OCCASIONAL PAPER

TECHNOLOGY AND THE ECONOMY: A REVIEW OF SOME CRITICAL RELATIONSHIPS

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TECHNOLOGY AND THE ECONOMY: A REVIEW OF SOME CRITICAL RELATIONSHIPS

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FOREWORD

In 1989, The Technology and Economy Project (TEP) was set up by the Science, Technology and Industry Directorate of the Organization for Economic Co-operation and Development (OECD). The project attempted, through seminars, conferences and a number of invited papers, to review what was known of the sources of economic growth. The goal was to provide a fresh understanding of the principal factors that connect technology production with economic performance. Accordingly, the paper summarizing that project was entitled *Technology and the Economy: the key relationships (OECD, 1992).* The analysis and discussion presented in this report highlight some of the developments since TEP that continue to challenge our understanding of the interactions between technology and the economy and their implications for science and technology policy.

TABLE OF CONTENTS

PART II

EXECUTIVE SUMMARY

In the text, the role of technological activities in economic growth is treated in terms of the importance of appreciative versus formal economic theorizing, and of the central role played by firms in knowledge generation. Competition takes place among firms, not nations. Therefore, each firm needs to make its own way in its chosen economic environment and not to be overly concerned by scare tactics about globalization and competition among nations.

The new "growth theory" attempts to take a fresh look at the ways in which new technology is generated. In this it has been much influenced by advances in our understanding of how firms behave, that is, of how they innovate. It is increasingly accepted that the role of science and technology in innovation, as in the economy as a whole, is complex and evolving. Theory needs to be informed by research coming out of science policy studies and studies of the innovative process, whether in terms of management practices, theories of the firm or organization theory.

Not only markets but also institutions are crucial to sound economic performance. Firms behave differently; therefore, diversity rather than convergence in terms of performance is to be expected. This is evidently true of firms, but differences between firms are reflected in differences in national economic performance. The evidence presented in the report supports divergence rather than convergence of trends in the international economy.

Variety is the natural outcome of growing competitiveness, and this has characterized the international economy over at least the last decade. Variety is bound to come about once the cumulative, path-dependent nature of technical change is appreciated. As firms innovate, they continue to learn. Much of the learning takes place locally. Local linkages — for example, user-producer ones — have been identified as important to successful innovation.

Learning is crucial, but much of the knowledge generated is tacit rather than codified. To "capture" that tacit knowledge in a sequence of innovations is the principal challenge facing most firms. In relation to this, we have noted the crucial role of the rate of development in information, computer and telecommunications technology (ICT) in the future innovation. The rate of ICT innovation is now seen to be a key factor governing the rate of innovation in many industrial and business sectors.

The general shift to information and knowledge focuses attention on the historical, cultural and institutional context of each country. This complexity is meant to be captured in the notion of national innovation systems. If it is partly because of their history that national systems of innovation differ in their effectiveness and in their learning profiles, then policy must move, initially at least, within the constraints of the local institutional environment to try to improve its "connectivity."

Firms operate within different financial systems. The evidence from the most recent Organization for Economic Co-operation and Development (OECD) analyses suggests that existing financial institutions are not sophisticated enough to deal with the different types of risk and uncertainty which accompany the innovation process at different stages. Current thinking about the reform of financial institutions is less about their capability to provide "patient" money and more to do with managing risk in the economy.

Unemployment continues to be problematic within OECD member countries. Whether it is chronic or structural, or a mixture of the two, is still the subject of debate. The reason seems to be that the notion of full employment is losing its meaning as is *full-time* employment. The structure of work is changing: jobs are being replaced by a range of occupations which may be more or less full time. The pattern is being complicated by the growth of services, and of a better idea of the economic importance of services and of what productivity in services might mean. The evidence presented here leans toward a structural interpretation rather than to the conventional economic interpretation in terms of imbalances or rigidities in labour markets.

Data, information, knowledge and learning are now seen as a key source of competitive advantage in the innovation process. For a firm this means developing strategies which make it possible to enhance their existing knowledge base through a carefully selected set of collaborative arrangements. This in turn, requires the development of national policies as well as strategies for firms to help manage the transition from collaboration to competition.

For governments, the centrality of information has once again raised questions about the role of state-funded research and raises, in an acute form, the problem of drawing national advantage out of research which is increasingly carried out internationally and on a collaborative basis. This has deep implications for those national institutions with a mandate for knowledge generation. In some countries, innovation policy has shifted to a concern with diffusion — less of products and process produced than of the knowledge on which they are based. This is exemplified in the attempt to classify national systems of innovation in terms of their distribution power. The policy aim here is to increase this power and to make existing knowledge available to those who need it at the time that they need it.

We begin this paper with a brief discussion of the Solow Paradox, that despite the fact that over the last 20 years there have been large-scale investments in technology, productivity growth has not risen. This paper argues that this paradox may be more apparent than real and arises from an oversight of the differences in terms of investment impact between incremental and radical innovation. Many advanced economies are going through a period of significant structural change, and because of this, nations are failing to capture the full benefits of research and development investment.

There seems little argument that the interrelated technologies which are leading this development are the new information, computer and telecommunication technologies. For governments, this means more than heavy investment in hardware development. Many advanced economies are in transition from policies focused on the generation of knowledge, to policies focused on the distribution of knowledge. This has deep implications for the knowledge-producing institutions that, in each country, make up the national innovation system and for the policies that will guide them.

The notion of globalization is undergoing a re-examination. Finance is currently the most globalized sector in the sense that existing computer and communication technologies now make it possible to carry out transactions to and from any place in the world.

Globalization is also evident in the markets for some standard commodities. In manufacturing, generally, there is still considerable evidence to suggest that the most sensitive research and development is still carried out locally, though its global sourcing seems to be increasing. We have argued that the *diffusion of variety in methods of production* may describe more precisely what is distinctive about globalization.

New science and technology indicators are being developed in several places, notably the OECD and the European Union (EU). In these, there is a greater concentration on inter-country and inter-sectoral comparisons and a general shift to more and better output indicators. We also note the beginning of data assembly for the countries of Eastern Europe and the former Soviet Union. In science indicators, specifically, we have noted the development of techniques which allow countries to identify nation-specific sectoral patterns which highlight the connectivity of the knowledge-producing institutions in national systems.

INTRODUCTION

In 1989, the Technology and Economy Project (TEP) was set up by the Science, Technology and Industry Directorate of the Organization for Economic Co-operation and Development (OECD). The project attempted, through seminars, conferences and a number of invited papers, to review what was known of the sources of economic growth. The goal was to provide a fresh understanding of the principal factors that connect technology production with economic performance. The paper summarizing that project was entitled *Technology and the Economy: the key relationships (OECD, 1992).* The analysis presented here highlights some of the developments since TEP that continue to challenge our understanding of the interactions between technology and the economy, and their implications for science and technology policy.

The interaction between technology and the economy is a complex question and involves a huge body of research literature. It was already clear from previous work that technical advance was a (if not the) principal source of economic growth, but the determination of its contribution was fraught with theoretical as well as methodological difficulties. However, during the 1970s, formal theorizing on the sources of growth went off the agenda, according to some, because such research was exhibiting diminishing returns. Hence, the concern of TEP to carry out a fresh consideration of the key relationships between technology and the economy was both necessary and timely.

Understanding the relationships between technology and the economy hinges, to a large part, on how "technology" is conceived. On this point, there has been considerable advance since the early days of formal growth theory in the late 1950s, though not always through formal theorizing. In formal economic terms, the intellectual change can be described as a somewhat belated recognition that technology is endogenous rather than exogenous to the process of economic growth, and there is a more determined attempt by economists to incorporate this in their mainline theoretical work. In this context, a nice distinction between formal and appreciative theory has been used by Nelson to assist in the analysis of the course of this development in the field of economics. In a recent paper, Nelson observed that:

> [P]erhaps because the subject matter and the operative mechanisms are so complex, theorising in economics tends to proceed on at least two levels of formality . . . appreciative theory and formal theory. Appreciative theorising tends to be close to empirical work and provides both guidance and interpretation. Mostly it is expressed verbally and is the analyst's articulation of what he or she really thinks is going on. Appreciative theory is very much an abstract body of reasoning. Certain variables and relationships are treated as important and others are ignored. There generally is explicit causal argument. However, appreciative theorising tends to stay relatively close to the empirical substance. In contrast, formal theorising almost always proceeds at some intellectual distance from what is known empirically, and where it does appeal to data for support, the appeal generally is to "stylised facts", or reasonably good "statistical fits". If the hallmark of appreciative theory is storytelling that is close to the empirical nitty-gritty, the hallmark of formal theorising is an abstract structure set up to enable one to explore, find and check logical connections. Appreciative theorising is rich, but often will contain logical gaps and sometimes inconsistencies. Good formal theorising usually will contain fewer strictly logical gaps and will be mostly consistent. Also, the logical inferences will tend to reach further than those of appreciative theorising. But formal theory will be significantly more distant from the empirical nitty-gritty. (Nelson, 1994)

According to Nelson, the two kinds of approach work in harness, though not without significant time lags between their various analytical concerns. At the present time, formal growth-theory theorists are trying to absorb the findings of an increasing amount of empirical research and appreciative theorizing in the fields of firm behaviour, management and organization. Thus, theoretical economists, in particular, are now trying to incorporate a more realistic set of assumptions in their formal models.

While TEP aimed to carry out an overview of the relevant literatures, it reviewed all of these in a rigorously systematic way. Limitations of time and money meant that the project would have to rely heavily on its international networks, and this implied making use of some experts more than others. As a consequence, the seminars and conferences generated more intense debate about the meaning and measurement of productivity than of the institutional factors that support growth, and more discussion of incremental adjustments to theory than analyses of structural change in the economy. This perhaps reflects in part the predilections of that section of the economics community which works with the OECD and partly the economic stance of the OECD itself. Interestingly, the contribution of new growth theory to changes in our understanding of the key relationships was not pursued very far, mainly, it was argued, because there was insufficient empirical material available to test its implications. Since the theorists of the new growth theory, perhaps the major innovation in economic science to emerge in the last 50 years, have neither absorbed current empirical work on studies of technological innovation, nor used it, heuristically, to suggest new relationships, some of the "key relationships" looked pretty much like the well known ones. In particular, the role of technology continues to hover uneasily between being an endogenous and an exogenous factor in economic growth. Pending further research, this crucial question has been left open. While this example applies only to some of the debates about the sources of economic growth, it was reflected in other areas of discussion as well, including employment and the structure of financial institutions. In these debates, the conventional economic thinking was, and is, still dominant. This is important because it shows that if a new synthesis is to become dominant it must at least be robust enough to challenge current neoclassical economic analyses in their various guises. So far, this has proved very difficult.

It is, then, inappropriate to look to TEP for a fresh synthesis of the key relationships between technology and the economy. Indeed, many of the ideas formulated in TEP as well as in the present report were already known before the project. More important is the point that, as a result of TEP, some of these ideas have moved a bit closer to being on the agenda of policy makers, while others have receded in importance. For example, arguments about the endogenous vs. exogenous nature of economic growth have directed fresh attention to the importance of human capital and, more important, the costs of maintaining or refurbishing it. Similarly, the persistent problems of smaller firms have directed attention to regional economics and to the role of financial institutions within national innovation systems. By contrast, concern about divergence in national levels of research and development funding has almost disappeared from the agenda as has discussion of the role of basic research as a key determinant of economic growth. No one has ever maintained either that human capital, small firms or financial institutions were unimportant in economic growth or that nowadays national investments in research and development are irrelevant. But continuing problems with productivity growth exhibited, for example, in the Solow Paradox, have forced economists and others to consider fresh approaches. Such reconsideration takes time. In this extended process, TEP provided an important focusing device.

Since many of the key ideas were already known, one might be tempted to conclude that not much has been learned since TEP. Perhaps. But the growth of appreciative theorizing in our understanding of the key relationships represents a reaffirmation of the role of empirical research from a wide variety of disciplines in our understanding of technology and economics. This is manifested in a new willingness to consider concrete models and simulations which explain actual, rather than theoretical, performance. The importance of this development should not be overlooked, even though a synthesis may be some way off. Similarly, problems to do with globalization, employment and the role of national systems of innovation in sustaining international competitiveness refuse to go away and continue to raise fresh problems for policy makers. Currently, many believe that the answers to these problems lie in the creation of "meso-level" institutions, forms of governance that lie between national economies and the global marketplace. TEP provided an opportunity to give some of these issues a fresh hearing.

This report falls into two main parts. The first looks somewhat narrowly at the growth of appreciative theorizing and at what this can tell us about the relationships between technology and economic growth. The principal conclusion from the literature is that divergence rather than convergence characterize national economic performance. If this is so, it would reverse much conventional thinking about how national economics evolve. Empirically, the increasing importance of divergence requires a fresh look at the functioning of national systems of innovation and the determinants of international competitiveness. As we argue, this has led many scholars to a consideration of the role of information, data, knowledge and learning in the innovation process. Competitiveness now seems to depend on getting the right information and knowledge to the right place at the right time. This is all the more important if one realizes that much data, information and knowledge is now produced and circulated internationally.

In contrast, the second part of this report is a selection of some ideas at the leading edge of science and technological policy work that has followed, in some cases directly, from TEP. In this section, some of the current theoretical and empirical work around issues of employment, globalization and the measurement of science and technological performance is presented. It would be premature to try to provide a synthesis of this work. Many of the ideas discussed are still being worked out; nonetheless, they are sufficiently developed to be of use to those trying to formulate new policies for national policy makers in science and technology. It was thought more important to try to convey the main thrust of some of this work than to prepare what would have to be a very subjective, interim synthesis. For this reason, the ideas and concepts that appear in the various chapters are presented without much discussion of how they may relate to one another or to the ongoing development of the subject. Still, the attempt to find some coherence has not been abandoned entirely. In each of the cases presented, the importance of process — diffusion, interactivity, information flow and knowledge transfer, etc. — are stressed. It is our view that any new syntheses, if and when they emerge, will stress these aspects, and their key concepts will be concerned with flows of data, with information knowledge and with the promotion of learning.

PART I
SUMMARY

Technology and the New Growth Theories

In the theoretical literature on growth, technological progress is conceived either as:

- *a "free good" (as "manna from heaven");*
- *a by-product of other economic activities; or*
- *the result of intentional research and development activities in private firms.*

A key insight, in terms of appreciative theory, is that firms are the important actors in generating new technologies. They do this by engaging in the innovation process — by engaging, strategically, in ongoing technology-market interactions, often on the basis of a pre-determined strategy. Technology develops then, in a structured way, and not every technological possibility becomes an economic probability.

New Models of Innovation

Since the Technology and Economy Project (TEP), policy research along this line has led to the development of a systems approach to innovation as a distinct alternative to linear, sequential approaches. The systems approach is not only analytically distinct from the previous linear models but also contains very different policy implications, both for *nations and* among *nations. In what follows, we contrast two new approaches to understanding the innovation process. The first is based on systems thinking and is derived from a European Community (EC) working group which puts forward an integrated approach to European innovation and technology-diffusion policy. The second — the systems integration and networking model — is derived from a close reading of the current management literature and identifies the crucial importance of the rate of change in information and communication technologies in determining the rate of innovation in product and process innovation generally. The two are related in* *that the systems approach identifies the importance of knowledge and learning in the innovation process generally, while the networking model pinpoints the principal locus of those activities and so provides a vantage point for understanding the dynamics of innovation.*

National Systems of Innovation

The notion that knowledge flows — and needs to flow — between individual knowledge-producing entities if firms are to remain competitive, gives rise at a higher level of analytical integration to the idea of national systems of innovation. Such systems are complex, reflecting the particularities — the histories, cultures and institutions — of each country. National systems were identified as important in TEP, partly because of their intrinsic ability to shed light on the nature of competitiveness and partly because of their potential as a tool for comparative analysis. In this latter respect, the idea of national systems was thought to be able to help explain different national experiences of economic growth and, in this way, help resolve the debate within formal economic theory between convergence and divergence in national patterns. Formal theorizing tends to prefer convergence, internationally, in growth rates and productivity as the "correct" tendency. By contrast, the thrust of appreciative theorizing tends to demonstrate the persistence of divergence, as with firms, so nations seem to travel down different economic paths conditioned by technological choices and the institutional set-up. In such a situation, divergence, rather than the converse, is to be expected.

1. TECHNOLOGY AND THE NEW GROWTH THEORIES

At least 10 new features have been found by Boyer to characterize the literature on technology and the new growth theories (Boyer, 1993).

- To get and preserve its competitive edge, innovation must be at the core of a firm's strategy. There is no longer a "helicopter" dropping innovations stochastically from the sky in the absence of deliberate efforts of individuals to find new products and processes. Contrary to the older neoclassical theories, this gives definite shape to the role of managers in which not every firm is bound to be a price-taker.

- Consumers are better off when they face more diversified goods. They are not "passive" consumers; they demand differentiation, particularly when renewing durable consumption goods. Consequently, price, quality and diversity are jointly to be considered when trying to explain a firm's market share. Basically, innovation is a method for continuously creating oligopolistic or monopolistic rents.

- The smooth and anonymous process of competitive equilibrium is replaced by the rivalry of strategic behaviour among firms themselves, or by a dynamic relationship between firms and consumers. In exploring these phenomena, researchers work with a wide variety of analytical tools, including game theory, micro-dynamic simulations and evolutionary models.

- Historically, in neoclassical growth theory, technological change shifted the whole production function or affected the "bias" of innovation between capital and labour. In contemporary research, however, innovations are initially regarded as taking place locally and only modify the productivity and capital per capita at the margin of the operating productive system. This is the source of the idea that firms can only explore specific paths within a given dominant design or technological paradigm. As a consequence, no general property can be derived from the success or failure of a given local innovation.

- Despite this, the diffusion of some generic technologies does spill over from one innovation to another, from the sector producing the technology to others using it. In this respect, some key innovations are finally interdependent since their development presupposes strong complementarities. Network externalities give one polar example of the dynamically increasing returns to scale, which are associated with the clustering of innovations, investments, information and knowledge.

- Innovation is a highly variegated phenomenon. New models are now being developed which include such factors. Spill-overs of research and development in new neoclassical theories (Romer, 1986), the role of education and on-the-job training as public goods for other models (Lucas, 1988), the impact of transport and telecommunications infrastructures, or learning by doing, interacting or using in the tradition of Kenneth Arrow (1962) have been alternatively selected by various authors. Interestingly, whichever variant is chosen, broadly similar mechanisms and externalities seem to prevail.

- The shift from micro- to macro-modelling also implies a greater focus on the precise characteristics of goods, their actual or perceived qualities and the number of varieties or models among the same product. Rather than perfect competition, imperfect competition is the force behind this continuous upgrading and diversification of goods. If extrapolated to the economy-wide level, this framework explains better some key factors in national competitiveness. The realism of the hypotheses and processes, when formalized, is bringing a common language to both managers and economists, and theoreticians and applied researchers.

- As a consequence, innovation becomes endogenous within each country and all the firms are competing for the same foreign and domestic markets. Consequently, the relative growth of open economies is closely related to the ability to innovate successfully and gain market shares among identical consumers. By contrast, most neoclassical models used to consider only closed economies, with mostly exogenous technical change.

- According to neoclassical theory, the economy, as it moved along its growth path, was in a quasi-stationary state if all the variables were deflated by total factor productivity. By contrast, the new models are mainly dynamic and sequential, since the economy is no longer at its full, long-run Marshallian equilibrium, but evolves from one temporary equilibrium to another, due to the renewal of innovations as a result of the competitive process itself.

- Last but not least, no single, unique-equilibrium growth-path usually exists: small differences in the initial endowments or in the parameters representing individual behaviour might trigger diverging development patterns. In some extreme cases, the rapid growth of one country is paid for by the relative decline of another. This is at odds with conventional international trade theory. The potential consequences for the role of markets and public interventions is important indeed.

In summary, in the theoretical literature on growth, technological progress is conceived as either:

- a "free good" (as "manna from heaven");
- a by-product of other economic activities; or
- the result of intentional research and development activities in private firms.

A key insight, in terms of appreciative theory, is that firms are the important actors in generating new technologies. They do this by engaging in the innovation process — by engaging, strategically, in ongoing technology-market interactions, often on the basis of a pre-determined strategy. Technology develops then in a structured way, and not every technological possibility becomes an economic probability.

Another related insight is that firms form part of the larger institutional context of a society, and that this larger framework is important in explaining differences in economic performance across countries, over time. Increasingly, research into why firms perform differently in terms of innovation comes to rest on the national institutional scene.

> Until recently, there were only a few empirical studies on the impact of technological gaps and other factors on differences in economic growth across countries. Following recent advances in theory, easier access to data, and — probably the introduction of econometric programs for the PC, this area of research has flourished. When the individual studies are put together, a rather *consistent picture emerges: the potential for "catch-up" is there, but is only realised by countries that have a sufficiently strong "social capability", e.g. those that manage to mobilise the necessary resources (investments, education, R&D, etc). The results also indicate that many of these factors should be seen as complements rather than as substitutes in economic growth* [author's emphasis].
>
> To some extent, there appears to be a convergence in assumptions between formal theorising and appreciative theorising. However, important differences remain. For instance, while formal theory still adopts the traditional neo-classical perspective of firms as profit maximisers, endowed with perfect information and foresight, appreciative theorising increasingly portrays firms as organisations, characterised by different capabilities (including technology) and strategies, and operating under considerable uncertainty with respect to future technological trends (Dosi, 1988). Although some formal theories now acknowledge the importance of firms for technological progress, these theories essentially treat technology as "blueprints" or "designs" that can be traded on markets. In contrast, appreciative theorising often describes technology as organisationally embedded, tacit cumulative in character, influenced by the interaction between firms and their environments and geographically localised (cf the notions of "national technology" and "national systems of innovation", and the Bertil Conference, Stockholm, 1994). Interestingly, the assumption of national (as opposed to global) technology spill-overs plays an important role for some of the more interesting predictions of the new growth theory (Grossman and Helpman, 1991), but in this no theoretical justification is offered. Another possible remaining difference in perspective relates to the need for government intervention, in particular with respect to financial markets, in supporting the growth of national technological capabilities. For instance, appreciative theorists — from Gerschenkron onwards — have repeatedly argued that imperfect financial markets act as a constraint to successful catch-up, and that intervention in financial markets is therefore a must. Formal theorising in this area has retained the traditional neo-classical framework of perfect capital markets, on a national or global level, and thus excluded this possibility by assumption. However, there is by now a well developed [body of] literature on financial market imperfections, and it is perhaps a safe bet that we will soon see formal models that combine the insights of this literature with a role for firms in generating technological progress. (Fagerberg, 1994)

At a deeper level of analysis, new technologies emerge from the generation and acquisition of knowledge. Underlying the changes outlined above is a shift from an artifact to a knowledge perspective, which opens a different way of conceiving the dynamics of technological development. The notion that technology is a form of knowledge underpins the idea that technologies evolve along specific trajectories, through a process of learning. Learning, in turn, makes technology, or technical advance, a cumulative, time-dependent phenomenon. This underlies the current notions that different firms behave in different ways and, in turn, produces the necessary variety or diversity on which markets acting as a selection environment operate. Equally, the cumulative, time-dependent nature of technological accumulation underlies the notions of "lock-in" and "lock-out." The dominant underlying models for handling such processes are evolutionary ones.

TEP picked up many of these developments in appreciative theorizing and has expressly abandoned linear sequential models in favour of the interactive, cumulative, time-dependent nature of the innovation process, not only in its analytical work but in its policy recommendations.

However, these developments merely push the question of the origins of growth deeper into the structure of firm behaviour. Once firms are seen as techno-economic laboratories, so to speak, one can ask how they acquire and generate knowledge. This is explained in terms of internal problem-solving capability (skills and competences) usually working within a dominant design, and external linkages (networks, strategic alliances, user-producer relationships, etc.) to other institutions, including (but not exclusively) knowledge-producing institutions. In other words, in trying to innovate, firms enter into combinations with other knowledge producers and have to communicate. Communication involves an exchange of knowledge, and so includes the diffusion of knowledge as well as the very technologies that the firms are developing.

From here, it is an easy step to argue that, because innovation depends on knowledge generation and acquisition, innovation needs to be supported by an environment which allows or promotes diffusion — of new knowledge and technologies, not only among firms but between firms and all the other knowledge-producing institutions such as universities, government research establishments, etc. — in the economy. Innovation requires a certain openness of communication channels and is a far cry from the diffusion models in which a single innovative firm calls forth a set of adopters, or imitators, as has characterized so much of the description of diffusion processes. Diffusion, henceforth, is a higher order (or systemic) feature of innovation and must concern institutional permeability and flexibility. That is why so much of contemporary technological policy is actually aimed at diffusion, and perhaps also why it was at the core of the TEP analysis and has remained there.

Investment in Technological Knowledge and Its Impact

Before leaving the question of the sources of economic growth, it is necessary to address an issue identified by TEP as a major problem needing explanation: the so-called Solow Paradox. Much of the research into the impact of investment on technological knowledge invites a reconsideration of the Solow Paradox. In a recent article, the distinguished American economist, Richard Nelson, has propounded the strong thesis that technological advance is not simply *a*, but *the*, source of economic growth (Nelson, 1994). This, despite the fact that Solow has demonstrated empirically that over the last 20 years, widespread availability of technology notwithstanding, productivity has stubbornly refused to grow. Further, because of the close correlation between economic growth and employment, the Solow Paradox is also implicated in explaining persistent unemployment, as we shall see in Section 6. From either productivity or employment data, it is but a short step to conclude that technology cannot be the mainspring of economic growth that Nelson believes it to be. To identify the sources of economic growth is a perennial preoccupation of economists. The existence of the Solow Paradox raises the fundamental question about the role of technological knowledge in growth. Those, like Nelson, who persist in claiming that it is crucial, need to show that the Solow Paradox is not really a paradox at all.

To resolve this divergence of views, a distinction needs to be drawn between radical and incremental innovation. As any production system develops over time, investments in research and development (R&D) appear to become less productive simply because the developmental potential of the underlying technical regime is becoming exhausted. The result is that despite increasing R&D expenditures, productivity gains are harder to obtain. If the current dominant modes of production are in fact approaching their technical limits, this would provide a partial explanation of the Solow Paradox, though it applies only to the mature sectors of the economy. However, not all sectors are equally mature. In these sectors, investments in R&D are increasing but their effects will not be evident until the shape of the new production system becomes more firmly established. In brief, incremental innovation is becoming more and more expensive, while the gains from radical innovation cannot yet be fully realized. It is our view that the limitations to productivity growth in each production system lie in the law of diminishing returns (Wolff's law) and, ultimately in institutional rigidities, and that these explain the sluggishness of productivity growth.

Let us consider, briefly, some of the evidence about productivity growth in different industrial sectors. When changes in labour productivity and in capital productivity over the last 20 years at a sufficiently disaggregated level are analysed, then we find the following picture.

Inside the electronics sector

The electronics sector (i.e., electronic industries and the electronic component industries) is the sector with the highest rates of growth in labour productivity. These are the industries which make the greatest use of their own technology for design, production, stock control, marketing and management. It is also the only industrial sector which showed a substantial rise in capital productivity, which demonstrated the advantages of the new technologies for everyone else and which may be described as the "carrier" or "motive" branches of a new technical regime. Baily and Chakrabarty (1985) have estimated that no less than half the total growth of US manufacturing productivity in the 1980s was due to the computer industry alone.

In those sectors which have been heavily penetrated by micro-electronics, both in their product and process technology, there is also evidence of a considerable rise in labour productivity in the most recent period. This applies, for example, to the scientific instruments industry, to the telecommunications industry and to part of the watch industry. These sectors have now virtually become a part of the electronics industry.

In sectors where micro-electronics has been used on an increasing scale over the last 10 years but where older technologies still predominate in product and process technology, there is a very uneven picture. Some firms have achieved very high productivity increases, some have stagnated, while others actually show a decline in productivity. This is the case, for example, in the printing industry, in the machine-building industry and in the clothing industry. The uneven picture is completely consistent with the spread of new technologies within established industries through new capital investment. In many cases information technology is introduced in a piecemeal fashion in one department or for one activity and not as part of an integrated system. For example, one or a few computer and numerically controlled (CNC) machine tools or a few robots or word processors are introduced. These are small "islands" of automation. This is not yet computer-integrated manufacturing or office systems and does not yet achieve anything approaching full potential in productivity gains. There may even be a temporary fall in productivity because of the lack of necessary skills in design, in software, in production engineering, in maintenance and in management, generally. Problems of institutional and social adaptation are extremely important, and flexibility in social response varies among countries, as well as among enterprises.

Outside the electronics sector

Outside the electronics sector, those sectors producing standardized homogeneous commodities on a flow-production basis in large plants have made considerable use of information technology in their process control systems and in various management applications. These were indeed among the earliest users of computers for these purposes. This applies, for example, to the petrochemical, oil, steel and cement industries in their use of energy and materials. But the gains in labour productivity have often been less than in the 1950s and 1960s, while capital productivity usually shows a marked decline. To understand this phenomenon, it is essential to recognize that these industries are among the most heavily affected by the shift from an energy-intensive and materials-intensive, mass-production, technological-production system to an information-intensive regime. At the height of the boom in consumption of consumer durable goods and vehicles in the 1950s and 1960s, they were achieving strong labour productivity gains based on big plant economies of scale. But with the change in technological regime, the slowdown in the world economy and the rise in energy prices in the 1970s, they now often face problems of surplus capacity and high unit-costs based on below-capacity production levels.

In services

Service sectors which are completely based on information technology (i.e., software services, data banks, computerized information services, design services, etc.) are among the fastest growing and (for individual firms) the most profitable activities in the leading industrial countries. But although their growth potential is enormous, so far they account for only a small proportion of the total service output and employment, and they suffer from acute skill shortages. Though productivity statistics are extremely difficult to generate, there is inferential evidence that suggests high rates of growth.

Other service sectors, such as banking, insurance and distribution, have been considerably affected by information technology. In these sectors, although the diffusion of new technology is extremely uneven, there is evidence of significant gains in labour productivity both by firm and by country, although measurement problems are acute. This phenomenon is rather important because until now it has often been observed that the service sector of the economy was not capable of achieving the type of labour-productivity gains achieved in manufacturing. Information technology now offers the potential (and in some cases already the actuality) of achieving such gains outside manufacturing. However, the progress of technology depends heavily on organizational, institutional and structural changes.

In most service sectors, information technology has dispersed only to a small extent, and these sectors are still characterized by very low labour-productivity gains, or none at all. While the stagnation in labour productivity may be attributed to the lack of information technology, it cannot be attributed to the impact of information technology. These account for the larger part of the tertiary sector by far.

Labour productivity

In many industrialized economies, there are sectors which have shown labour-productivity gains over the last 10 years which are due far more to structural rationalization than to the direct impact of new technology. Examples include the textile industries and also some of those sectors discussed above, where plant closures and rationalization have been implemented (as in the UK steel industry and the European petrochemicals industry). Since in any industry there is always a "tail" of low productivity plants, a significant rise above average labour productivity can always be achieved simply as a result of scrapping older generations of plants, even without any further technical improvements in the newer plants which can now work closer to full capacity.

Freeman concludes his analysis of the distribution of productivity change by sector in the following words:

> It is not difficult to see that the slowdown in average labour productivity gains over the 1970s and 1980s which has been a world wide phenomenon by comparison with the 1950s and 1960s, is precisely the aggregate outcome of a structural crisis of adaptation or change of [technical regime], which has accentuated the uneven development in different sectors of the economy . . . . On the one hand, the previously dominant energy-intensive mass production . . . [technical regime] . . . was reaching limits of productivity and profitability gains, due to a combination of exhaustion of economies of scale, market saturation in some sectors, diminishing returns to technical activities . . . and cost pressures on input prices. On the other hand, the new technical regime which offers the possibility of renewal of productivity gains and increased profitability, has so far deeply affected only a few leading edge industries and services. (Freeman, 1989)

Following Freeman, we would contend that there is strong evidence for the fact that the nest of interrelated production technologies is showing diminishing return to investment. But the same is not true of the radical innovations that are taking place in ICTs, biotechnology and some branches of the engineering materials sector. In these sectors, investment appears to be growing, but what is lacking is the appropriate institutional change to allow the full benefits of these investments to be realized. Governments have, to a certain extent, realized this. Investment in radical innovation underlies, in part, policies aimed at promoting research in generic technologies, of which ICTs are perhaps the paradigm case. More radically, however, recent EC policy for science and technology is focused on the concept of diffusion and the sorts of institutional change necessary to move information around and across national innovation systems. These polices represent a major departure from previous technology policies which were often aimed at generating new knowledge rather than diffusing what already existed. This matter is discussed more fully in Section 3.

2. NEW MODELS OF INNOVATION

Since the Technology and Economy Project (TEP), policy research along this line has led to the development of a systems approach to innovation as a distinct alternative to linear, sequential approaches. The systems approach is not only analytically distinct from the previous linear models but also contains very different policy implications, both for nations and between nations. In what follows, we contrast two new approaches to understanding the innovation process. The first is based on the systems thinking and is derived from a European Community (EC) working group which puts forward an *Integrated Approach to European Innovation and Technology Diffusion Policy* (Soete and Arundel, eds, 1993). The second, the systems integration and networking model, is derived from a close reading of the current management literature and identifies the crucial importance of the rate of change in information and communication technologies in determining the rate of innovation in product and process innovation generally. The two are related in that the systems approach identifies the importance of knowledge and learning in the innovation process, while the networking model pinpoints the principal locus of those activities and so provides a vantage point for understanding the dynamics of innovation.

The Systems Approach

The systems approach to innovation decisively abandons linear, sequential models in favour of one which regards innovation as a complex, cumulative process which contains both self-reinforcing feedback loops and multi-directional linkages. Whereas linear, sequential models tend to fragment the innovation process, the systems approach tries to consider technical change as a coherent whole.

The diffusion of integrated development techniques within production processes during the last decade has increased the density of links between the various phases of the innovation process and implies a gradual disintegration of the boundaries that have organizationally as well as analytically separated stages. The systems approach takes on board a great deal of empirical research on technical change at an aggregate level testifying to an increase in collaborative alliances between companies to share research and development (R&D) expertise and costs, or to investigate opportunities through the fusion of different technologies. Linkages or networks have also developed among and between private and publicly funded R&D laboratories. These alliances increase the density of links within a particular stage. Tighter linkages between and within different stages appear to have been partly undertaken by private firms in order to improve their competitiveness.

Empirical studies also show that technical change does not develop over time through a series of sequential stages, as indicated by many of the stage models. Instead, technical change is more accurately described as a complex process which contains both cumulative feedback loops and multi-directional links.

The existence of a large variety of multi-directional links and cumulative effects suggests using a systems approach to technical change. Such an approach makes it possible to keep a comprehensive view of the whole, on the one hand, while focusing on the interactive links between different stages and the composition of these linkages, on the other hand.

These complex interactions are united into a system by means of "communication paths." A systems approach to technical change developed in the 1980s, partly in response to studies on the organization of innovation in successful firms, suggested a model which described the process of innovation within firms as a "complex" set of communication paths, both intra-organizational and extra-organizational, linking together the various in-house functions and linking the firm to the broader scientific and technological community and to the marketplace. Communication paths are used in the model presented here, but there are two important differences. This model pays particular attention to two roles.

- The role of different actors in technical change: these actors consist of both individuals such as scientists, engineers, technicians and marketing staff, and the institutions involved in technical change, including public and private institutions such as production plants, research institutes and universities.

- The structure, composition and organization of the communication paths: this leads to the recognition that the cumulative creation of knowledge through learning plays a central role in technical change. This role requires greater elaboration.

The communication paths that link different activities and actors are made up of more or less straightforward information flows but, more important, exist through the transfer of knowledge. Typically, information takes one of three forms. It is contained in artifacts such as equipment, instruments and materials that are used in production; it is available as data or in written documents such as reports, journal articles and books; and it is held in the minds of individuals. The first two forms of information are characterized by the fact that they are not tied to any particular individual because they are in a codified form. However, of greater importance to innovation is knowledge, which is often tacit in the sense that it is not codified information and, by definition, is held by individuals and moves with them. As has been argued above, knowledge is the essential requirement for technical change since it encompasses the know-how, skills and experience to innovate. Knowledge is obtained and increased through a process of learning, either from codified sources of information, from direct experience as a result of doing or from other individuals as a result of interacting.

The development of knowledge through a range of activities based on learning is defined here as a process of assimilation, while the ability of firms to apply assimilated knowledge to productive uses is defined as "accommodation" or sometimes as its absorptive capacity. Since much of the most relevant knowledge either is not codified or, if it is, access is unclear, the most effective means of linking different activities in the innovation process is often through direct contact between knowledgeable individuals.

Thus individuals and organizations accumulate knowledge through assimilation. It is the result of learning and is one of two essential factors that drive technical change. Given the capacity within public or private firms to assimilate information, knowledge will gradually build up over time as more information is obtained from either internal or external sources. Such accommodation permits further technical developments and the exploration of new solutions.

To be effective, and this is the second essential factor, there must be a system of institutional and economic incentives and disincentives that direct and guide the search for new knowledge into economically profitable areas.

Within a systems approach, the focus is on information, learning and knowledge. This requires a more careful expansion of the usual meaning of diffusion than has been used in previous stage models, where diffusion is defined as the physical diffusion of new product or process technology. The systems approach adds the diffusion of information and knowledge. In this respect, the systems approach emphasizes that the transfer of the ability to assimilate new technologies through learning is a necessary complement to the physical diffusion of new products and processes. Thus, the transfer of a technology across regions, such as within a country or between developed and less developed countries, is dependent on the transfer of the ability to use a technology between different actors (for example, from researchers working in university laboratories to researchers working in R&D departments of private firms). In addition, the multi-dimensional and cumulative characteristics of technical change, combined with differences in the accumulation of knowledge and a wide range of historical and regional factors, ensure that the details of the development and diffusion of each innovation are unique.

The systems model of innovation can be expressed in terms of five main characteristics of technical change. Each characteristic can be used as a focus to develop recommendations for innovation and diffusion policy.

- The existence of multi-directional linkages which occur at the same time: this characteristic points to the need for a well-developed communications infrastructure to facilitate networking and the circulation of information and knowledge among the various actors and activities involved in innovation.

- Constitutive processes which are cumulative and self-reinforcing over time: the accumulation of knowledge and the effect of institutional and economic incentives lead to the gradual development of areas of technological expertise among individuals, firms or regional clusters of firms and public institutions. These cumulative processes can be very beneficial when they result in innovations and lower production costs, but they can also lead to dependence on a declining industry or to being locked into an inferior technology.

- The central role played by knowledge and learning: technical change depends on the capacity of both individual actors (such as scientists and engineers) and institutional actors (such as private firms and public research organizations) to accumulate knowledge, know-how and skills through learning from codified sources of information, from direct experience or from other individuals. Educational policies are important to create and renew work forces and to support transfer and interdisciplinary sciences that help link basic research with practical social and economic needs.

- The unique development pattern of each innovation due to a unique set of temporal, locational, industrial and other factors: this suggests that few policies are universally appropriate for all innovations and under all conditions. Rather, there is a need for generic policies that are designed for specific technological areas or which can flexibly adjust to changing circumstances.

- The systemic and interdependent features of technical change which are the sum of the preceding four: it is increasingly important to develop complementary, mutually reinforcing policies that aim to achieve a common goal.

Economic growth and diffusion

The link with economic growth lies in the fact that economic impact of technological innovation takes place through diffusion. New technologies (novel products and processes) that do not diffuse, or acquire market share, can have little economic impact, at least in the long term. Equally, when considering the knowledge dimension, diffusion is as much a property of the institutional environment as it is of the intrinsic characteristics (including prices) of the products and processes that are being diffused. In relation to diffusion, it is possible to ask whether national economies differ in their ability to support technical advance through learning and, hence, in their ability to grow. However, as knowledge moves to the centre of the picture, the nature of the diffusion process alters. Parallel to the normal diffusion of hardware, whether products or processes, there is the deeper and more fundamental movement of knowledge, information and data between experts in various institutional settings. This constitutes a further or "secondary" process of diffusion which in the systems model is the more important because, without knowledge transfer, the hardware may well be purchased and travel to its desired destination but its effectiveness will be inhibited unless there is a concomitant diffusion of knowledge which allows the user to master the new technology.

The interactive model outlined above represents a significant consolidation of an enormous amount of literature on the economics of innovation. Some of this is listed in the bibliography. By way of an example, some of the implications for policy that arise from adopting this approach are presented in Table 2.1.

Table 2.1
Implications for Diffusion Policy of a Systems Approach to Technical Change

Major Characteristic	Aggregate Policies	Firm-specific Policies
1. Multi-directional linkages at the same point in time	- Provide developed communication and transport systems - Support networking and co-operation among and between research institutes and firms and the infrastructure of supporting services	- Support research and education that improve the organization of innovation
2. Cumulative process over time	- Design policies to minimize undesirable linkage and feedback loops - Force a switch from diversity to standardization when needed - Provide policies to support faster diffusion rates	- Provide policies to assist firms in unlearning when needed and to develop new areas of expertise
3. Dependence on knowledge and the assimilation of information	- Maintain an educated and skilled work force -Support transfer and interdisciplinary sciences	- Provide support for the retraining of staff - Facilitate technology transfer and demonstration programs
4. Each innovation is unique	- Ensure broad range of programs to support diversity - Provide appropriate mix of both general and specific policies	- Preserve a diversity of future options by nurturing the technological capacity of firms - Develop customized programs to deal with the specific needs of SMEs
5. Interdependent system	Ensure complementary and coherent policies	

Source: Soete and Arundel (1993)

A more specific application of the systems approach is given in Table 2.2, which illustrates the shift in emphasis in policy orientations for "mission-oriented" projects from the "older" defence and aerospace type to the "newer" types of projects aimed at developing environmental technologies.

Table 2.2
Characteristics of Old and New "Mission-oriented" Projects

Old: Defence, Nuclear and Aerospace	New: Environmental Technologies
The mission is defined in terms of the number of technical achievements with little regard to their economic feasibility.	The mission is defined in terms of economically feasible technical solutions to particular environmental problems.
* The goals and the direction of technological development are defined in advance by a small group of experts.	* The direction of technical change is influenced by a wide range of actors including government, private firms and consumer groups.
* Control is centralized within a governmental administration.	* Control is decentralized with a large number of agents involved.
* Diffusion of results outside the core of participants is of minor importance or actively discouraged.	* Diffusion of the results is a central goal and is actively encouraged.
* Participation is limited to a small group of firms owing to the emphasis on a small number of radical technologies.	* The emphasis is on the incrementalist development of both radical and incremental innovations in order to permit a large number of firms to participate.
* Projects are self-contained with little need for complementary policies and scant attention paid to coherence.	* Complementary policies are vital for success and close attention is paid to coherence with other goals.

Source: Arundel and Soete, (1993)

As important as the systems approach is for understanding the relationship between innovation and diffusion, it fails to specify how the dynamics of the innovation process are changing. There is a great deal of ongoing research which points to the transformative importance of the new informational and communication technologies (ICTs). No doubt, for the innovation process generally, new communication paths are opening up and are increasing in "density." This is made possible by the ICTs. But the ICTs are imparting a particular momentum to the innovation process which the systems approach has recognized but not developed. Rothwell, in particular, has argued that the change in momentum given to the innovation process through the diffusion of ICTs is now driving the innovation process itself. Clever use of ICTs themselves is becoming a source of competitive advantage for firms. Some elements of this new dynamic are outlined in the following section.

Systems Integration and Networking — Rothwell's SIN

Underlying the systems model with its focus on interactivity, accumulation and time-dependence are innovations in the ICT area and the effects that these are having on the innovation process as a whole. Rothwell has highlighted the emergence of a new process or "meta-process" within the conventional innovation process which he argues is coming to determine the rate of innovation. To grasp what he is getting at and to place it within the history of innovation studies, it is useful to review his schema in terms of five generations of innovation.

- First Generation: early research on the innovation process is characterized by a technology push. Models employ simple linear, sequential processes with an emphasis on R&D at the front end. In this stage, markets are simply "receptacles" for the fruits of R&D.

- Second Generation: here, "need pull" starts to replace technology push but the simple linear, sequential process remains. By comparison with the first generation innovation process, there is greater emphasis on marketing. In this stage, the market becomes a source of ideas for directing R&D, which is conceived as responding, or reacting, to identified market "needs."

- Third Generation: at this stage a little more complexity is added in the form of coupling between the sequential stages. The model is still a linear one, but interactions involve a number of feedback loops, thus creating push, pull or push–pull combinations. R&D and marketing are brought more into balance and increasingly integrated into the production process.

- Fourth Generation: the introduction of parallel product and process development with multi-skill, cross-functional development teams gives rise to integrated models. Here, there are strong upstream supplier linkages and close coupling with leading edge customers. The emphasis is on integration between R&D and manufacturing (design for marketability). Horizontal collaboration (joint ventures, networks alliances, etc.) become a feature of the innovation process. Note that at the fourth generation, the general lineaments of the "systems" approach are beginning to emerge.

- Fifth Generation: through systems integration and networking (SIN), the multiplication of linkages has now effectively destroyed the linear model and fully integrated, parallel development has taken its place. Expert systems and simulation modelling in R&D now constitute an essential part of the design and production process. There are strong linkages with leading edge customers; "customer focus" is at the forefront of strategy. There is also strategic integration with primary suppliers including co-development of new products and linked computer-assisted design (CAD) systems. Horizontal linkages multiply through joint ventures, collaborative research groupings, collaborative marketing arrangements, etc. In organizational terms, the emphasis is on corporate flexibility and speed of development (time-based strategy). There is increased focus on quality and other non-price factors.

Rothwell has characterized the last stage as the "5G-SIN" innovation process. It has four primary enabling features.

- Greater overall organizational and systems integration:
  - parallel and integrated (cross-functional) development process
  - early supplier involvement in product development
  - involvement of leading-edge users in product development
  - establishment of horizontal technological collaboration where appropriate.

- Flatter, more flexible organizational structures for rapid, effective decision making:
  - greater empowerment of managers at lower levels
  - empowered product champions.

- Fully developed internal data bases:
  - effective data-sharing systems
  - product development metrics, computer-based heuristics and expert systems
  - electronically assisted product development using 3D-CAD systems and simulation modelling
  - linked CAD/CAE systems to enhance product development

flexibility and product manufacturability.

- Effective external data links:
  - co-development with suppliers using linked CAD systems
  - use of CAD at the customer interface
  - data links with R&D collaborators.

The thrust of the 5G-SIN model is evident. It is not so much that information systems now lie at the heart of the innovation process, though they do. It is rather that the rate of technical change in information technology is itself coming to control the pace of product and process innovation. Note that there are two "rates" involved. What is new here is that the rate of aggregate technical advance is being driven by the rate of technological progress in ICTs. The role of ICTs in the 5G innovation process is analogous to the one played by machine tools in an earlier stage of the industrialization process. In that case, it was soon realized that the rate of economic growth depended not so much on introducing machines as on the technical advance in "the machines that make machines," that is, in the development of a distinct machines tool sector. Analogically, as the drivers of the innovation process become more dependent on data, information and knowledge, then the technologies available to process that information become more central, and the rate of technical change in ICT becomes crucial to maintain competitiveness.

Given this, it is hardly surprising that so many firms are reorganizing drastically not only their relationships to R&D, but also to sub-contractors and suppliers. The network firm, the virtual organization, the explosion in strategic alliances of all kinds are manifestations of the uncertainty generated when a generic technology is itself undergoing rapid rates of technological change.

Table 2.3
Percentage Rates of Growth of Exports in 1980-1989

ALL PRIMARY COMMODITIES	2
of which	
food	3
raw materials, ores, minerals	4
fuels	5
ALL MANUFACTURES	8
of which	
iron and steel	4
textiles	6
chemicals	7
clothing	10
machinery and transport	8
of which	
ICT goods	13

Source: GATT (1990)

The 5G-SIN model is a new research paradigm offering many opportunities for empirical work whether at the level of the industry or the firm. According to recent surveys, the share of ICT products and services has indeed increased on a vast scale. They are now the fastest growing group in world trade (Table 2.3) and account for a very high proportion of total exports from countries such as Japan and the "Four Dragons" (Singapore, South Korea, Taiwan and Hong Kong) (Table 2.4). They also account for a significant proportion of total employment and of new investment especially in the service industries. There can be no doubt that ICT is already a pervasive technology, but we have barely begun to examine the second-order effects of this presence on the rate of innovation.

Table 2.4
Share of Office Machinery and Telecom Equipment in Total Merchandise Exports
(Ranked by Value of 1989 Exports)

	1980	1989
1. Japan	14	28
2. USA	8	13
3. FRG	5	5
4. UK	5	9
5. Singapore	14	34
6. South Korea	10	22
7. Taiwan	14	25
8. Hong Kong	12	16
9. France	4	7
10. Netherlands	5	7
11. Canada	2.5	4
15. Sweden	6	8
Brazil	(2)	(3)

Source: GATT, Table IV.40. Vol. I

Conclusion

By a somewhat circuitous route, we have now returned to the problems facing formal economic theorizing about economic growth. The intellectual challenge is how to incorporate knowledge — in its technical, organizational and managerial dimensions — into formal theory. Such incorporation will almost certainly involve the use of "proxy indicators" for knowledge. To date, GDP per capita, R&D investment and personnel, and average levels of educational attainment in the work force have been the ones most prominently used. It is no longer clear whether these proxies capture the essence of what is meant by the term "knowledge." The problem of measurement is recurrent and is one of the reasons that TEP stressed the need for more fundamental work to be done on indicators, particularly output indicators to measure performance (see Part II, Section 7).

3. NATIONAL SYSTEMS OF INNOVATION

The notion that knowledge flows — and needs to flow — between individual knowledge-producing entities if firms are to remain competitive, gives rise, at a higher level of analytical integration, to the idea of national systems of innovation. (Note: national systems of innovation are not the same as technological systems as used by Freeman and others.) Such systems are complex, reflecting the particularities — the histories, cultures and institutions — of each country. National systems were identified as important in TEP, partly because of their intrinsic ability to shed light on the nature of competitiveness and partly because of their potential as a tool for comparative analysis. In this latter respect, the idea of national systems was thought to be able to help explain different national experiences of economic growth and, in this way, help to resolve the debate within formal economic theory between convergence and divergence in national patterns. Formal theorizing tends to prefer convergence, internationally, in growth rates and productivity as the "correct" tendency. By contrast, the thrust of appreciative theorizing, tends to demonstrate the persistence of divergence. As with firms, so nations also seem to travel down different economic paths conditioned by technological choices and the institutional set up. In such a situation, divergence, rather than the converse, is to be expected.

A Review of the Literature

Since TEP there has been some empirical work, for example, by Nelson, Freeman, Lundvall, Mjoset, among others, on the nature and characteristics of national systems of innovation; but, perhaps due to complexity, the notion of a "national system of innovation" has, so far, been primarily heuristic. The principal thrust of much current work is based on the assumption that more than research and development (R&D) is required to account for national innovative performance. The "additional factors" include the particular mix of institutions that operate in a given country, and there is more than a hint that the successful economies are the ones in which the performance of the system as a whole is greater than the sum of the institutions which comprise it.

A national system of innovation, then, is a set of concretely functioning relationships between firms as technological generators and the institutional environment in which they exist. One of the first exponents of the notion of national systems of innovation was Lundvall. In *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning,* Lundvall built a theory of innovation based on learning which has many similarities to the systems approach that has been outlined above. In particular, the idea that institutions are linked in different ways in different countries and that these translate into differences in innovative performance and rates of diffusion has received some attention. A frequently cited example concerns different national approaches to information, computer and telecommunications technologies (ICTs).

> At the national level it is clear that institutions are extremely diverse and some may not be as well adapted as others to the successful exploitation of new technologies, particularly ICT. In this technological specialism, for example, in many countries there has been a problem of skill shortages and skill mismatches, especially in the area of software development and applications. There have also been major problems of system connectivity and incompatibility of standards in manufacturing systems, office systems and telecommunications. (Lundvall, 1992)

The principal characteristics of a national innovation system

At one time it was fashionable to compare countries in terms of their R&D systems, as in the case of the Organization for Economic Co-operation and Development (OECD) "Science Policy Reviews." But it has been increasingly recognized that a national system of innovation is far more than an R&D system. It is imperative to consider the *qualitative* features of an innovative system as well as *quantitative* ones such as the level of R&D expenditure. On the qualitative side, recent research has shown the importance of user-producer relationships, of sub-contracting networks, of external linkages within the science/technology system, of training systems in industry, and of linkages between R&D, production and marketing. In this context, the example of Japan has been particularly influential and often quoted by economists (see Table 3.1).

Table 3.1
Social Innovations in the Japanese National System of Innovation (1970s-1990s)

1.	Horizontal information flows and communications networks within firms and groups yield shorter lead times and better processes — the factory as laboratory.
2.	The firms function as continuous learning and innovating organizations by universal training and retraining.
3	Capital market provides funds for long-term investment in R&D, training and equipment.
4.	Collaborative research networks are facilitated by "Kieretsu" structure and stimulated/co-ordinated by central government with long-term strategic perspective (vision).
5.	"Fusion" research is facilitated and stimulated by the same approach (Mechatronics, Chematronics) engineering research associations.
6.	Links form between basic research organizations through increasing performance of basic research in industry.

Source: Freeman, (1995)

The case of sub-contracting networks illustrates very well the great variety of institutional arrangements and the extent to which these may affect the diffusion of technologies. For example, research comparing British and Japanese sub-contracting networks with the same industries shows that the contrast in approach is very different. In the former, it consists of formal, legal contractual arrangements with rather few high-level contacts; in the latter, it is oral communication at many different levels with little regard for formal legal arrangements. The British arm's length approach was typically short term and involved little technical collaboration, while the Japanese "obligated" approach typically looked for long-term partnerships with increasing technical collaboration (Sako, 1992).

As research has revealed the importance of these types of arrangements in promoting national innovative performance, it has become increasingly common to group them as characteristics of the type of national systems of innovation, originally proposed by Lundvall. The list of such characteristics is now quite large and includes:

- user-producer relationships
- sub-contractor networks
- science-technology networks
- R&D production linkages
- reverse engineering
- skills and tacit knowledge
- consultancy system and markets
- technology import capability
- science and technology systems (STS) linkages with R&D.

A common feature of this range of characteristics is that they are about capabilities and relationships. Thus, national systems of innovation may be expected and may be explored in relation to their different underlying competences and their degree of connectivity or interactivity.

The development of national innovation systems throughout the '70s and '80s

As empirical evidence and analysis began to accumulate about industrial R&D and about innovation in Japan, the United States and Europe, it became increasingly evident that the success of innovations, their rate of diffusion and the associated productivity gains depended on a wide variety of other influences as well as formal R&D.

- Incremental innovations came from production engineers, from technicians and from the shop floor, and were strongly related to different forms of work organizations.

- Many improvements to products and to services came from interaction with the market and with related firms, such as sub-contractors, suppliers of materials and services.

- R&D was usually decisive in its contribution to incremental innovations but it was not a sufficient force in the generation and diffusion of radical innovation.

- Both inter-firm relationships and external linkages with the narrower professional science-technology system were decisive, especially for innovative success with radical innovations.

- The systemic aspects of innovation were increasingly influential in determining both the rate of diffusion and the productivity gains associated with any particular diffusion process.

- The success of any specific technical innovation, such as robots or CNC, depended on other related changes in systems of production.

These systemic aspects of innovation point to the existence and importance of differences in the performance of national systems of innovation. For example, Freeman has analysed the stark differences between the Japanese and the former USSR's national systems of innovation (see Table 3.2). The most striking contrast, of course, was the huge commitment of Soviet R&D to military and space applications with little direct or indirect spin-off to the civil economy. It has now been shown that the desire to keep pace with the United States in the super-power arms race led to about three quarters of the massive Soviet R&D resources going into defence and space research. This amounted to nearly three percent of GNP, so that only about one percent remained for civil R&D. This civil R&D:GNP ratio was less than half of most West European countries and much smaller than the Japanese ratio.

Nevertheless, Freeman concludes:

> [T]he USSR system could have been far more productive if the social, technical and economic linkages in the system and the incentives to efficient performance had been stronger. The Soviet system grew up on the basis of separate Research Institutes and the Academy system (for fundamental research), for each industry sector (for applied research and development) and for the design and import of technology (the Project Design Organisations). The links between all these different institutions and enterprise-level R&D remained weak despite successive attempts to reform and improve the system in the 1960s and the 1970s. Moreover, there were quite strong negative incentives in the Soviet system retarding innovation at enterprise level, such as the need to meet quantitative planned production targets. Thus, whereas the integration of R&D, production and technology, important at firm level, was the strongest

feature of the Japanese system, it was very weak in the Soviet Union except in the aircraft industry and other defence sectors. Finally, the user-producer linkages which were so important in most other industrial countries were very weak or almost non-existent in some areas in the Soviet Union. (Freeman, 1995)

Table 3.2
Contrasting National Systems of Innovation — 1970s

Japan	USSR
High GERD/GNP ratio (2.5%) Very low proportions of military/space R&D (less than 2% of R&D)	Very high GERD/GNP (c. 4%) Extremely high proportion of military/space R&D (greater than 70% of R&D)
High proportions of total R&D at enterprise level and company financed (approximately 66%)	Low proportion of total R&D at enterprise level and company financed (less than 10%)
Strong integration of R&D, production and import of technology at enterprise level	Separation of R&D, production and import of technology and weak institutional linkages
Strong user-producer and sub-contractor network linkages	Weak or non-existent linkages between marketing, production and procurement
Strong incentives to innovate at enterprise level involving both management and work force	Some incentives to innovate made increasingly strong in 1960s and 1970s but offset by other negative disincentives affecting both management and work force
Intensive experience of competition in international markets	Relatively weak exposure to international competition except in arms race

Source: (Freeman, 1995)
GERD: Government Expenditure on Research and Development

As far as similarities go, both had (and still have) good educational systems with a high proportion of young people participating in tertiary education and a strong emphasis on science and technology. Both also had methods of generating long-term goals and perspectives for the science-technology system; however, whereas in the Japanese case the long-term "visions" are generated by an interactive process involving not only the Ministry of International Trade and Industry (MITI) and other organizations but also industry and universities, in the USSR the process was more restricted and dominated to a greater extent by military/space requirements.

Freeman has extended his analysis to illustrate other contrasts between national innovation systems, using as an example that between the national systems of innovation typically present in Latin American in the 1980s and those in the Four Dragons of East Asia (Table 3.3), and especially between two newly industrializing countries (NICs) in the 1980s: Brazil and South Korea (Table 3.4). He argues that:

> [T]the Asian countries started from a *lower* level of industrialisation in the 1950s, but whereas in the 1960s and the 1970s, the Latin American and East Asian countries were often grouped together as very fast growing NICs, in the 1980s a sharp contrast began to emerge: the East Asian countries' GNP grew at an average annual rate of about 8%, but in most Latin American countries, including Brazil, this fell to less than 2%, which meant in many cases falling per capita income

and concludes that

> there are of course many explanations for this stark contrast. Some of the Asian countries introduced more radical social changes, such as land reform and universal education than most Latin American countries and clearly a structural and technical transformation of this magnitude in this time was facilitated by these social changes. (Freeman, 1993a)

Table 3.3
Divergence in National Systems of Innovation in the 1980s

East Asia	Latin America
Expanding universal education with high participation in tertiary education and with high proportion of engineering graduates	Deteriorating educational system with proportionately lower output of engineers
Import of technology typically combined with local initiatives in technical change and, at later stages, rapidly rising levels of R&D	Much transfer of technology, especially from the United States, but weak enterprise-level R&D and little integration with technology transfer
Industrial R&D rises typically to >50% of all R&D	Industrial R&D typically remains at <25% of total R&D
Development of strong science-technology infrastructure and, at later stages, good linkage with industrial R&D	Weakening of science-technology infrastructure and poor linkages with industry
High levels of investment and major inflow of Japanese investment and technology with strong yen in 1980s; strong influence of Japanese models of management and networking organization	Decline in (mainly US) foreign investment and generally lower levels of investment; low level of international networking in technology
Heavy investment in advanced telecommunications infrastructure	Slow development of modern telecommunications
Strong and fast-growing electronic industries with high exports and extensive user feedback from international markets	Weak electronic industries and little learning by international marketing

Source: Freeman (1995)

In the case of Brazil and South Korea, it is possible to give more detailed quantitative indicators of some of these contrasting features. As Table 3.4 shows, the contrast in educational systems was very marked as was enterprise-level R&D, telecommunications infrastructure and the diffusion of new technologies.

Table 3.4
National Systems of Innovation: 1990s:
Some quantitative indicators

Various indicators of technical capability and national institutions	Brazil	South Korea
Percent of age group in third level (higher) education	11 (1985)	32 (1985)
Engineering students as percent of population	0.13 (1985)	0.54 (1989)
R&D as percent of R&D	0.7 (1987)	2.1 (1989)
Industry R&D as percent of total	30 (1988)	65 (1987)
Robots per million empl. (T)	52 (1987)	1,060 (1987)
CAD per million empl. (T)	422	1,437 (1986)
NCMT per million empl. (T)	2,298 (1987)	5,176 (1985)
Growth rate electronics	8% (1983-87)	21% (1985-90)
Telephone lines per 1000 (1989)	6	25
Per capita sales of telecommunications equipment (1989)	$10	$77
Patents (US) (1989)	36	159

Source: Freeman (1995)

National systems of innovation are evidently complex animals. From research already completed, it is evident that there is considerable diversity among systems. Whether this diversity is sufficient to explain differences in national economic performance is an empirical question, and the evidence so far accumulated is not conclusive, either way. But in nation after nation the policy emphasis is moving away from exclusive reliance on an elite knowledge-generating sector and devoting more attention to such qualitative factors as average educational attainment of the work force, opportunities for retraining and user-producer relationships. Again, the differences between nations appear to be greater than their similarities. All of this strengthens the importance of the national innovation system which must reflect the requirements of each particular country. Still, given their great diversity, the question remains: can a way be found to capture the essence of a particular national system in a way which allows realistic comparisons to be made?

One answer to this question has been provided by the work of Paul David and Dominique Foray in a study recently completed for the OECD. These, authors however, are critical of the national systems concept.

> *Neither the idea of learning as central to the activities of individual economic agents and organisations; nor the pertinence of the systems approach to analysing the determinants of innovation and adaptive capability, imply that the national economy should be the unit of analysis* [emphasis added]. To postulate that it is national systems that are the most meaningful entities for study would seem to imply an additional claim, namely, that there exists a higher degree of systemic integrity for those processes in which participation is limited on grounds of national affiliation, or where control is asserted by national governments. Now it is obvious that national governments do make policies and impose rules and regulations within their respective sovereign domains, and that influences the behaviour of individuals and organisations that operate there, and, further, that it is the nation states that must provide the wherewithal to enforce supranational agreements governing the activities of private corporations and individuals.
>
> Moreover, geography matters. *There is a significant spatial dimension to many kinds of learning activities which can substantially confine them within national boundaries.* Particular industrial agglomerations, located in one place, rather than in some other, create environments in which production experience can be accumulated, exchanged and preserved in the local workforce and entrepreneurial community. The ability to assimilate and transfer scientific and technological knowledge that is not completely codified, likewise, is greatly affected by the opportunities for direct personal contact among the parties involved. Informal and formal networks of association, linking scientists and engineers in private companies, and research workers in educational and public research institutions constitute important channels for the distribution of knowledge — supporting both application and further inquiry. And these social communication channels are in great measure shaped by commonalities in language, educational system, academic and business culture, all of which come under the participants' consciousness of their national identity, as well as legal constraints and incentives created by national governments. Beyond this is the institutional infrastructures that shape the functioning of the more formally organised and financed R&D activities (both private and public) is very immediately affected by national policy action; most of the science and technology policies decisions are taken by governments, while corporate strategies in science and technology are affected by a large range of government measures. Thus, it is important to keep the national government as a relevant actor in the analysis, and to recognize the systemic influences of factors that are co-determined within the boundaries of the nation state. (David and Foray, 1994)

Access to the Knowledge Base: Distribution Power

Despite this rather fundamental disagreement about the validity of the notion of a national system, this study still represents one of the most ambitious developments to date to bring some analytical and empirical clarity to the idea of the national systems. First, the authors have tried to make use of existing theoretical work on the classification of knowledge and to use this as the analytical basis to characterize national scientific and technological infrastructures in terms of their "distribution power" and "learning profiles." David and Foray are happier with the notion of profiles than with national systems because of the temptation to use existing national boundaries to define the system's limits to the possible exclusion of transnational networks which they argue are growing in importance as far as innovation is concerned where so many knowledge linkages seem to transcend national boundaries.

> Before proceeding further, it should be noted that although one of our main goals is to develop a framework within which comparative studies (using both quantitative and non-quantitative data) can be carried out on a national basis, and that this is a purpose that parallels the stated aim of Nelson in organising the set of national studies recently appearing in the volume entitled *National Systems of Innovation* (1992) under his editorship, the approach we have adopted is far less inclusive than the one Nelson proposes. However great the influence of long-run "performance" of modern business firms and economies we attribute to their command over knowledge about technical and scientific opportunities and constraints — and we accept the view that such knowledge is a critical factor in the capacity to remain competitive through successful innovation, the scope of the framework articulated here remains less comprehensive than would be required to accommodate Nelson's broad definition of "innovation" as "what is required if firms if they are to stay competitive" in industries where technological advance is significant." (David and Foray, 1994)

The David and Foray framework has a number of distinguishing features.

- It focuses on the effectiveness of private organizations and public institutions, and on the ways in which they *interact* in the production and distribution of knowledge.

- It focuses also on *learning* systems for scientific and technological knowledge, while accepting that the scope and forms of such knowledge are broad but varied enough to include both codified and highly abstract information and tacit knowledge of a very practical kind concerning methods of organizing and carrying out productive tasks.

- It uses a *systems-theoretic* approach in examining the relationship between a society's knowledge base and its capacity to generate and utilize economically beneficial innovations. This approach, furthermore, involves going beyond the enumeration and description of the ways in which a particular society satisfies each of those minimal requirements and examines the interconnections and interdependence among them. Seen from the level of the innovating firm, influences emanating from information about market conditions and technological opportunities flow over a multiplicity of linkages and feedback loops among the various activities that are not always clearly distinguished in the linear stage model.

- It discards the classical linear stage model in favour of articulating the interdependence and interactions among the sub-processes in the overall system governing the production, distribution and use of economically relevant knowledge. The process of scientific and technological advance, in this view, is seen within a general evolutionary framework to be a phenomenon of *organized complexity* that results in cumulative, irreversible, long-run change in which successive events are uncertain, highly contingent and difficult to forecast.

- It emphasizes, at levels of aggregation higher than the firm, features that affect systemic performance such as the feedbacks and interactions among advances in technology and science, the dynamic interdependence of innovation and diffusion processes mediated by markets, and the indirect impact of institutions and organizational arrangements designed to meet some functional requirement on the performance of other functions.

All this means that comparative studies should be careful not to treat implicitly national units of observation as if they were closed, independent systems, whose innovative "performance" could be related simply to their respective internal institutional structures and government policies. At the very least, it should be recognized that, to the extent that national systems of innovation can be identified, most will be embedded in (or entangled in) larger, more complex transnational relationships. Therefore, rather than analysing "national systems of innovation,"

> our goal is to identify and reveal national profiles in systems of learning and innovation based on scientific and technological knowledge: how do science and technology learning opportunities created by the industrial structure, the institutions, and the patterns of government and company expenditure that can be associated with a specific country — that is to say, its "profile" — appear in relationship to the profiles of other countries? Do various country characteristics, such as economic and geographical size, the prevailing per capita income and wealth levels, the degree of economic integration with the international economy, and the density of involvement in international political arrangements, have discernible influences on these profiles? Are there clusters that can be associated with certain policy orientations, or which can be explained in terms of similarities in historical experience and consciously mimetic behaviour across national boundaries? (David and Foray, 1994)

Although systems, on the one hand, and national policy infrastructures, on the other, are important elements of this approach to science and technology learning, David and Foray are hesitant

> about automatically coupling the two and speaking about "national systems" — thereby tending to de-emphasise if not obscure from view the significance of other sub-national and supra-national systems whose workings may also be no less critical in shaping technological opportunities and the way the latter are exploited. Several reasons may be cited for our resistance to accepting "national innovation systems" (or systems of innovation) as the appropriate term of art to employ in describing the subject with which we are dealing. (David and Foray, 1994)

They take this stance for four reasons.

- It is evident that much activity in science and technology is organized and conducted internationally; many key elements of institutional infrastructure are transnational in their sphere of operations, so it is a distortion to confine the analysis strictly within national boundaries.

- It is apparent that it would be equally misleading to suppose that everywhere within those boundaries the educational infrastructures, research facilities, and formal and informal communication networks are homogeneous in their ability to support industrial innovation activities.

- Corporate entities that co-ordinate economic activities which involve learning in the sphere of science and technology, increasingly, have become multinational in their nature — even if they find it advantageous to appear in the role of "local" or "regional" enterprises in many different nations simultaneously.

- Furthermore, complementarities and linkage effects among nations represent a great issue in the explanation of the emergence and development of different systems of learning in science and technology — national policies and their impact on economic performance need to be interpreted, and the effectiveness assessed in the context of international interdependencies.

Distribution-oriented innovation systems

In developing the idea of learning profiles, the key organizing concept is the "distribution power" of an innovation system, which means its capability to ensure timely access by innovators to the relevant stocks of knowledge. The report identifies the characteristics of a distribution-oriented system, as well as the specific capabilities in the adjacent domains of education and training, financing and industrial organization (Japan is taken as an example). Furthermore, the authors argue that a distribution-oriented system is not a transitory state, designed to meet the innovation requirements of a technological borrower committed to a strategy of "catching-up." It is an organizational mode of innovation that is able to support the various steps of the process of technological advance.

What is a distribution-oriented system?

The identification of the characteristics of a distribution-oriented system requires three kinds of questions.

- What kinds of capabilities in the domains of training and education, finance and industrial production are required for such a system?

- Since such a system is likely to facilitate the generation of a certain category of innovation (incremental innovation, redesign, recombination), can these systems be considered essentially as a transitional state, designed to meet the innovation requirement of a technological follower committed to a strategy of catching up?

- Does the co-existence of a small number of distribution-oriented systems with high distribution power and a large number of systems characterized by a weak distribution power introduce some important distortions in the global economy?

Characteristics of distribution-oriented systems

David and Foray take a distribution-oriented system to be one whose institutions, incentive mechanisms and co-ordination arrangements have these four proximate objectives.

- To encourage innovative agents to enter into co-operative games, based on the reciprocal and successive production and exploitation of complementary additions to the stock of knowledge.

- To reduce the problems of institutional incompatibility.

- To enlarge the space of the search for information to increase the potential area of knowledge exploitation.

- To increase the relative importance of codified knowledge.

In a distribution-oriented system, the proportion of public and private knowledge that is disclosed should strongly increase in relation to restricted-access knowledge. The principal problem — if we follow the line of thought of H. Simon — resides in the storage of information and its accessibility: "designing organisations for an information rich world." To operate in such an environment, entities must make substantial investments in skills, interfaces and research tools

(Steinmuller, 1992). Although financial markets have not developed instruments to support these intangible modes of capital formation, to a greater degree than ever before, these investments and capacities are the source of enterprises' competitive advantage.

The Elements of a Possible Model

Five blocks of useful indicators are identified with which to assess distribution power of a system of innovation. These are outlined below but a fuller statement of what they include is given in the associated Technology and Economy Project (TEP) fact sheets which can be found in Appendix 1.

Block 1: proportion of knowledge ready-for-distribution

Mechanisms supporting the expression of knowledge in "forms facilitating distribution" include:

- Knowledge-products which take codified forms, such as scientific publications (e.g., TEP Fact Sheet 4). It is desirable to estimate a ratio: number of publications to research expenditures in scientific institutions (e.g., National Science Foundation Science Indicators) as a measure of the recourse of academic researchers to publication.

- Knowledge products which take codified forms through intellectual property rights, such as patents, copyrights, utility models (TEP Fact Sheet 2). It is desirable to estimate a ratio linking the importance of patenting activities to the importance of trade secrecy, as alternative appropriation strategies (e.g., innovation surveys).

- Knowledge products embodied in prototypes, software, instrumentation and research tools, and high-tech products (TEP Fact Sheet 5).

- Indicators of intensity of codification (production of expert systems, engineering publications, etc.).

Block 2: critical domains

Critical domains of distribution include various indicators.

- Indicators of patenting activities of universities:
    - bridging and transfer institutions (including mixed laboratories, mixed research position, framework agreements, agencies and organizations to support information exchanges
    - importance of spin-offs

- Indicators of absorptive capacities of the firms:
    - in-house R&D
    - acquisition of science-based firms by domestic companies
    - trends in scientific and research employment in firms
    - technology licensing and transfer activities
    - importance of co-operation for sharing knowledge (dynamics of research networks — inside and outside the firm)
    - mobility of scientists and researchers towards firms.

- The role of the public sector in knowledge distribution:
    - indicators of technology policy — resources allocated to programs explicitly oriented toward diffusion at both national and regional levels
    - indicators of dual development, such as mixed laboratories, co-publications and dual use of large scale instruments
    - importance of large technological programs, including universities, public agencies and large firms.

Block 3: transfer mechanisms

Transfer mechanisms (market and non-market) include:

- Capabilities of market transaction (synthesis of indicators of Block 2, dealing with market knowledge transactions).

- Capabilities of non-market transactions (synthesis of indicators of Block 2 , dealing with non-market knowledge transactions).

Block 4: connection indicators

Connection indicators used to assess distribution power include:

- Patents, publications — indicators of co-citations (e.g., data from EPRO-CESPRI).
- Coherence between scientific and technological specialization profiles (e.g., the data compiled by Archibugi and Pianta).
- Indicators of inter-sectoral connections for convergent technologies (e.g., data compiled by Kodama).
- Indicators of technological diffusion (diffusion rate of new products and processes).

Block 5: performances

The purpose of the performances category of indicators is to depict a given country's propensity to innovate and its dominant procedures for seeking novelty. Relevant indicators could include:

- Number and type of innovations (new products for the firms and the markets); new products for the firm but already existing on the market; major development of an existing product for new markets; major development of an existing product for existing markets).
- Innovation intensity (the fraction of sales corresponding to recently introduced innovative products).
- Technological competitiveness.
- Position of the system in international knowledge flows:
    - technology balance of payments (TEP Fact Sheet 3)
    - acquisition of foreign science-based firms and sale of science-based firms to foreign companies
    - international migration of scientific research personnel.

The core of indicators dealing with distribution power of the system is related to the characterizations of training and educational capabilities, financial structures and industrial manufacturing capabilities. The general model of this process could be represented as suggested in Figure 3.1.

Figure 3.1
Overall indicator framework

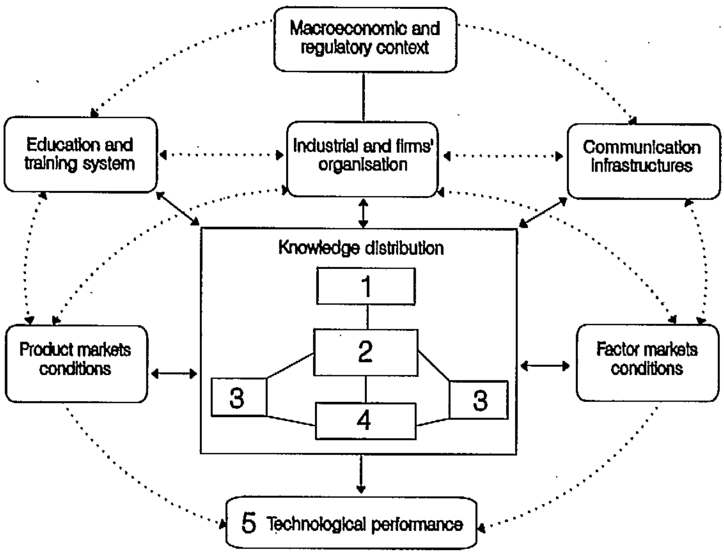
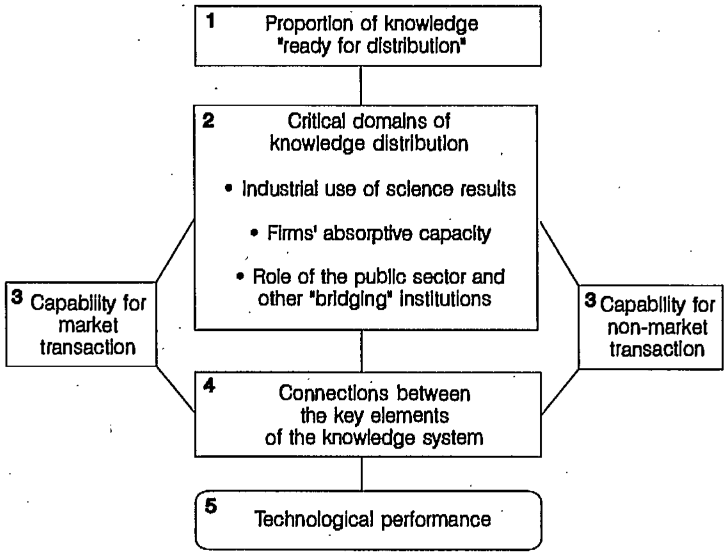


Figure 3.2 represents an agenda which allows a given country to have a better picture of its own and other nation's status in this regard and, symmetrically, of the magnitude of the losses of innovative potential due to the limitations of its knowledge distribution and knowledge-pooling capabilities. It is relatively easy to fill up Block 2 and thus to have a better picture of the performance of the system regarding the distribution of knowledge. Some strengths are revealed (e.g., the industrial transferability of scientific knowledge in the case of the United States, the role of public sectors for France, the absorptive capacities of the firms and the role of public sectors in Japan, a combination of the three factors for the Nordic countries and Germany, etc.). From this point on, however, the compilation of data toward a more complete learning profile requires more careful analytical work if

the necessary syntheses are to be useful. So, one must move with subtlety through the subsequent stages of this process.

Figure 3.2
Indicators of the distribution power of a national innovation system



General transferability capabilities (market and non-market) can be derived from Block 2 by summation and aggregation, and are synthesized in Block 3. These capabilities are then expressed in terms of "indexes of distribution power" in Block 4 and can be related to general performances of the system in Block 5. The most difficult task is to fill up Block 1: that is, to quantify the stock of knowledge "ready for distribution."

PART II
SUMMARY

Part II is devoted to identifying some of the leading-edge work in four areas identified by TEP as needing further study: national systems for financing innovation, technology and employment, technology and globalization, and developments in science and technology indicators.

National Systems for Financing Innovation

The discussion of national systems of innovation has been adjusted to the shift toward a knowledge economy that, by common agreement, seems to be taking place throughout the Organization for Economic Co-operation and Development (OECD). So far, research has concentrated on the interaction of technology and institutions, the knowledge-generating sector with the various other institutions which support knowledge generation. That financial institutions form a crucial element in national systems of innovations has been implicitly assumed. Yet, if firms have to transform themselves continually to accommodate the new technologies, it is reasonable to inquire whether the system of financial institutions that provides investment has had to make similar, parallel adjustments. A recent report produced by the OECD attempts to engage this important, but relatively unexplored, area. Specifically, it addressed a number of questions which were believed to be of interest to the member countries.

Technology and Employment

The OECD Technology and Economy Project (TEP) was understandably perplexed by the persistence of high rates of unemployment among OECD member countries and sought to identify the sources of these rates. Conventional economics tells us that, historically, high output-growth, high employment and high productivity-growth tend to go together because diffusion depends on high incomes to fund consumption. It was natural, then, to look to demand growth to raise employment. The principal means for doing *this is through innovation — or by using new technologies — but somehow employment levels have failed to respond; this is the Solow Paradox. Much of TEP was given over to trying to understand this paradox and formulate policies to ameliorate its effects. Conventional economics is of little help, because under its theory there is no reason why raising growth rates should not also lead to increasing employment. Under conventional theory, all that is required is to increase physical investment. From such investment the rest should follow. The tables presented in this section support the principal conclusions of the various studies quoted. They also provide an idea of the range of data which needs to be assembled to support the notion that patterns of work are shifting from employment to jobs.*

Technology and Globalization

Since TEP, globalization has gone into retreat, perhaps because it is not clear exactly what it denotes. Nonetheless, the problems with which it was originally associated — particularly the fear of a countervailing techno-nationalism among the Triad (the United States, the European Community and Japan), exclusion of developing economies, etc. — remain. To counter these fears, TEP concluded its analysis by recommending a raft of policies aimed at promoting international scientific and technological co-operation, particularly the sharing of information freely in large basic science projects. There follows a brief review of the relevant literature and a discussion of the novel approach to the globalization issues developed by Coriat (1993), and Coriat and Dosi (1994).

Developments in S&T Indicators

TEP was also driven to consider the extent to which any of the problems raised could be better dealt with through the provision of better S&T indicators. The principal need was for more and better output indicators, both for science and technology and for innovative performance. Consideration needs to be given to a new source of S&T indicators. This work, which is being co-ordinated by the Maastricht Economic Research Institute on Innovation and Technology (MERIT) in Maastricht, represents an attempt to create a nest of S&T indicators to parallel, for Europe, what is being done by the National Science

Foundation (NSF) for the United States. The first report is just available but has not been distributed widely yet.

No attempt has been made to synthesize the ideas presented in this section. Rather, they are intended to inform the policy analysts about some of the current research, particularly that being done by the various committees of the OECD where TEP is now being followed up. Much of this research is in its early stages but it can still be useful to those trying to formulate science and technology policy.

4. NATIONAL SYSTEMS FOR FINANCING INNOVATION

As indicated already, the discussion of national systems of innovation has been adjusted to the shift toward a knowledge economy that, by common agreement, seems to be taking place throughout the Organization for Economic Co-operation and Development (OECD). So far, research has concentrated on the interaction of technology and institutions, that is, the interaction of the knowledge-generating sector with the various other institutions which support knowledge generation. It has been implicitly assumed that financial institutions form a crucial element in national systems of innovations. Yet, if firms have to transform themselves continually to accommodate the new technologies, it is reasonable to inquire whether the system of financial institutions that provides investment has had to make similar, parallel adjustments. A recent report produced by the OECD attempts to engage this important, but relatively unexplored, area. Specifically, it addressed a number of questions which were believed to be of interest to the member countries. The questions relate to three areas.

- The effects of financial deregulation on innovation: specifically, are there national evaluations of costs/benefits of financial deregulation? Is there a risk of chronic under-investment in innovative activities? If yes, has it become worse over the last decade? How do we interpret the deceleration of expenditure growth in research and development recorded in many countries in the second half of the 1980s?

- The role of finance in technological competitiveness: specifically, do international differentials in the cost of capital remain an important factor? What other factors are gaining importance as a result of the financial revolution? What role should be assigned to corporate governance?

- Start-up finance for innovating firms and the financing of innovation in small- and medium-sized enterprises (SMEs): specifically, have the conditions of this private-sector finance deteriorated? What judgment should be made on trends in venture capital over the last decade? What are the consequences for the orientation and instruments of government support?

The report attempts to answer these questions, among others, but not before trying to present an analytical framework within which differences in financial systems can be highlighted. This is a complex and difficult task, because there are as many financial systems for supporting innovation as there are countries — the importance of diversity again. Yet, if particular national experience is to be available to others, it will need to be guided by some sort of analytical perspective, and this is what this research is trying to provide.

The report addresses three fundamental questions.

- How do financial systems support innovation efforts?
- Does their efficacy depend on the type of national financial mechanisms that are available?
- Has this efficacy been increased by the recent deregulation/globalization of financial markets?

An attempt is made to lay the basis for a comparative study of the links between innovation and financial systems. This is made necessary by the general shift toward knowledge and innovation which has characterized the development of so many advanced industrialized countries. The key question is to find a way to determine whether the structural changes that are taking place at the heart of innovation are matched by changes in national financial systems. The approach is primarily analytical with a view to providing a base for future comparative research.

The general approach can be summarized by nine propositions.

- Innovation is not a specialized *economic* activity but is, nonetheless, the mainspring of economic development.
- To innovate means to invest. Much research on innovation is undertaken without much attention to the role of investment.
- The content of innovation-related investment and the uncertainties brought about by its deployment create specific

financing problems.

- These problems cannot be usefully analysed in isolation from more general problems about the reconciliation of specific financial and industrial arrangements.

- This reconciliation takes different forms in different countries.

- The resulting national financing systems (including the role of government finance) have strong specificities corresponding to particular technological specializations.

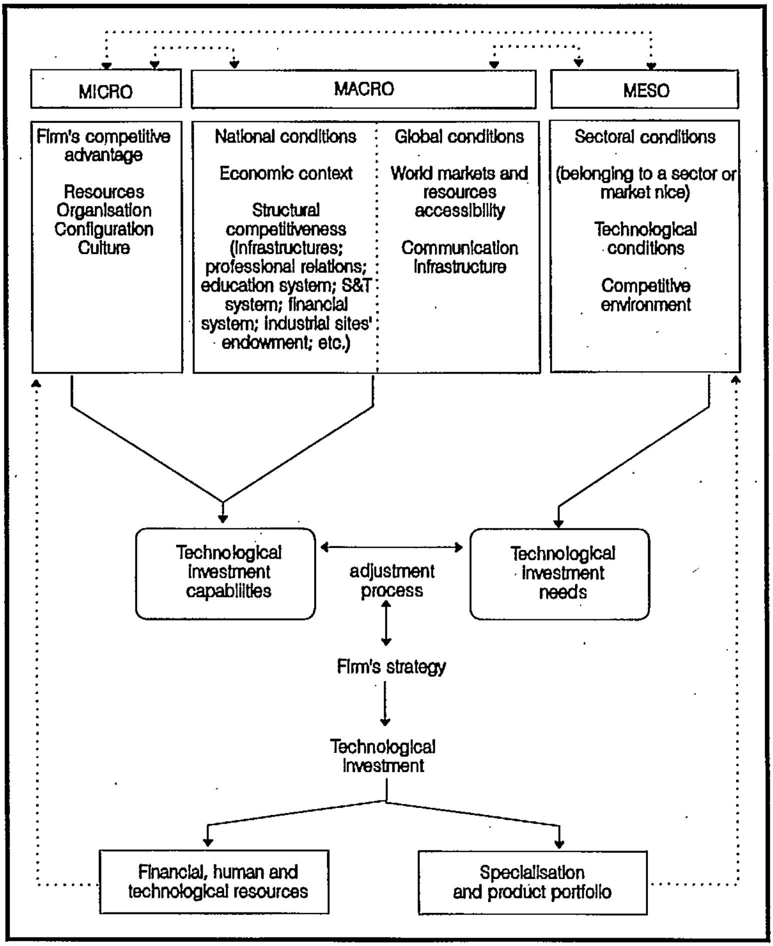
- The deregulation and globalization of financial markets facilitate the financing of some types of investment but tend to destabilize national financial systems by not automatically steering them toward the most urgent tasks for structural adjustment.

- In the absence of an adaptation, there is the risk that a failure of the systems will be added to that of markets to create a chronic insufficiency in technology investment.

- This insufficiency concerns the global level of investment and its content (e.g., material vs. immaterial), its orientation (e.g., process vs. product innovation) and its distribution (e.g., SMEs vs. large firms).

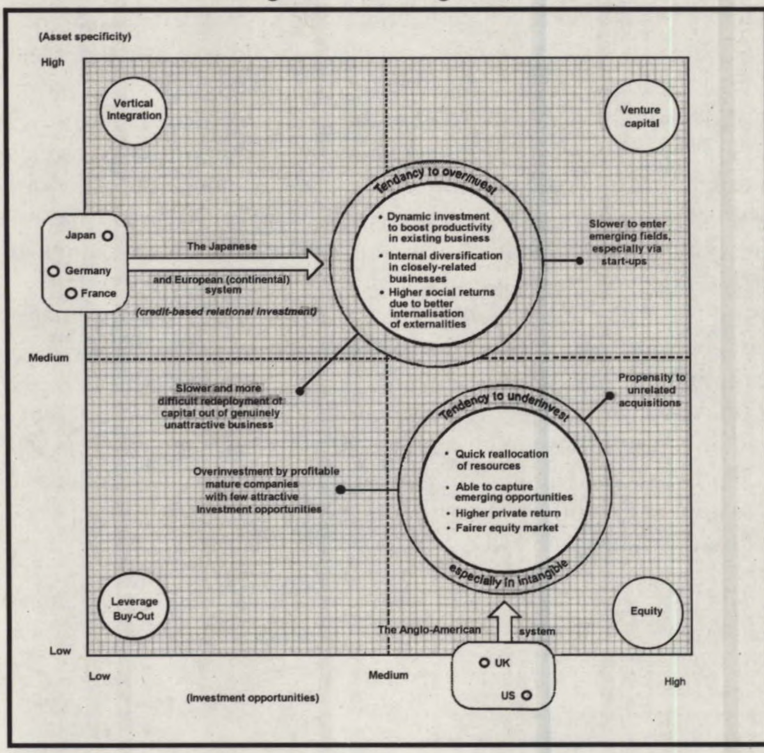
The basic idea in the analysis is to present trends in innovation-led investment needs and link them to competitive conditions. It offers a definition of "technology investment" which, though quite complicated, at least contains the most important elements. The notion is that investment in innovation is not simply "investment." Rather, such investment has a structure which needs to be articulated, particularly if the long-term aim is to carry out comparative research. The basic elements of the definition present technological investment as an adjustment process that is taking place continuously among the firm's strategy, technological investment capabilities and technological investment needs. Of course not all of these "negotiations" take place within the firms, but typically involve other actors, banks, governments and so forth (see Chart 4.1). This definition highlights gaps in knowledge of innovation-related investment needs, since it requires a reciprocity of perspectives (between production and financial economics) which current statistical categories do not highlight sufficiently.

Chart 4.1
The dynamics of technological investment



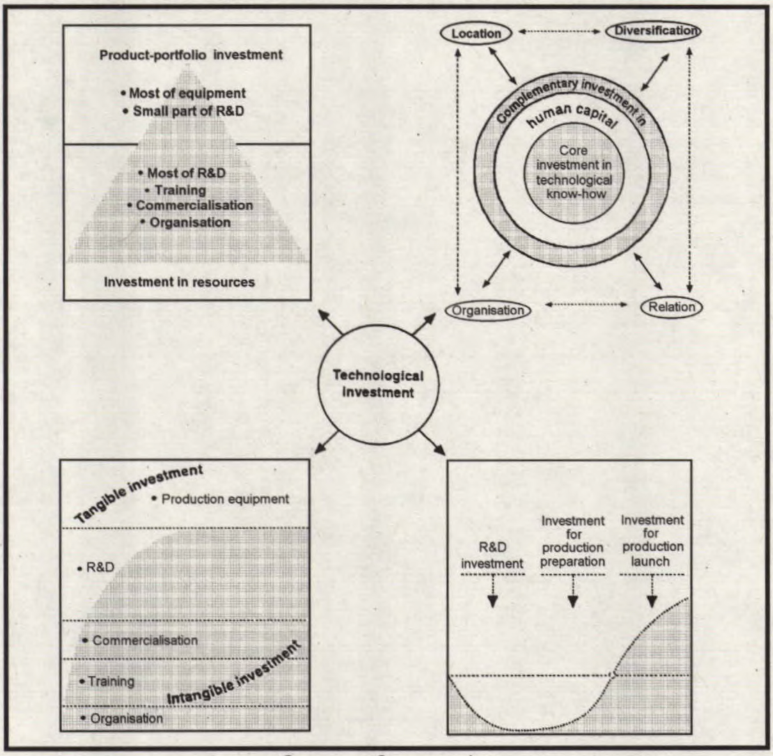
As with the notion of national systems of innovation, there are equally difficult questions of definition and delimitation in respect of the financial system. The main burden of the analytical work is aimed at defining the notion of a national financing system. The research shows that such systems remain analytically valid and useful despite the transformations that have taken place in the financial scene over the last decade. From the definition, the analysis proceeds to study the impact of these transformations on financing conditions (e.g., reduction in international differences in the cost of capital), investor behaviour (e.g., greater liquidity and yield requirements from financial investors) and the content of investment (e.g., the greater relative difficulties in financing the creation of non-negotiable assets). This very complex situation is summarized in Chart 4.2, which positions various financial systems according to their asset specificity and investment opportunities. A key conclusion that emerges from the analysis — and it is currently a popular belief — is that "the UK and the US operate with financing systems which tend to under-invest in innovation particularly in the creation of intangible assets. By contrast Japan and Europe appear to work within systems that have a tendency to over-invest in innovation." (OECD, 1992)

Chart 4.2
Areas of dominance by various financial systems (governance regimes)



Given what has been said about the convergence in appreciative theorizing of the innovation, management and organizational literature, the idea of "technological investment" developed here highlights the importance of identifying clearly the perspective from which investment is being considered. Four distinct perspectives are presented for consideration: management theory, function, physical content and product cycle. The results are presented graphically in Chart 4.3.

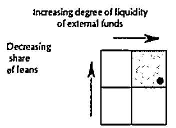
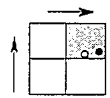
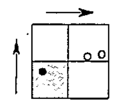
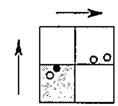
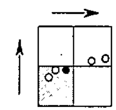
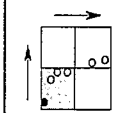
Chart 4.3
Four different perspectives on technological investment



Source: Secretariat

The analysis further shows that market imperfections in financing innovation are more important than generally thought and that, in spite of the improved efficiency of resource allocation mechanisms coming from liberalization or deregulation in the 1980s, some — particularly those arising from imperfect appropriability of innovation profits — have increased. The requirements to meet these imperfections vary according to system and national characteristics, especially the form of industrial organization and the type of financial system. A typology based on credit- and market-based national financing systems is suggested together with several variants of each. This is summarized in Chart 4.4 which exhibits differences. The typology reveals a much more complicated set of parameters than is usually dealt with when trying to compare national financial systems in terms of their propensities to provide "patient" money, venture capital or support for small firms.

Chart 4.4
National financial systems - A simplified typology

Major groupings		Market-based systems		Credit-based systems			*(Pro memoria)*
Sub-groupings		Weakly mediated	Strongly mediated	Global contractual governance	Participatory governance	Bank-centered governance	*Relational banking*
Representative country		United States	United Kingdom (Australia - see appendix)	Japan	Germany	France (Sweden)	*Many developing c.*
Industry financing patterns	Debt /equity ratio	Relatively low		Relatively high			*Very high*
	Major financing instruments	Retained earnings and, to a lesser extent, bonds and new equity issues		Loans and retained earnings			*Loans*
	Nature of external financing						
Price mechanisms of capital allocation		Market processes (including speculation) determine key prices		Markets are imperfectly cleared by prices Traditionally, government exercises significant influence on key prices and restores market balance through credit rationing; but this influence is continuously decreasing	The market power of major financial institutions gives them a significant influence on prices	Traditionally, government exercises significant influence on key prices and restores market balance through credit rationing; but this influence is continuously decreasing	*Price mechanisms are weak*
Ownership patterns	Number of listed companies	Large (1.16 per billion $ of GDP)	Very large (1.84 per billion of GDP)	Relatively small (0.61 per billion of GDP)	Small (0.39 per billion of GDP)	Relatively small (0.68(0.53) per billion of GDP)	*Very small*
	Dominant shareholders	Households	Non-bank financial institutions	Financial institutions and industrial firms	Industrial firms and banks	Financial institutions and industrial firms	*Financial institutions and individuals*
	Concentration of ownership	Very low	Medium	Medium	High	High	*Very high*
	Stability of ownership	Low	Relatively low	High	Very high	High	*Very high*
	Extent of cross-shareholding	Low		Large	Medium	Medium	*Low*
	Foreign ownership	Low but rapidly increasing	Significant	Very low	Significant	Significant	*High*
Patterns of monitoring	Main financial actors	Anonymous participants in the financial markets	Large non-bank financial institutions	Main banks	Universal banks	Universal and specialised investment banks	*Banks*
	Type of linkage	Unidimensional Separation of ownership from control (monitor role is given only to shareholders, which however may lack both incentives and capabilities to exercise it)		Multidimensional with main bank, as lender and shareholder, at the epicenter of the multi-layer network of factor providers (government may be an active or sleeping partner)	Multidimensional (universal bank plays a key role through both control of large share of voting stock and lender's influence)	Multidimensional in the case of universal bank and unidimensional in the case of specialised investment bank (through equity)	*Unidimensional through equity*

	Basic monitoring principle		Direct outsider control by exit based on standardised criteria	Outsider control by exit (mediated by financial institutions) based on standardised criteria	Insider control by voice			*Reverse control*
	Mode of control	Type	Dispersed among specialised institutions		Exchange-centered with contingent strong bank influence	Bank-centered and participatory	Bank-centered	*Private owners-centered*
		ex ante	Investment banks, venture capitalists, underwriters, etc.		At each stage, focus on supporting efficient exchange of information between participants into the network At *interim* and *ex post* stages, the control is shifted from management to bank only in case of financial difficulties.	The controlling power of the bank is counterbalanced by the presence of employees representatives on supervisory board	Active monitoring by specialised investment banks Looser involvement of universal banks	*Banks are often owned by industriafists Risk diversification is very fimited*
		interim	Security analysts, rating institutions, market arbitrageurs, etc.					
		ex post	Boards, take-over raiders, LBO associates, etc.					
Built-in capability to cope with	Acute adjustment problems		Leverage Buy-out (LBO) Bankruptcy procedures (Chapter 11) government-led bail-out, but difficult to implement	Same market instruments but less developed Stronger tradition and institutional capabilities for government intervention	Main bank-led restructuring Well-proven procedures for activating governments role within the network to which belong the troubled firms	Universal bank-led, but co-determined (employees' voice) restructuring Govemment support in extreme cases	Bank-led restructuring Strong tradition of government intervention	
	High risk and uncertainty		Venture capital and other creative financial instruments Large (defence-related activities) to medium-scale government support	Less developed venture capital Large (defence-related activities) to medium-scale government support	Intra-preneurship within the network. Rapid development of creative financial instruments Medium-scale government support	Banks consortia Diversification of large banks towards support to SMEs' creation and development Bank-supported intra-preneurship in large firms Medium-scale government support	Banks consortia Government entrepreneurship and large scale support	
Emerging trends			Globalisation and deregulation of financial markets promote international convergence in financing patterns					
			In the 80s, increase in the debt to equity ratio reflecting a decrease in the relative cost of debt In the 90s, institutionalisation of stockholdings (increase in the share of stocks held by pension and mutual funds), and return to more active monitoring by some financial intermediaries, especially pension funds		Diversification and internationalisation of available financial instruments Decrease of debt to equity ratio in large firms which make greater use of securities as financing instruments	Decreased dependency of large firms on universal banks' loans through increase in self-financing Correlative diversification of large banks' loans	Steady growth of the financial market Continuous decline in State ownership and influence on capital allocation	
Some critical issues			Short-termism Problematic financing of intangibles, especially human capital Venture capital market shows signs of decline Mixed record of Mergers & Acquisitions as a way to discipline usage of capital, especially when one considers their effect on R&D activities		Deficiency in disciplining the usage of free cash flow – a fairly new problem in Japan – (to prevent it from being invested in projects with negative return) The efficiency of the dominant corporate governance system is debatable in certain types of activity (e.g. biotechnology; software) where seizing technological and commercial opportunities calls for more flexible organisational modes	The dominant corporate governance system is weakened by the tendency for large firms to drift away from bank-financing and by the turbulences that the reunification creates on the labour market, which make codetermination more difficult. Diversification of large banks towards small firms calls for a problematic adaptation of their assessment and monitoring procedures.	State retreat from traditional areas of financial intervention has been a continuous but not always a smooth process. The French financial system, including government support, is still generally discriminating against small firms Lack of venture capital or good substitutes	

The central analytical task, then, is to find a way to draw together these empirical characteristics of different financial systems so that comparative analysis can be made. In this study, the burden of this is borne by the concept of *risk management as the core of a financial system*. The basic idea is to distinguish various functional uses of investment according to whether they are intended to support resource use, creation or allocation, or to monitor resources. Chart 4.5 illustrates these elements but as the authors caution, the diagram "has no other ambition than to provoke thought." As can be seen from Chart 4.5, the whole diagram converges on a single point, symbolizing the notion that *risk management, more than being merely an important task, is indeed a financial-systems core-role in the economy*. Therefore, a financial system may be described as a combination of forms of capital investment in industry and of industrial risk-evaluation and risk-assumption procedures. Chart 4.6 shows how industrial risks percolate down through the institutional/procedural network and are transmitted into financial risks when they are assumed by the suppliers of capital. It is a hard chart to work with, but it is worthwhile to try to work out one or two examples because this will flesh out the concept of risk management that the authors are using.

Chart 4.5
Managing risks as the core function of a financial system

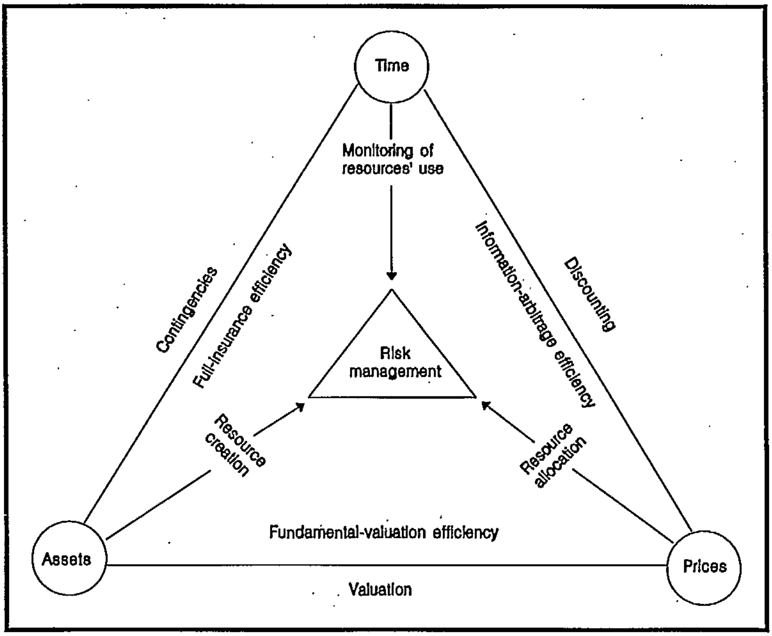
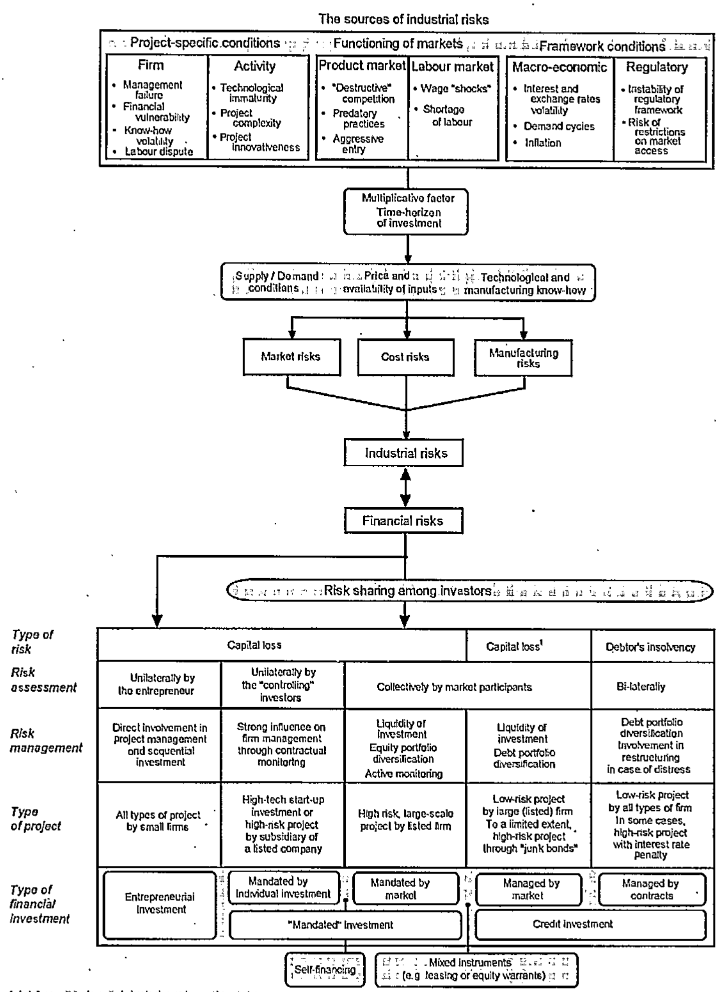


Chart 4.6
The financial management of industrial risks



1. Including sensitivity of securities' prices to changes in current interest rates.

Source: Secretariat on the basis of an analysis by R. Gonenc – see in the Annex.

The exploration of the links between financial systems and technology specialization are of special importance when considering key relationships between technology and the economy. Unfortunately, this research has not yet reached the stage where its contribution in this regard can be evaluated. Nonetheless, there is some plausible evidence which shows that when a country under-performs when compared with the average in a particular sector, this under-performance is reflected in patenting performance in that sector. This set of indicators needs to be explored further.

Further analyses intend, first, to examine the efficiency of specialized channels of finance in innovative projects (e.g., risk capital and public support) to take account of the overall characteristics of the financial system of which they are a part. Each type of financial system has its strengths and weaknesses and, thus, takes part in the creation of national competitive advantages by influencing the innovation strategies of firms. Second, the extent to which national financial systems have modified the rules of the game, and thereby imposed an imperative to adapt on national finance systems, need to be clarified further.

Although this report is not yet fully completed, it represents a bold attempt to bring the extreme diversity of national systems of finance under a common analytical framework. Some of the concepts are still rather abstract, but they are in a form that invites their integration with the other projects being pursued within the OECD, which are attempting to characterize more fully the notion of national systems of innovation.

5. TECHNOLOGY AND EMPLOYMENT

In the innovation process, most of the knowledge acquired or generated is not codified knowledge but is obtained by contact with people in problem-solving situations, whether inside the firm or in networks. This knowledge remains with them as personal skills or as tacit knowledge, or becomes bound to the organization though its routines and management practices. The Organization for Economic Co-operation and Development, Technology and Economy Project (OECD/TEP) certainly picked up on the idea of human resources — in terms of skills and competences — and stressed the relative importance of intangible investment — in research and development (R&D), in average levels of educational attainment and through career training — to innovation and competitiveness compared to physical investment.

The OECD/TEP was understandably perplexed by the persistence of high rates of unemployment among OECD member countries and sought to identify its sources. Conventional economics tells us that, historically, high output-growth, high employment and high productivity-growth tend to go together because diffusion depends on high incomes to fund consumption. It was natural, then, to look to demand growth to raise employment. The principal means for doing this is through innovation — or by using new technologies — but somehow employment levels have failed to respond; this is the Solow Paradox. No small part of TEP was given over to trying to understand this paradox and formulate policies to ameliorate its effects. Conventional economics seems of little help because of the belief that raising growth rates should also lead to increasing employment. Under conventional theory all that is required is to increase physical investment; from such investment the rest should follow.

However, if technical advance is generated endogenously by firms, albeit conditioned by other institutional factors, as TEP argued, then the ability of firms to absorb investment — which usually means having to acquire new technology — is strictly limited by their skill levels as well as by management competencies and organizational routines. As we have seen, the lack of appropriate skills and competencies slows diffusion, particularly of the most advanced technologies, as do some institutional factors. In the most advanced countries, this leads initially to the failure of demand to grow and finally to the persistence of high rates of unemployment.

This leads on to the notion that the "absorptive capacity" of firms or of institutions generally depends on the skills and competencies of its employees. In general, low levels of skill mean low absorptive capacity, but this can also mean inappropriate kinds of skills no matter what their quality. Low absorptive capacity leads to low rates of diffusion. Together, these contribute to the notion of institutional "drag," that is, the idea that the rate of institutional change — management and organizational innovation — is too low and, therefore, firms systematically fail to take full advantage of the potential of the new technologies. But the diffusion of radical innovation takes time. The hypothesis is that while the necessary institutional changes are taking place, demand by itself is powerless to decrease unemployment. Many mature industries are forced by increasing competition to reduce costs and when technological change is slow, or in some cases static, the only thing to do is to make efficiency savings by reducing labour. Conversely, when radical innovations are undermining traditional ways of doing things, the demand for new jobs is not yet present. This seems to be our current predicament. It is a particularly severe lack of accommodation between technology and institutions, and is a source of a particularly stubborn kind of unemployment — usually called structural unemployment — which does not respond in the normal way to conventional economic stimuli.

In following the main developments of appreciative theory, we are led to view economic growth in terms of relationships of accommodation between technology and institutions, including, of course, firms as the key generators of new technology. Within this framework, there is ample scope to explore the much-vexed question of why growth rates differ as well as to throw some light on the convergence/divergence controversy in formal economics.

Relationships of accommodation are unproblematic when one is dealing with incremental innovation. In this case, changes in skill requirements, organizational change and management practice might be expected to evolve together — they co-evolve in the sense of Nelson — and adjustments can be made at the margins (Nelson, 1994). There is little disruption because the basic, underlying techno-economic framework remains fundamentally unaltered. However, there can be times when the underlying framework itself starts to creak. The institutions that originally supported techno-economic advance seem no longer to work. They appear unable to adapt to new sets of requirements. Signs that things may be going wrong are evident in slowing output growth, sluggish productivity despite a lot of innovation (Solow Paradox) and, of course, high and persistent unemployment.

According to the "institutional" school, the particular lack of accommodation which we are currently experiencing is the result of the emergence, evolution and diffusion, albeit slowly, of the new information and communication technologies (ICTs). These technologies are pervasive in that they affect many industries, but are also transformative in that their implementation requires different forms of skills, organization and management, and different types of regulatory and other support institutions from those which currently exist. They require a different form of "common sense." (Perez, 1983)

Much of the debate on the future of employment has turned on perceptions of the nature and extent of the transformations being induced by ICTs. In economic terms, these perceptions depend on whether one operates from within a neoclassical framework or a neo-Schumpeterian one. In the former, explanation of employment levels is in terms of the operation (or the failure to operate) of various compensating mechanisms within a homogeneous labour market. In the latter, the explanation is in terms of a new techno-economic paradigm which underlies the emergence of a "learning" or "knowledge" economy.

This dichotomy was already evident in the discussions that took place in TEP. Since then, the whole question of the relationship between technology and employment has been reviewed again (OECD, 1994b). But the key empirical question would seem to be to establish the nature and extent of the diffusion of ICTs because these technologies are generic in the sense that they affect many industries.

One of the fundamental question facing all countries, but particularly the OECD, is whether or not persistent unemployment is due to such large scale structural change and, more precisely, whether it is due to the emergence of a new techno-economic paradigm based on radical innovations in information and communication technologies. To a large extent this is an empirical question, though scenario arguments — optimistic or pessimistic — about it continue to be produced often, independent of evidence and despite the fact that at least some of the relevant data is available. It is important to try to answer this question not only because the effects of "dis-accommodation" are often painful and "re-accommodation" is a slow process. It is also important because the diffusion of radical innovation requires different policies from those aimed at incremental innovation.

We consider three studies which throw some light on the nature of ICT and its relationship to changing patterns of employment. In the first we present a review of recent work on technology and employment done, post-TEP, by the OECD itself.

The OECD Review of Technology and Employment

The principal conclusions of this analysis are listed.

- In periods of economic slowdown, when mounting unemployment coincides with the development of pervasive new technologies, there has always been a temptation to see a major source of unemployment in technological change. But, historically, in the industrialized world, rising levels of output have gone hand in hand with rising employment levels and productivity whose growth is largely attributable to technological change. Although true in the long term, it must not overshadow current concerns about the possible impact on employment in the short run and especially on particular sectors, occupations and regions.

- Whether in the context of closed or open economies, the development and efficient diffusion of new product and process technologies is a necessary condition for structural adaptation to new patterns of demand, adjustment in the labour force and job creation, and thus the key to rising standards of living. Empirical analyses based on cross-country comparisons tend to confirm the fact that the employment record has been better in those countries with the best performance in relation to structural change, technological specialization, investment rates and productivity gains.

- While technological change is an enabling factor in economic growth, it does not determine, of itself, growth and employment paths. Rather, the employment impact of the introduction and adoption of new technologies will depend to a large extent on the strength of demand and the growth rates of the economy. The necessary structural adaptations will be much easier in an environment of growth, while a depressed macro-economic environment is bound to accentuate the "job-destruction" aspects of new technology.

- The employment displacement effects, which virtually all studies identify, agree that unless a country's labour force has the mobility and skills to move from the jobs eliminated to those created, there could be a serious mismatch between labour demand and supply, and a resulting state of high, unmet demand in some areas and occupations but unemployment at the aggregate level.

- Information technologies (ITs) have great potential for employment generation. But they have distinct specificities not only in their pervasiveness, but also in that their efficient implementation often calls for substantial changes in work organization and skill requirements: capital investment required for their introduction must be complemented by intangible investment in research and development, training and organizational changes.

- Because of these characteristics, ITs increase the potential for economic growth and productivity gains at the same time as they broaden the mismatches between labour demand and supply in terms of skills and qualifications. These factors probably explain to a large extent why, except in some service activities such as finance and insurance, and of course in industries involved in the production of information-related equipment and services, the employment potential of IT has so far been realized only to a limited degree.

- *Little support was found for the assertion that rapid technical and structural change lies behind the present unemployment problem* (but see Freeman and Soete, below). Rather, empirical work tends instead to point to an environment where

technological change and changes in international competition are driving important structural changes. In particular, two features of this environment are worth emphasizing:
- All indicators point to a technology-driven movement toward an increasingly knowledge-based economy. Within manufacturing, the science-based industries have been the only ones consistently expanding employment since the 1970s. In manufacturing, as well as in services, the knowledge-intensive sectors have been expanding their employment more rapidly than the rest of the economy. The importance of high-technology products has increased continuously in international trade (they have been its fastest growing component as well as in value added).
- The data indicate that the most successful countries in terms of job creation seem to be those which have moved fastest in promoting knowledge intensity. This has two aspects. On the one hand, it is a question of upgrading the skills of the work force and making sure that they adapt to new skill demands as these emerge. On the other hand, it is a question of creating framework conditions which promote the advance of knowledge-based industries and activities. Evidence on trade specialization and structural change suggests that Japan has been the most successful country in both these respects, while the large European countries have had greater difficulties in promoting the new knowledge-based growth industries.

- The technology/employment relationships have to be conceived in a dynamic perspective which emphasizes the role of innovation and technological advance in the very processes of growth and structural change. Such a perspective highlights the importance of policies and institutions aimed at enhancing the diffusion of new technologies across the entire spectrum of economic activities and at easing the efficient absorption of technology by firms and final consumers. In this respect the most important policy orientations appear to be the promotion of social and physical infrastructure which facilitates the diffusion of technology, the support of intangible investments which ease the implementation of technological and organizational best-practices, the parallel development of increased labour-market flexibility and the intensified efforts in training and retraining of the labour force.

- From the point of view of employment creation, four different policy issues follow this analysis:
  - the employment impact of developing and diffusing *product* innovations can be expected to create more employment than *process* innovation;
  - the difficulties in absorbing information technology and getting the full benefits of its potential for creating new services and jobs reflect, to a certain extent, a lack of national and international information infrastructures;
  - there seems to be a big gap between best-practice management models and the models actually practised in the majority of firms when it comes to the introduction and efficient use of new technologies; and
  - innovation and the process of producing and using knowledge tend increasingly to become an international and even a global process.

The Active Society

In this section, some of the most recent data are laid out — some arising out of TEP, which can be brought to bear on this question. Fortunately, surveys of vast amounts of empirical work and appreciative theorizing — including some new data prepared by Sakuri (OECD, 1993) showing some relationships between the growth of ICT and changing patterns of employment — have recently been carried out by Freeman and Soete (1994).

Their principal conclusions are outlined below, but they come to rather different conclusions about the role of structural change in employment creation than do the authors of the OECD study referred to above.

- While economic theory has pointed to compensation mechanisms generating new employment to replace jobs which are lost through technical change, no one has claimed that this process is instantaneous or painless. Economists differ, however, on the extent to which they would rely on self-adjusting market-clearing mechanisms or on active public investment and labour market policies.

- Virtually all economists agree that the world economy has experienced a deep crisis of structural adjustment in the 1980s and 1990s and hence that various forms of structural unemployment have become a very serious problem (tables 5.1, 5.2, 5.3).

Table 5.1
Unemployment in Various Countries 1933-1994
(as a % of the labour force)

Country	1993	1959-1967 average	1982-1992 average	1992	1993	forecast 1994
Belgium	10.6	2.4	11.3	10.3	12.1	13.0
Denmark	14.5	1.4	9.1	11.1	12.1	11.9
France	4.5*	0.7	9.5	10.4	11.7	12.4
Germany	14.8	1.2#	7.4	7.7	8.9	10.1
Ireland	na	4.6	15.5	17.2	17.6	17.8
Italy	5.9	6.2	10.9	10.7	10.2	11.1
Netherlands	9.7	0.9	9.8	6.8	8.3	9.3
Spain	na	2.3	19.0	18.4	22.7	23.8
UK	13.9	1.8	9.7	10.1	10.3	10.0
Austria	16.3	1.7	3.5	3.7	4.2	5.3
Finland	6.2	1.7	4.8	13.1	18.2	19.9
Norway	9.7	2.1	3.2	5.9	6.0	5.9
Sweden	7.3	1.3	2.3	5.3	8.2	8.8
Switzerland	3.5	0.2	0.7	2.5	4.5	5.0
US	24.7	5.3	7.1	7.4	6.9	6.5
Canada	19.3	4.9	9.6	11.3	11.2	11.0
Japan	na	1.5	2.5	2.2	2.5	2.9
Australia	17.4	2.2	7.8	10.7	10.9	10.4

* 1936 na = not available
# The Federal Republic for the period 1959-1981
Source: Maddison (1991) and OECD, "Employment Outlook" (1993).

Table 5.2
The profile of OECD (1992) unemployment

	Unemployment rates					
	Total (standardised definiton)	Total[1]	Youth	Women	Ratio of lower secondary education unemployment rate to total rate[2]	Long-term unemployed as a share of total unemployment (per cent)[3]
North America	7.7	7.8	14.6	7.3	-	6.4
Canada	11.2	11.3	17.8	10.4	1.5	7.2
United States	7.3	7.4	14.2	6.9	2.3	6.3
Japan	2.2	2.2	4.5	2.2	2.7	17.9
Oceania	10.6	10.7	19.5	9.9	-	24.3
Australia	10.7	10.8	19.7	10.0	1.6	24.9
New Zealand	10.3	10.2	18.5	9.5	-	21.3
European Union	9.4	9.5	18.4	11.5	-	45.8
Belgium	7.8	8.2	17.6	12.2	1.3	61.6
Denmark	-	9.5	11.4	10.8	1.7	31.2
France	10.2	10.0	21.8	12.5	1.3	38.7
Germany	4.8	4.5	4.0	5.1	2.0	45.5
Greece	-	9.2	-	15.4	-	47.0
Ireland	16.1	17.8	27.6	19.4	1.1	60.3
Italy	10.5	10.1	27.9	15.7	0.9	67.1
Luxembourg	-	1.9	3.8	2.8	-	28.3
Netherlands	6.7	6.7	10.6	8.7	1.0	43.0
Portugal	4.1	4.8	10.3	6.5	1.7	38.3
Spain	18.1	18.0	32.5	25.5	1.2	49.1
United Kingdom	10.0	10.8	17.0	9.2	1.8	28.1
EFTA	-	5.5	9.3	5.0	-	12.9
Austria[1]	-	3.6	3.6[5]	3.8	-	15.2
Finland	13.0	13.1	23.5	10.7	1.4	9.1
Norway	5.9	5.9	13.9	5.2	1.1	20.6
Sweden	4.8	4.8	10.8	3.8	1.4	4.4
Switzerland[6]	-	2.7	4.7	3.4	-	19.8
Turkey[7]	-	7.8	15.2	7.2	1.5	39.2

Source: OECD (1993
[1] Comparable unemployment rates for the EC countries and national estimates for the other countries
[2] For adults aged 25-64. Data refer to 1989 for all countries, except japan (1987), Denmark (1988), the Netherlands (1990) and Turkey (April 1990).
[3] Long-term unemployed refers to all persons unemployed in 1991 for 12 months or more.
[4] Unemployment rates refer to the first half of 1992
[5] Estimates
[6] All data refer to the second quarter of 1992
[7] Unemployment rates refer to October 1992

Table 5.3

Extract from the OECD Report to Ministers on Unemployment

The seriousness of the present situation

There are thus a number of disturbing, perhaps alarming, aspects of the current situation:

- In EFTA and in the European community until relatively recently almost no job grown occurred in the private sector, virtually all taking place in the non commercial public sector. So far, significant reversal of this trend has been seen only in (the western part of) Germany, the Netherlands and the United Kingdom.

- The present recession-induced increase in unemployment comes on top of already-high inherited structural unemployment. In the European Community, unemployment appears to be `ratcheting up' from each cyclical trough to the next. As a result, almost half of the unemployed have been out of work for 12 months or more.

- The United States unemployment has been more cyclical. Longer-term structural problems have nevertheless manifested themselves, both in a secular fall of real wages below a (normatively set) poverty threshold for low-skilled workers, and in the withdrawal of significant numbers of prime-age male workers from the labour force.

- The EFTA countries, which hitherto had been successful in maintaining full employment, are now experiencing drops in employment and rises in unemployment, in some cases dramatically so.

- During the recent recession job losses for low-skilled workers have occurred not only in manufacturing but also in the service sectors.

- Youth unemployment remains stubbornly high in many countries, notwithstanding significant youth programmes and the receding effects of the baby boom.

- Last, this poor labour market situation is rendering the effective integration of legally admitted immigrants more difficult, adding to social tensions.

Source: OECD 1993), p.20

Table 5.4
Estimates of Increase in ICT Capacity

Area of Change	(1) Late 1940s - Early 1970s	(2) Early 1970s - Mid 1990s	(3) Mid 1990s Onwards "Optimistic" Scenario
OECD Installed Computer Base (Number of machines)	30,000 (1965)	Millions (1985)	Hundred Millions (2005)
OECD Full-time Software Personnel	> 200,000 (1965)	> 2,000,000 (1985)	> 10,000,000 (2005)
Components per Micro-electronic Circuit	32 (1965)	1 mega-bit (1987)	256 Mega-bit (late 1990s)
Leading Representative Computer: Instructions per second	10_3 (1955)	10_7 (1989)	10_9 (2000)
Personal Computer (PC) instructions per second	-	10_6 (1989)	10_8 (2000)
Cost: Computer Thousand ops. per $US	10_5 (1960s)	10_8 (1980s)	10_{10} (2005)

Table 5.5
Change of Techno-Economic Paradigm in OECD Countries: A Summary

Area of Change	(1) Late 1940s - Early 1970s	(2) Early 1970s - Mid 1990s	(3) Mid 1990s Onward "Optimistic" Scenario
I. INFORMATION AND COMMUNICATION TECHNOLOGY			
\. Electronic Computers	Early valve-based machines mainly in military applications. Future potential often under-estimated. Big improvements in architecture, memory, peripherals lead to take-off in commercial market in 1950s. Huge improvements in reliability and performance from use of transistors and integrated circuits. Main-frame computers in large firm data-processing dominant but mini-computers take off in 1960s.	From 1971 the micro-processor leads to small, cheap, powerful personal computers diffusing to households as well as huge numbers of business users. These change the nature of the computer industry. Large main-frames and centralised data-processing departments play diminishing role as work-stations and PCs gain greater share of market.	Universal availability of PCs and of portable and "wallet" type computers linked to networks. Computers so unobtrusive in so many applications that they pass unnoticed (like electric motors in the household today). Super-computers and parallel processing for RD and other applications such as data banks where truly vast memory capacity and speed of processing is needed.
3. Computer. Software	First programming languages in 1950s. Hardware companies developing and supplying software to own standards. As applications multiply scientific users in R&D do their own software programming. Big DP departments develop software teams working with hardware suppliers. Emergence of independent software companies giving advice and support to users and designing systems.	Very rapid growth of software industry and consultancy especially in United States. Packaged user-friendly software facilitates extraordinarily rapid diffusion of computer hardware, especially to Small & Medium-sized Enterprises, but customised software and modified packages business also grow very rapidly. Movement to Open Systems in the late 1980s facilitates inter-connections and networking. Shortages of software personnel acute in 1970s and 1980s but abating in 1990s.	Reductions in requirement for software labour from (1) standard packages, (2) automation of coding and testing, (3) reduced mainframe support, (4) improved skills of users. But these trends offset by new software demand from (1) Parallel processing, (2) Multi-media and virtual reality and expert systems, (3) changing configurations because of continuing organisational and technical change. Renewed surge of demand for more skilled software design and maintenance.
:. Semi-:onductors and ntegrated Circuits	From valves to transistors in 1950s and integrated circuits in 1960s to large-scale integration (LSI) in 1970s. Orders of magnitude improvement in reliability, speed, performance almost doubling the number of components per chip annually and drastically reducing cost.	From LSI to VLSI and wafer-scale integration. With the micro-processor from 1970s onwards, many small firms enter computer design and manufacturing. Huge capacity of VLSI circuits leads to vastly increased capacity of all computers and huge reductions in cost.	Chips have become a cheap commodity. Both technical and economic limits to present stage of miniaturisation reached in early 21st Century leading ultimately to "Bio-chips" or other radically new nano-technology.
). Tele-:ommunications ınd Infrastructure	Electro-mechanical systems predominate in 1950s and 1960s. Traffic mainly voice traffic and telex limited by coaxial cables (plus microwave and satellite links from 1960s). Large centralised public utilities dominate the system with oligolistic supply of telephone equipment by small ring of firms.	Massive R&D Investment leads to fully electronic stored-programme-controlled switching systems, requiring less maintenance and permitting continuous adaptation to new traffic, including a wide variety of voice, data, text, and images. Many new networking services develop. Optical fibres permit orders of magnitude increase in capacity and cost reduction. Break-up of old monopolies.	Widespread availability of bandwidths up to a million times that of the old "twisted pair" in coaxial cables. "Information Highways" using access to data banks and universal ISDN providing cheap networked services for business and households and permitting tele-commuting on an increasing scale for a wide variety of activities. Mobile phones and videophones diffusing very rapidly, linked to both wireless and wired systems.

II. INDUSTRIES AND SERVICES

A. Manufacturing	Mass production industries based on cheap oil, bulk materials and petrochemicals predominate in 1950s and 1960s boom. Electronic capital goods industries still small though very fast growing. Consumer goods (radio and TV) fit into general pattern of household consumer durables. Early CAD and CNC introduced as "islands" of automation mainly in aero-space and promoted by government.	Electronic industries become leading edge in 1980s. Rapid diffusion of CAD, CNC and Robotics in metalworking and later other industries. Productivity increases and diffusion slowed by learning problems, site-specific variety, skill mis-matches and lack of management experience. Integration of Design Production and Marketing slow to take off. FMS and CIM have big teething troubles.	Generalisation of electronic-based equipment and control in all industries. "Systemation" of various functions within firms through CAD-CAM, etc. Flexible manufacturing systems in most industries. Larger labour and capital productivity increases in OECD countries. Layere incorporation of Third World countrie in expanding world manufacturing output and trade.
B. Services	Mass production style spreads to many service industries, especially tourism (packaged holidays, cheap air and bus travel, etc.) distribution and fast food. Rapid growth of (public) social services and of central and local government employment. Hierarchical centralised management systems in large organisations, whether government or private.	Many services become capital-intensive through introduction of computer systems, especially financial services. Service industries also begin to do R&D and more product innovation. "Diagonalisation" of services based on capability in ICT (tourism companies into financial services and vice-versa; banks into property services, etc.). Big learning problems and software failures. Word processors become universal.	Vast proliferation of networking services, producer services, consultancy and information systems. Tele-shopping, tel-banking, tele-learning, tele-consultancy, tele-commuting, based on cheap universa computing and very cheap telecommunications (Fax, E-mail, video-phones, mobile phones, etc.). Growth of labour-intensive craft services, "caring" services and creativ services on personal customised basis and local networks.
C. Scale Economies, Firm Size and Industrial Structure	Increasing size of plant in many industries in 1950s, and 1960s (steel, oil, tankers, petro-chemicals). Big scale economies facilitate growth of large firms and concentration of industry. MNCs spread investment world-wide especially in oil, automobiles and chemicals. In late 60s and early 70s increasing evidence of "limits to growth" of energy-intensive mass production style.	Production scale economies sometimes reversed but scale economies in R&D, Marketing, Finance, etc. still important. In 1980s and 1990s intense competition, computer systems and cultural revolution lead to "down-sizing" of some large firms - with reduction of both white and blue collar employment. Many new SMEs side by side with high mortality in recessions.	Continued high rate of small firm formation especially in new technology and new service areas. Some re-concentration in capital-intensive and R&D-intensive sectors, leading to world-wide oligopolies in symbiosis with myriads of small networking firms at local level. Conglomerates with complex and shifting alliances in various regions.
D. Organisation of Firms	Hierarchical departmental structures with many management layers and vertical flow of information typical of large firms. Computers fit into existing structures and often into existing data processing departments based on tabulating machines. In manufacturing computers introduced as process control instruments of existing processes or as "islands" in existing production systems.	Cheap widespread computer terminals lead to "cultural revolution" in firms based on de-centralisation of some functions, horizontal information flows, lean production systems and networking within and between firms. Acute stress and conflict attends clash of cultures, reorganisation of production and systemation, and out-sourcing of many functions.	New flexible management style predominates. More stable employment for core personnel with networks of smaller firms and part-tim workers. Greater participation of cor work-force at all levels of decision-making, but some tendencies to segmentation.

III. THE MACRO-ECONOMY AND EMPLOYMENT

A. Economic Growth and Business Cycles	"Golden Age of Growth" in mass production industries, services and systems. Rather stable Keynesian regulation of "vertebrate" economy providing stability and confidence for investment and consumer spending. Inflationary pressures and social tensions of late 60s and early 70s herald structural crisis of this paradigm as it reaches limits. Bretton Woods system provides fairly stable international framework until it breaks down in early 1970s.	First structural downswing crisis of mid-70s leads to desire to "get back on course" (e.g. McCracken Report). Second crisis of early 80s leads to recognition of structural problems but only in the third crisis of early 90s is their depth and difficulty appreciated. Huge productivity potential of ICT offset by rigidities in social system. The conflict of alternative paradigms is increasingly fought out in the political sphere as governments search for solutions and as public opinion tires of the invertebrate economy with its excessive turmoil.	Combination of technical and social change together with political reform leads to new pattern of sustainable growth, renewed confidence for investment and new pattern of consumer spending. Changes in UN and Bretton Woods family of international economic institutions lead to stable global framework of expansion. "Forgotten" elements of Keynes' 1940s vision restored and provide greater resources for Third World "catching up". A new "vertebrate" world economy emerges

. Employment and Unemployment	"Full employment" policies rather successful based mainly on full-time adult male employment 16-65. Relatively low but rising female participation rates. Very low structural unemployment. Recessions of relatively short duration. Low levels of youth unemployment. Expanding secondary and tertiary education systems.	Structural unemployment becomes more severe with each recession. Big increase in part-time employment and in female participation. Big increase in training and re-training to change skill profile of work-force but problems remain especially for less skilled and less educated. Long-term and youth unemployment become major problems.	Economy reverts to shallow recessions with much lower levels of structural unemployment. More self-employment and more flexible part-time work and life-time education and training for both men and women. "Active Society" providing work for all who seek it. Labour-intensive craft, caring and creative occupations and services proliferate. Shorter working hours for all and greater male participation in child care and house-work.

CAD = Computer-Aided Design
CNC = Computer Numerical Control (Machine Tools)
MS = Flexible Manufacturing Systems
CIM = Computer-Integrated Manufacturing
CAD = Computer-Aided Design
CNC = Computer Numerical Control (Machine Tools)
MS = Flexible Manufacturing Systems
CIM = Computer-Integrated Manufacturing

Table 5.6
CHANGE OF TECHNO-ECONOMIC PARADIGM

"Fordist" Old	ICT New
Energy-intensive	Information Intensive
Design and engineering in "drawing" offices	Computer-aided designs
Sequential design and production	Concurrent engineering
Standardised	Customised
Rather stable product mix	Rapid changes in product mix
Dedicated plant and equipment	Flexible production systems
Automation	Systemation
Single firm	Networks
Hierarchical structures	Flat horizontal structures
Departmental	Integrated
Product with service	Service with products
Centralisation	Distributed intelligence
Specialized skills	Multi-skilling
Government control and sometimes ownership	Government information, co-ordination and regulation
"Planning"	"Vision"

Source: Adapted from Perez (1990)

Table 5.7
Outlook: 1990-2005: Occupational Employment Forecasts for the United States
Occupations with the largest job growth, 1990-2005, moderate alternative projection (Numbers in thousands)

Occupation	Employment		Change	
	1990	2005	Numerical	Per cent
Salespersons, retail	3,619	4,506	887	24.5
Registered nurses	1,727	2,494	767	44.4
Cashiers	2,633	3,318	685	26.0
General Office Clerks	2,737	3,407	670	24.5
Truckdrivers, light & heavy	2,362	2,979	617	26.1
General managers and top executives	3,086	3,684	598	19.4
Janitors and cleaners, including maids and housekeeping cleaners	3,007	3,562	555	18.5
Nursing aides, orderlies and attendants	1,274	1,826	552	43.4
Food counter, fountain and related workers	1,607	2,158	550	34.2
Waiters and waitresses	1,747	2,196	449	25.7
Teachers, secondary school	1,280	1,717	437	34.2
Receptionists and information clerks	900	1,322	422	46.9
Systems analysts and computer scientists	463	829	368	78.9
Food preparation workers	1,156	1,521	365	31.6
Child care workers	725	1,078	353	48.8
Gardeners and groundkeepers, except farm	874	1,222	348	39.8
Accounts and auditors	985	1,325	340	34.5
Computer programmers	565	882	317	56.1
Teachers, elementary	1,362	1,675	313	23.0
Guards	883	1,181	298	33.7
Teacher aides and educational assistants	808	1,086	278	34.4
Licensed practical nurses	644	913	269	41.9
Clerical supervisors and managers	1,218	1,481	263	21.6
Home health aides	287	550	263	91.7
Cooks, restaurant	615	872	257	41.8
Maintenance repairers, general utility	1,128	1,379	251	22.2
Secretaries, except legal and medical	3,064	3,312	248	8.1
Cooks, short order and fast food	743	989	246	33.0
Stock clerks, sales floor	1,242	1,451	209	16.8
Lawyers	587	793	206	35.1

Source: US Bureau of Labour Statistics

- There is widespread agreement that this crisis of structural adjustment has been associated with the diffusion of a set of revolutionary new technologies — the ICTs (Table 5.4).

- These technologies, although they have a vast range of present and future applications, do not easily match the inherited skill profile, management organization, industrial structure or general institutional framework (tables 5.5, 5.6, 5.7).

- Countries differ widely in the occupational and sectoral composition of their labour force, in the speed of their structural adjustment, in the flexibility of their work-force organization, etc., in their response to new technologies and in the relative growth rates of new sectors and of trade (figures 5.1, 5.2 ,5.3, 5.4, 5.5).

- A major new factor in the world economy has been the very rapid catch-up of the Eastern and, increasingly, South Asian economies. They have experienced the most rapid structural change, the highest rates of employment growth and the most rapid diffusion of ICT (Figure 5.6).

- Strongly, but not exclusively, related to this Asian success has been the intensified international competition. This can no longer be disregarded as a factor in employment loss in OECD countries, especially for less skilled workers in both manufacturing and services (Figure 5.7).

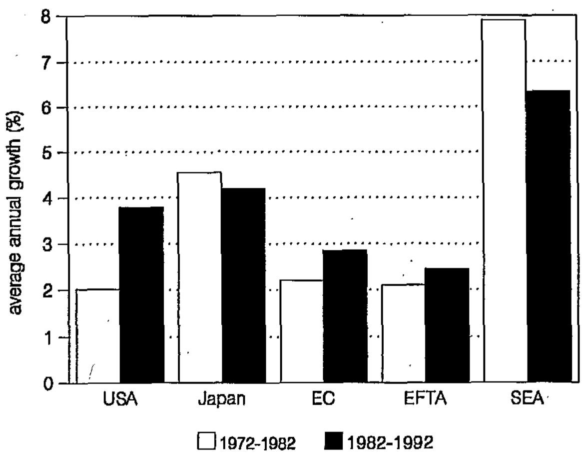
- "Flexibility" as a response to this intensified competition can take various forms: reduction of wages and social benefits or a more pronounced structural shift toward high skill and high value-added sectors and activities. The educational infrastructure is still largely geared to earlier production systems. Success in the latter strategy involves, therefore, big changes in education, training, skills, R&D design and management (tables 5.8 to 5.13).

- The present transportation and communications infrastructure has been developed to handle a vast, and still increasing, number of cars, trucks and airplanes. The overloading of this infrastructure is bumping up against the limits of urban congestion and atmospheric pollution.

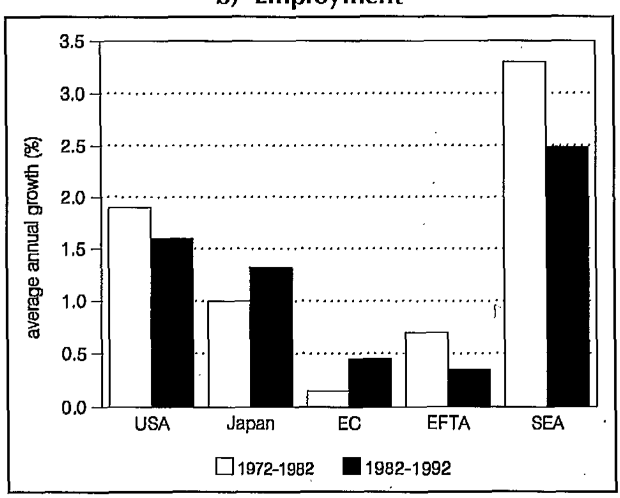
- ICT has the potential to alleviate some of these problems but the necessary new infrastructure and services are still in the early stages of development.

Figure 5.1 (a-c)
Average annual growth 1972-1992
(Productivity growth - output growth per man hour)

a) Production



b) Employment



c) Productivity

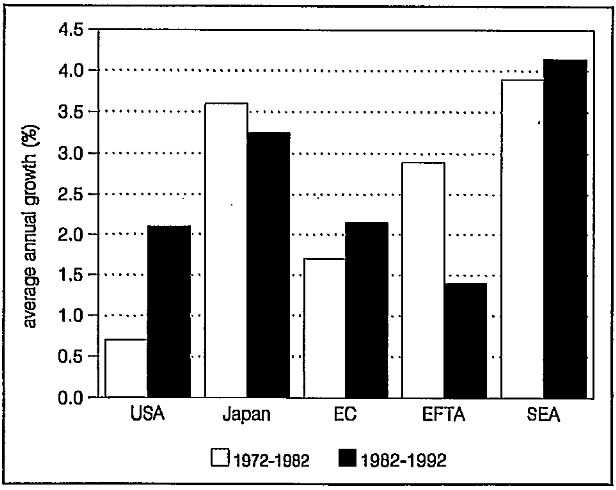


Figure 5.2
Sectoral employment shares, 1990

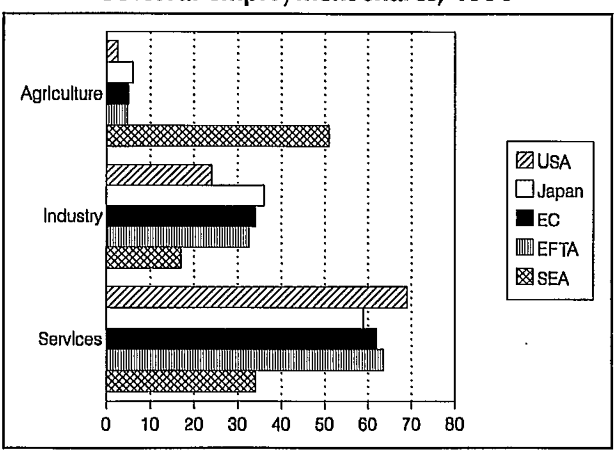
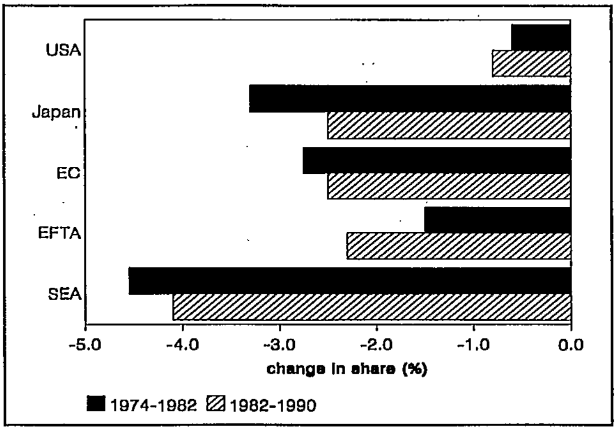
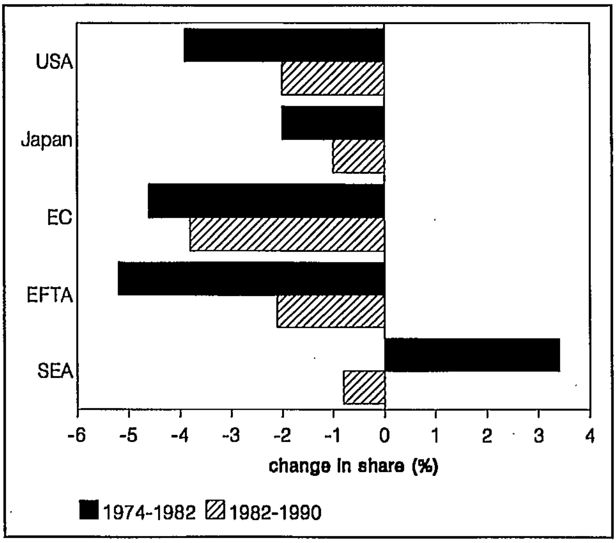


Figure 5.3 (a-c)
Change in employment shares, 1974 - 1990

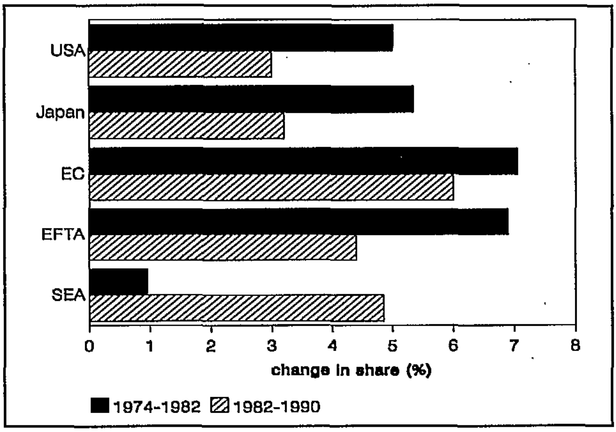
a) Agriculture



b) Industry



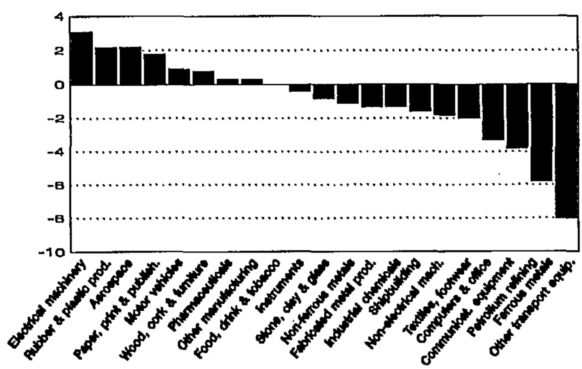
c) Services



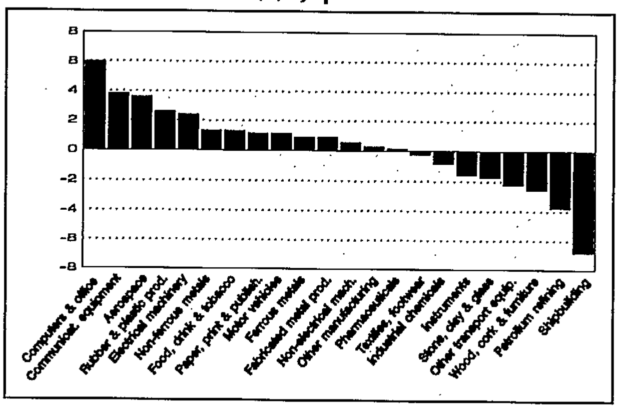
Source: ILO (1992).

Figure 5.4 (a-c)
Average annual employment growth in various sectors, 1980-1990 (%)

(a) United States



(b) Japan



(c) European Union

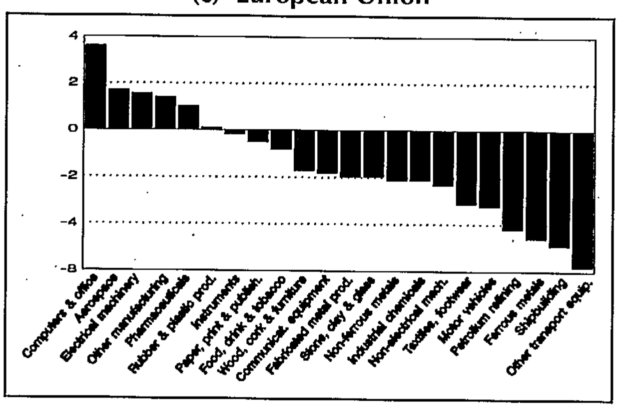
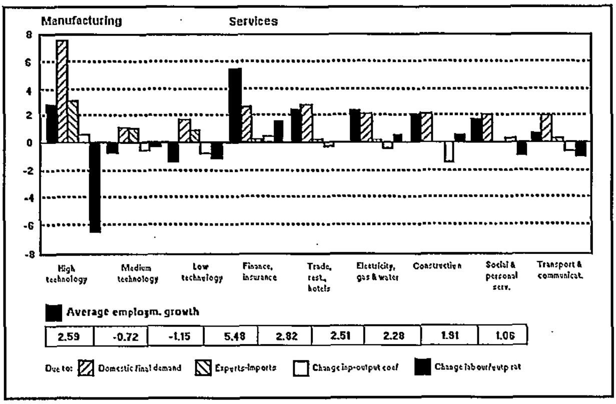
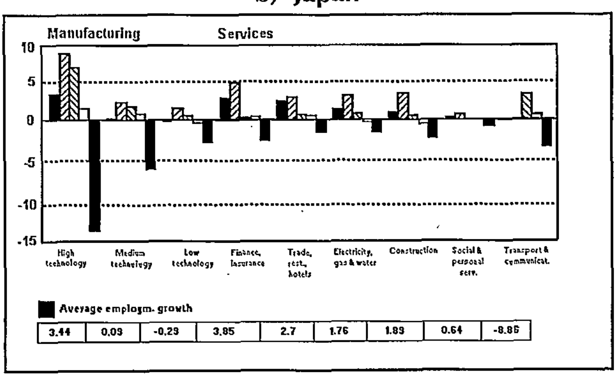


Figure 5.5 (a-c)
Estimated growth in employment in various sectors, 1972-1985 (% p.a.)

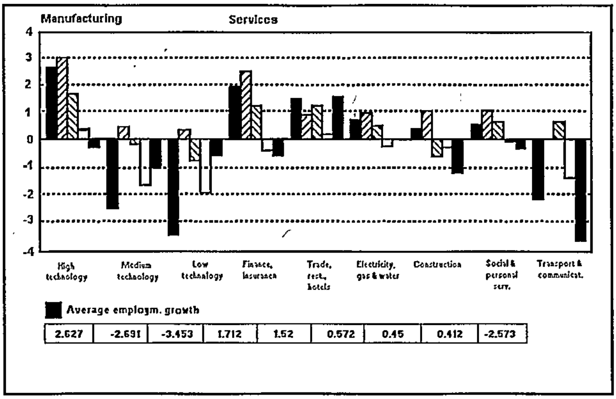
a) United States



b) Japan



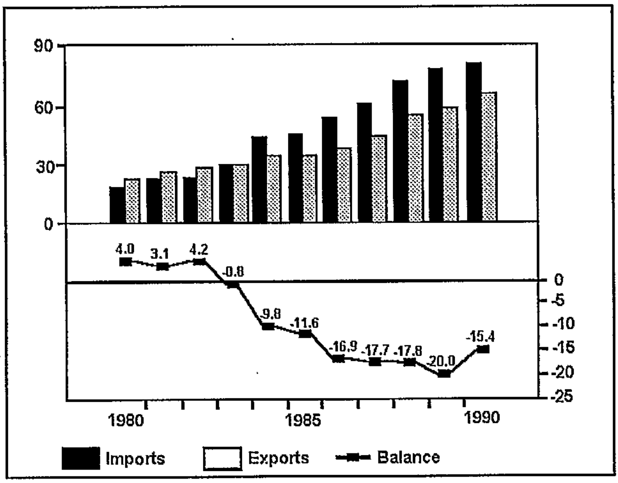
c) European Union



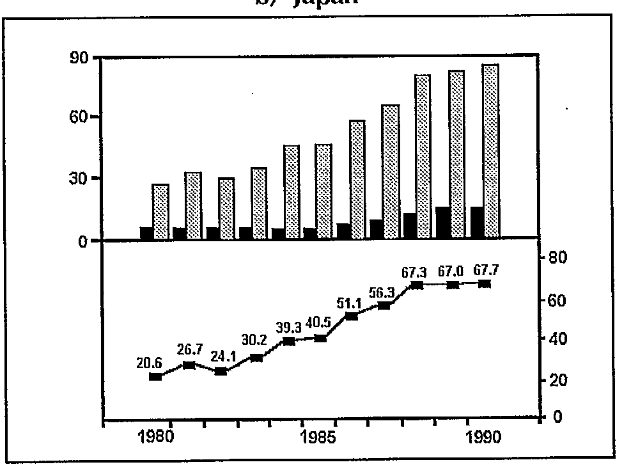
Source: Sakurai (1993).

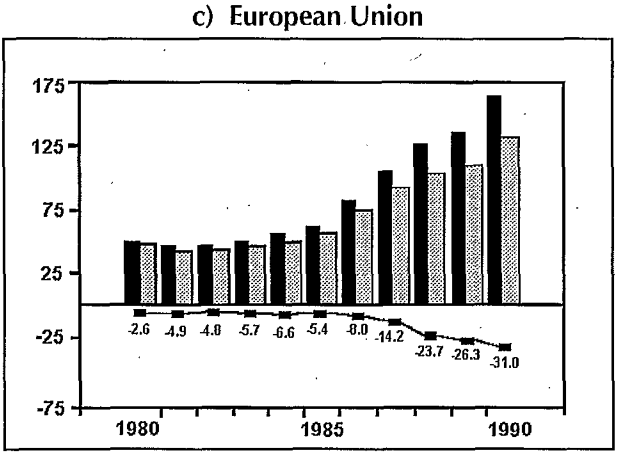
Figure 5.6 (a-c)
Imports and exports of IT-sectors
1980 - 1990 ($bn)

a) United States



b) Japan

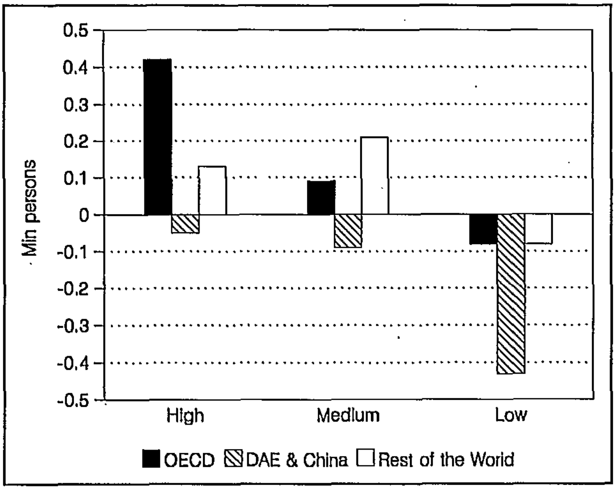




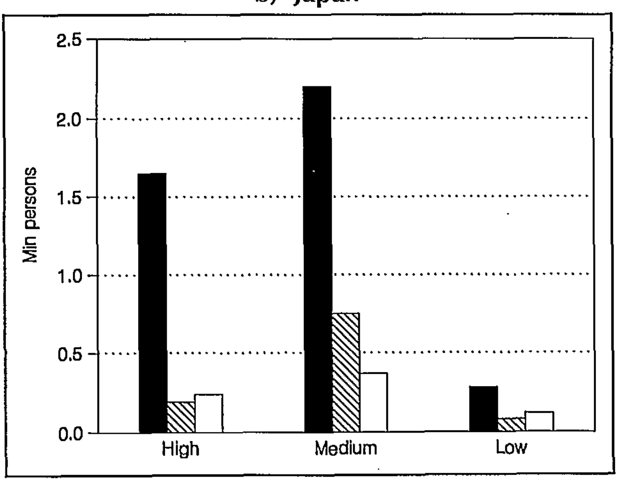
Source: OECD and MERIT Data Bases

Figure 5.7 (a-c)
Trade impact on employment, 1972-1985
***DAE Dynamic Asian Economics:**
Hong Kong, Singapore, South Korea and Taiwan

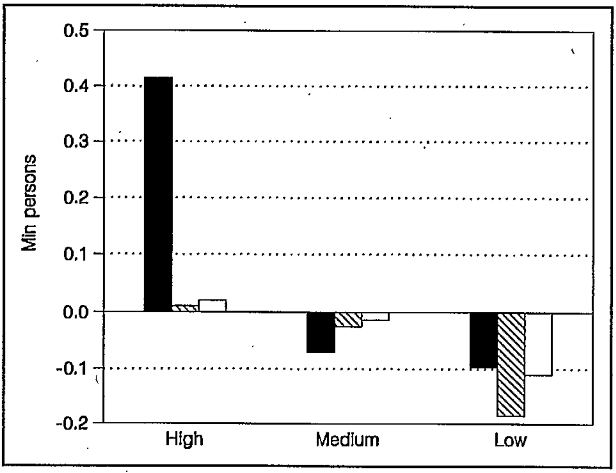
a) United States



b) Japan



c) European Union



Source: Sakurai, 1993.

Table 5.8
Labour Force Participation Rates by Sex, 1973-1992 (%)

	Men						Women					
	1973	1979	1983	1990	1991	1992[c]	1973	1979	1983	1990	1991	1992
Australia	91.1	87.6	85.9	85.9	85.6	85.3	47.7	50.3	52.1	62.1	62.2	62.4
Austria	83.0	81.6	82.2	80.1	80.5	81.3	48.5	49.1	49.7	55.4	56.3	58.3
Belgium	83.2	79.3	76.8	72.7	72.8	–	41.3	46.3	48.7	52.4	53.2	–
Canada	86.1	86.3	84.7	84.9	83.9	83.4	47.2	55.5	60.0	68.1	68.1	67.9
Denmark	89.6	89.6	87.6	89.6	88.5	–	61.9	69.9	74.2	78.4	78.9	–
Finland	80.0	82.2	82.0	80.6	79.6	78.5	63.6	68.9	72.7	72.9	71.8	70.6
France	85.2	82.6	78.4	74.6	74.5	–	50.1	54.2	54.4	56.1	56.8	–
Germany	89.6	84.9	82.6	80.8	80.6	80.1	50.3	52.2	52.5	57.0	58.1	59.0
Greece	83.2	79.0	80.0	82.1	–	–	32.1	32.8	40.4	39.9	–	–
Ireland	92.3	88.7	87.1	82.2	81.9	–	34.1	35.2	37.8	38.9	39.9	–
Italy	85.1	82.6	80.7	78.9	79.4	79.2	33.7	38.7	40.3	44.9	45.8	46.3
Japan	90.1	89.2	89.1	87.8	88.9	89.3	54.0	54.7	57.2	60.4	61.5	61.7
Luxembourg	93.1	88.9	85.1	–	77.7	–	35.9	39.8	41.7	–	44.8	–
Netherlands	85.6	79.0	77.3	79.9	80.3	–	29.2	33.4	40.3	53.0	54.5	–
New Zealand	89.2	87.3	84.7	82.2	82.3	–	39.2	45.0	45.7	62.4	62.8	–
Norway	86.5	89.2	87.2	84.5	82.9	83.0	50.6	61.7	65.5	71.2	71.1	70.9
Portugal[a]	100.8	90.9	87.6	86.1	85.9	–	32.1	57.3	57.2	60.4	62.8	–
Spain	92.9	83.1	80.2	76.8	76.0	74.9	33.4	32.6	33.2	40.9	41.2	42.1
Sweden	88.1	87.9	85.9	85.3	84.5	82.7	62.6	72.8	76.6	81.1	80.3	78.7
Switzerland[b]	100.6	94.6	93.5	96.2	95.3	–	54.1	53.0	55.2	59.6	59.8	–
United Kingdom	93.0	90.5	87.5	86.5	86.1	85.6	53.2	58.0	57.2	65.3	64.5	64.5
United States	86.2	85.7	84.6	85.8	84.7	85.0	51.1	58.9	61.8	68.6	68.4	68.9
North America	86.2	85.8	84.6	85.7	84.6	84.8	50.7	58.6	61.6	68.5	68.4	68.8
OECD Europe[d]	88.7	84.8	82.3	80.6	78.3	–	44.7	48.6	49.8	54.8	54.0	–
Total OECD[d]	88.2	85.9	84.3	83.7	82.4	–	48.3	53.1	55.1	60.7	60.5	–

[a] Labour force data include a significant number of persons aged less than 15 years.
[b] Data disaggregated by age and sex exclude a certain number of foreign seasonal workers; these are included int eh estimates of the working population.
[c] Secretariat estimates.
[d] Above countries only.
Source: OECD (1993), *Employment Outlook*, p. 192.

Table 5.9
Size and Composition of Part-time Employment, 1973-1992 (%)

	Part-time Employment as a Proportion of Employment											
	Men						Women					
	1973	1979	1983	1990	1991	1992	1973	1979	1983	1990	1991	1992
Australia	3.7	5.2	6.2	8.0	9.2	10.5	28.2	35.2	36.4	40.1	40.9	43.3
Austria	1.43	1.5	1.5	1.6	1.5	–	15.6	18.0	20.0	20.2	20.1	–
Belgium	1.0	1.0	2.0	2.0	2.1	–	10.2	16.5	19.7	25.8	27.4	–
Canada	4.7	5.7	7.6	8.1	8.8	9.3	19.4	23.3	26.1	24.4	25.5	25.9
Denmark	–	5.2	6.6	10.4	10.5	–	–	46.3	44.7	38.4	37.8	–
Finland	–	3.2	4.5	4.4	5.1	5.5	–	10.6	12.5	10.2	10.2	10.4
France	1.7	2.4	2.6	3.4	3.4	3.6	12.9	16.9	20.0	23.6	23.5	24.5
Germany	1.8	1.5	1.7	2.6	2.7	–	24.4	27.6	30.0	33.8	34.3	–
Greece	–	–	3.7	2.2	2.2	–	–	–	12.1	7.6	7.2	–
Ireland	–	2.1	2.7	3.4	3.6	–	–	13.1	15.5	17.6	17.8	–
Italy	3.7	3.0	2.4	2.4	2.9	2.7	14.0	10.6	9.4	9.6	10.4	10.5
Japan	6.8	7.5	7.3	9.5	10.1	10.6	25.1	27.8	29.8	33.4	34.3	34.8
Luxembourg	1.0	1.0	1.0	1.9	1.9	–	18.4	17.1	17.0	16.7	17.9	–
Netherlands[a]	–	5.5	7.2	15.8	16.7	–	–	44.0	50.1	61.7	62.2	–
New Zealand	4.6	4.9	5.0	8.4	9.7	10.3	24.6	29.1	31.4	35.0	35.7	35.9
Norway[b]	5.9	7.3	7.7	8.8	9.1	9.8	46.5	50.9	63.3	48.2	47.6	47.1
Portugal	–	2.5	–	3.6	4.0	4.2	–	16.5	–	10.1	10.5	11.0
Spain	–	–	–	1.6	1.5	2.0	–	–	–	11.8	11.2	13.7
Sweden[c]	–	5.4	6.3	7.3	7.6	8.4	–	46.0	45.9	40.9	41.0	41.3
United Kingdom	2.3	1.9	3.3	5.3	5.5	6.1	39.1	39.0	42.4	43.2	43.7	44.6
United States	8.6	9.0	10.8	10.0	10.5	10.8	26.8	26.7	28.1	25.2	25.6	25.4

[a] Break in series after 1985.
[b] Break in series after 1987.
[c] Break in series after 1986.

Table 5.10
Number of Self-employed Persons (including agriculture) as a Percentage of the Total Number of Persons Employed, 14 OECD Countries, 1970, 1980, 1990

	1970	1980	1990
Australia	12.9	16.4	15.4
Belgium	19.1	16.4	17.9
Canada	11.6	9.8	9.7
Germany	16.6	11.7	10.6
Denmark	19.3	15.1	11.3
Finland	20.9	14.5	11.8
France	20.9	16.3	14.2
United Kingdom	7.8	7.9	12.6
Italy	30.7	30.2	31.5
Japan	33.6	26.6	20.0
Netherlands	15.7	13.0	12.3
Norway	17.4	12.7	10.6
Sweden	10.9	8.4	7.4
United States	9.1	9.0	8.0

Source: OECD

Table 5.11
Number of Self-employed Persons (excluding agriculture) as a Percentage of the Total Number of Persons Employed, 14 OECD Countries, 1970, 1980, 1990*

	1970	1980	1990
Australia	8.6	13.0	12.6
Belgium	15.5	14.1	16.2
Canada	7.0	6.9	7.6
Germany	10.1	7.9	8.2
Denmark	12.0	9.8	7.9
Finland	6.3	4.8	5.5
France	12.1	10.2	10.0
United Kingdom	6.7	7.0	11.8
Italy	21.8	24.1	27.8
Japan	19.2	17.9	13.6
Netherlands	11.1	9.2	9.2
Norway	8.6	6.9	6.3
Sweden	6.3	5.2	5.3
United States	7.0	7.5	7.8

* For the United States 1990 is in fact 1989
Source: OECD

Table 5.12
Average Hours Actually Worked Per Person Per Year[a]

	1970	1973	1975	1979	1983	1990	1991	1992
Total Employment								
Canada	1890	1865	1837	1794	1730	1733	1713	1709
Finland	1982	1915	1885	1859	1798	1756	1758	1728
France	1962	1904	1865	1813	1711	1669	1667	1666
Italy	1969	1885	1841	1788	1764	–	–	–
Japan	–	2185	2100	2110	2081	2003	–	–
Norway	1766	1694	1653	1501	1471	1415	1408	1417
Spain	–	–	–	2148	2052	1941	1931	1911
Sweden	1641	1557	1516	1451	1453	1480	1468	1485
United States	1886	1875	1833	1808	1788	1782	1771	1769
Dependent Employment								
France	1821	1771	1720	1667	1558	1539	1540	1542
Germany	1885	1804	1737	1699	1670	1573	1557	–
Netherlands	–	–	–	1591	1530	1433	1423	–
Spain	–	–	–	2032	1946	1858	1847	1828
United States	1836	1831	1791	1767	1754	1749	1737	1736

[a] Includes part-time work

Sources:
Canada: Data supplied by Statistics Canada
Finland: Data estimated from National Accounts data
France: Data supplied by INSEE on a National Accounts basis
Germany: Data supplied by the German Institut für Arbeitsmarkt-und Berusforschung
Italy: Data supplied by the Italian authorities (ISTAT)
Japan: Secretariat estimates based on data from the *Monthly Labour Survey of Establishments and the Labour Force Survey*
Netherlands: Data are annual contractual hours on the basis of Labour Accounts data and were supplied by the national authorities (CBS)
Norway: Data supplied by the Central Bureau of Statistics
Spain: Data estimated from the quarterly *Labour Force Survey*
Sweden: Data estimated from National Accounts data
United States: Data provided by the Bureau of Labor Statistics

Table 5.13
Part-time Opportunities for Civil Servants

Country	Eligibility	Hours	Pay/Conditions	Return to Full-time	Duration
Australia	All with 3 mths service	15-30	*Pro rata*	Right to retum after agreed period	By agreement
Austria	Women with children 1-4	Half-time	-	Ditto	1 or 2 yrs; 4 yrs total
Belgium	Permanent civil servants with family/social needs; for personal convenience	50%-80% nomal hrs	*Pro rata*	Ditto	3 mths-2 yrs at one time; 5 yrs total
Canada	All	Minimum 1/3 normal hrs	*Pro rata*	-	-
France	All	50%-90% normal hrs	*Pro rata*	Ditto	6 mths minimum
Germany	All with child below 18 or dependent adult	Minimum 50% normal hrs		With permission	Up to 15 yrs
Italy	All; limit on total part-time posts	Minimum 50% normal hrs	*Pro rata*	-	-
Luxembourg	All with child below 15 or 'well-motivated' personal reasons; very senior posts excluded	Half-time	*Pro rata* for pensions; does not count towards promotion	Only if full-time vacancy	No limit
New Zealand	All, for personal reasons	-	*Pro rata*	-	-
Portugal	All with 3 yrs service, with children under 12, sick relative or educational needs; except directorate or executive positions	Half-time	*Pro rata*	Right to return on request	6 mths; can be extended
Sweden	All	Compatible with service	*Pro rata*	-	No limit
USA	All up to grade GS-16	Compatible with service 16-32 hrs	*Pro rata*	-	-

- indicates no information given
Source: Conditions of Work Digest: Part-time Work, Geneva, International Labour Office, 1989; Hewitt, 1993.

Technology and *The Work of Nations*

Robert Reich in his recent book *The Work of Nations* (1991) assumes the eventual diffusion of ICTs and probes into the changing nature of work in an information economy. Rather than talking in terms of standard classifications of occupations, he prefers to talk about the roles of knowledge workers in terms of problem identifiers, problem solvers and problem brokers, thereby accentuating the transformative effects on occupations being brought about by the diffusion of ICT. His grim arguments concerning the implications for employment in a transition to a knowledge economy, in which four fifths of the population of the United States is being supported effectively by the remaining one fifth who are providing high-value added information and knowledge services at the front end — R&D, design, prototype development of the innovation chain — provide a scenario replete with implications, not only for the fate of those supported, but for socio-economic instability.

These three studies reflect fundamentally different economic orientations. The differences come out most clearly in the policy prescriptions that each study proposes, but the basic tension is one of economic orientation — whether one adopts the neoclassical framework and looks for market imperfections or the neo-Schumpeterian framework with its emphasis on institutional rigidity. It is uncontested that countries which have grown rapidly or have been able to absorb the new information and communication technologies also show lower unemployment rates, but there is no agreement about which is cause and which is effect.

6. TECHNOLOGY AND GLOBALIZATION

TEP was also concerned with the phenomenon of "globalization." Though the term defies unequivocal definition, many in government and industry feel threatened by the spread of multinational firms and by the emergence of global markets which they are believed to satisfy. Some felt too, that globalization would have adverse consequences for many smaller economies and for most of the developing world. There was thought to be a need for "new rules of the game" to keep the process of world development on course and to avoid the adverse effects of unbridled competition among the members of the Triad — the United States, the European Union and Japan.

Since TEP, globalization has gone into retreat, perhaps because it is not clear exactly what it denotes. Nonetheless, the problems with which it was originally associated — particularly, the fear of a countervailing techno-nationalism among the Triad, exclusion of developing economies, etc. — remain. To counter these fears, TEP concluded its analysis by recommending a raft of policies aimed at promoting international scientific and technological co-operation, particularly the sharing of information freely in large basic science projects. There follows a brief review of the relevant literature and a discussion of the novel approach to the globalization issues developed by Coriat (1993), and Coriat and Dosi (1994).

Globalization and National Systems of Innovation

It has been suggested above that national institutions have powerfully affected the relative rates of technical change and hence of economic growth in various countries. The variation in national systems which have been presented are, of course, extreme contrasting cases and intended to be primarily illustrative. Nevertheless, national systems have certainly been important features of world development in the second half of the 20th century and point to uneven development of the world economy and divergence in growth rates. In fact, much of the recent economic literature does not seem to lend strong support to any convergence thesis. Moreover, differences in national systems are also very important among Japan, the United States and the European Community (EC), and among European countries themselves, as the major comparative study of more than a dozen national systems of innovation amply illustrates (Nelson, 1993). The comparative study of Ireland to other small countries by Mjoset (1992) also demonstrates this point as does the comparison of Denmark and Sweden by Edqvist, while that of Lundvall (1993) shows that large differences exist between neighbouring countries which superficially appear very similar. Moreover, Archibugi and Pinta (1992) have demonstrated the growing pattern of specialization in technology and trade, and Fagerberg (1992) has shown the continuing importance of the home market for comparative technological advantage. In brief, diversity abounds.

Any globalization thesis, then, would seem to founder on the manifest and growing diversity of firm behaviour, on the one hand, and performance of national systems of innovation, on the other. But, the idea of national *differences* in innovative capabilities determining national performance can be challenged on the grounds that transnational corporations (TNCs) are changing the face of the world economy in the direction of globalization, if they haven't done so already. For example, Ohmae (1990) in his book *The Borderless World*, argues that national frontiers are melting away in what he calls the "ILE" (inter-linked economy) — the Triad of the United States, the EC and Japan, now being joined by NICs. This inter-linked economy is becoming "so powerful that is has swallowed most consumers and corporations, made traditional national borders almost disappear, and pushed bureaucrats, politicians and the military towards the status of declining industries." Against this, Michael Porter, in *The Competitive Advantage of Nations* (1990), has argued that:

> Competitive advantage is created and sustained through a highly localised process. Differences in national economic structures, values, cultures, institutions and histories contribute profoundly to competitive success. The role of the home nation seems to be as strong or stronger than ever. While globalisation of competition might appear to make the nation less important, instead it seems to make it more so. With fewer impediments to trade to shelter uncompetitive domestic firms and industries, the home nation takes on growing significance because it is the source of the skills and technology that underpin competitive advantage.

Further, conventional economic reasoning leads one to expect diversity. Lundvall has argued that if uncertainty, localized learning and bounded rationality are introduced as more realistic assumptions about micro-economic behaviour, rather than the traditional assumptions of perfect information and hyper-rationality, then it must follow that local and national variations in circumstances may often lead to different paths of development and to increasing diversity rather than to standardization and convergence (Lundvall, 1993).

Since TEP's initial concern about growing globalization was put forward, the debate has continued between those who see creeping globalization driven essentially by multinational companies and those who see persistent diversity supported by local conditions. As ever, the truth seems to lie on the middle ground. Thus, after an extensive analysis of the factors for and against globalization Freeman concludes:

> However, it would be unwise to assume that these tendencies [toward globalization] are the only or even necessarily the strongest tendencies within the world economy. Nor are they so unequivocally desirable that they should be promoted by both national and international economic policies. In fact, the arguments for preserving and even encouraging diversity may sometimes outweigh the shorter term advantages of the scale economies derived from standardisation and their propagation through trans-national companies, free trade and free flows of investment. *In fact both processes (globalisation in some areas but increasing diversity in others) co-exist.*
>
> Whilst there are certainly some products and services, where there is indeed a demand which is "global" in nature and where local variations in taste, regulation, climate and other circumstances can be largely or wholly ignored, *there are far more products and services where such variations cannot be ignored without dire consequences.* For example, where climatic conditions affect the performance of machines, instruments, vehicles and materials and even more examples are obvious in relation to variation in national standards, specifications and regulations. Whilst it is true that international standardisation is a countervailing force through the activities of the International Standards Organisation (ISO) and many other bodies attempting to achieve harmonisation of technical standards, it is also true that the experience of the European Community over the past 20 years demonstrates the extreme difficulties attending this process in many areas (as well as the feasibility in others). And all this still does not take into account the cultural aspects of the problems which deeply affect such areas as food, clothing and personal services. (Freeman, 1995)

Globalization and radical innovation

Advocates of a strong globalization thesis would, of course, accept most of these points, although they might argue that some of them still constantly diminish as the media and travel, educational and international organizations all exert their long-term influence. For example, as has been shown above, Rothwell (1992) has pointed to the "electronification" of design as an important factor facilitating the internationalization of design and R&D (see Section 3). It can be argued further that local variations can easily be dealt with inside the framework of global strategies of the multinational corporations. Indeed, globalization of R&D has already led to local adaptation and modification of products to meet national variations, as a normal and almost routine activity of TNCs. Companies such as Honda go one step further and claim to have a strategy of diversity in worldwide design which goes beyond the simple modification of a standard product to the idea of local variation at the design stage in several different parts of the world. However, the vast majority of Japanese-based TNCs remain essentially Japanese companies, and the same is true of US firms and most other MNCs in relation to their home environment.

In this connection, it is difficult to disagree with the findings of Pavitt and Patel (1994) that *most R&D activities of MNCs are still overwhelmingly based on the domestic platform*. The statistics are hard to obtain, but analysis of all available data and cross-checking with patent statistics (Patel, 1994) suggests that the R&D activities of US companies outside the United States amount to less than 10 percent of the total, while those of Japanese companies outside Japan are much lower — less than two percent, though rising. The picture in Europe is more complex, both because of the development of the EC and the single European market and because of the existence of several technically advanced small countries, where the domestic base is too small for the strong MNCs which are based there (Netherlands, Sweden, Belgium, Switzerland). A larger part of national R&D activities in these countries and most other parts of Europe is undertaken by foreign multinationals and their "own" TNCs perform much more R&D abroad than is the case with the United States or Japan. Only a small part of total world-R&D is conducted outside the leading industrial countries and only a very small part of this is financed by TNCs.

Similarly, qualitative analysis of the transnational activities of corporations shows that most activity is either local design modification to meet national specifications and regulations or research to facilitate monitoring of local science and technology. The more original research, development and design work is still overwhelmingly concentrated in the domestic base, although there are important exceptions in both the drug and electronics industries where specialized pools of scientific ability play an important role.

The point we are making is that, as long as one is dealing with a static array of products and discussing only minor variations to adjust to local consumer tastes and environments, then the standardization arguments, the globalization arguments and even some of the simplifying neoclassical assumptions about perfect information are at the border of credibility and usefulness. "But once we leave this world and enter the dynamic world of radical innovations, both technical and organisational, and of extremely uneven and unequal access to new developments in science and technology, then the whole picture is transformed. More realistic assumptions and a more realistic vision are essential if economic theory is to be of any help in policy making." (Freeman, 1995)

Lundvall (1993) points out that, even in the case of continuous incremental innovation in open economies, the drive toward standardization is limited. Geographical and cultural proximity to advanced users and a network of institutionalized (even if often informal) user-producer relationships are an important source of diversity and of comparative advantage, as is the local supply of managerial and technical skills and accumulated tacit knowledge. He gives several examples of such localized learning generating strong positions in the world market. While he accepts that TNCs might locate in such "national strongholds" in order to gain access to the fruits of this interactive learning process, he points out that it is not always simple to enter such markets because of the strength of non-economic relationships involved. Competing standards for the global market may be important weapons in such situations as well as other forms of product differentiation and quality improvement.

When it comes to *radical* innovations, the importance of institutional variety and localized learning is even greater. Technological gaps and imitation lags are of fundamental importance here because it may be many years before imitators are capable of assembling the mix of skills, the work organization and other institutional changes necessary to launch into the production and marketing of entirely new products.

In the global diffusion of radical innovations, TNCs have an extremely important role. More than most firms, they are in a position to transfer specialized equipment and skills to new locations and to stimulate and organize the necessary learning processes. They are also in a position to make technology exchange agreements with rivals and to organize joint ventures in any part of the world. It is for this reason that many governments in Europe as well as in developing nations and the ex-socialist countries have been anxious to offer incentives to attract a flow of investment and associated technology transfer from firms based in Japan and the United States.

However, such efforts will meet with only limited success unless accompanied by a variety of institutional changes designed to strengthen technological capability within importing countries. This is especially true of those generic technologies which have been at the centre of the worldwide diffusion process over the last two decades. Here it is essential to emphasize the inter-dependencies between innovations and between technical and organizational innovations. Theories of globalization and technical change which ignore these inter-dependencies are no more helpful than a theory of economics which ignores the inter-dependencies of prices and quantities in the world economy.

While innovation can be easily accommodated to the globalization thesis, this is less the case with radical innovations which by definition involve an element of creative-destruction. When large clusters of radical innovations combined with rapid processes of incremental innovation are central, then the problems of structural and social adjustment can be very great. This is quite obvious when we consider such aspects as the change in management techniques and skill-mix which are called for; but it also applies to many other types of institutional change in standards, patents, new services, new infrastructure, government policies and public organizations.

In this context the concept of "national systems of innovation" assumes great importance and, in light of this approach, it is not surprising that the recognition of the scope and depth of the computer *revolution, which was accelerated by the micro-processor in the 1970s, has been followed by a growing recognition of the importance of organizational and managerial change (multi-skilling, lean production systems, downsizing, just-in-time stock control, worker participation in technical change, quality circles, continuous learning, etc.*

It is ironic that just as the importance of technological and industrial policies has been increasingly recognized in OECD and developing countries alike, the limitations of national policies are increasingly questioned and the relevance of national systems increasingly questioned. The global reach of transnational corporations, the drastic cost reductions and quality improvements in global communications networking and other rapid and related changes in the world economy must certainly be taken into account in any satisfactory analysis of national systems (Chesnais, 1992) but so also must the diversity of local conditions. Both geographers and economists have convincingly demonstrated the importance of regional characteristics for network developments and new technology systems. They have argued that local infrastructure, externalities, especially in skills and local labour markets, specialized services and, not least, mutual trust and personal relationships contributed greatly to flourishing regions. In brief, the further development of the globalization thesis depends on developing a framework in which transnational intentions of multinationals can be combined with the "local" conditions in which they must be embedded, Further, these factors must be applied to an environment dominated by radical rather than incremental innovation.

Globalization and Production: Identifying the New Challenges

The ideas presented here take the largely phenomenological and descriptive work that has so far characterized thinking on globalization a further, and important, step. According to this approach, globalization is not really about globalization of markets (if this means homogenization): the Coca-Cola and McDonald's phenomena. Nor is it really about the differentiation of mass-produced products to take account of shifting, or even the sophistication of consumer tastes. It is not even about increasing the flexibility of production, that is, extending the capabilities of mass-production techniques to shorter runs or more variability of products. Rather, it is about the accommodation of the methods production to "the constraints of variety." There are an increasing number of such methods of production. Globalization is about the diffusion of these innovative methods of production to centres all over the world.

The second point is that the search for innovative methods of production drives firms into novel forms of collaborative relationships — partnerships, alliances, networks. Increasingly, these linkages take on a global dimension because knowledge is now distributed widely throughout the world. Again, a great deal of attention has been given to the emergence of these partnerships and alliances, but the significance of the global sourcing of R&D by firms seems to disappear once it is described. It seems difficult to ground the significance of a globalization thesis on the worldwide sourcing of R&D.

The third point is that the "innovation" in "innovative methods of production" is more organizational than technological. Of course, the firm now has a reservoir of increasingly sophisticated technical devices to configure in the production process but the choices are more than technical ones. The relevant innovations here are concerned with the "invention" of organizational routines to deal with particular segments of productive activity. It is these, perhaps more than the technologies which are of significance in understanding globalization. *What is diffusing globally is knowledge about how to produce in a regime of variety.*

The problems of definition arise primarily because we have no vocabulary for dealing with increasing variety in methods of production. Initial descriptions in terms of "taylorist," "fordist," "toyotist," etc., production regimes do not grasp the dynamics of what is going on. Globalization and internationalization are often used carelessly and interchangeably, thereby mixing two different diffusion phenomena: the diffusion of the existing, single mode, regime of production (internationalization) with the diffusion of a whole panoply of different modes of production. To be sure, the wider diffusion (that is, internationally) of existing mass-production modes carries with it all the strains of adoption and adaptation, from the loss of productive capability at home (Cohen and Zysman, 1987) to the disruption or destruction of local economies in the developing world.

The fourth point then, is how to characterize this new regime of production. Coriat has labelled this new regime as a "regime of variety." It has four features characterized by the management of "virtual" demand, reactivity, stockless production and enhanced quality assurance. In the end, a permanent regime of variety becomes a regime of supply. Let us spell this out more fully with reference to the automobile sector as an exemple of a much more comprehensive set of transformations. To a greater or lesser extent, all mass-production sectors are encountering concerns about how to cope with the "constraints of variety." (Coriat, 1993)

An example of the order of variety

The automobile industry is passing from a regime centred on production and organized around the principles of specialization, to one with the organizing logic dictated by the constraints of variety. Confronted with supplier markets in which, beyond the strategies of differentiation, the capacity to move about in a universe organized around multiplicity has become both a condition of survival and an essential source of relative multiple advantages, automobile makers have progressively dealt with variety not just as a simple "constraint" of demand but as the central axis of their production and supply strategies. The entire productive order has swung toward new forces and bases that have come into their own with the movement towards variety.

From an analytical point of view, a new production regime is needed to grasp this general change in the market and the behaviour of suppliers (Coriat's "regime of variety"). This new regime of production must be set apart from the previous regime, the "fordist" one, that can be characterized as a regime of specialization. The regime of variety offers attributes that set it apart from the regime of specialization. One important function of this regime of specialization was to keep uncertainty within limits, and to make it predictable and programmable. By contrast, the regime of variety brings its entire operation into a realm of "virtuality." Rather than trying to manage uncertainty by limiting its scope and trying to make it predictable, the principle of non-predictability is accepted in order to manage efficiently within the regime of variety. In the automobile industry, for example, managers try less to predict the effective occurrence of demand on each of the hundred thousand models available, than to conceive organizations capable of reacting to every demand. Even if it is known and admitted that the occurrence of effective demand of every model is unequal, *the productive structure is designed to integrate the virtual possibility of satisfying each potential demand as much as possible.*

Features of the regime of variety: some basic stylized facts

- Variety is a regime of "virtual" production based on the property of reactivity. It is clear that variety in its larger sense demands, apart from flexibility and adaptability of production structure, an operating speed which can be adjusted — that is "de-multiplied" — within a very wide range. This defines the property of "reactivity." Flexibility is useless unless its effective time span lets it satisfy variety and its own order. *Market time span is not production time span and new technical and organizational methods must bring these two into line.* By contrast with the previous production regime, one could say that apart from flexibility, the reactivity that characterizes the regime of variety must be considered as the possibility of a rapid response to a large range of virtual demands.

- Variety is a regime of non-stock production and just-in-time production. The passing over to a permanent regime of variety can only be done by reducing drastically every type of stock. It is out of the question to stock work in process necessary for the manufacturing of hundreds of thousands of models that only consist of virtual demands. Models only get their true existence, and only have an object of manufacture, if a sale has brought about their existence. *To exist in the regime of variety is to exist without stock but to be able to produce the item demanded just in time.* This property of variety is bound to bring an upheaval in the relationships between suppliers and contractors, in this case, between the car makers or contractors and their suppliers and sub-contractors.

- Variety means a regime of original and better quality. Production without stock must bring about a leap forward in quality. If market time schedules have to be respected without stock, the manufactured products must be faultless. As soon as the security of stock disappears, production must be able to guarantee quality, otherwise there is the danger of total collapse of the system. Thus, a regime of variety necessarily means a regime of better quality. This property, just as the preceding one, will become a central element in the relationship between the contractors and sub-contractors. In practice, the passing over to a regime of variety goes alongside the assembler's decision to set up drastic procedures of selection for sub-contractors where quality criteria are decisive. This is also the basis of "new routines" in the relationships between contractors and sub-contractors, profoundly affecting manufacturing methods, both of the contractor and the sub-contractor.

- In the end, a permanent regime of variety is a regime of supply. In this characterization of the regime of variety a last step has to be made. Considerations of demand have occupied a central place in the creation of a regime of variety because it was these that pushed forward the elaboration of new procedures and routines. However, if the regime of variety is considered a permanent regime, it must be analysed as a regime of supply. Even if the consumer seems to be king, with the possibility of choosing between hundreds of thousands of variants of one particular model, we must not forget that the firm first chose to give the consumer this possibility. *It is the firm choosing to put itself into a situation of virtual variety that, in the first place, gives rise to the existence of the regime.*

  The reason for that choice is, paradoxically, that passing over to a regime of virtual supply provides for firms, in a given state of competitive relationships, a means of limiting the commercial and financial risks that accompany every act of production. In a situation of quasi-permanent innovation, of unpredictability of product life cycle and shrinking product life cycles, passing over to handling virtual demand, even if this means moving over into a universe of new constraints, also brings with it advantages of a wider nature. Indeed entering into the regime of variety means entering into a series of new constraints, linked to the general remoulding of production routines. In particular, as has been indicated already, the reactivity demanded by production without stock and the tightening of the regime of quality, means passing over to forms of internal organisation and to modes of inter-firm co-ordination that have been quite unknown, so far. In addition, virtual variety means a policy of design that can both shorten a product's life cycle but can equally develop the product within

> each loop to meet the demands that concern hundreds of thousands of virtual variants. (Coriat, 1994).

Much of the discussion of the "new rules of the game" has been carried out in terms of the diffusion of the regime of mass-production and, as such, it fails to grasp what is being globalized. We have tried to present an alternative view here which identifies the novelty of globalization in terms of the worldwide diffusion of new innovative production methods, of which some are technical and others are managerial or organizational. Globalization is about the spread of a new regime of production that can cope with the constraints of variety.

7. DEVELOPMENTS IN INDICATORS

The Technology and Economy Project (TEP) was also driven to consider the extent to which any of the problems raised could be better dealt with through improved science and technology (S&T) indicators. The principal need was for more and better output indicators, both for S&T and for innovative performance.

Measurement

A wide variety of statistics for the measurement of various aspects of technical change — sciento-metrics, techno-metrics, patents, research and development (R&D) expenditures and personnel, innovations, diffusions and so forth, have been developed over the years. Initially, the lead was taken by the Organization for Economic Co-operation and Development (OECD), Directorate for Science, Technology and Industry, but lately support has also come from the US National Science Foundation (NSF) and UNESCO, and from the EC on science and technology indicators. The OECD initiated the standardization of R&D statistics and has worked hard at improving them (OECD, 1993). It has also stimulated the development of new statistics intended to measure R&D "output" (OECD, 1992b).

There are still some serious gaps in, and problems with, the available statistics. In particular, it is often unsatisfactory to use R&D expenditure statistics as a surrogate for all the firm's activities which are directed toward knowledge accumulation, technical change and innovation. Measures exist for "capital intensity" and "energy intensity" but not yet for "knowledge intensity." There will always be problems in defining and measuring knowledge intensity, but a more serious attempt will be needed in the 1990s and 21st century, particularly now that the role of intangible investment has been generally recognized as equal in importance to, or even more important than, fixed investment (World Bank, 1991; OECD, 1992b).

Another major gap where some progress has already been made is in the measurement of innovation outputs (OECD, 1992b). The

OECD STI review reports the results of innovation measurement and survey work in six European countries OECD (1992b). As the introduction points out, these surveys are "quite heterogeneous in terms of objectives, methods, definitions and so on" but nevertheless add considerably to our knowledge about innovation. Moreover, these efforts and earlier works have made it possible for the OECD to produce guidelines for statistical practice in this field (*The Oslo Manual*) and to work with the EC on a European innovation survey in 1993 based partly on the manual. These indicators are the result of the interaction between academic research, national statistical offices in various countries, industrial agencies and firms, and international organizations which, together, have been able to generate valuable new data and analyses. As has been indicated, further work on scientific and technical services, intangible investment, diffusion of innovation and skills is needed but there are still big problems of definition, classification and measurement in all these areas.

The European Community's STI Review

Consideration needs to be given to a new source of science and technology indicators. This work, which is being co-ordinated by MERIT in Maastricht, represents an attempt to create a nest of S&T indicators for Europe to parallel what is done by the National Science Foundation for the United States. Though the first report is not yet available, it soon will be and so perhaps it is worthwhile to describe at least in outline what it will contain. The report is the outcome of a range of academic and other groups who have, in the past, collected indicators of various kinds, including the IMF, the World Bank, UNESCO, ILO, OECD, WIPO, ISI as well as national statistics.

To date, the aim of the report has been to assemble a range of indicators which together will provide a view of the strengths and weaknesses of European science and technology — in the sense of the EU — in relation to both the public and private sectors, vis à vis world performance. Indicators with this particular geographical focus have not been produced before and, as one might expect, there are considerable problems of access and comparability across the various S&T systems which comprise the current European Union. To add to this problem, an attempt has also been made in this report to assemble data on Eastern Europe and the former Soviet Union. This is an important precondition to an adequate understanding of the problems facing economies in transition, but as a data collection exercise the tasks involved seem formidable.

On the positive side, the report does try to assemble both input and output indicators not only in respect of economic performance (competitiveness), innovative performance (R&D expenditures and patents by sector) and S&T performance (expenditures, and publications by discipline), but also on human resources (demographic characteristics and trends, student numbers in higher education, the numbers graduating and employment in R&D). It will present bibliometric data on both the inputs and outputs of the scientific enterprise and chart the patterns of interaction that exist among scientists within the EU, as measured by co-citation patterns and collaborative research and technology agreements. A further set of indicators is being developed for regional scientific and technological competencies and for the characteristics reflecting the performance of small- and medium-sized enterprises (SMEs) (*The European Report on S&T Indicators*, Commission of the European Community, 1994).

The SPRU/BESST Research Project

In this connection attention should be drawn to some recent work at the Science Policy Research Unit (SPRU) aimed at developing data bases that will permit a more detailed and precise analysis of the contribution of S&T activities to industrial performance. In 1993, SPRU embarked on the Bibliometric Evaluation of Sectoral Scientific Trajectories (BESST) project, which uses bibliometric techniques to explore the sectoral relationships within the UK scientific community using, as indicators, publications contained in the 1981-1991 *Science Citation Index*. There are several objectives:

- To determine the share of UK national scientific output in various scientific fields contributed by universities, industry, research council laboratories, government laboratories, hospitals, charities, etc., and to determine how this has changed over the last decade.

- To map the changes during the 1980s in patterns of inter- and intra-sectoral collaboration in different scientific fields.

- To investigate changes in the patterns of collaboration between UK institutions and the EU and non-EU institutional partners.

- To develop computer-generated graphics to assist policy makers and analysts to visualize how collaborative activities change over time.

- To investigate such policy-relevant questions as: how do economic factors affect UK scientific output? How significant are hospitals in the UK science base? Which sectors are putting more emphasis on scientific research and which are cutting back? Have individual sectors shifted emphasis among scientific fields? Who are the preferred partners for collaborative research? Has this shifted over time in response to government programs?

The BESST project has made some progress in developing specialized software packages to render the *Science Citation Index*, a useful resource in answering some of these questions, into a form appropriate for desk-top PCs. These techniques, therefore, can be used as an analytical tool for individual scholars and policy analysts especially when computer power has presented a distinct limitation. A report of the study is mentioned here not only because of the significant advance that it is making in the handling of large and complex data sets, but also because of the potential of these techniques to contribute to the further development of distinctive scientific and technological indicators, which is now at the focus of much EC policy research.

8. SUMMARY AND CONCLUSIONS

Research into the innovation process has shifted from the abstract to the concrete. In the text, this is treated in terms of the growing importance of appreciative versus formal theorizing in economics, and of the central role played by firms in knowledge generation. It is hard to disagree with Krugman when he argues that competition takes place among firms, not nations, and to apply the concept to nations is either a misnomer or a category mistake. Each firm needs to make its own way and not be overly concerned by scare tactics about globalization and competition among nations.

Formal "growth theory" has been much influenced by advances in our understanding of how firms behave and of how they innovate. This case has been well argued by Nelson, among others. The role of science and technology in innovation, as in the economy as a whole, is complex and evolving. According to one theorist, Romer, the new growth theory needs a period of time to reflect on the insights of science policy studies and research into the innovative process, whether in management, theories of the firm or organization theory. The study of institutions and of how they shape and are shaped by science and technology seems to be coming back onto the agenda.

Firms behave differently. Therefore, diversity rather than convergence in terms of performance is to be expected. But differences among firms are reflected in differences in national economic performance. There is little evidence to support the view that, despite the enormous variety at firm level, there is some law or force pushing national economies toward similarity in terms of performance. Variety is the natural outcome of growing competitiveness and this has characterized the international economy over at least the last decade.

Variety is bound to come about once the cumulative, path-dependent nature of technical change is appreciated. As firms innovate and as they continue to learn how to improve their initial design configurations, they leave behind other firms that are less efficient at doing so. Learning also takes place locally. This leads to a recognition of the importance of "local conditions" in promoting clusters of innovating firms. Linkages (for example, user-producer ones), whether local, national or international, have been identified as important to successful innovation. One reason for this is that linkages provide channels of communication along which knowledge flows and learning occurs.

In many of the most recent theories on innovation, learning is crucial. Once the perspective shifts from technology as artifact to technology as knowledge, the emphasis is bound to turn to learning, to how knowledge resources are acquired and how competences developed. The role of training — the average level possessed by the work force — will also be important in discriminating weak sectors of the economy from strong ones. In these pages, much attentions has been given to the insight of Nelson: important knowledge for innovation lies in organizational routines. How such routines change is clearly an important matter for further research but it is already clear that, with the spread, on the supply side, of highly differentiated forms of specialized knowledge, tacit knowledge may be more important than codified knowledge in the innovation process. To "capture" that tacit knowledge is problematic. We have also noted the crucial role of the rate of ICT in the future innovation. This is now seen to be a key factor governing the "rate" of innovation in many industrial and business sectors.

The general shift from the abstract to the concrete also focuses attention on the historical, cultural and institutional context of the nation state. This complexity is meant to be grasped in the notion of national innovation systems which is currently at the centre of much science and technology policy. If, partly because of their history, national systems of innovation differ in their effectiveness and in their learning profiles, then policy must move, initially at least, within the constraints of the local institutional environment.

Firms operate within different financial systems. Post-TEP, the capability of traditional financial institutions to provide the wide range of instruments needed to the support innovation process has been a growing concern about. As with every other aspect of the innovation process, finance is also a specialized activity. The evidence from the most recent OECD analyses suggests that existing financial institutions are seldom sophisticated enough to deal with the different types of risk and uncertainty which accompany the innovation process at different stages. The Organization for Economic Co-operation and Development (OECD) is developing the idea of financing innovation in terms of the nest of institutions which have as their collective objective the management of risk in the economy. In this way, it hopes to break away from the fact that, in some national economies, financial institutions systematically underinvest in innovation while in others they overinvest.

Unemployment continues to be problematic within OECD member countries. Whether it is chronic, structural or a mixture of the two is still the subject of debate. The evidence presented here leans toward a structural interpretation rather than to the conventional economic interpretation in terms of imbalances or rigidities in labour markets. Perhaps the notion of full employment is losing its meaning as is *full-time* employment. The structure of work is changing; jobs are being replaced by a range of occupations which may be more or less full time. The pattern is being complicated by the growth of services, and by a better idea of the economic importance of services and of what productivity in services might mean. Still to be dealt with are the consequences, in terms of understanding, of knowledge as a source of competitive advantage. As yet, there is little in the way of theoretical guidance as to what the "productivity of knowledge" might mean or how it might be measured. Yet, it is already clear that productivity indices will differentiate country performance in the way that total factor productivity and R&D intensity have heretofore.

Globalization is, to some extent, in retreat because it is so difficult to be precise about what it means. Finance is currently the most globalized sector, in the sense that existing computer and communication technologies now make it possible to carry out transactions to and from any place in the world. Some types of fast food and soft drinks are produced and marketed globally but it must be admitted that the rate of technical change locally is often severely restricted by franchise agreements. The same conditions, however, do not apply to product and process innovations. In manufacturing, there is considerable evidence to suggest that the most sensitive R&D is still carried out locally, though the global sourcing of R&D seems to be increasing. We have argued that the *diffusion of variety in methods of production* describes better what is distinctive about globalization. The increasing variety in methods of production is potentially of more significance than either the globalization of finance or of markets for standardized mass-produced products. New production technologies make it possible to bridge the gap between constantly shifting patterns of supply and demand and to carry out production locally. It also allows the phenomenon of globalization to be connected with the main thrust of innovation and competitiveness that firms face.

New science and technology indicators are being developed in several places, notably the OECD and the EU. In these, there is a greater concentration on inter-country and inter-sectoral comparisons and a general shift to more and better output indicators. We also note the beginning of data assembly for the countries of Eastern Europe and the former Soviet Union. In science indicators, specifically, we have noted the development of techniques which allow countries to identify nation-specific sectoral patterns, for example, linkages between university research and industry or linkages between industrial research and clinical research. Such indicators will highlight the connectivity of the knowledge-producing institutions in national systems, and connectivity, as we have seen, is one of the key features characterizing national systems of innovation.

In general, there has been a shift in the value attributed to data, information, knowledge and learning as the source of competitive advantage in the innovation process. For firms this means developing strategies which make it possible to enhance their existing knowledge base through a carefully selected set of collaborative arrangements. Assembling all the "possibly necessary" knowledge in-house is now regarded as too difficult, too risky and too expensive. On the other hand, most firms know already that there is no access to advanced forms of knowledge without participation in its creation, and this drives them to seek access to networks of various kinds and, increasingly, to signal their competence by publishing in the best scientific and engineering journals.

For governments, this development has once again raised questions about the role of state-funded research and raises the problem of drawing national advantage out of research which is increasingly carried out internationally and on a collaborative basis. At the very least, this change has deep implications for those national institutions with a mandate for knowledge generation, most particularly the universities and government research establishments. As we have seen, the thrust of innovation policy has shifted to a concern with diffusion, not so much of the products and process but of the knowledge on which they are based. This is exemplified in the attempt to classify national systems of innovation in terms of their distribution power. The policy aim here is to increase this power and to make existing knowledge available to those who need it at the time that they need it. The ability to move knowledge, whether codified or tacit, rapidly around an innovation system is replacing the generation of knowledge in policy importance in many countries, particularly those of the European Union. As has been outlined in the text, this shift leads to very different science, technology and innovation policies.

We began this paper with a brief discussion of the Solow Paradox: despite large scale investments in technology over the last 20 years, productivity growth has not risen. It has been argued that the paradox can be partially explained by distinguishing between radical and incremental innovation. The slowdown in productivity derives from the technological exhaustion of particular sets of inter-related technologies — systems of production. As a consequence, rising investment exhibits diminishing returns. At the same time, investment is increasing in radical innovations but the institutional structure is not yet in place to allow the full benefit from these investments to be realized. This paradox reflects the fact that many advanced economies are going through a period of significant structural change.

There seems little argument that it is the new information, computer and telecommunication technologies (ICTs) which are leading this development. For governments, this means more than heavy investment in hardware development. As we have tried to argue throughout the text, the increasing centrality of ICTs in the innovation process means that data, information knowledge and learning need to move, and are moving, to the centre of policy formulation in many countries. This development is perhaps most evident in the new framework being developed in the EC in which diffusion is the central concept leading the development of policies for science and technology. In broad terms, countries are in transition from policies focused on the generation of knowledge to policies focused on the distribution of knowledge. This shift in perspective has deep implications for the knowledge-producing institutions that make up the national innovation system in each country.

APPENDIX
OECD FACT SHEETS

Fact Sheet 1: Research and development statistics

Aim

To measure the investment in the creation of new scientific and technological knowledge by the performance of research and experimental development (R&D). To assess the scale, structure and direction of such R&D activities in various countries, sectors of the economy, industries, fields of science and technology, etc., by measuring the amount of financial and human resources (inputs) involved.

Methodology and coverage

The *Proposed Standard Practice for Surveys of Research and Experimental Development,* otherwise known as, "the Frascati Manual" was the first in the OECD series of Manuals on "The Measurement of Scientific and Technical Activities" (OECD, 1981*b* and 1989*i*). First issued in 1963, it is the generally acknowledged international standard for such surveys. The draft of the fifth edition was discussed at a conference in Rome in Autumn 1991 and should be formally adopted in 1992.

Research and experimental development covers creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications. R&D is a term covering three activities: basic research, applied research and experimental development.

In principle, R&D statistics are collected from the bodies who carry out the projects rather than those who finance them (except in the case of budget-based series). Financial resources include both current and capital expenditures with depreciation payments excluded. Human resources are collected in terms of "full-time equivalent" (FTE) on R&D and may be broken down either by occupation or by level of qualification.

R&D is an innovation activity (Fact Sheet 6) and are an important component of intangible investment (Box 6).

Data collection

The OECD maintains a substantial data base of R&D statistics with time series back to the late 1960s (OECD 1990e). It is updated in detail by biennial benchmark surveys addressed to Member governments (known as ISY surveys and by bi-annual surveys of the main series for the *Main Science and Technology Indicators* publication, also available on diskette. More detailed statistics are available in a publication entitled *Basic Science and Technology Statistics* and on tape and on diskettes.

Fact Sheet 2: Patent statistics

Aim

To use data collected by national and international patent agencies to construct indicators for the level, structure and evolution of inventive activities in countries, industries, companies and technologies by mapping changes in technology dependency, diffusion and penetration.

Methodology and coverage

The growing role of international patents organisations is contributing to greater comparability between the patent data available for individual countries, although these are still affected by special characteristics of patents. At the moment, there are no international guidelines for the use of patent statistics as science and technology indicators. The OECD plans to produce such a volume (for reviews of current literature see Basberg, 1987 and Griliches, 1990). A guideline for the use and interpretation of patent data as an indicator of S&T is being prepared. A first draft will be ready next spring.

A patent is a right granted by a government to an inventor in exchange for the publication of the invention; it entitles the inventor to prevent any third party from using the invention in any way, for an agreed period.

Patent data cover applications and grants classified by field of technology. International applications series distinguish four subcategories: *i)* patents taken out by residents of a country in that country; *ii)* patents taken out in a country by non-residents of that country; *iii)* total patents registered in the country or naming it; *iv)* patents taken out outside a country by its residents. Data on patents granted only distinguish between patents awarded to residents and to non-residents.

Patent descriptions also contain much technological information unavailable elsewhere and therefore constitute a significant complement to the traditional sources of information for measuring diffusion of technological/scientific information (see Fact Sheet 4 on bibliometrics).

Data collection

The raw data are available from national and international patent offices. The OECD assembles, stocks (1990e) and publishes total applications data for its Member countries for the four categories identified above in *Main Science and Technology Indicators* and *Basic Science and Technology Statistics* and the associated diskettes and tapes. It also holds a base of patents applied for in the United States broken down by the country of residence of applicants and by industry.

Fact Sheet 3: The technology balance of payments (TBP)

Aim

To measure the international diffusion of disembodied technology by reporting all intangible transactions relating to trade in technical knowledge and in services with a technology content between partners in different countries.

Methodology and coverage

The OECD issued the *Proposed Standard Method of Compiling and Interpreting Technology Balance of Payments Data - TBP Manual* in 1990 (OECD, 1990*k*). It is the second in the series of OECD Manuals on Science and Technology Indicators.

The following operations should be *included* ij the TBP: patents (purchase, sales); licenses for patents; know-how (not patented); models and designs; trade-marks (including franchising); technical services; finance of industrial R&D outside national territory.

The following should be *excluded*: commercial, financial, managerial and legal assistance; advertising, insurance, transport; films, recordings, material covered by copyright; design; software.

The international comparability of national TBP indicators is only improving progressively as national practices are changed to match the guidelines of the new Manual.

Data collection

National TBP data may be collected by means of special surveys but more often are assembled from existing records kept by Central Banks, exchange control authorities, etc.

The OECD has assembled a data base of "macro" TBP data for most of its Member countries covering total transactions (receipts and payments) by partner-country back to 1970 (OECD, 1990e). Data for recent years have been published in *Main Science and Technology Indicators* and *Basic Science and Technology Statistics* and the associated diskettes and tapes. It has recently created a new international data base for detailed TBP series (broken down by industry, type of operation and geographical area) starting with Japan, Germany, Italy and Sweden, and a special international survey was launched in Summer 1991. In parallel, detailed data based on national practices and classifications have been assembled and updated for about ten countries.

Fact Sheet 4: Bibliometrics

Aim

To use data on the number and authors of scientific publications, articles and the citations therein (and in patents), to measure the "output" of research teams, institutions and countries, to identify national and international networks and to map the development of new (multi-disciplinary) fields of science and technology.

Methodology and coverage

Bibliometric methods have essentially been developed by university groups and by private consultancy firms. As yet there are no official international guidelines for the collection of such data or for their use as science and technology indicators. During the TEP, the OECD commissioned a report on the "state of the art" in bibliometrics (van Raan and Tijssen, 1990) which constitutes a basis for an OECD manual on the use and interpretation of bibliometric indicators. It may be prepared and issued in co-operation with the European Commission (European Network on S&T Indicators of the MONITOR-SPEAR Program).

Bibliometrics is the generic term for data about publications. Originally, work was limited to collecting data on numbers of scientific articles and publications, classified by authors and/or by institutions, fields of science, country, etc. in order to construct simple "productivity" indicators for academic research. Subsequently, more sophisticated and multidimensional techniques based on citations in articles (and more recently also in patents) were developed. The resulting citation indexes and co-citation analyses are used, both to obtain more sensitive measures of research quality and to trace the development of fields of science and of networks.

Data collection

Most bibliometrics data come from commercial companies or professional societies. The main general source is the Science Citation Index (SCI() set of data bases created by the Institute for Scientific Information (United States) on which are based several major bases of science indicators developed by Computer Horizons Inc. (for the National Science Foundation). Other specialised bases are Medline (United States) and Excerpta Medica (Netherlands) for medical bibliometrics, and Chemical Abstracts (United States).

A number of other international and/or national databases, frequently interlinked, are currently being developed. The OECD currently has neither plans, resources nor competence to undertake basic data collection, although bibliometric data are regularly used in its analytical reports.

Fact Sheet 5: High technology products and industry

Aim

To construct indicators to measure the technology content of the goods produced and exported by a given industry and country with a view to explaining their competitive and trade performance in "high-tech" markets. These markets are characterised by rapid growth in world demand and oligopolistic structures, they offer higher than average trade returns, and they affect the evolution of the whole structure of industry.

Methodology and coverage

Indicators on trade in high-tech products/industries were originally designed as measures of the "output" or "impact" of R&D; they are now seen as having a wider use in the analysis of competitiveness and globalisation.

There are yet no officially approved international standards for identifying high-tech industries and products. Two main approaches have been used to date, by *industry* where OECD work (drawing on earlier studies by the US Department of Commerce) has been the basis for most exercises in individual countries and by *product*. The OECD plans to produce a volume of recommendations covering both approaches.

a) In the *industry* approach, used by the OECD, the main criterion used in the past has been R&D expenditures as a percentage of the production, turnover or value added of the industry concerned. Industries were divided into three categories, "high", "medium" and "low" R&D intensity (OECD, 1986c). Further work will allow industries to be divided up according to their "technology content", taking into consideration not only direct investment in R&D but the indirect acquisition of its domestic results incorporated in *i)* intermediate consumption *ii)* capital goods, and *iii)* results of foreign R&D-incorporated in imported goods. All these technology inputs must be estimated econometrically using input-output matrices.

b) The *product* approach has the advantage of allowing more detailed analysis and identification of the technology content of products and hence a weeding out of mature products manufactured by otherwise R&D intensive industries. This approach requires the use of detailed R&D data by product field.

Data collection

To date the OECD has favoured the industry approach. Using an OECD trade data base classified by ISIC, a set of import-export ratios for the main R&D-intensive industries has been set up and published twice a year in *Main Science and Technology Indicators* and the associated diskette. Series for trade by high, medium and low R&D-intensive industries are analysed in the annual *Review of Industrial Policy in OECD Countries* and summarised in *OECD Figures.* In addition to the other improvements mentioned above, a new trade base by product that will offer greater analytical possibilities will be established in 1992.

Fact Sheet 6: Innovation statistics

Aim

To measure aspects of the industrial innovation process and the resources devoted to innovation activities. To provide qualitative and quantitative information on the factors enhancing or hampering innovation, on the impact of innovation, on the performance of the enterprise and on the diffusion of innovation.

Methodology and Coverage

The *OECD Proposed Guidelines for Collecting and Interpreting Innovation Data - Oslo Manual,* prepared jointly by the OECD and the Nordic Fund for Industrial Development (Nordisk Industrifond, Oslo) in 1990, is currently under revision. It will then be officially adopted by the OECD as the third in the "Frascati" family of manuals and should be issued late in 1991 or early in 1992.

Technological innovations comprise new products and processes and significant technological changes of products and processes. An innovation has been *implemented* if it has been introduced on the market (product innovation).

- *Major product innovation* describes a product whose intended use, performance characteristics, attributes, design properties or use of materials and components differ significantly compared with previously manufactured products. Such innovations can involve radically new technologies or can be based on combining existing technologies in new uses.

- *Incremental product innovation* concerns an existing product whose performance has been significantly enhanced or upgraded. This again can take two forms. A simple product may be improved (in terms of improved performance or lower cost) through use of higher performance components or materials, or a complex product which consists of a number of integrated technical subsystems may be improved by partial changes to one of the subsystems.

- *Process innovation* is the adoption of new significantly improved production methods. These methods may involve changes in equipment or production organisation or both. The methods may be intended to produce new or improved products which cannot be produced using conventional plants or production methods or to increase the production efficiency of exiting products.

Data collection

National data on innovation activities are generally collected by means of surveys addressed to industrial firms. Over half of the OECD Member countries have organised such surveys, and it is on their experience that the Manual is based (OECD, 1990*d*).

It is also possible to collect data on the number and nature of actual innovations. Such information can be obtained by special surveys or assembled from other sources such as the technical press.

So far, the only internationally comparable series of data are those collected under the auspices of the Nordic Industrial Fund. The OECD is planning to set up an international survey of innovation activities, working in close cooperation with the Nordic Fund and the Eurostat.

Fact Sheet 7: Measuring the use of advanced manufacturing technology

Aim

To measure the extent of use of different kinds of manufacturing technology, including the patterns of diffusion and the effects of use (disadvantages, difficulties, constraints and barriers to wider use) as well as skills and training and employment issues.

Methodology and coverage

A list of "Key Survey Questions" was published in *Government Policies and the Diffusion of Micro-electronics* (OECD, 1989a). These questions covered the applications of micro-electronics in processes where they are used for monitoring and controlling purposes as well as in products. The OECD has been playing a clearing-house role in this area, regularly reviewing and exchanging information on surveys that have been carried out or are under way, and promoting greater comparability between national surveys. The diffusion and use of manufacturing technology was reviewed in *Managing Manpower for Advanced Manufacturing Technology* (OECD, 1991a.

Advanced manufacturing technology is defined as computer-controlled or micro-electronics based equipment used in the design, manufacture or handling of a product. Typical applications include computer-aided design (CAD), computer-aided engineering (CAE), flexible machining centres, robots, automated guided vehicles, and automated storage and retrieval systems. These may be linked by communications systems (factory local area networks) into integrated flexible manufacturing systems (FMS) and ultimately into an overall automated factory or computer-integrated manufacturing system (CIM).

Data Collection

National data have been collected through special surveys of manufacturing firms. About half of the OECD Member countries have carried out surveys, and their comparability has improved due to the use of common survey questions.

So far detailed international comparisons of the use of AMT have been made in France, Germany and the United Kingdom, and subsequently in Canada and the United States. Other countries have made more limited comparisons. The OECD has followed and encouraged these comparisons and is planning to carry out further work on comparisons and date collection in 1992.

Fact Sheet 8: Science and engineering personnel

Aim

To establish coherent data bases on the current and possible future supply, use and demand (at home and abroad) for science and engineering (S&E) personnel with a view to evaluating the consequences for future research and industrial performance, planning education and training, measuring the diffusion of knowledge incorporated in human resources and assessing the roles of women (and minorities) in science and technology activities.

Methodology and coverage

There are, as yet, no international standards for measuring stocks and flows of S&E personnel. The main exponent of this type of work is the National Science Foundation (United States). The OECD is undertaking a review of the current state of studies and data in its Member countries prior to preparing some initial guidelines.

S&E personnel may be defined in terms of their qualifications or their current employment. In the former case, the appropriate classification is the International Standard Classification of Education (ISCED) and, in the latter, the International Standard Classification of Occupations (ISCO). They may cover only persons with university qualifications/professional occupations or also include those with other post-secondary qualifications and technical jobs. A combination of both criteria and levels is needed if supply and demand issues are to be analysed correctly.

A typical system should cover total national stocks of S&E personnel at a given point in time, broken down by employment status and by sector and type of employment and the intervening inflows (mainly educational output and immigration) and outflows (mainly retirement and emigration). Both stocks and flows should be broken down by field of science and technology, age and sex and possibly also national or ethnic origins.

Data collection

While a few very small OECD countries are able to maintain complete nominal registers of all S&E graduates and their whereabouts, data bases on S&E personnel have to be built up in most countries from several sources, notably education statistics (numbers of teachers and graduates), employment statistics, and population censuses supplemented by special surveys. UNESCO collects and publishes data annually on total national stocks of scientists and engineers (UNESCO, 1990). The OECD hopes to build a more sophisticated set of indicators. The establishment of a consolidated data base for the higher education sector (see Academic STAN) could contribute to supplying this data.

Fact Sheet 9: Education statistics and indicators

Aim

To provide comprehensive and reliable international education statistics and indicators which take full account of the complexity of providing adequate education in modern societies in order to assist with policy formulation and debate.

Methodology

The underlying OECD methodology for education statistics is still basically that suggested in *Methods and Statistical Needs for Educational Planning* (OECD, 1967), although educational structures and international classification systems have since evolved considerably. UNESCO's International Standard Classification of Education (UNESCO, 1976) gives guidelines on fields and levels of education which have been adopted by the OECD.

The definition of "education" is conventional (but increasingly problematic given the growing diversity of provision), as it concerns only education provided in schools, universities and other establishments considered as part of the overall education system, with access to each level normally possible only on completion of the preceding level. All training activities for adults or specific target groups such as young people seeking jobs, the unemployed, etc., are thus excluded.

The OECD is currently working to develop the methodology for sets of more refined, internationally comparable education indicators of greater interpretative utility. This is still in a development phase but will feed into the work on educational statistics from 1992 in the form of a handbook that considers methodology, definitions and measurement.

Data collection

The OECD currently collects education statistics using a set of questionnaires common to the OECD, UNESCO and Eurostat. These cover, first, data on enrolments, qualifications, and teachers in pre-primary, primary, and secondary education; second, similar breakdowns for further and higher (third level) education; third, educational expenditure and financing. This data is stored in a data base and published in *Education in OECD Countries: A Compendium of Statistical Information* (OECD, 1989*m* and 1990*n*).

After a stocktaking, consolidation and review exercise, the surveys and data base will be overhauled; both the new needs identified and modern methods of data transmittal and access will be taken into consideration.

Fact Sheet 10: Training statistics

Aim

To collect data on the amount, costs and beneficiaries of "structured" training provided and sponsored by employers. Subsequently, to identify what determines employer spending, the costs and benefits to employers and employees, and the success of different types of training. The information will contribute to the design of policies for dealing with loss of competitiveness, an ageing work force and the challenges posed by new technologies. Data on training expenditure will contribute to measuring "intangible investment".

Methodology and coverage

There is as yet no international statistical framework for the collection and analysis of training statistics. However a group of OECD experts has reviewed the available national statistical information on training activities for about a dozen participating Member countries in order to propose useful and appropriate definitions and methodologies for measuring training for policy purposes and to allow meaningful inter-country comparisons.

The first results are given in a restricted report now being considered by the OECD Education Committee and Employment, Labour and Social Affairs Committee. It covered enterprise-based training, i.e., education and training activities organised or sponsored by enterprises, as described in surveys of employers and employees. The next task will be to develop a set of definitions for the most commonly used training terms and to work towards comparable surveys of employers and employees that are more transparent with respect to the definition of the components of training; and the associated classifications, reference periods and practical survey methods.

Data collection

All the participating countries conducted surveys of individuals to discover who received training, although in varying degrees of detail. Most countries also conducted surveys of employers on employer-based training but only a few covered expenditure on training. Only one or two countries had time series. National surveys were undertaken using different methodologies, definitions and reference periods and asking different questions. Some approaches worked better than others.

The actual data are not given in the methodological report cited above. There has, however, been a parallel and closely related exercise assessing the scale and pattern of enterprise training whose results were published in the 1991 OECD *Employment Outlook* (1991*j*).

Fact Sheet 11: Structural statistics and indicators

Aim

To make available annual series over a long period for the main industrial variables (see below) broken down by industry; they can be used either alone or in connection with science and technology statistics and trade statistics, to construct derived indicators, to measure structural change and to assess government adjustment policies.

Methodology and coverage

Structural statistics are among the oldest series collected by OECD countries. The variables concerned are: production, value added, employment, total investment (of which investment in machinery and equipment), the number of firms or establishments, labour costs and hours worked.

There are two main types of data: *a)* responses to surveys of industrial firms; *b)* series derived from National Accounts. The former are based on methodology established by the United Nations (UN, 1986c) which can differ significantly from that in the SNA. The latter include a wide range of service industries; the former deal almost exclusively with manufacturing, but provide more industrial detail than the SNA (3 or 4 digits in ISIC).

Data collection

The OECD organises an annual survey on structural statistics and the resulting data go back up to twenty years depending on the variables concerned. They are published annually in *Industrial Structure Statistics.* Other data bases with similar contents have been established by the United Nations (United Nations Statistical Office at New York, United Nations Industrial Development Organisation in Vienna) and by Eurostat. All these are assembled and fed into the OECD structural analysis data base (STAN) (see Box 62).

Fact Sheet 12: Short-term industrial indicators

Aim

To supply information on trends in the volume of activities in the main industrial sectors (with a lag of at most one-quarter) in order to assess the current industrial climate and to update the indicators based on structural statistics (Fact Sheet 11) in order to give timely support for industrial policy and analysis.

Methodology

There are no established world-wide methodological guidelines for the collection and comparison of short-term industrial indicators other than those associated with the OECD quarterly survey (see below).

Short-term indicators are collected and presented on a monthly and quarterly basis. They are generally expressed as indices and are systematically corrected for seasonal variations.

The indicators concerned are: production, deliveries, production prices, new orders and unfilled orders and employment of operatives. Other qualitative indicators are collected, notably:

judgements on stocks of finished goods, on order books, on total order inflow, on production prospects, on capacity utilisation and on labour force expectations. The basic classification is by industry defined in terms of ISIC. At the OECD the quantitative data are available for about 25 industries (levels 2, 3 and 4 of ISIC) whereas the qualitative series are available only at level 2 of ISIC.

Data collection

National data are collected by means of monthly and quarterly surveys. The OECD has been holding a quarterly international survey since 1975. It covers monthly, (seasonally adjusted) quarterly, and annual series. The resulting data base is the only international source of up-to-date statistics by industry. In future it is intended to extend the data base to include selected high-tech industries and additional variable, notably for investment and certain financial indicators. The data are published quarterly in *Indicators of Industrial Activity* and are used in the *Annual Review of Industrial Policy in OECD Countries.*

Fact Sheet 13: The OECD's subsidies and structural adjustment project

Aim

To fulfil a Ministerial mandate by quantifying the scope of government programmes to support industry and the trends therein, to improve international transparency and to evaluate the subsidy element of these programmes and their impact, notably on competitiveness.

Methodology and coverage

A standard international methodology is being developed as the project progresses. In the present phase, the Net Cost to Government (NCTG) measurement has been added to the Gross Government Budget Expenditure (GGBE); it gives a better approximation of the subsidy equivalent of government support for industry. Two categories of support are identified: financial instruments and fiscal aid.

The main financial instruments included are: direct subsidies (grants, non-repayable advances, repayable advances and interest rate subsidies), loans (included in the budget or accorded via financial intermediaries), loan guarantees and the provision of equality capital.

Fiscal aid covers tax exemption, tax allowances, tax credits, special rate reliefs, tax deferrals and accelerated depreciation. Civil and military procurement are also taken into consideration.

The different types of budgetary expenditure are broken down into eight policy areas: sectoral measures, enterprises in difficulty, research and development, regional policy, investment aid, SMEs, employment and training, and exports and trade-related assistance.

In the next phase, support programmes will be classified into more homogeneous categories, so as to be able to identify their direct economic impacts.

Data collection

There have been two surveys undertaken for the exercise. The results of the second one, covering the period 1986-89, are held in a data base at the OECD. The results are not simple statistics but give a quantitative and qualitative description of some 800 industrial support programmes which can be used to establish new classifications and measure the impact on competitiveness. Given the nature of this information and certain problems of confidentiality, it is stocked and analysed in local mode.

Fact Sheet 14: Foreign direct investment

Aim

Within the framework of the globalisation of industrial activities, to collect annual data on stocks and flows of FDI, broken down by industry, which are comparable with other industrial and technological statistics, in order to quantify the impact of flows of foreign investment on trade, technology transfer and the industrial structure and competitiveness of the investor and host countries.

Methodology and coverage

The basic world-wide definitions are those developed by the International Monetary Fund. The OECD is preparing a revised Detailed Benchmark Definition of Foreign Direct Investment which is compatible with the forthcoming revised versions of the "IMF Balance of Payments Manual" (fifth edition to be published at latest in 1992) and of the SNA.

A foreign direct investor is an individual, incorporated or unincorporated enterprise which possesses a subsidiary, associate or branch operating in a country other than the country or countries of residence of the investor. This should involve ownership of at least 10 per cent of the ordinary shares in the voting stock of the enterprise in which the investment is made. Depending on the degree of control "foreign direct investment enterprises" may be:

- Subsidiaries, i.e., where the parent company owns more than 50 per cent of the voting stock of an incorporated enterprise (or has the right to appoint or dismiss the majority of its directors).
- Associated corporations, i.e., where the parent company owns 10-50 per cent of the voting stock of an incorporated enterprise which enables it to influence its management.
- Branches, i.e., non-incorporated enterprises (treated as a quasi-corporation in the SNA) set up by the parent company with others, involving the purchase or rent of land or buildings and the acquisition of other fixed assets for use in a significant level of production.

Data collection

Data on foreign direct investment are collected in most OECD countries by Ministries of Finance, Central Banks and Ministries of Industry and Trade. The three main categories of data are:

- the amounts of flows of investment within and out of each country by sector (industry and services) and by geographic zone;
- the value of stocks of investment (or failing this, the cumulative sums over a long period), within and outside the country by industry and zone;
- the characteristics of firms whose capital is more than 50 per cent owned by non-residents, broken down by industry. The variables concerned are the number of firms, employment, gross production, value added, gross capital formation, gross operating surplus, gross capital stock, investments in R&D, exports, imports and technology transfers.

The OECD has surveyed the third category of FDI, and data are available for 12 countries and for various years during the period 1972-87. Information on the first and second categories is available from national sources only.

Fact Sheet 15: Environmental indicators

Aim

To develop indicators to be used for the integration of environmental and economic decision-making at the national, international and global levels.

To inform the ongoing process of policy dialogue among countries and to lay the basis for international co-operation and agreements. To respond to the public's "right to know" about basic trends in air and water quality and other aspects of their immediate environment affecting health and wellbeing.

Methodology and coverage

There is no universal set of environmental indicators; rather, there are sets of indicators responding to specific conceptual frameworks and policy purposes.

Three broad families of indicators are involved:

i) Indicators for reporting environmental conditions and trends and broadly measuring environmental performance where the existing OECD statistical framework is currently being improved and extended.

ii) Indicators for the integration of environmental concerns in sectoral policies; i.e., the development of sectoral indicators showing environmental efficiency and the linkages between economic policies and trends in key sectors (e.g., agriculture, energy, transport) on the one hand, and the environment on the other.

iii) Indicators for the integration of environmental concerns in economic policies more generally through environmental accounting, particularly at the macro-economic level. Priority is being given to two aspects: the development of satellite accounts to the system of national accounts, and work on natural resource accounts (e.g., pilot accounts on forest resources).

All the above methodological work is undertaken in close co-operation with other international organisations, notably Eurostat.

Data collection and publication

The OECD maintains a core set of statistics on the state of the environment in Member countries in its SIREN data base, and data are published regularly in *Compendia of Environmental Data* (OECD, 1991*i*). The results of this and other work on environment indicators are presented in the series of reports on the state of the environment prepared about every five years for Ministerial meetings at the OECD. A special publication *Environment Indicators: A Preliminary Set* was issued for the 1991 meeting (OECD, 1991e).

NOTES

1. These cover only the main categories. For a fuller description see OECD (1990*j*).

2. The general concept of science and technology indicators was addressed in the early 1960s but was not raised again seriously until the publication in 1973 of the first of the US National Science Board reports on Science Indicators (later Science and Engineering Indicators). The OECD definition quoted here is developed from ideas in these reports and first appeared in the general conceptual paper prepared by the Secretariat for the major OECD Science and Technology Indicators Conference held in 1980.

3. On S&T indicators see, for example, United States, National Science Board (1989) and for environmental indicators see "Public Opinion" in OECD (1991e).

4. Unlike the EC or the United Nations, the OECD does not have a separate Statistical Office or Directorate. Statistical divisions, units or individual staff are situated within the Directorates concerned. The work covered by this paper is carried out in the Directorate for Science Technology and Industry (Scientific and Technological and Industrial Indicators Division), the Directorate for Social Affairs, Manpower and Education, the Centre for Education Research and Innovation, the Economics and Statistics Department (Economic Statistics and National Accounts Division) and the Environment Directorate.

5. Such a major change in the economic and social system is currently in process in Central and Eastern Europe where official

statistical agencies are having to adopt completely new statistical frameworks and methods.

6. EC (1990), *General Industrial Classification of Economic Activities within the European Communities* (NACE, Rev.1). NACE-70 will continue to be used up to 1993, at which time this new version of the classification will be applied.
   EC (draft), Central Product Classification of the European Communities (CPC-COM).

   EC (1987), *Combined Nomenclature* (CN). It has replaced the Common Customs Tariff and the Nomenclature of Goods for the External Trade Statistics of the Community and Statistics of Trade between Member States (NIMEXE).

7. These basic definitions have also been adopted by UNESCO for its world-wide statistics. See UNESCO (1978).

8. A forthcoming number of the OECD *STI Review* will be devoted to presenting the results of selected innovation and manufacturing technology surveys.

9. See, for example, the MERIT data quoted in Chapter 10.

10. In the TEP framework, "sites" are large agglomerations such as Silicon Valley or Sophia-Antipolis in which are concentrated high-level R&D laboratories, prestige universities and high-technology firms organised in networks. These sites provide significant positive externalities for the industrial development of the regions in which they are situated and act as poles of attraction for highly qualified manpower, high-tech industries and foreign investors.

11. It has been suggested, rather late in the TEP, that statistics should also be collected on technicians. In fact, a data base covering persons with at least university level qualifications in science and technology would already include most higher level technicians. Obtaining information on "shop floor" technicians with lower and more practical qualifications or in-house training would be best associated with general surveys of the quality of the labour force.

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