).
27 *Independent* (30 August 2000).
28 *Guardian* (7 March 2013).
29 Luhmann (1998: 85). Thanks to Roger Lee for this.
30 Malecki and Hu (2006) and Warf (2006, 2007) provide useful analyses of satellite and cable systems.
31 Malecki and Hu (2006: 7).
32 *Financial Times* (28 July 1998).
33 Castells (2013: 132).
34 Zook (2005) provides an excellent analysis of the development of the Internet. See also Castells (1996, 2008, 2013), Dodge and Kitchin (2001), Graham (2010), Malecki (2002).
35 Castells (1996: 341).
36 International Telecommunication Union statistics. For a detailed accounts of the global spread of mobile phones see Comer and Wikle (2008). Castells et al. (2007) explore the social implications of mobile communications.
37 International Telecommunication Union (ITU) statistics.
38 Warf (2013: 224, 225, 226).
39 *The Economist* (11 August 2001: 18).
40 Stross (2008) quoted in the *Guardian* (1 November 2008).
41 Major contributions include Dodge and Kitchin (2001), Graham (2012, 2014), Graham et al. (2012), Zook (2001, 2005, 2007).
42 *The Economist* (12 March 2005: 9).
43 See Graham (2014).
44 Graham (2009: 3). See also Graham et al. (2011).
45 Graham (2012: 156, 157).
46 Perez (1985).
47 *Financial Times* (4 June 2012).
48 Marsh (2012).
49 *Financial Times* (10 June 2013).
50 *Financial Times* (27 December 2013).
51 Berger (2005: 61; emphasis added).
52 See Berger (2005), Sturgeon (2002, 2003).
53 Miles et al. (1999).

54 Metcalfe and Dilisio (1996: 58).
55 Archibugi and Michie (1997: 2).
56 See Archibugi and Michie (1997), Archibugi et al. (1999), Freeman (1997), Lundvall (2007), Lundvall and Maskell (2000), Patel and Pavitt (1998).
57 WIPO (2008: 7).
58 *Financial Times* (26 January 2010).
59 There is a vast literature on this topic. See, for example, Asheim (2007), Asheim and Gertler (2005), Bathelt et al. (2004), Bunnell and Coe (2001), Gertler (1995, 2003), Gertler et al. (2000), Mattsson (2007), Morgan (2004), Sonn and Storper (2008), Storper (1997), Storper and Venables (2004).
60 Gertler (2003). See also Asheim (2007), Howells (2012a, b).
61 Fields (2004), Law (1986).
62 Bathelt et al. (2004: 32).
63 Storper (1995: 208).
64 Howells (2000: 58–9).
65 Bathelt et al. (2004), Gertler (1995), Storper and Venables (2004), Sturgeon (2003).
66 Bathelt et al. (2004: 45–6).
67 See, for example, Manning (2013: 380–1).

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