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Information Technology in the Learning Economy: Challenges for Developing Countries

Dieter Ernst and Bengt-Åke Lundvall

Dieter Ernst is a Senior Fellow and Theme Leader for Economic Studies at the East-West Center. Previous affiliations include the OECD, Paris (as Senior Advisor); the Berkeley Roundtable on the International Economy (BRIE), at the University of California at Berkeley (Senior Fellow); and the Copenhagen Business School (SSF-Research Professor).

Bengt-Åke Lundvall is a Professor in Economics at the University of Aalborg, Denmark. Previous affiliations include the OECD, Paris (as Deputy Director of the Science, Technology and Industry Directorate); The Danish Social Science Research Council, and the University Louis Pasteur (BETA) in Strasbourg, France (as guest professor).

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Information Technology in the Learning Economy: Challenges for Developing Countries

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‘The engine of growth should be technological change, with international trade serving as a lubricating oil and not as fuel.’
(Lewis 1978, 74)

‘Both the pace and the acceleration of innovation are startling; nay terrifying. . . . No one can predict the . . . range of skills, which will need to be amassed to create and take advantage of the next revolution but one. (And thinking about the next but one is what everyone is doing. The game is already over for the next.)’
(Anderson 1997)

Research in industrialised countries has shown that the ability to learn determines the economic success not only of firms and industries but also of whole regions (industrial districts) and countries (OECD 1996a, 1996b, 1996c). This has given rise to the concept of the learning economy, which is based on the following propositions (Lundvall and Johnson 1994; Lundvall 1994, 1996): Learning is an interactive, socially embedded process; its efficiency depends on the institutional setup, the national innovation system. The content of the knowledge generated through learning is critical: Tacit knowledge is essential for adjusting to change (flexibility) and for implementing change (innovation).

This essay inquires how the concept of the learning economy can be applied to the requirements of developing countries (DCs). Its main purpose is to develop an analytical framework for understanding how learning and capability formation can foster industrial upgrading, with special emphasis on the spread of information technology (IT): Under what conditions can DCs use this set of generic technologies to improve their learning capabilities? As a growing amount of knowledge becomes accessible through worldwide information networks, the establishment of national IT capabilities should help to accelerate knowledge creation and diffusion. But the IT revolution also poses new challenges: It increases the inequality of access to knowledge while accelerating the pace of economic and technical change. To cope with these new opportunities and challenges it is imperative that DCs broaden their capability base. This essay emphasises the need to improve learning capabilities in all parts of the economy. We argue that IT should not be regarded as a potential substitute for human skills and tacit knowledge. Instead, its main role should be to support the formation and use of tacit knowledge. We proceed in four steps.

First, we describe the challenges DCs face today in their attempts to cope with globalization and to upgrade their industrial sectors. We show that trade has lost its predominant role as the engine of growth; instead, DCs are eager to participate in the international production networks (IPNs) of transnational corporations. This requires upgrading DCs’ sources of competitiveness: A shift is necessary to an alternative development paradigm, with learning and capability formation as the core elements of development strategy.

Second, we explain why tacit knowledge is essential for adjustment to rapid change in markets and technology as well as for innovation. We show that as globalization of competition, shorter product cycles and rapid technical change have combined to increase uncertainty, tacit knowledge has increased in importance.

Third, we discuss how the diffusion of IT affects the access to tacit knowledge for local agents in DCs. We show that a massive transfer of tacit knowledge into information systems in principle provides DCs with better access to new recipes (process technology as well as products) developed in rich countries. At the same time, IT speeds up the rate of economic change and increases uncertainty, with the result that DCs must permanently restructure and upgrade.

Finally, we ask which institutional features of a national production system are best suited to improving the diffusion of tacit knowledge. We compare two stylised models of the learning economy, the Japanese versus the American model,¹ focusing on the role of tacit knowledge. The Japanese model explicitly promotes and exploits tacit knowledge whereas the American model seeks to reduce the importance of tacit knowledge and to transform it into information – that is, into explicit, well-structured and codified knowledge. The American model emphasises market selection, competition, income inequality and strict control by financial markets as ways of promoting learning whereas the Japanese model emphasises cooperation, social cohesion and long-term social relationships.

We show that each of these models has peculiar strengths and weaknesses. Their usefulness to any particular DC depends on its stage of development. Neither model gives a complete answer. DCs need to develop their own hybrid forms of institutions, which combine the advantages of both models in a way which is appropriate to their idiosyncratic needs and capabilities.

THE CHALLENGE FOR DEVELOPING COUNTRIES

DCs have gone through a long history of unequal integration into the world economy. As W.A. Lewis observed in 1980: ‘For the past hundred years the rate of growth of output in the developing world has depended on the rate of growth of output in the developed world. When the developed grow fast, the developing grow fast, and when the developed slow down, the developing slow down’ (Lewis 1980, 555).

This linkage continues to hold.² Yet the forms of this integration have changed considerably, and this has had important implications for development strategies. These changes result from the combined impact of globalization and the spread of a set of generic technologies, especially IT, with a large potential for productivity enhancement. The result is that learning and knowledge creation, more than ever before, determine the success or failure of development strategies.

Globalization

International trade was the main engine of growth for DCs until the mid-1970s, the period covered by W.A. Lewis’s 1980 article. Lewis’s main concern was that stagflation in industrialised countries would slow down North–South trade with the result that it could no longer act as an engine of growth. He suggested strengthening South–South trade through a variety of selective regional trading blocs among DCs.

This well-intentioned scenario did not materialise. Attempts to promote South–South trade almost invariably ended in failure. World trade remains highly concentrated on industrialised countries and the concentration is rising: the North’s share of world trade rose from 81 per cent in 1970 to 84 per cent in 1989.³ North–South trade has fallen as a proportion of the total and the share of South–South trade remains insignificant.

World trade growth slowed during the 1980s and 1990s relative to output growth: The ratio fell from 1.65 in 1965–80 to 1.34 in 1980–90 (World Bank 1992, tables 2 and 14). Trade continues to grow considerably faster than gross domestic product does, however. This implies that an increasing share of production goes to foreign markets. This raises the importance of foreign markets relative to domestic markets. The result is that a country’s relative income, its welfare, becomes more dependent on the ability of its firms to compete against imports in the domestic market and against other producers in foreign markets. This is as true for DCs as for industrialised countries.

Since the mid-1970s Japan and later a handful of so-called newly industrialising economies (NIEs), primarily in Asia, have emerged as important new competitors in a variety of industrial manufacturing sectors. Over time their focus has shifted from low-end, labour-intensive products (such as textiles and household appliances) to capital- and knowledge-intensive products (such as cars and computer-related products). Furthermore, since the mid-1980s international investment has grown considerably faster than international trade (UNCTAD 1996). By the 1990s sales by the foreign affiliates of transnational corporations (TNCs) far outpaced exports as the principle vehicle to deliver goods and services to foreign markets. Increasingly the focus of international market share expansion has shifted from exports to international production, with the result that a growing number of national

economies have become mutually interconnected through cross-border flows of goods, services and factors of production.

This has destabilised established patterns of competition: Formerly stable national oligopolies have been considerably eroded.⁴ Competition today cuts across national and sectoral boundaries – hence the term ‘global competition’.⁵ Firms are now forced to compete simultaneously in all major growth markets. Cost leadership has to be combined with product differentiation. This has led to a rapid expansion of international production: New production sites have been added with breathtaking speed at lower-cost locations outside the industrial heartlands of Europe, North America and Japan.

Yet quantitative expansion is only part of the story. Of equal importance are qualitative changes: a shift from partial to systemic forms of globalization. In order to cope with the increasingly demanding requirements of global competition, companies are forced to integrate their erstwhile stand-alone operations in individual host countries into increasingly complex IPNs.⁶ Companies break down the value chain into discrete functions and locate them wherever they can be carried out most effectively and where they are needed to facilitate the penetration of important growth markets. Reduction of transaction costs is one important motivation. Of equal importance, however, are access to clusters of specialised capabilities and contested growth markets and the need to speed up response time to technological change and to changing market requirements.

The Neoliberal Concept of Globalization

Pressure to liberalise capital and financial markets has further accelerated the pace of globalization. Yet relatively little of the literature dealing with DCs has addressed the impact of globalization.⁷ The dominant view is that globalization will act as a powerful equaliser, over time leading to greater uniformity of development potentials.⁸ Among nations, liberalisation reduces distortions in international trade; as more and more nations liberalise, national policies converge. Convergence is also expected among firms. Faced with similar constraints, firms are expected to converge in their organisation and strategies, irrespective of their national origin (Vernon 1971, 1977; Graham and Krugman 1992). Boyer summarises the underlying logic: ‘Everywhere firms facing the same optimising problems find the same solution in terms of technology, markets and products, for there is one best way of organising production – a single optimum among a possible multiplicity of local optima.’⁹

This dominant view also argues that globalization will accelerate the decline of the nation state as the relevant unit of policy making and that anything which smacks of industrial policy is unlikely to improve local competitiveness. Governments, in this view, should concentrate on the pervasive deregulation and liberalisation of national economies. The more willing a government is to embrace sweeping liberalisation, the more this country can use international trade and investment as engines of growth.

The Critical Importance of Local Capabilities

We disagree with this neoliberal concept of globalization. Nothing is predetermined about the impact of globalization.¹⁰ It can increase geographical inequality if left to the invisible hand of the market and to the quite visible hand of TNCs because TNCs have become much more selective and demanding in their choice of locations. Low labour costs are taken for granted, and alternative locations are judged by the quality of certain specialised capabilities, which the TNC needs in order to complement its own core competencies. Countries, which cannot provide such capabilities, are left out of the circuit of international production. Thus, vast areas of the international economy – involving a majority of the world’s population – have experienced a dramatic decline in their development potential.

Those countries which can provide such capabilities and, as a result, can attract higher value-added investments may benefit, however. Leading multinationals construct IPNs in order to gain quick access to lower-cost external capabilities, which are complementary to their own competencies. In order to mobilise and harness these external capabilities, multinationals are forced to broaden their capability transfer to individual nodes of their IPN.¹¹ This opens up new entry possibilities for small, specialised suppliers in DCs. Although in some cases (screwdriver contract assembly, for example) such entry may be short-lived, it is not necessarily. Outsourcing requirements have become more demanding and have moved up to include a variety of high-end support services

such as engineering, product design, and research and development. This creates new gaps and interstices which can be addressed by small, specialised suppliers. Over time they may be able to upgrade their position from simple contract manufacturers to providers of integrated service packages, and hence increase the benefits which they can reap from network participation.

Successful late industrialisation in Korea and Taiwan are cases in point.¹² Take the development of Korea's electronics industry, which arguably has been the most impressive example of such successful late industrialisation: An industry which barely existed 25 years ago has been able to transform itself into a credible international competitor in a very short time.¹³

Rather than letting foreign firms establish local subsidiaries and decide on the speed and scope of technology diffusion, Korean firms focused on learning and knowledge accumulation through a variety of links with foreign equipment and component suppliers, technology licensing partners, OEM clients and minority joint venture partners. By licensing proven foreign product designs and by importing most of the production equipment and the crucial components, Korean electronics producers were able to focus most of their attention on three areas:¹⁴

1. The mastery of production capabilities, initially for assembly but increasingly also for related support services and for large mass production lines for standard products
2. Some related minor change capabilities, ranging from reverse engineering techniques to analytical design and some system engineering capabilities, which are required for process re-engineering and product customisation
3. Some investment capabilities, especially the capacity to carry out at short notice and at low cost investments to expand capacity and/or modernise plants and to establish new production lines.

In order to succeed, Korean electronics firms had to develop the knowledge and skills necessary to monitor, unpackage, absorb and upgrade foreign technology. Equally important was a capacity to mobilise the substantial funds for paying technology licensing fees and for importing 'best practice' production equipment and leading-edge components.¹⁵ Most Korean electronics producers arguably would have hesitated to pursue such high-cost, high-risk strategies had they not been induced to do so by a variety of selective policy interventions by the Korean state. Getting relative prices 'wrong' has been important (Amsden 1989). By providing critical externalities such as information, training, maintenance and other support services and finance, the Korean government has fostered the growth of firms large enough to hurdle high entry barriers.

Because of these particular historically conditioned circumstances Korea's electronics firms were able to reverse the sequence of technological capability formation (Dahlman et al. 1987). Rather than proceeding from innovation to investment to production, they could take a shortcut and focus on the ability to operate production facilities according to competitive cost and quality standards. Production capabilities thus were used as the foundation for developing capabilities in investment and adaptive engineering, and product and market development and process innovation were postponed to a later stage of development. Through judicious reverse engineering and other forms of copying and imitating foreign technology and by integrating into the increasingly complex IPNs of American, Japanese and some European electronics companies, Korean electronics firms were able to avoid the huge cost burdens and risks involved in R&D and in developing international distribution and marketing channels.

The Role of the State

The Korean approach to capability formation reflects the fact that markets are notoriously weak in generating such capabilities. They are subject to externalities: investments in capabilities are typically characterised by a gap between private and social rates of return (Arrow 1962). National policy interventions must compensate for these market failures. In addition to the subsidies and tax incentives suggested by Arrow, these interventions require a variety of organisational and institutional innovations. There is now a much greater need for national and regional policies to develop local capabilities, which can attract high value-added investment.

But there is also now more space for national policy and politics to vary and to make a difference. A growing body of research on economic policy making in advanced industrial countries has demonstrated that choice is possible in terms of institutions and policy instruments and that this applies to macroeconomic as well as industrial and technology policies.¹⁶ The same is true for DCs. The real question, then, is no longer whether national

policies can make a difference but rather what kind of policies and institutions are most conducive to improving local competitiveness.

Few people understand the time dimension involved. Policy requirements keep changing over time for two reasons: increasing complexity and greater exposure to the international economy. As a DC moves from simple and labour-intensive to more complex products, much more sophisticated policies are required because entry barriers tend to rise with increasing complexity. This implies that local enterprises need to have access to more demanding externalities which would enable them to overcome their disadvantages in terms of size and weak proprietary assets.

Externality requirements vary, depending on the market segment and the stage of development of a particular industry. Obviously they are less demanding for textiles than for semiconductors. And within the same product group (semiconductors, for example) such requirements become much more complex once the focus shifts from low-end discrete devices for consumer applications to higher-end design-intensive devices.

Greater exposure to the international economy is a second reason why industrial development policies need to develop over time. Increasing complexity of the domestic industry necessitates more international linkages. Such linkages are necessary to facilitate local capability formation. They encompass not only critical imports of key components and capital equipment and inward FDI; such linkages also involve participation in IPNs as well as in a variety of specialised and informal 'international peer group' networks which are essential carriers of knowledge creation.

The dynamics of change thus is of crucial importance for industrial development policies. Peter Evans's model of four archetypal roles, which the state has played in industrial transformation, can help in this context (Evans 1995)

Among 'developmental states' such as Korea, Brazil and India, and in the information sector in particular, Evans argues, one can distinguish four archetypal roles the state has played, sometimes separately and sometimes in combination. These are (1) the custodian role, in which the state regulates the market, generally privileging the policing function over promotional policies; (2) the 'demiurge' role, in which the state acts as entrepreneur, not just to provide public goods but out of an assumption that private capital is not adequate to fund the whole gamut of production; (3) the midwife role, in which instead of substituting for the private sector the state tries to shape it out of a belief that the capacity of the private sector is malleable; and (4) the husbandry role, in which the state takes a long-term view, recognising that even if it successfully induces private groups to tackle promising sectors in its role of midwife, that may not be sufficient. As global changes challenge these firms, the state must continue to cajole and assist private groups to meet these challenges by signalling opportunities, reducing risks, engaging in R&D, and so on.

According to Evans (1995, 14), 'sectoral outcomes depend on how roles are combined.' Brazil and India 'made less use of midwifery, got bogged down in restrictive rule making and invested heavily in direct production of IT goods by state-owned enterprises. Their efforts to play custodian and demiurge were politically costly and absorbed scarce state capacity, leaving them in a poor position to embark on a program of husbandry which would help sustain the local industries they had helped create.' Not so Korea, which built up firms through midwifery and then through husbandry helped them to meet competitive challenges in IT.¹⁷

In addition to cross-country comparisons, this classification can guide our understanding of how industrial development policies have changed over time in a given country. The case of Taiwan illustrates how the state has moved from the custodian which regulates the market to the 'demiurge' which takes on productive activities itself rather than leaving them to private capital (Ernst 2000c). Once the limits to these two functions of the state were reached during the 1960s, the Taiwanese state then moved on to midwifery and husbandry, actively introducing a variety of institutional and policy innovations which allowed small enterprises to grow and to become more efficient while providing an environment conducive to learning and innovation.

A Focus on Learning and Capability Formation

As a result of globalization, DCs today face new challenges: In order to sustain access to markets and technology, they need to continuously upgrade the sources of their competitiveness. This has given rise to debates on the role firm strategies and government policies can play in the transition from traditional forms of competitiveness, based on cheap labour, natural resource endowments and currency devaluation, to more sustainable forms of competitiveness, based on a wide diffusion of technological capabilities and organisational competence. One important example is the current debate between accumulation theorists,¹⁸ for whom growth is largely a result of ‘a rapid movement along prevailing production functions’ (Krugman 1994), and innovation theorists, who argue, following Schumpeter, that development requires learning and innovation.¹⁹

Our research does not support the assumption that development can be reduced to efficiency gains due to capital accumulation – that is, investment (Lundvall 1992; Ernst 1994b, 1997h). In siding with Nelson and Pack (1995), we argue that investment needs to be complemented by learning and the formation of capabilities in order to achieve sustainable development. That economic growth requires innovation is as true for DCs as it is for OECD countries. Recent econometric analysis, for example, shows that ‘the main factors influencing differences in international competitiveness and growth across countries are technological competitiveness and the ability to compete on delivery. . . . Cost-competitiveness does also affect competitiveness and growth to some extent, but less so than many seem to believe’ (Fagerberg 1990, 370–71).

To put it bluntly, there is no way to reduce poverty other than to place learning and knowledge creation at the centre of development strategy. Foreign aid and windfall profits from oil and other natural resources can produce sustained development only if these resources are channelled into the formation of local capabilities. The question is what specific learning requirements DCs face today.

We distinguish two components of technological knowledge. The first component covers all codifiable items such as engineering blueprints and designs and the underlying generic scientific knowledge plus management manuals and handbooks describing system features, performance requirements, materials specifications and quality assurance criteria and the organisational methods and routines which are used to implement them. As Nelson has shown, this component also includes individual practitioners’ knowledge of the way such scientific, engineering and organisational principles are applied and of how things work in practice (Nelson 1990).

The second component of technological knowledge is tacit and firm-specific. It is embodied in the organisational routines and collective expertise or skills of specific production, procurement, R&D and marketing teams. This is the part of technology which differentiates firms and which cannot be exchanged among them, as it is derived from and tied to the localised and collective learning experience of a given company through its own development of technological capabilities.²⁰ Whereas the first element of technology may be traded between firms, the second element is the essence of firm-specific competitive advantage. It is nontradable and relies on learning, either within a firm or within an IPN.²¹

Technological learning in DCs faces two challenges: acquiring the codified knowledge element of technology and developing tacit, firm-specific knowledge. Access to codified knowledge may at times be constrained by patenting, aggressive IPR strategies and the proliferation of ‘high-tech neomercantilism’.²² This first challenge results from some basic failures of international technology markets. Although not even the tightest technology appropriability regime can prevent technology leakages, such restrictions can substantially delay the actual entry of such knowledge into the public domain. Codified knowledge remains subject to the constraints of entry deterrence strategies pursued by both firms and governments (Ernst and O’Connor 1992, chapters 1 and 2). Technology leaders, for instance, can substantially increase the cost of external technology sourcing by charging high licensing fees.²³

This first challenge is of particular relevance to countries like Korea and Taiwan, which today confront the ‘successful catching-up trap’ (Ernst and O’Connor 1989). As these countries move closer to the technological frontier, they face a number of new constraints with regard to access to technology and markets. Access to codified knowledge becomes more difficult and costly, especially if it involves new product designs and core components. Although such access to technology constraints are real and often quite serious, it would be misleading to focus our attention exclusively on them. Both Korea and Taiwan have reached a critical level in the development of their

domestic capabilities. One way or another they will always be able to circumvent such access to technology constraints.²⁴

This brings us to the second challenge for DCs, which is far more important than the first. In addition, it applies to all kinds of DCs. Even if all firms can gain access to a common pool of codified knowledge, they must undertake a costly and invariably time-consuming learning process in which they develop the tacit capabilities required to use, adapt and further develop the imported technology.

THE CRITICAL IMPORTANCE OF TACIT KNOWLEDGE

The creation of tacit knowledge is the decisive prerequisite for successful development. A weak tacit knowledge base, in our view, constitutes a major barrier which delays or in some cases even obstructs international technology diffusion to DCs. This implies, of course, a broad definition of knowledge and learning. Wealth-creating knowledge includes practical skills established through learning by doing as well as competencies acquired through formal education and training, and it includes management skills learnt in practise as well as new insights produced by R&D efforts.

It is important to emphasise that learning takes place in all parts of the economy, including in so-called low-tech and traditional sectors. Indeed, learning in traditional and low-tech sectors may be more important for economic development than learning in a small number of insulated high-tech firms. The learning potential (technological opportunities) may differ between sectors and technologies but in most broadly defined sectors there will be niches where the potential for learning is high.

Finally, all kinds of labourers have skills and learning capacity, including those misleadingly called 'unskilled workers'. We make this point in order to avoid having the learning economy hypothesis lead to a neglect of the developmental potential of those parts of the economy which rely less on formally acquired knowledge.

In short, tacit knowledge is at least as important as formal, codified, structured and explicit knowledge.²⁵ Both types of knowledge hang together; they are symbiotic. Even though codified knowledge can be exchanged, to make it operational a firm needs to develop supporting tacit knowledge. This is in line with Edith Penrose's observation that 'a firm's rate of growth is limited by the growth of knowledge within it' (Penrose 1959, xvi and xvii). Nonaka and Takeuchi (1995) have convincingly demonstrated that a firm's learning efficiency critically depends on an institutional setup, which facilitates a spiral-type interaction between tacit and codified knowledge.

One difficulty with such a broad definition of knowledge is that it is not easy to illustrate empirically the validity of the basic hypothesis. Almost all indicators of knowledge-intensity and learning activities refer to formal education and R&D efforts, and generally they support the hypothesis of the learning economy. It can be shown that modern economic growth is biased in the direction of more intensive use of human capital, that sectors intensive in their use of trained labour and in their investments in R&D are the ones expanding their employment most rapidly and, finally, that there is a strong tendency towards a polarisation in labour markets in favour of skilled labour (Foray and Lundvall 1996). But these indicators, even if pointing in the right direction, give a biased picture of the learning economy. They do not reflect the importance of tacit knowledge and the results of learning taking place within regular economic activities of marketing, production and development.

What Is Tacit Knowledge?

The distinction between tacit and nontacit knowledge is not always clear; it might be helpful to illustrate the distinction with some examples. The first would be the classical one of the skilled worker/artisan who uses tools and materials to form a final product. It could be a baker who mixes flour with milk and eggs to produce pancakes. If the quality of ingredients and the process equipment were completely standardised and the environment completely stable, this tacit knowledge could easily be reduced to a formula (2 eggs + 1 cup of flour + 1 litre of milk = 5 pancakes) which nonexperts could use with success and which could be easily transferred. But if the ingredients vary in quality and the environment is unstable the proportions and the work process need to be adapted to get good

results. This example illustrates that the degree of complexity and the rate of change in quality and environment may determine how far tacit knowledge might be transformed into nontacit knowledge.

A second example of tacit knowledge involves the management of firms. Should firm A take over firm B or should it leave things as they are? To make such a decision involves the processing of an enormous amount of information and attempts to analyse a multitude of relationships between ill-defined variables. Guesstimates and hunches about future developments are crucial to the outcome. Evaluating the human resources in the other firm is a complex social act. In this case there is no simple arithmetic to refer to (depending on future developments, $1 + 1$ may equal -2 , $+2$ or even $+10$). It is obvious that the competence needed in this case is not easily transferred through formal education or information systems. It should also be observed that the decision is unique rather than one in a series of very similarly structured problems. Attempts to design formal decision models to cope with this kind of problem will not be meaningful; the knowledge remains tacit and local. Of course it is possible to learn the skills of artisans and business leaders, but this learning will typically take place in a kind of apprenticeship in which the apprentice or the young business administrator learns by operating in close cooperation with more experienced colleagues.

In short, tacitness has its roots in complexity and in variations in quality. It prevails in situations where there is a need to use several different human senses simultaneously, where skillful physical behaviour is involved and where understanding social relationships is crucial. Globalization and the spread of IT have reinforced these reasons for tacitness, as they have dramatically accelerated the pace of change in economic life. If we were in a steady state (circular flow), a gradual movement from tacit toward nontacit knowledge might take place. But because the long-term economic success of agents increasingly reflects their ability to adapt to change (flexibility) and their ability to impose change (innovation), tacit knowledge will remain crucial for economic success.

THE IMPACT OF INFORMATION TECHNOLOGY

Codification of Knowledge

There is a strong normative bias in Western civilisation in favour of explicit and well-structured knowledge and there are permanent efforts to automate human skills. One historical example is Taylorism's effort to transfer the knowledge of skilled workers to machinery. Present efforts to develop general business information systems and expert systems move in the same direction.

So far automating human skills has proved to be economically successful only in relation to relatively simple, repetitive tasks performed in a reasonably stable environment. Highly automated process industries may be extremely cost-efficient, but when their products are superseded by more attractive substitutes, these industries leave behind them rust-belt problems that are difficult to solve.

Let us take a closer look at how IT affects different elements of knowledge. It is claimed that the increased use of IT enhances both the incentives and the possibilities for codifying knowledge (David and Foray 1995). We suggest that the connection between the IT revolution and the learning economy is more complicated.

While some skills will be transformed into a codified form, demand will grow for complementary tacit knowledge. The very growth in the amount of information, which is made accessible to economic agents, increases the demand for skills in selecting and using information intelligently. For this reason experience-based learning might become even more important than before. The major impact of the IT revolution on the process of learning might, however, be that it speeds up the process of change in the economy. The codification, standardisation and normalisation of certain parts of the knowledge stock increases the rate with which some stages in the innovation process are progressing, and the diffusion of this kind of knowledge might also be accelerated. In order to see why skills and the formation of skills will remain a core element behind economic performance, we need to take into consideration the relationship between learning and change.

Learning and Change

Learning and change are closely related and the causality works both ways. On the one hand, learning is an important and necessary input in the innovation process. On the other hand, change imposes learning on all agents affected by the change. In this context it is important to note that a significant and growing proportion of the labour force is designated to promote change; for the rest of the labour force, change is imposed from above.

In a market economy there is a strong incentive to create and exploit novelty. Producing the same thing in the same way is not very rewarding in the long run. Finding new and more efficient methods of production and introducing new and more attractive products to the market are necessary for survival in most competitive markets. Learning in connection with production and in an interaction with users is fundamental for the success in process and product innovation (Lundvall 1985). Learning involves finding and defining the problems to be solved – developing an agenda for problem solving – as well as forming the know-how necessary for problem solving. Being able to learn from earlier experiences and to use the experiences from earlier rounds of problem solving is also important.

Learning creates change and promotes innovation. But it is equally true that the change instituted by innovating actors imposes further change on the other agents. When a competitor introduces a more efficient process or a more attractive product, the pressure for change increases. Consumers, when confronted with new products, have to change their behaviour as well. And change involves learning. In this sense learning is a self-reinforcing process.

Acceleration of Learning and Change?

We hypothesise that the rate of change and learning in the economy has accelerated since the 1980s. There is little doubt that over a longer time span this has been the case: Change has accelerated enormously since the beginning of the industrial revolution, and people have been forced to learn to do things differently in order to survive.

But what about the shorter term? It is not easy to find reliable and valid indicators in this field. The number of scientific articles is growing exponentially, but this might have more to do with the institutional context than with an increase in the rate of learning. Patent statistics and other indicators of technical progress may also indicate an acceleration, but again the institutional setting may be more important than the actual rate of learning in explaining such patterns. The rate of growth of the economy is actually slower than in the 1950s and the 1960s, and changes in the sectoral composition of production and employment do not give any clear indication of structural change. Although changes in the structure of employment seem to have slowed down in the 1980s, the output of sectors during the same period seems to have accelerated slightly (OECD 1994a, 1994b).

Given the difficulty of obtaining reliable and valid data, let us turn to anecdotal evidence of three trends. First, in 1993 the theme of the annual conference of European R&D managers – EIRMA – was ‘Accelerating Innovation’, and among the experts present there was little doubt that there had been an acceleration since the 1980s at least in some crucial respects. The key to success in innovation, they agreed, was speed – moving as rapidly as possible from the original idea to the introduction of the innovation in the market. The major theme at the conference was how to attain this goal. When these strategic agents of change accelerate their activities they impose the need for more rapid learning on the other agents in the economy.²⁶

A second tendency, which involves a broader set of actors than the R&D-INTENSIVE firms, is the movement towards flexible specialisation, in which producers compete through rapid response to volatile markets. This movement has been widely recognised by scholars and consultants, and many firms have drastically changed their organisation in order to meet this challenge. Again rapid change demands the ability to learn and to respond to new needs and markets.

A third phenomenon has to do with the introduction of competition into sectors which have previously been protected from it. Competition may come from the opening of national markets for services to imports or from deregulation and privatisation of activities. In this process the rate of change will accelerate even more rapidly than

it will in sectors, which have been used to competition. The rate of learning will accelerate throughout the organisation; new learning will include the development of completely new management concepts as well as new organisational forms.

There are thus several indications of an acceleration of change and learning. Easier access to codified knowledge may be one factor reinforcing these tendencies since some elements in the process of innovation now will take place with less delay than before. The truth might be more complex than we want it to be, however; while change has accelerated in some dimensions and segments of the economy, it might have slowed down in others. Let us now look at one of the few, but very original, attempts to measure the rate and costs of change.

Anne P. Carter (1994, 1996) introduced a new perspective on economic change. Her analysis, which covers only manufacturing, demonstrates that there is a strong correlation between the proportion of non-production workers and the rate of change in a sector. Sectors with high proportions of non-production workers grow more rapidly, their rate of productivity grows more rapidly and they include among them the most science-based activities. On this basis, Carter argues that the majority of non-production workers are engaged in either promoting or adapting to change. R&D personnel are most visible in promoting change, but many other professions do this as well. Why would one need so many engineers, accountants, sales personnel and managers if there was no or very little change?

An Alternative Perspective: IT as a Flexible Tool Supporting Interactive Learning

The most fundamental problems of IT have to do with difficulties in absorbing, allowing for and promoting change. In a stable environment characterised by a high degree of standardisation in inputs and outputs, it would be possible and economically attractive to build information systems which substituted for at least some of the functions which had previously been performed by skilled labour and human intelligence. But when materials, processes, product, markets and regulations all change, efforts to mechanise often prove counterproductive – they become barriers to flexible adaptation. It is also difficult to pursue innovative activities in an organisational environment in which human skills are automated.²⁷

In short, the main impact of IT is not to reduce the importance of tacit knowledge but rather to speed up specific phases of the innovation process. Such a speed-up might increase the demand for tacit skills. When the rate of change accelerates it confronts all economic agents with a need to analyse and react to a complex and rapidly changing flow of knowledge. We know that the exclusive use of strictly analytical models does not work in such situations. We conclude that tacit knowledge – in the forms of gut reactions, creativity and pragmatic intuition – is needed both to adapt to change and to impose change. We further conclude that attempts to impose overly ambitious analytical models hamper rather than stimulate decision making in such a context.

IT may be regarded from a different perspective, in which the emphasis is upon its potential to reinforce human interaction and interactive learning. Here the focus is not upon its ability to substitute for tacit knowledge but rather on its ability to support and mobilise tacit knowledge. E-mail systems connecting agents sharing common local codes and frameworks of understanding can have this effect, and broad access to data and information among employees can further the development of common perspectives and objectives for the firm. Multimedia exchange may be helpful in transferring elements of tacit knowledge, for instance, by using combinations of voice and pictures interactively.

Let us assume an ‘information economy’ where all practical knowledge has been successfully transformed into simple recipes which can be accessed and applied by everyone. In such an economy – which corresponds to the assumptions of complete mobility of technical knowledge made in neoclassical trade theory – there would be no transnational corporations, and regional disparities in wealth would reflect only differences in the accumulation of tangible capital.

Introducing tacit knowledge, including shared tacit knowledge rooted inside firms or in local knowledge-intensive networks of firms, changes the workings of global competition completely. In such a world it becomes

profitable for firms to exploit their specific knowledge assets all over the world and it becomes clear why the access to such knowledge for local agents in less developed regions is limited. This implies also that any kind of systematic changes in the borderlines between tacit knowledge and information are of fundamental importance for the prospects of DCs.

An optimistic scenario would be one in which a massive transfer of tacit knowledge into information systems gives DCs access to new recipes (process technologies as well as new products) developed in the rich countries at a lower cost and much more rapidly than before. This would imply an acceleration of the catching-up process and prospects of narrowing global inequalities.

The experience of East Asian firms with learning from IPNs, described in the first part of this essay, provides reason for cautious optimism. The crux of such arrangements is an increased exposure to modern methods of organising not only production but the complex interaction between different stages of the value chain. This indicates that participation in IPNs can help, over time, to accelerate the formation of a variety of technological and organisational capabilities, provided that (1) a certain minimum threshold of such capabilities already exists, (2) DC firms pursue active strategies of learning and technology acquisition, and (3) the government and other intermediary institutions in the DC play a very active role as suppliers of necessary externalities.

The main remaining institutional problem in such a world would be to establish appropriately balanced intellectual property right (IPR) regimes which on the one hand stimulate the creation of new technology and on the other hand do not restrict the diffusion of new knowledge to late industrialising countries.

Two alternative scenarios, which are less optimistic and more realistic, must be considered. One is that access to the new recipes is limited by ability to master the language and codes connected to IT and that access can be gained only by countries and firms having a well-trained labour force with an ability to master symbolic languages. But there are much more mundane and fundamental constraints. In a great number of DCs, especially in the so-called least-developed countries, many firms are not logging on to the Internet. Either they lack computers or Internet access nodes and providers or the cost of telecommunications is prohibitive (Ernst 1997a). Research is needed to uncover the content and structure of network linkages which firms in the third world are maintaining, and how these network linkages affect the firms' access to tacit knowledge.²⁸

These constraints prevent many DCs from catching up economically with the industrialised countries. It will not be easy to overcome these constraints. Most of these countries have experienced a drastic decline in inflows of foreign capital, both concessionary and commercial. Access to capital has further deteriorated as a result of the crisis of the global finance markets caused by the bursting of the 'bubble economies' of East Asia. Most of the incoming capital is used for the purchase of equipment, leaving very little for crucial investments in human capital. Without such investments, DCs are doomed to perpetual exclusion from the marvels of the learning economy.

But this is only part of the story and much more is required in order to reap the benefits of IT. In essence, DCs need to create institutions to provide both the incentives and the externalities necessary for domestic learning, which we define as learning within the domestic economy by both national and foreign actors. Learning efficiency is critically dependent on the existence of such institutions. They are shaped by the interaction of policies, firm strategies (including those pursued by interfirm networks) and markets. Such institutions need time to develop, and there is no single optimum solution. Each individual country has to find the idiosyncratic mix of policies, market structure and firm organisation which best fits its own strengths and weaknesses. Nor is there any guarantee of success: Institutions can also experience malignant growth or they can get stuck with obsolete features which once were useful but now have become barriers to a further upgrading of local capabilities. In short, the dynamics of institutional change matters, but nothing is predetermined about the impact of these processes on capability formation (Ernst 2000a).

Probably the greatest challenge for DCs, however, results from the fact that IT accelerates creative destruction. Let us consider a third scenario, which follows from our earlier discussion. This scenario takes as its starting point that IT, in the context of globalization, speeds up the rate of economic change and that, as a result, the need for rapid learning of tacit as well as codified knowledge has dramatically increased. This requires not only

increasing investment in human and fixed capital but also constant and frequently drastic changes in existing strategies and organisational patterns. Both constraints are real and difficult to overcome.

Developments in Korea show that even if there are sufficient investment resources available, the rigid and hierarchical structure of firm and industry organisation and of regulatory institutions can act as a major barrier to such change.²⁹ Accumulating tacit knowledge, required for a quick response to changing markets and technologies, has turned out to be a bit easier in the very different organisational and institutional context of Taiwan (Ernst 2000c). This has important implications for DCs in terms of what institutional setup is most conducive to learning and capability formation.

WHAT KIND OF LEARNING ECONOMY IS APPROPRIATE FOR DEVELOPING COUNTRIES?

The New Challenge Recapitulated

We have seen that the spread of IT has changed the role of information: IT enhances the divisibility and storage of information, its processing, transportation and communication, and consequently its accessibility and tradability. In principle, this has improved access to codified knowledge. Yet, in order to benefit from this improved access, DCs need to strengthen their tacit knowledge base.

This has far-reaching implications for the process of knowledge creation: Its effectiveness critically depends on linkages and interactions among participants in this process. Knowledge generation within a society 'is strongly influenced by the network of relations among its firms, . . . with externalities, communication and interdependence playing crucial roles' (Antonelli 1997, 2).

The same is true for international networks (Ernst 1997b). For DCs, such international linkages are of critical importance in overcoming the vicious circle of underdevelopment (Ernst 2000a). Many of these countries are stuck with a truncated sectoral specialisation, dominated by low-end, homogeneous products (commodities) with limited productivity-enhancing potential.³⁰ The limited size of the domestic market constrains the degree of specialisation and places tight restrictions on its ability to function as a buffer against heavy fluctuations in international demand. Insufficient domestic market size also constrains the development of sophisticated 'lead users' which could stimulate innovation.³¹ It also limits the scope for technological spillovers.³² Finally, the limited size of the national knowledge and capital base restricts the choice of industries in which such nations might successfully specialise.

At least in principle, the spread of IT could help to break this vicious circle. By allowing for increasing specialisation in the production of knowledge, it could improve the chances for DCs to participate in and to benefit from IPNs. Knowledge generation now shifts from vertically integrated hierarchies to networks: 'The vertical integration structure of knowledge, characteristic since the Second World War, is being progressively replaced by the institutional creation of an information exchange market, based on real-time, on-line interaction between customers and producers' (Antonelli 1997, 3). In other words, the spread of IT facilitates and promotes the formation of separate and specialised knowledge markets.

Two Competing Models of the Learning Economy: The Japanese versus the American Model

Under what conditions can DCs benefit from these developments? And, more specifically, what types of institutional arrangements are most conducive to enhancing the formation of learning capabilities?

In what follows, we compare two stylised models of the learning economy, the Japanese versus the American model.³³ The models differ in their approach to tacit knowledge.³⁴ The Japanese model is explicit in its promotion and exploitation of tacit knowledge whereas the American model is driven by a permanent urge to reduce the importance of tacit knowledge and to transform it into information – that is, into explicit, well-structured and codified knowledge. The American model emphasises market selection, competition, income inequality and strict

control by financial markets as ways of promoting learning, whereas the Japanese model emphasises cooperation, social cohesion and long-term social relationships. Furthermore, the two models differ in terms of firm organisation (including the organisation of interfirm networks) and in their approaches to international linkages through trade and investment.

Knowledge Creation in Japanese Firms

Nonaka and Takeuchi (1995) give a series of examples of how large and well-managed Japanese TNCs organise the process of product innovation in ways, which explicitly take into account the important role of tacit knowledge. Japanese managers do not give their innovation teams detailed instructions. Instead they promote the search for innovative solutions by formulating metaphors and analogies. These are based on management's intuition and they leave ample room for creativity and the formation of new intermediate concepts. An intermediate layer of project team leaders make these open concepts interact with the tacit knowledge of skilled workers and engineers. They formulate somewhat more concrete slogans and gradually the new product is conceptualised.

All through the process face-to-face interaction and hands-on experimentation are given high priority. IT is used to give all participants easier access to banks of information to support knowledge creation, but these efforts are always combined with direct human interaction. They are not regarded as substitutes for it.

Nonaka and Takeuchi argue that the organisational model best suited to the creation of new knowledge is a 'hypertext organisation' in which there is one regular divisional structure, which is overlaid with ad hoc horizontal teams directly aiming at creating new products and new knowledge. Members of these teams should be taken completely out of their regular functions and divisions.³⁵ The analysis is limited to management strategies in connection with product development in big knowledge-based firms. It is, however, possible to extend the basic perspective in order to understand other characteristics of the Japanese innovation systems such as the long-term close interfirm relationships, the labour market and the lifetime employment contracts, the patient capital market with a long-term perspective, and so on.³⁶

In short, the Japanese model of the learning economy places midlevel team leaders at the centre of innovation. Top management gives direction to innovation in the form of metaphors and analogies. They establish frameworks promoting direct social interaction (face-to-face) and hands-on experimentation in order to mobilise and develop tacit knowledge at all levels of the firm. Monetary incentives are secondary and income differences are suppressed. Job circulation is stimulated in order to avoid narrow specialist perspectives. Markets are characterised by long-term relationships between sellers and buyers, and they transmit qualitative as well as quantitative information. Direct interaction with customers is a key element when marketing new products.³⁷ The creation of trust and communication channels is crucial to the success of developing and introducing new products.

Key Elements of the American Model

Central to the American model is an attempt to transform tacit knowledge into explicit knowledge through the automation of human skills. This is in line with a strong normative bias in Western civilisation in favour of explicit and well-structured knowledge and the high priority given to formal natural science as the ideal for all other sciences. Engineering and especially disciplines with weak science bases have much lower status. In practical life there are permanent efforts to structure and formalise or automate tacit knowledge. Economists tend to share and reinforce this bias because economic models have even greater difficulty analysing tacit knowledge than analysing information.³⁸

Typical of the American model is a hierarchical understanding of competence – competence is concentrated at the top. Operators on the shop floor have very limited roles in learning and knowledge creation. This goes hand in hand with an approach to labour management, which emphasises top management as the authority selecting competent teams and designing material incentives to stimulate the top teams in the firm. If anything, this model assumes that compensation is biased against the most competent participants. This model does not accept the idea that social cohesion could promote learning and innovation.

In product markets, American firms favour low entry barriers and fierce competition, which are perceived as creating the best environment for experimentation and for eliminating inefficient noninnovative firms. Interfirm cooperation as a solution is still considered second best to the free play of market forces. The most important function of the financial market is to intervene and enforce a shift in top management when it fails to produce the return on investment required by the market. Capital markets combining takeover threats, junk bond markets and venture capital are presented as the ideal. Little is said about the problem of short-termism in Anglo-Saxon financial markets.

Finally, one of the basic credos of the American model is that the government should not intervene in the market mechanism because government is by definition incompetent when it comes to recognising and correcting its own mistakes – a key competence of successful firms. There is no reference to historical cases where active governments have stimulated economic development by indicating broad trajectories for industrial development.

In short, the American model is characterised by a clear hierarchy, and the main responsibility for promoting innovation rests at the top. This responsibility is performed by hiring, firing and promoting competent people and by designing incentive systems. Monetary incentives predominate: Inequality in competencies should be reflected in inequalities in earnings. Specialised expertise is crucial to problem solving.

Finally, competition dominates interfirm relationships. Industrial markets as well as markets for consumption goods are regarded as characterised by arm's length and anonymous relationships between sellers and buyers. Markets serve as media for information exchange when the tacitness of knowledge constrains the scope for organisational learning.

Hybrid Models and Economic Development: Implications for Developing Countries

We have seen that both models of the learning economy have peculiar strengths and weaknesses. For any particular DC, their usefulness depends on its stage of development. The American model promotes short-term static allocation efficiency but neglects two equally important types of efficiency problems: distributive and learning efficiency. For DCs, this may have negative consequences for long-term capability formation.³⁹ The Japanese model, in turn, is conducive to rapid capability formation, which can facilitate economic catching up. This, however, comes at a cost in static allocation efficiency and reduced speed to market.

For the majority of DCs, the main concern is to create the necessary institutions to provide incentives for and externalities necessary for domestic learning. For these countries, the US model has less to offer than the Japanese model: Its disregard of the importance of tacit knowledge leads to a misconception of the role of IT in the learning economy. For those countries, however, which have reached a certain degree of development and need to upgrade their existing institutions, neither of the stylised models give the full answer. These countries need to develop hybrid institutions, which combine the advantages of both models in a way which is appropriate to their idiosyncratic needs and capabilities.

Such pragmatic new combinations may become more realistic in a world in which the two models converge. On the one hand, the reason American firms have regained their competitiveness is that they have started to use organisational solutions which are much closer to the Japanese model than the American ideology would indicate. On the other hand, the ongoing debate about industrial restructuring in Japan emphasises the limitations of the old catching-up strategy and the need to borrow institutional elements from the US model in order to promote individual entrepreneurship and short-term flexibility.⁴⁰

NOTES

1. For related papers which compare the Korean and the Taiwanese models see Ernst 1994b, 1998a, 2000b.
2. Note, however, that this linkage did not hold during the two twentieth-century world wars, which led to breakdowns of the international economy. During these two wars countries such as Brazil, Argentina, colonial India and Egypt experienced bouts of growth based on import substitution. Classic sources include Hirschman 1968 and Furtado 1970. For a review of these debates see Ernst 1973.

3. 'North' refers to developed market economies, virtually identical with OECD member countries. UNCTAD 1991, table 3.4. in appendix 1.
4. See the growing literature on 'contestable markets', which shows that high concentration can go hand in hand with high contestability or openness to entry (Baumol et al. 1982). For a review of this literature see UNCTAD 1997, part 2, 'Foreign direct investment, market structure and competition policy'. For a case study of how globalisation affects competition in the electronics industry see Ernst 1998b.
5. The following is based on Ernst 1997b, chapter 1.
6. The concept of an IPN is an attempt to capture the spread of broader and more systemic forms of international production which cover all stages of the value chain and which may or may not involve equity ownership. This concept allows us to analyse the globalization strategies of a particular firm with regard to four questions: (1) Where does a firm locate which stages of the value chain? (2) To what degree does a firm rely on outsourcing? What is the importance of interfirm production networks relative to the firm's internal production network? (3) To what degree is the control over these transactions centralised or decentralised? And (4) how do the different elements of these networks hang together? The IPN concept has been developed in studies prepared for the OECD (Ernst 1994a), the Sloan Foundation (Ernst 1997b) and the Brookings Institution (Ernst 2000b).
7. For a detailed analysis of the impact of globalization on industrialisation in DCs see Ernst and O'Connor 1989, 1992. For an analysis of how Korea and Taiwan have tried to cope with the globalisation challenge see Ernst 1994b, 1998a, 2000c.
8. For a typical example of this neoliberal globalisation doctrine see Ohmae 1991.
9. Boyer 1996, 47 and 40. We agree with Boyer's conclusion: 'This syllogism that equates globalization with convergence is logically flawed, and its premise may not correspond to the current state of the world economy' (50).
10. The following is based on Ernst 2000a.
11. Consider a stylised IPN: It combines a lead firm, its subsidiaries, affiliates and joint ventures, its suppliers and subcontractors, its distribution channels and VARs (value-added resellers), as well as its R&D alliances and a variety of cooperative agreements (such as standards consortia). The lead company derives its strength from its control over critical resources and capabilities and from its capacity to coordinate transactions between the different network nodes. One such source of strength, for instance, is the intellectual property and knowledge associated with setting, maintaining and continuously upgrading a de facto market standard. This requires perpetual improvements in product features, functionality, performance, cost and quality. It is such 'complementary assets' which the lead firm increasingly outsources. For empirical evidence see Ernst 1997b.
12. On Korea see Amsden 1989 and Ernst 1994b. On Taiwan see Wade 1990 and Ernst 2000c.
13. The following is based on Ernst 1998a.
14. For the underlying conceptual framework of capability formation see Ernst et al. 1998. See also the excellent analysis in Bell and Pavitt 1993.
15. Already in the 1970s most Korean electronics firms had to pay roughly 3 per cent of their gross sales for technology licensing fees, a share which since then has increased to more than 12 per cent (Lee Jin-Joo 1992, 132, 139).
16. For macroeconomic policies see Frieden 1991 and Frankel et al. 1992. For industrial and technology policies see the contributions by Boyer, Wade, etc., in Berger and Dore 1996.
17. Although Peter Evans's classification is a highly innovative theoretical approach, it is hard to agree with his choice of Korea as the positive role model in the computer industry. Taiwan is much better qualified to play this role (Ernst 2000c). This is not to belittle Korea's tremendous achievements in consumer electronics and standard precision components such as DRAMs. For a detailed analysis see Ernst 1994b, 1998a.
18. Young 1993; Kim and Lau 1994; Krugman 1994.
19. Freeman 1982, 1991; Lundvall 1988, 1992, 1996; Bell and Pavitt 1993; Nelson 1993; Nelson and Pack 1995; Maskell 1996a, 1996b.
20. The nature of these technological capabilities has been analysed in Ernst et al. 1998.
21. For analyses of IPNs and their impact on technology diffusion see Ernst 1994a, 1997b.
22. Today's arsenal of policy instruments available for such 'high-tech neomercantilism' is impressive and includes subsidies for investment or research, restrictions on access to the domestic market by similar goods from foreign producers, restrictions on direct investment in the domestic market by foreign firms, and procurement policies which favour the domestic producer of a high-technology good. For evidence see Ernst and O'Connor 1989, 26 *passim*; Tyson 1992.
23. For evidence see note 15.
24. For evidence see Ernst 1994b, 2000c.
25. The concept of tacit knowledge was originally developed by Michael Polanyi (1958, 1966).
26. EIRMA 1993. In this context, it is relevant to quote from the introductory remarks of the EIRMA president, Dr E. Spitz: 'In a time of intensive global competition, speeding up the innovation process is one of the most important ingredients which enable the company to bring to the market the right product for the right price at the right time. . . . We know that it is not only the R&D process which is important; we have to put emphasis on the integration of technology in the complete business environment, production, marketing, regulations and many other activities essential to commercial success. These are the areas where the innovation process is being retarded. This subject is a very deep seated one which sometimes leads to important, fundamental rethinking and radical redesign of the whole business process. In this respect, especially during the difficult period in which we live today, where pressure is much higher, our organisations may, in fact, need to be changed' (EIRMA 1993, 7).
27. The difficulties with automating tacit knowledge do not rule out new attempts to formalise and structure tacit knowledge; it is reasonable to assume that the growing importance of IT will further stimulate such attempts. Already one can see a number of new applications which change the character of knowledge creation at certain stages of the innovation process. Computer-aided development and testing of drugs and aircraft and computer-aided design in many other areas illustrate successful transfers of problem-solving skills from humans to computers (Foray and Lundvall 1996, 14–15).
28. On some of these issues see UNCST (forthcoming), chapters 3 and 5.
29. For evidence see Ernst 1994b, 1998a.
30. The classical source remains Fajnzylber 1989.

31. Von Hippel defines 'lead users of a novel or enhanced product, process, or service' as those which 'face needs that will be general in the market place, but . . . [who] face them months or years before the bulk of that marketplace encounters them' and who will 'benefit significantly by obtaining a solution to those needs' (Von Hippel 1988, 107).
32. Innovation theorists (Lundvall 1992; Nelson 1993) as well as new growth theorists (Grossman and Helpman 1991, 1993) assume that technological spillovers are primarily domestically generated. If this is so, then large countries will benefit more from an investment in R&D than smaller countries, where some of the spillovers of R&D are likely to benefit their trading partners (Zander and Kogut 1995).
33. Both models are ideal types which do not exist in real life. There are, of course, substantial variations among both American and Japanese firms. There are also instances of selective convergence between the models. On both issues see Ernst 1997b, 1997c. Nevertheless, the two models capture essential differences in the process of knowledge creation which reflect the very distinct patterns of economic development and institutions in the two countries. See also note 1.
34. There are, of course, equally important criteria for comparing different paradigms of the learning economy. For instance, American and Japanese firms differ substantially in how they approach the development and application of IT. For a discussion of some of these issues see Ernst 1997b, 2000b.
35. The analysis is much more complex than indicated by this summary. For instance, Nonaka and Takeuchi develop a model of knowledge creation which assumes the process to be a spiral movement moving from tacit to explicit and then back to tacit knowledge. The conversion between these forms plays a crucial role in the theory. This point is worth critical attention. In some of Nonaka and Takeuchi's examples it is not clear whether what is illustrated is an interaction between the different forms of knowledge or a conversion of one into the other.
36. For an attempt to cover these broader aspects of knowledge creation in Japanese firms see Fruin 1997.
37. The case of Nissan developing its Primera model for the European market is an extremely interesting illustration of how Japanese firms try to absorb local tacit knowledge from their potential markets (Nonaka and Takeuchi 1995, 2000ff).
38. Eliasson (1996) shows that the fascination with automation in the form of generic business information systems again and again has proved out of proportion with reality. An enormous number of articles have been written on the fully automated factory, but the real counterpart has been of negligible importance. The same has been true for office automation. This bias has been costly for many firms. The case studies of Hatchuel and Weil (1995) show that so far automating human skills has been economically successful only for simple, repetitive tasks performed in a reasonably stable environment. Their work on expert systems shows that even when the tasks are reasonably simple, the mode of operation of the expert system developed will differ radically from the operation of the expert.
39. This is in line with research on the 'specialisation dilemma'. Andersen (1996, 105) shows that specialisation may involve substantial trade-offs: Pushing static allocation efficiency gains to the limit could undermine a firm's and a country's capacity for knowledge creation.
40. For an analysis of these issues see Ernst 1997b, 2000b.

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