Cambridge Journal of Economics 1995, 19, 5–24

The 'National System of Innovation' in historical perspective

Chris Freeman*

Contrary to some recent work on so-called 'globalisation', this paper argues that national and regional systems of innovation remain an essential domain of economic analysis. Their importance derives from the networks of relationships which are necessary for any firm to innovate. Whilst external international connections are certainly of growing importance, the influence of the national education system, industrial relations, technical and scientific institutions, government policies, cultural traditions and many other national institutions is fundamental. The historical examples of Germany, Japan and the former USSR illustrate this point, as well as the more recent contrast between East Asian and Latin American countries.

Introduction: The National System of Friedrich List

According to this author's recollections, the first person to use the expression 'National System of Innovation' was Bengt-Åke Lundvall and he is also the editor of a highly original and thought-provoking book (1992) on this subject. However, as he and his colleagues would be the first to agree (and as Lundvall himself points out) the idea actually goes back at least to Friedrich List's conception of 'The National System of Political Economy' (1841), which might just as well have been called 'The National System of Innovation'.

The main concern of List was with the problem of Germany overtaking England and, for underdeveloped countries (as Germany then was in relation to England), he advocated not only protection of infant industries but a broad range of policies designed to accelerate, or to make possible, industrialisation and economic growth. Most of these policies were concerned with learning about new technology and applying it. The racialist and colonialist overtones of the book were in strong contrast to the internationalist cosmopolitan approach of the classical free trade economists and List's belief that Holland and Denmark should join the German 'Bund' and acquire German nationality because of their 'descent and whole character' reads somewhat strangely in the European Community of today. Nevertheless, despite these unattractive features of his outlook, he clearly anticipated many contemporary theories.

After reviewing the changing ideas of economists about development in the years since the Second World War, the World Bank (1991) concludes that it is intangible investment in knowledge accumulation which is decisive rather than physical capital investment, as was at one time believed (pages 33–35). The Report cites the 'New Growth Theory'

Manuscript received 8 March 1993; final version received 23 July 1993.

*University of Sussex. I am grateful to two anonymous referees for useful comments on an earlier draft.

0309–166X/95/010005+20 $08.00/0

(Romer, 1986; Grossman and Helpman, 1991) in support of this view but the so-called 'New' Growth Theory has in fact only belatedly incorporated into neoclassical models the realistic assumptions which had become commonplace among economic historians and neo-Schumpeterian economists. Indeed, it could just as well have cited Friedrich List (1841), who, in criticising a passage from Adam Smith, said:

> in opposition to this reasoning, Adam Smith has merely taken the word *capital* in that sense in which it is necessarily taken by rentiers or merchants in their book-keeping and their balance sheets . . . He has forgotten that he himself includes (in his definition of capital) the intellectual and bodily abilities of the producers under this term. He wrongly maintains that the revenues of the nation are dependent only on the sum of its material capital. (p. 183)

and further:

> The present state of the nations is the result of the accumulation of all discoveries, inventions, improvements, perfections and exertions of all generations which have lived before us: they form the intellectual[1] capital of the present human race, and every separate nation is productive only in the proportion in which it has known how to appropriate those attainments of former generations and to increase them by its own acquirements. (p. 113)

List's clear recognition of the interdependence of tangible and intangible investment has a decidedly modern ring. He saw too that industry should be linked to the formal institutions of science and of education:

> There scarcely exists a manufacturing business which has no relation to physics, mechanics, chemistry, mathematics or to the art of design, etc. No progress, no new discoveries and inventions can be made in these sciences by which a hundred industries and processes could not be improved or altered. In the manufacturing State, therefore, sciences and arts must necessarily become popular. (p. 162)

It was thanks to the advocacy of List and like-minded economists, as well as to the long-established Prussian system, that Germany developed one of the best technical education and training systems in the world. This system was not only, according to many historians, (e.g. Landes, 1970; Barnett, 1988; Hobsbawm, 1968) one of the main factors in Germany overtaking Britain in the latter half of the nineteenth century, but to this day is the foundation for the superior skills and higher productivity of the German labour force (Prais, 1981) in many industries. Many British policies for education and training for over a century can be realistically viewed as spasmodic, belated and never wholly successful attempts to catch up with German technological education and training systems.

Not only did List anticipate these essential features of current work on national systems of innovation, he also recognised the interdependence of the import of foreign technology and domestic technical development. Nations should not only acquire the achievements of other more advanced nations, they should increase them by their own efforts. Again, there was already a good model for this approach to technological learning in Prussia: the acquisition of machine tool technology. It was British engineers (especially Maudslay) and mechanics who were responsible for the key innovations in machine tool technology in the first quarter of the nineteenth century. This technology was described by Paulinyi (1982) as the 'Alpha and Omega of modern machine-building' because it

[1] I have used the expression 'intellectual capital' rather than 'mental capital' used in the early English edition, [C.F.]

enabled the design and construction of metal-working precision machinery for all other industries. Those involved attempted to maintain a considerable degree of secrecy, but its importance was recognised by the Prussian government, who took decisive steps to acquire the technology, despite the fact that the British government was attempting to ban the export of machine tools (with the imposition of heavy fines for contravention).

The Prussian government, which had set up Technical Training Institutes (Gewerbe-Institut), made sure that they received imported British machine tools for reverse engineering and for training German craftsmen, who then disseminated the technology in German industry (Paulinyi, 1982). British craftsmen were also attracted to Prussia, as much of the technology depended on tacit knowledge. (Three out of four of the leading machine tool entrepreneurs in Britain at that time had themselves spent years with Mawdslay in his workshop.) The transfer of technology promoted and coordinated by the Prussian state was highly successful: the German machine tool industry and machine-building proved capable of designing and manufacturing the machinery necessary to make steam locomotives in the 1840s and 1850s. This set Prussia (later Imperial Germany) well on the road to overtaking Britain. Thus, although he did not cite this particular example, List was not talking in a purely abstract way about industrialisation and technology transfer but about a process which was unfolding before his eyes. It was summed up by Landes (1970):

> Only the government could afford to send officials on costly tours of inspection as far away as the United States; provide the necessary buildings and equipment; feed, clothe, house, and in some cases pay students for a period of years. Moreover, these pedagogical institutions were only part—though the most important part—of a larger educational system designed to introduce the new techniques and diffuse them through the economy; there were also non-teaching academies, museums, and, most important perhaps, expositions.
>
> Finally, the government provided technical advice and assistance, awarded subventions to inventors and immigrant entrepreneurs, bestowed gifts of machinery, allowed rebates and exemptions of duties on imports of industrial equipment. Some of this was simply a continuation of the past—a heritage of the strong tradition of direct state interest in economic development. Much of it, in Germany particularly, was symptomatic of a passionate desire to organize and hasten the process of catching up.
>
> In so far as this promotional effort stressed the establishment of rational standards of research and industrial performance, it was of the greatest significance for the future. (p. 151)

Not only did List analyse many features of the national system of innovation which are at the heart of contemporary studies (education and training institutions, science, technical institutes, user-producer interactive learning, knowledge accumulation, adapting imported technology, promotion of strategic industries, etc.) he also put great emphasis on the role of the state in coordinating and carrying through long-term policies for industry and the economy. Here, as often, he took issue with Jean-Baptiste Say, the favourite target in his polemics with the classical school, who had argued that governments did not make much difference, except in a negative way.

The United States was of course even more successful than Germany in overtaking Britain in the second half of the nineteenth century and List had learnt a great deal from his residence in the United States and especially from Hamilton's (1791) *Report on Manufactures*. The widespread promotion of education (though not of industrial training) was even more remarkable in the United States than in Germany. However, the abundance of cheap, accessible materials, energy and land together with successive waves of immigration imparted to the United States' national system some specific characteristics without parallel in Europe. The pro-active role of the state was greater in Germany whilst foreign investment played a greater role in the United States.

Although List anticipated many features of the contemporary debate about national systems of innovation (even though his terminology was different), it would of course be absurd to imagine that he could have foreseen all the changes in the world economy and national economies over the next century and a half. In particular, he did not foresee the rise of in-house professionalised Research and Development (R&D) in industry, still less the rise of multi-national (or transnational) corporations (TNCs), operating production establishments in many different countries and increasingly also setting up R&D outside their original base. These are major new developments which deeply affect the whole concept of national systems. This paper will discuss the rise of R&D in Section 2, and types of comparison of national systems which this has led to in Section 3. It will discuss the role of TNCs and the ways in which they may affect the performance of national economies in different continents in Section 4.

2. The rise of specialised research and development

Bjørn Johnson (1992) in an excellent chapter in the Lundvall book on 'National Systems of Innovation' emphasises the important point that institutions are often thought of simply as a source of 'institutional drag' (i.e. of inertia in the system), whereas of course institutional innovations may also give new impetus to technical and economic change.

Appropriately enough it was in Germany that the major institutional innovation of the in-house industrial R&D department was introduced in 1870. Product and process innovation by firms took place of course for more than a century before that, but it was the German dyestuffs industry (Beer, 1959) which first realised that it could be profitable to put the business of research for new products and development of new chemical processes on a regular, systematic and professional basis. Hoechst, Bayer and BASF have continued and strengthened this tradition down to the present day, when their R&D labs now employ many thousands of scientists and engineers. Undoubtedly such discoveries and innovations as synthetic indigo, many other synthetic dyestuffs and pharmaceuticals and the Haber-Bosch process for fertilisers were the main factors in establishing the German chemical industry's leading position before and after the First World War. When the three companies merged in 1926 to form the giant IG Farben Trust they further reinforced their R&D (Freeman, 1974) and made many of the key innovations in synthetic materials, fibres and rubbers (PVC, polystyrene, urea-formaldehyde, Buna, etc.).

The enormous success of the German chemical industry led to imitation of the social innovation of the R&D Department in the chemical firms of other countries (e.g. CIBA in Switzerland). The in-house R&D lab also emerged in other industries which had the same need to access the results of basic research from universities and other research institutions and to develop their own new products. In the United States and German electrical industries, in-house R&D labs appeared in the 1880s, but contract labs, such as Edison's Institute, played a bigger part in the US system (Hughes, 1989).

From their origins in the chemical and electrical industries gradually during the latter part of the nineteenth century and the first half of the twentieth, specialised R&D labs became characteristic features of most large firms in manufacturing industry (although not of the vast majority of small firms or of service industries) (Mowery, 1980, 1983;

Table 1. *Estimated gross expenditure on research and development as a fraction of GNP, (GERD/GNP ratio) 1934–1983*

	1934	1967	1983	1983 civil R&D only
USA	0·6	3·1	2·7	2·0
EC*	0·2	1·2	2·1	1·8
Japan	0·1	1·0	2·7	2·7
USSR	0·3	3·2	3·6	1·0

*Estimated weighted average of 12 EC countries.

Source: Author's estimates based on Bernal (1939) adapted to 'Frascati' definitions (1963), OECD statistics, and adjustments to Soviet statistics based on Freeman and Young, (1965).

Hounshell, 1982; Hughes, 1989). This change in industrial behaviour and the growth of government laboratories, of independent contract research institutes and university research impressed many observers and led to the comment by a leading physicist that the greatest invention of the nineteenth century was the method of invention itself. A great many inventions had of course been made for centuries or indeed for millennia before 1870, but the new professional R&D labs seemed like a giant step forward. This perception was powerfully reinforced in the Second World War. Science was already important in the First World War—more important than most people realised at the time—but it was the Manhattan Project and its outcome at Hiroshima which impressed on people throughout the world the power of science and especially, as it seemed, Big Science. Many other developments on both sides, such as radar, computers, rockets and explosives, resulted from large R&D projects, mobilising both government, industrial and academic engineers and scientists.

It was, therefore, hardly surprising that in the climate which existed after the Second World War, the prestige of organised, professional R&D was very high. The proposals made by a visionary physicist (Bernal, 1939), to increase British R&D by an order of magnitude seemed absurdly Utopian at the time but this was in fact achieved in the new political climate after the Second World War. A similar rapid expansion occurred in all industrial countries in the 1950s and 1960s (Table 1) and even in Third World countries there was a trend to establish research councils, national R&D labs and other scientific institutions, to do nuclear physics and in some cases to try and make nuclear weapons (e.g. Argentina, India, Brazil, Israel, Yugoslavia). It was hardly surprising either that a simplistic linear model of science and technology 'push' was often dominant in the new science councils that advised governments. It seemed so obvious that the Atom Bomb (and it was hoped nuclear power for electricity) was the outcome of a chain reaction: basic physics → large-scale development in big labs → applications and innovations (whether military or civil). The 'Linear Model' was specifically endorsed in the influential Report of Vannevar Bush, 'Science, the Endless Frontier' (see Stokes, 1993).

This meant that the R&D system was seen as *the* source of innovations—an impression that was reinforced by the system of measurement which was adopted, first by the National Science Foundation in the United States and later during the 1950s and 1960s by all the other OECD countries. This was standardised by the so-called 'Frascati Manual' (OECD, 1963A) and, despite the fact that the authors pointed out that technical change did not depend just on R&D but on many other related activities, such as education, training, production engineering, design, quality control, etc. etc., nevertheless R&D measures were very frequently used as a surrogate for all these activities which helped to promote new and improved products and processes. Furthermore, the importance of all the feedback loops from the market and from production into the R&D system was often overlooked or forgotten. The simple fact that the R&D measures were the only ones that were available reinforced these tendencies.

Their effect could be seen in many national Reports as well as in the 'Science Policy Reviews' conducted by the OECD in its member countries in the 1960s and 1970s. The admirable aim of these reviews, like the reviews of member countries' economic policies, which still continue and on which they were modelled, was to produce a friendly but independent and critical assessment of each country's performance by an international comparative yardstick. In practice they concentrated mainly on the formal R&D system and technical education. This was of course still quite a useful thing to do but it meant that the 'national system' was usually defined in rather narrow terms. Academic research on invention and innovation had amply demonstrated that many factors were important for innovative success other than R&D. However, the practical difficulties of incorporating these factors in international comparisons were very great. 'League table' comparisons of R&D were much easier and more influential.

Gradually, during the 1950s and 1960s, the evidence accumulated that the rate of technical change and of economic growth depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations. This was reflected in the change of emphasis in various OECD Reports (OECD, 1963B, 1971, 1980, 1988, 1991, 1992) and in the introduction of Country Reports on 'Innovation'. Basic science was of course still recognised as being very important but much more was said about technology and diffusion than hitherto.

Although various OECD Reports are a convenient record of changing ideas and policies for science and technology, they rarely originated these changes. The OECD documents summed up and reflected recent experience and changes in the member countries and disseminated what were thought to be the lessons of this experience. The OECD was also, however, more ready than most international organisations to involve independent researchers so that their reports also embody some input from academic research on technical change as well as from industrial R&D management sources. The next section will very briefly summarise the relevant results of some of this work (more fully surveyed in Freeman, 1994) and especially the results of international comparisons. Comparisons with Japan were especially influential after Japan joined the OECD in the 1970s.

3. Some contrasting features of national systems of innovation in the 1970s and 1980s

As empirical evidence and analysis began to accumulate about industrial R&D and about innovation, both in Japan and in 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. In particular, *incremental* innovations came from production engineers, from technicians and from the shop floor. They were strongly related to different forms of work organisation (see especially Hollander, 1965). Furthermore, 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 (see especially von Hippel, 1976, 1988, Lundvall, 1985, 1988, 1992; Sako, 1992). Formal R&D was usually decisive in its contribution to *radical* innovations but it was no longer possible to ignore the many other contributions to, and influences upon the process of technical change at the level of firms and industries (Carter and Williams, 1957; Jewkes *et al.*, 1958; Mansfield, 1968, 1971; Nelson, 1962).

Not only were inter-firm relationships shown to be of critical importance, but the external *linkages* within the narrower professional science–technology system were also shown to be decisive for innovative success with radical innovations (NSF, 1973; Gibbons and Johnston, 1974). Finally, research on diffusion revealed more and more that 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 (see especially Carlsson and Jacobsson, 1993). The success of any specific technical innovation, such as robots or CNC, depended on other related changes in *systems* of production. As three major new 'generic' technologies (information technology, bio-technology and new materials technology) diffused through the world economy in the 1970s and 1980s, systemic aspects of innovation assumed greater and greater importance.

At the *international* level two contrasting experiences made a very powerful impression in the 1980s both on policy-makers and on researchers: on the one hand the extraordinary success of first Japan and then South Korea in technological and economic catch-up; and on the other hand the collapse of the Socialist economies of Eastern Europe.

At first, in the 1950s and 1960s, the Japanese success was often simply attributed to copying, imitating and importing foreign technology and the statistics of the so-called 'technological balance of payments' were often cited to support this view. They showed a huge deficit in Japanese transactions for licensing and know-how imports and exports and a correspondingly large surplus for the United States. It soon became evident, however, as Japanese products and processes began to out-perform American and European products and processes in more and more industries, that this explanation was no longer adequate even though the import of technology continued to be important. Japanese industrial R&D expenditures as a proportion of civil industrial net output surpassed those of the United States in the 1970s and total civil R&D as a fraction of GNP surpassed USA in the 1980s (Table 1). The Japanese performance could now be explained more in terms of R&D intensity, especially as Japanese R&D was highly concentrated in the fastest growing civil industries, such as electronics. Patent statistics showed that the leading Japanese electronic firms outstripped American and European firms in these industries, not just in domestic patenting but in patents taken out in the United States (Patel and Pavitt, 1991, 1992; Freeman, 1987).

However, although these rough measures of research and inventive activity certainly did indicate the huge increase in Japanese scientific and technical activities, they did not in themselves explain how these activities led to higher quality of new products and processes (Grupp and Hofmeyer, 1986; Womack, Jones and Roos, 1990), to shorter lead times (Graves, 1991; Mansfield, 1988) and to more rapid diffusion of such technologies as robotics (Fleck and White, 1987; Mansfield, 1989). Moreover, the contrasting example of the (then) Soviet Union and other East European countries showed that simply to commit greater resources to R&D did not in itself guarantee successful

Table 2. *Contrasting national systems of innovation: 1970s*

Japan	USSR
High GERD/GNP Ratio (2·5%) Very low proportion of military/space R&D (<2% of R&D)	Very high GERD/GNP Ratio (*c.* 4%) Extremely high proportion of military/space R&D (>70% of R&D)
High proportion of total R&D at enterprise level and company-financed (approx. 67%)	Low proportion of total R&D at enterprise level and company-financed (<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 subcontractor network linkages	Weak or non-existent linkages between marketing, production and procurement
Strong incentives to innovate at enterprise level involving both management and workforce	Some incentives to innovate made increasingly strong in 1960s and 1970s but offset by other negative disincentives affecting both management and workforce
Intensive experience of competition in international markets	Relatively weak exposure to international competition except in arms race

innovation, diffusion and productivity gains. It was obvious that *qualitative* factors affecting the national systems had to be taken into account as well as the purely *quantitative* indicators.

Some major differences between the two national systems of Japan and the Soviet Union as they were functioning in the 1970s are summarised in Table 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 USA 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 3% of GNP, so that only about 1% 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 (Table 1).

Nevertheless, it 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 within the Academy system (for fundamental research), for each industry sector (for applied research and development) and for the design of plant and import of technology (the Project Design organisations) (Barker and Davies, 1965; Amann *et al.*, 1979). The links between all these different institutions and enterprise-level R&D remained rather weak despite successive attempts to reform and improve the system in the 1960s and 1970s.

Moreover, there were quite strong negative incentives in the Soviet system retarding innovation at enterprise level (Gomulka, 1990), such as the need to meet quantitative planned production targets. Thus, whereas the integration of R&D, production, and technology imports at firm level was the strongest feature of the Japanese system (Baba, 1985; Takeuchi and Nonaka, 1986; Freeman, 1987), 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.

Table 3. *Divergence in national systems of innovation in the 1980s*

East Asia	Latin America
Expanding universal education system with high participation in tertiary education and with high proportion of engineering graduates	Deteriorating education 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
Development of strong science–technology infrastructure and at later stages good linkages 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 organisation	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 with low exports and little learning by international marketing

There were some features of their national systems in which both countries resembled each other, and both did of course enjoy high economic growth rates in the 1950s and 1960s. Both had (and still have) good education 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, but whereas in the Japanese case the long-term 'visions' are generated by an interactive process involving not only MITI and other government organisations but also industry and universities (Irvine and Martin, 1984) in the USSR the process was more restricted and dominated to a greater extent by military/space requirements.

A similar sharp contrast can be made between the national systems of innovation typically present in Latin American countries in the 1980s and those in the '4 Dragons' of East Asia (Table 3) and especially between two 'newly industrialising countries' (NICs) in the 1980s: Brazil and South Korea (Table 4). The Asian countries started from a *lower* level of industrialisation in the 1950s but, whereas in the 1960s and 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 a falling per capita income. There are of course many explanations for this stark contrast. Some of the Asian countries introduced more radial social changes, such as land reform and universal education, than did most Latin American countries and clearly a structural and technical

Table 4. *National systems of innovation: 1980s, some quantitative indicators*

Various indicators of technical capability and national institutions	Brazil	South Korea
Percent age group in third level (higher) education	11 (1985)	32 (1985)
Engineering students as a percentage of population	0·13 (1985)	0·54 (1985)
R&D as percentage of GNP	0·7 (1987)	2·1 (1989)
Industry R&D as a percentage of total	30 (1988)	65 (1987)
Robots per million in employment	52 (1987)	1060 (1987)
CAD per million in employment	422	1437 (1986)
NCMT per million in employment	2298 (1987)	5176 (1985)
Growth rate electronics	8% (1983–1987)	21% (1985–1990)
Telephone lines per 100 (1989)	6	25
Per capita sales of telecommunication equipment (1989)	$10	$77
Patents (US) (1989)	36	159

transformation of this magnitude in this time was facilitated by these social changes. In the case of Brazil and South Korea it is possible to give some more detailed quantitative indicators of some of these contrasting features. As Table 4 shows, the contrast in educational systems was very marked as well as enterprise-level R&D, telecommunication infrastructure and the diffusion of new technologies (see R. Nelson (ed.), 1993, for more detailed comparisons and Villaschi (1993) for a detailed study of the Brazilian NS).

4. 'Globalisation' and national systems

It has been argued in Section 3 that a variety of *national* institutions have powerfully affected the relative rates of technical change and hence of economic growth in various countries. The variations in national systems which have been described are of course extreme contrasting cases. Nevertheless, they have certainly been important features of world development in the second half of the twentieth century and they point to *uneven* development of the world economy and *divergence* in growth rates. Moreover, differences in national systems are also very important between Japan, the United States and the EC and between European countries themselves, as the major comparative study between more than a dozen national systems of innovation illustrates (Nelson (ed.), 1993). The comparative study of Ireland with other small countries by Mjøset (1992) also demonstrates this point, and the comparison of Denmark and Sweden by Edqvist and Lundvall (1993) shows that big differences exist between neighbouring countries which superficially appear very similar in many ways. Moreover, Archibugi and Pinta (1991) have demonstrated the growing pattern of specialisation in technology and trade and Fagerberg (1992) has shown the continuing importance of the home market for comparative technological advantage.

However, the whole concept of *national* differences in innovative capabilities determining national performance has been recently challenged on the grounds that transnational corporations (TNCs) are changing the face of the world economy in the direction of globalisation. 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 USA, EC and Japan, now being joined by NICs. This 'ILE' is becoming 'so powerful that it 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' (p. xii).

As against this, Michael Porter (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.(p. 19)

In addition to Porter's argument, Lundvall (1993) points out that if uncertainty, localised learning and bounded rationality are introduced as basic and more realistic assumptions about microeconomic behaviour, rather than the traditional assumptions of perfect information and hyperrationality, 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 standardisation and convergence.

At first sight, the activities of multinational corporations might appear to offer a powerful countervailing force to this local variety and diversity. The largest corporations in the world, whether their original domestic base was in Europe, the United States, Japan or elsewhere, have often been investing in many different new locations. This investment, even though initially it may have been in distribution and service networks, or in production facilities, has more recently also included R&D. Whilst the greater part of the 1980s' investment has been within the OECD area itself and in oil-producing countries and could be more accurately described therefore as 'triadisation' rather than 'globalisation', it has also flowed, even though very unevenly, to other countries of the Third World and there is now a small trickle to the former socialist group of countries.

As Harry Johnson (1975) long ago pointed out, in this sense the multinationals do indeed unite the human race. Since the basic laws of physics, chemistry, biology and other sciences apply everywhere, there is an underlying unified technology which can in principle be applied anywhere with identical or very similar results. Insofar as large 'global' TNCs are able to sell their products and services world-wide and to produce them in many different locations, they can and do act as a very powerful agency tending towards the world-wide standardisation of technology and output. As the model developed by Callon (1993) indicates, the diffusion process can tend to enhance similarities between adopters.

Even in the case of consumer goods where it might be reasonable to suppose that there would continue to be wide variations in consumer tastes, we are all sufficiently familiar with such products as 'Coca Cola' and such services as those provided by McDonalds to recognise the reality of such global production and distribution networks, offering standardised products and services world-wide. Is it not realistic to suppose that an ever-larger proportion of world production and trade will take this form? Supporting such a view are not only the obvious examples of hotel chains, soft drinks, canned beer, tourist agencies and credit cards but theoretical economic arguments based on static and dynamic economies of scale in production, advertising, marketing, design and finance, as well as the ability of large multinationals to take advantage of surviving differences between nations in costs of capital, labour, energy and other inputs.

However, it would be unwise to assume that these tendencies 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 transnational companies, free trade and free flows of investment. In fact both processes (global standardisation in some areas but increasing diversity in others) co-exist.

Whilst there are certainly some products and services, such as those already mentioned, 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 certainly cannot be ignored without dire consequences. Innumerable examples leap to mind where climatic conditions affect the performance of machines, instruments, vehicles and materials and even more examples are obvious in relation to variations 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 its feasibility in others). And all this still does not take into account the cultural aspects of the problem which deeply affect such areas as food, clothing and personal services.

So far we have been discussing mainly the case of established products and pointing to some factors which limit global standardisation even in the simplest cases. Advocates of a strong globalisation hypothesis would of course accept most of these points, although they might argue that some of them will constantly tend to diminish as the media, travel, education and international organisations all exert their long-term influence. Rothwell (1992) has pointed to the 'electronification' of design as an important factor facilitating the internationalisation of design and R&D. It can be argued further that local variations can easily be dealt with inside the framework of the global strategies of the multinational corporations. Indeed, globalisation 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 world-wide 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 with international operations rather than truly international companies and the same is true of US and most other MNCs in relation to their home environment (Hu, 1992). Most R&D activities of MNCs are still overwhelmingly conducted in the domestic base of the company and are heavily influenced by the local national system of innovation. Moreover, ownership and control still remain overwhelmingly based on the domestic platform.

The statistics are rather poor but analysis of all the available data and cross-checking with the patent statistics (Patel and Pavitt, 1991; Patel, 1993) suggests that the R&D activities of US companies outside the USA amount to less than 10% of the total, whilst those of Japanese companies are much lower—less than 2%—though rising. The picture in Europe is more complex both because of the development of the European Community 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 multi-nationals and their 'own' TNCs perform much more R&D abroad than is the case with the USA 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.

Qualitative analysis of the transnational activities of corporations shows that most of it 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 the drug industry and electronics industry where specialised pools of scientific ability play an important role.

As long as we are dealing with a static array of products and discussing only minor variations to adjust to local consumer tastes and environments, then the standardisation arguments, the globalisation arguments and even some of the simplifying neoclassical assumptions abut perfect information are at the border-lines 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..

Lundvall (1993) points out that, even in the case of continuous *incremental* innovation in open economies, the drive towards standardisation is limited. Geographical and cultural proximity to advanced users and a network of institutionalised (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 localised learning generating strong positions in the world market. Whilst 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 the 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 localised learning is even greater. Posner's (1961) theory of technology gaps and imitation lags is of fundamental importance here. It may be many years before imitators are capable of assembling the mix of skills, the work organisation and other institutional changes necessary to launch into the production and marketing of entirely new products.

It is of course true that in the global diffusion of radical innovations, TNCs may have an extremely important role. They *are* in a position to transfer specialised equipment and skills to new locations if they so wish and to simulate and organise the necessary learning processes. They are also in a position to make technology exchange agreements with rivals and to organise joint ventures in any part of the world. It is for this reason that many governments in Europe as well as in the Third World and the ex-socialist countries have been anxious to offer incentives to attract a flow of inward investment and associated technology transfer from firms based in Japan and USA.

However, such efforts will meet with only limited success unless accompanied by a variety of institutional changes designed to strengthen autonomous technological capability within the importing countries. This is especially true of those generic technologies which have been at the centre of the world-wide diffusion process over the past two decades. Here it is essential to emphasise the interdependencies between innovations and between technical innovations and organisational innovations. A theory of technical change which ignores these interdependencies is no more helpful than a theory of economics which ignores the interdependencies of prices and quantities in the world economy.

Perez (1983) has pointed out that the social and institutional framework which is hospitable to one set of technologies will not be so suitable for a radically new technology. Whereas incremental innovations can be easily accommodated, this may not be the case with radical innovations which by definition involve an element of creative destruction. When we are talking about large clusters of radical innovations combined with rapid processes of incremental innovation, 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 organisations.

It is in this context that the concept of 'national systems of innovation' assumes such great importance and in the 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 microprocessor in the 1970s, has been followed by a growing recognition of the importance of organisational and managerial change ('multi-skilling', 'lean production systems', 'down-sizing', 'just-in-time' stock control, worker participation in technical change, quality circles, continuous learning, etc., etc.).

The diffusion of a new techno-economic paradigm is a trial and error process involving great institutional variety. There are evolutionary advantages in this variety and considerable dangers in being locked in too early to a standardised technology. A technological monoculture may be more dangerous than an ecological monoculture. Even when a technology matures and shows clear-cut advantages and scale economies it is important to retain flexibility and to nourish alternative sources of radically new technology and work organisation.

National and international policies thus confront the need for a sophisticated dual approach to a complex set of problems. Policies for diffusion of standard generic technologies are certainly important and these may sometimes entail the encouragement of inward investment and technology transfer by MNCs. But also important are policies to encourage local originality and diversity.

5. Conclusions

This paper has attempted to show that historically there have been major differences between countries in the ways in which they have organised and sustained the development, introduction, improvement and diffusion of new products and processes within their national economies. These differences can perhaps be most easily demonstrated in the case of Britain in the late eighteenth and early nineteenth centuries when she achieved leadership in world technology and world trade and could temporarily claim to be 'the workshop of the world'.

Historians (von Tunzelmann, 1993; Mathias, 1969) are generally agreed that no single factor can explain this British success; it can be rather attributed to a unique combination of interacting social, economic and technical changes within the national economic space. It was certainly not just a succession of remarkable inventions in the textile and iron industries, important though these were. Among the more important changes were the transition from a domestic 'putting out' system to a factory system of production; new ways of managing and financing companies (partnership and later joint stock companies); interactive learning between new companies and industries using new materials and other inputs as well as new machinery; the removal of many older restrictions on trade and industry and the growth of new markets and systems of retail and wholesale trade; a new transport infrastructure; a hospitable cultural environment for new scientific theories and inventions and, certainly not least important, the dissemination and widespread acceptance of economic theories and policies which facilitated all these changes. It was the British Prime Minister who said to Adam Smith: 'We are all your pupils now'. The benefits from foreign trade and in some cases piracy and plunder also played their part, especially in the process of capital accumulation, but it was the mode of investment of this capital within the national economy, rather than the simple acquisition of treasure or luxury expenditure, which was a decisive impulse to economic growth.

Of course, many of these changes also took place within other European countries, but there were distinct and measurable differences in the rate and direction of institutional and technical change, the rate of economic growth, of foreign trade and of standards of living, which were fairly obvious at the time as well as to historians since. This can be seen not only from the writings of economists but from novelists and travellers. It was therefore hardly surprising that Friedrich List and other economists on the Continent of Europe were concerned to develop theories and policies which would help them to understand the reasons for British commercial supremacy and enable Germany (and other countries) to catch up. Section 1 attempted to show that in this endeavour, List anticipated many contemporary ideas about 'national systems of innovation' including the crucial importance of technological accumulation through a combination of technology imports with local activities and pro-active interventionist policies to foster strategic 'infant' industries.

In the second half of the nineteenth century, new developments in the natural sciences and in electrical engineering led to progressive entrepreneurs and reformers realising that in the new and fastest growing industries, learning by doing, using and interacting in the old British ways had to be accompanied or replaced by more professional and systematic processes of innovation and learning. The organisational innovation of the in-house R&D department put the introduction of new products and processes on a firmer foundation whilst new institutions and departments of higher education and secondary education provided the new, more highly qualified scientists, engineers and technicians. Section 2 of the paper argued that it was in Germany and the United States that these institutional innovations began and made the greatest impact on national systems in the second half of the nineteenth century and early twentieth century.

The rapidly widening gap between a small group of industrialised countries and the rest of the 'under-developed' world (Durlauf and Johnson, 1992; Dosi *et al.*, 1992), as well as the 'forging ahead', 'catching up' and 'falling behind' (Abramovitz, 1986) among the leaders, clearly called for some explanation of why growth rates differed so much. The brave simplifying assumptions of neoclassical economics might lead people to expect convergence rather than divergence in growth rates (perfect information and costless, instant transfer of technology). Nor did formal growth theory and models provide much help since most of the interesting phenomena were confined to a 'residual' which could not be satisfactorily disaggregated and because of the interdependencies involved (Nelson, 1973).

Many economic historians and proponents of what have now become known as 'national systems of innovation' would claim that the differences were due to varying types of institutional and technical change which may be the subject of qualitative description, even though difficult to quantify. Sections 2 and 3 of the paper argued that the over-simplification of quantitative R&D comparisons was an inadequate method in itself. Section 3 attempted to show by the examples of Japan and the former Soviet Union, and of the East Asian and Latin American 'NICs', that institutional differences in the mode of importing, improving, developing and diffusing new technologies, products and processes played a major role in their sharply contrasting growth rates in the 1980s.

Finally, in Section 4 the paper discussed the controversial issue of 'globalisation' and its bearing on national systems of innovation. It is ironical that just as the importance of technology policies and industrial policies has been increasingly recognised alike in OECD and in developing countries, the limitations of *national* policies are increasingly emphasised and the relevance of *national* systems increasingly questioned (see, for example, Humbert (ed.), 1993). The global reach of transnational corporations, the drastic cost reductions and quality improvements in global telecommunications 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).

It is tempting at first sight to follow Ohmae and to discard national economies and nation states as rapidly obsolescent categories. The speed of change and the difficulties of focussing analysis may be illustrated by the confusion in terminology. Ohmae maintains that nation states are losing their power and their influence both 'upwards' and 'downwards', on the one hand to supra-national institutions (the EC, NAFTA, UN organisations etc. as well as transnational companies) and, on the other hand, to sub-national (or 'infra-national') provincial, urban or local authorities and organisations (the disintegration of federal and centralised states, the growing importance in some areas of local government agencies and even of various forms of Tariff-Free Zones, and of 'Silicon Valleys'). Unhappily, at least in the English language, the same word 'regions' has to be used to describe both processes—the very large 'regional' trading blocs such as NAFTA, or the emerging East Asian 'region' and the much smaller sub-national 'regions'. Some terminological innovation is needed here and for the purposes of this paper, the expressions 'upper regions' and 'nether regions' will be used. It is undoubtedly important to keep track of both and of their inter-action with national systems.

The work of geographers as well as economists (e.g. Storper and Harrison, 1991; Saxenian, 1991; Scott, 1991, Lundvall, 1992; Antonelli, 1993) has convincingly demonstrated the importance of nether regions for network developments and new technology systems. They have argued that local infrastructure, externalities, especially in skills and local labour markets, specialised services and not least, mutual trust and personal relationships have contributed greatly to flourishing nether regions. It should not be forgotten, however, that 'nether-regional systems of innovation' and 'economies of agglomeration' have always under-pinned national systems from the beginnings of the industrial revolution (Arcangeli, 1993). Marshall (1890) already stressed the importance of what were then known as 'industrial districts' where 'the secrets of industry were in the air' (Foray, 1991). Piore and Sabel (1984) have especially underlined the importance of these nether regions in many parts of Europe both in the nineteenth century and again today.

Moreover, the vulnerability of national economies to external shocks is also by no means a new phenomenon of the last decade or two, even though the liberalisation of capital markets and international flows of trade and investment combined with computerisation and new telecommunications networks may have increased this vulnerability. Small and distant nations were already affected by shocks from the City of London under the Gold Standard and the Popular Front Government in France suffered just as severely from the 'flight of capital' in the 1930s as the Socialist government of France in the 1980s.

This paper has argued that nation states, national economies and national systems of innovation are still essential domains of economic and political analysis, despite some shifts to upper and nether regions. Indeed, Michael Porter (1990) may well be right in his contention that the intensification of global competition has made the role of the home nation more important, not less. Particularly from the standpoint of developing countries, national policies for catching up in technology remain of fundamental importance. Nevertheless, the interaction of national systems both with 'nether-region systems of innovation' and with transnational corporations will be increasingly important, as will be the role of international cooperation in sustaining a global regime favourable to catching up and development.

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