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Internationalization of innovation systems: A survey of the literature☆

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Abstract

While there is a large literature on the internationalization of economic activity (including R&D) at the corporate level, there are not many studies of the degree of internationalization of innovation systems. The few studies that exist show that national innovation systems are becoming internationalized, even if the institutions that support them remain country-specific. To the extent that the far more numerous studies of internationalization of corporate R&D discuss innovation systems at all, they point to the continued importance of national institutions to support innovative activity, even though that activity is itself becoming increasingly internationalized.

Keywords: Innovation systems; Internationalization; National institutions; Literature

1. Introduction

What do we know about internationalization of innovation systems? That is the question in this paper.

It seems fitting at a conference honoring the work of Keith Pavitt in the area of innovation to take up a particular strand in Pavitt's research over the last 10–15 years focusing on the extent of internationalization of the R&D activities of large business firms (Patel and Pavitt, 1991; Pavitt, 2001, 2002; Pavitt and Patel, 1999). This research also deals with the relationship between "global" corporations and so-called national systems of innovation. This is what motivates this paper. Pavitt's findings may be summarized as follows:

- The skills and know-how that give firms competitive advantage are less internationalized than all other dimensions of corporate activity. Even very large corporations in most cases perform most of their R&D at home.

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- "As a consequence, companies' innovative activities are significantly influenced by their home country's national system of innovation: the quality of basic research, workforce skills, systems of corporate governance, the degree of competitive rivalry and local inducement mechanisms, such as abundant raw materials, the price of labor and energy, and persistent patterns of private investment of public procurement" (Pavitt and Patel, 1999, p. 94).
- "In general terms, basic research and related training improve corporate (and other) capacities to solve complex problems. Most of the contributions are person-embodied and institution-embodied tacit knowledge, rather than information-based codified knowledge. This explains why the benefits of basic research turn out to be localized, rather than available indifferently to the whole world" (Pavitt and Patel, 1999, p. 103).
- "[T]he technological competitiveness of firms inevitably depends on national systems of innovation, and national systems of innovation inevitably depend on government policy. The level of business-funded R&D is influenced by national policies (e.g. competition, macroeconomics), and also by the behavior of national institutions (e.g. agencies funding basic research, banks and stock markets, systems of corporate governance)" (Pavitt and Patel, 1999, p. 110).

Some of these findings, especially the first claim, are in many ways contrary to the popular view of the increasing importance of globalization of economic activity. They are therefore controversial. Much of the controversy stems from viewing internationalization from different perspectives. Most of the literature on globalization focuses on the activities of firms as manifested in international trade and foreign direct investment. These activities have unquestionably increased over the last several decades. One of the important contributions of Keith Pavitt's research on internationalization is that it focuses on the *R&D activities* of firms as distinct from other activities within firms and finds that this type of activity is less internationalized than others. Another perspective on internationalization is obtained if one looks at networks or alliances among firms; these are observed to be increasingly international while also being oriented towards R&D. Other perspectives on internationalization involve viewing not only the activities of firms but also financial institutions, universities, business and policy agencies, laws, culture and social norms at regional or national levels.

Pavitt's work in this arena coincided with the emergence of research on innovation systems, particularly *national* innovation systems, and influenced, as well as was influenced by, this new research. It is interesting, therefore, to examine what the literature on innovation systems has to say on these matters, and how the findings on innovation systems relate to those viewing innovative activities from other perspectives. Are Pavitt's views confirmed or not, and where do they fit?

The paper is organized as follows. We begin with a bit of background on the study of innovation systems. We then review the literature on innovation systems with respect to internationalization, beginning with direct empirical studies of internationalization of innovation systems. This is followed by a review of studies on globalization/internationalization of corporate R&D, viewed from an innovation systems perspective. We then examine the literature on institutional barriers to internationalization and related issues. The findings are discussed in the concluding section.

2. Background: the study of innovation systems

The study of innovation systems began at SPRU in the 1980s. Given the origin at SPRU, Pavitt was certainly aware of this work, even if he was not directly involved in it. The notion of 'innovation system' is rooted in Friedrich List's concept 'national systems of production' (List, 1841). According to Lundvall (2003), Freeman (1982) first used the term 'national system of innovation' in an unpublished paper. The idea was picked up by several scholars in both Europe and the United States networking with Freeman and his colleagues at SPRU. Lundvall (1985) at Aalborg University published a book in 1985 in which the concept 'innovation system' appeared (although without the adjective 'national'). The first publication using the term 'national innovation system' was Freeman's book on Japan (Freeman, 1987). The following year, an edited volume on *Technology and Economic Theory*

(edited by Dosi et al., 1988) contained four chapters on national innovation systems (Freeman, 1988; Lundvall, 1988; Nelson, 1988; Pelikan, 1988). Another book published the same year (Freeman and Lundvall, 1988) also contained a couple of chapters on national innovation systems (Andersen and Lundvall, 1988; Gregersen, 1988).

A national system of innovation may be defined as

that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts, which define new technologies. The element of nationality follows not only from the domain of technology policy but also from elements of shared language and culture which bind the system together, and from the national focus of other policies, laws and regulations which condition the innovative environment (Metcalfe, 1997, p. 289).

It was soon recognized that, depending on the purpose of the inquiry, the most useful definition of innovation systems might not coincide with national borders. Thus, in 1988 a group of Swedish scholars commenced parallel work on 'technological systems' focusing on innovations in particular techno-economic areas. Such systems may or may not be geographically and institutionally localized within nations or regions but they may have links to supporting institutions elsewhere. This work has resulted in a stream of publications beginning with Carlsson and Stankiewicz (1991) and summarized in books edited by Carlsson (1995, 1997, 2002). Somewhat later the term 'regional innovation systems' was used, focusing on innovative activities within geographic regions at the sub- or supra-national level (Cooke, 1992). Similarly, in 1997 the notion of 'sectoral innovation systems' was launched (Breschi and Malerba, 1997). Thus, there are now four definitions of innovation systems commonly used in the literature: national, regional, sectoral and technological. In addition, recently there has emerged a branch of literature dealing with other concepts of innovation systems, particularly at the firm level.

The notion of innovation systems has spawned a rich field of research in economics and related disciplines. By the end of 2002, about 750 publications had appeared.[1] This literature is surveyed in Carlsson (2003). The task in the present paper is to examine this literature with regard to internationalization of innovation systems. About 250 of the 750 innovation system studies have terms such as "global" or "international" in their title, keywords or abstract (or table of contents, in the case of books). After careful screening, about 35% (87 entries) are labeled "global" or "international" in the classification scheme used in the study (see Carlsson, 2003 for details). Most of these are 'international' in the sense that they make international comparisons of systems at various levels (national, regional, sectoral or technological). Only 36 entries deal with the process of internationalization or globalization of technology or of innovation systems. It should be noted, however, that there is a vast literature on internationalization of corporate R&D, only a portion of which appears in this database that deals only with innovation systems. Twenty-two of the 36 entries are journal articles; the rest are books and book chapters.

For the purposes of this study, the entries were grouped under the following headings:

(1) empirical studies of internationalization of innovation systems;
(2) internationalization/globalization of (corporate) R&D;
(3) institutional barriers to internationalization;
(4) other studies.

3. Empirical studies of internationalization of innovation systems

It turns out that there are only five studies explicitly examining internationalization empirically at the system level (Niosi and Bellon, 1994, 1996; Bartholomew, 1997; Fransman, 1999; Niosi et al., 2000).

[1] There were several precursors (Bowers et al., 1981; Krupp, 1984; Saviotti, 1986) based on the engineering concept of 'technological systems' referring to complex systems of physical artifacts such as large electrical systems (Hughes, 1983; Bijker, Thomas and Pinch, 1987; Mayntz and Hughes, 1988). This literature is not included in this number.

The most comprehensive of these studies are those by Niosi and Bellon (1994, 1996).[2] These authors studied the degree of openness of national innovation systems in the United States, Japan and leading countries in Europe. Internationalization was measured by R&D in multinational firms, international technical alliances, international technology transfer, international trade of capital goods and international flows of scientific and technical personnel. They concluded that

(1) There are wide national differences between countries in the rate and types of globalization of their NIS. Smaller countries are at one end of the spectrum, with high levels of flows of scientific and technological knowledge and embodied technology crossing their borders, while larger countries are more self-sufficient and thus less affected by international technological and scientific flows.
(2) All the types of flows studied are considerable, most figures being in the 10–30% range as compared with national stocks. Also, all types of international flows are growing and the rate of growth of some of them has been accelerating over the past 10 years, as if globalization trends were speeding up. NISs may appear less 'national' today than they did 20 years ago.
(3) Different types of flows differ in their intensity, with patents enjoying the highest degree of international globalization (but being also the least indicative of actual flows), and researchers (one of the best indicators of flows) probably the lowest. Scientific international cooperation flows tend to be more intense than technological ones, reflecting the disembodied nature of pure knowledge, government support of internationalization and scientific creation within mostly public or semi-public institutions.
(4) The European Union appears to be the only major supranational scientific and technological block now emerging. Japan seems to be much less internationalized (and its internationalization is aimed principally at the USA), and Canada–USA interaction (in spite of NAFTA) is less evident than in the EU.
(5) Finally, national policies seem to play a key role, with some countries filtering the flows (Japan), and others being more open to the entry and exit of science and technology resources and products (like the USA and Canada) (Niosi and Bellon, 1996, pp. 153–154).

The overall conclusion of Niosi and Bellon is that through imitation, technology diffusion and transfer, national systems may converge up to a point. They also note that there are impediments to convergence in the form of "different natural factor endowments, cumulative effects of industrial organization and specialization, different national stocks of knowledge, different national economic and political institutions" (Niosi and Bellon, 1996, p. 156). Thus, while national innovation systems are becoming more intertwined and complex, the local and national networks are still important.

Bartholomew (1997) also studied the interdependence of national systems in several countries, namely the United States, United Kingdom, Japan and Germany. But the study is limited to biotechnology, and thus covers only a portion of the overall national innovation system in each country. Bartholomew found that national patterns in biotechnology R&D are linked to the configuration of country-specific institutional features to form a system that either supports or impedes the accumulation and diffusion of knowledge between the scientific and industrial communities. She argued that the "particular characteristics of national systems of biotechnology innovation form the basis for complex interdependence within the global system, through international technological cooperation and the cross-border adoption and adaptation of institutional forms and practices" (p. 141). She concluded that

tapping into foreign innovation systems through international cooperative alliances gives firms access to a wider range of solutions to technological problems. Forming cross-border alliances thus may be one of the most important means for firms to enhance their innovative capability in biotechnology, underscoring the growing significance of inter-firm partnering in the new age of alliance capitalism (p. 262).

Fransman (1999), on the other hand, made an in-depth study of a national innovation system and its degree of internationalization, but the analysis is

[2] Niosi et al. (2000) focuses primarily on Canada's system of innovation but touches also on the extent of its integration with that in the United States.

restricted to only one country, Japan, and the development of its national innovation system in the 1970s and 1980s. Fransman used measures of internationalization similar to those used by Niosi and Bellon, applying them to the activities of companies and government as well as universities. He concluded that even though Japan still lags behind other countries in terms of the globalization of its science and technology system, the degree of internationalization has increased significantly over the last decades; the Japanese system is now less 'self-contained' than it was previously (pp. 177–178). Fransman also discussed the role of the Japanese government, particularly MITI (the Ministry of International Trade and Industry), in strengthening the science and technology base of Japanese companies. He noted that

while foreign companies were both allowed and encouraged to join MITI's national R&D programmes from 1989, these programs continue to be set with national objectives in mind. The objectives include strengthening the competitiveness of Japanese companies and increasing basic and scientific research capabilities in Japan. In other words, while foreign companies are encouraged to join these programs, they are not allowed to influence the choice of program in the first place nor the objectives of the program (p. 188).

Fransman summarized the role of MITI in the following way:

MITI has responded to the globalization of science and technology by retaining its objectives of strengthening both the competitiveness of Japanese companies and Japanese competencies in basic research and science; by internationalizing its national cooperative R&D programs by allowing and encouraging the participation of foreign companies; and by taking the initiative in establishing fully internationalized cooperative research programs whose objectives and *modus operandi* are negotiated with the other participating countries (p. 189).

Thus, the evidence we have from empirical studies of internationalization of innovation systems is not extensive, but it seems to point uniformly to increasing interdependence of innovation systems in various countries. It is less clear how important this interdependence is, for example, is the 10–30% figure reported by Niosi and Bellon a large or small number? The quality, content, type and therefore significance of interaction are difficult to capture, especially at the national level. More research is clearly needed. However, each of the authors also emphasizes the importance of national policies and institutions. That is, to say, whatever the degree of internationalization of innovation systems, national policies and institutions still play a crucial role.

4. Internationalization/globalization of R&D

Most studies on globalization of innovative activity deal with R&D at the corporate level.[3] Given that the focus in the present paper is on the national or other system level, only that part of the literature which links corporate R&D to the system level is reviewed here.

There is no doubt that the R&D activities of firms are being increasingly internationalized (as measured, for example, by the proportion of industry R&D expenditures financed from foreign sources, the number of international alliances, etc.), although the degree of internationalization varies among countries. Rather, the question is how to interpret the evidence.

Patel and Pavitt (1991), Tidd et al. (1997), Patel (1997), Pavitt and Patel (1999) and Patel and Vega (1999) question the idea that technology is becoming global even if R&D activities are being internationalized. Thus, Patel (1997) concludes that "there is no systematic evidence ... to suggest that widespread globalization of the production of technology occurred in the 1980s. The evidence ..., based on the US patenting activities of 569 firms (based in 13 countries and in 17 product groups), shows that for an overwhelming majority of them technological activities are located close to the home-base" (p. 211). This is consistent with the evidence on patenting activities abroad. Patel concedes that there has been an increase in the proportion of activities undertaken by firms from overseas locations but notes that "the largest increases in internationalization have occurred as a result of mergers and acquisitions and not by means of organic growth" (p. 212). He finds that UK large firms are the

[3] Overviews of this literature are available in Archibugi and Michie (1995, 1997), Archibugi et al. (1999) and a special issue of *Research Policy* (vol. 28, 2–3, March 1999).

most and Japanese firms the least internationalized in terms of their technological activities. The main idea is that even if the R&D activities of multinational firms are increasingly being carried out away from the home center, the internationalization has not gone very far; R&D is much less internationalized than other corporate activities, notably production.

Other authors take a different view. While it is widely known that the volume of FDI has been increasing rapidly over the last two decades, several authors note that the increase in FDI is closely linked to the strategies of firms with respect to technology acquisition, diversification and exploitation and that these strategies have varied over time (Cantwell, 1995, 1997; Cantwell and Piscitello, 2000; Carlsson and Mudambi, 2003; Cantwell et al., 2004; Piscitello, 2004; Le Bas and Patel, 2005). In the inter-war and early post-war years, large firms tended to diversify their technological competence by taking advantage of scale economies, especially via exports from the home country. Their internationalization was aimed primarily at the wider exploitation in foreign markets of the basic competence they had already established at home. R&D activities were internationalized only to a limited extent and mostly oriented to adapting products to each market.

By the mid-1970s, these opportunities for large-scale production had been gradually exhausted. Firms began investing instead in broadening their competence base for existing product lines while also expanding their product lines (Granstrand and Sjölander, 1990, 1992).

In the 1990s, the rate of technological change speeded up and it became increasingly difficult for firms to diversify their technology base at a sufficient pace. Firms began increasingly to rely on international networks in order to exploit the competence of foreign centers of excellence. "A newly emerging complementarity between competence accumulation and the diversification and internationalization of corporate technology is thus at work" (Cantwell and Piscitello, 2000, p. 44).

Thus, in the early post-war period, technology was an important driver of exports and eventually of FDI primarily in production facilities as the companies' presence in foreign markets increased. More recently, the desire to acquire technology has been a major motive for multinational firms to locate R&D facilities abroad. The required investments have tended to cluster in certain geographic regions . . .. This explains why there has been a shift in attention away from the multinational corporations (MNCs) as a mere vehicle of technology transfer towards the crucial role it plays as a creator of innovation and technological knowledge" (Carlsson and Mudambi, 2003, p. 104).

Cantwell (1997) shows that not only the extent but also the character of international R&D activities of MNCs have changed. Instead of exploiting home country-based advantages abroad they are now doing R&D abroad.

Technology leaders have altered the nature of international technology creation by pioneering the international integration of MNC facilities into regional or global networks. Globalization in this sense involves the establishment of new international structures for technology creation. In the past, foreign technological activity exploited domestic strengths abroad, it was located in response to local demand conditions, it assisted in the growth of other high-income areas, and its role ranged from the adaptation of products to suit local tastes through to the establishment of new local industries. At that time the capacity to develop internationally dispersed innovations derived from a position of technological strength in the firm's home country base, and led to similar lines of technological development being established abroad. By contrast, today, for companies of the leading centres, foreign technological activity now increasingly aims to tap into local fields of expertise, and to provide a further source of new technology that can be utilised internationally in the other operations of the MNC. In this respect, innovation in the leading MNCs is now more genuinely international or, in the terminology used here, it has become 'globalized' (Cantwell, 1997, p. 236).

Cantwell notes, however, that

[i]t is still true that the home country is generally the single most important site for corporate technological development . . .. The affiliates of the leading companies in other major centers may be thought of as constituting an interactive network. Cross-investments between the major centers in the most technologically dynamic industries . . . have probably helped to

reinforce the existing pattern of geographical specialization, and the importance of these centers as locations for innovation. Having been the first to establish an international spread of technological activity, MNCs from the leading centers in a given industry now exploit locational diversity in paths of innovation to a greater extent than do other firms (Cantwell, 1997, p. 237).

Taking the analysis one step further, Cantwell and Santangelo (2000), writing on corporate networks and using US patent data, show that MNCs are now more likely than in the past to expand their R&D activities beyond their home-base, but they also find that the technologies they develop abroad are less science-based and less dependent upon tacit knowledge than those developed at home. However, within the science-based industries, firms may generate abroad some technologies that are heavily dependent on tacit knowledge, but normally in fields that lie outside their own core technological competencies. Thus, the knowledge base at home still plays an important role.

Le Bas and Sierra (2002) confirm this view. They studied the strategies of the 345 multinational firms with the greatest patenting activity in Europe. They found that nearly 70% of the firms locate their activities abroad in technological areas or fields where they are strong at home, with home-base augmenting FDI in R&D being a more prevalent strategy than home-base exploiting FDI. Technology-seeking and market-seeking FDI in R&D turned out to be much less frequent strategies.

On this latter point, Meyer-Krahmer and Reger (1999) take a slightly different view. They find that qualitative motives, such as learning from technological excellence in lead markets and dynamic interactions within the value chain, are increasingly driving R&D location decisions. They also find that the process of internationalization in research and technology has been accompanied by an increasingly selective focus on only a very few locations and the concentration of innovation activities on worldwide centers of excellence. Like many other scholars they note that international R&D activities are still heavily focused within the 'triad' of the United States, Europe and Japan.

The overall impression one gets from this literature on internationalization of corporate R&D is that the degree of internationalization has indeed increased over the last couple of decades and that the nature of R&D activity abroad has changed in the following ways: it is largely conducted within corporate networks (i.e. it is inter-national but intra-firm), it tends to augment home-base technological competence rather than simply exploiting it abroad, it tends to be less science-based than the R&D conducted at home, and in the cases when it does involve science-based activities it tends to be in fields outside the companies' core competencies.

"Technological competition has increasingly become global in scope and related technology life cycles have shortened; firms have correctly responded to this new order by implementing multifaceted innovation strategies that reflect a new philosophy about the interdependence of competing firms. Speed in innovation is increasingly becoming the strategic benchmark upon which competitive survival will be benchmarked. As such, firms are partnering with other firms, organizations and institutions in an effort to survive, and are thus trading off a loss in appropriability for timing" (De la Mothe and Link, 2002, p. 266).

These findings provide partial confirmation of Pavitt and Patel's views. Not only have the R&D activities of firms become increasingly internationalized (as acknowledged by Pavitt and Patel); there are also indications that through international networks, often within multinational firms, technology has also become increasingly globalized (contrary to Pavitt and Patel) at least after 1990.[4]

Does this mean that national policies and national innovation systems are becoming irrelevant? That is the question to which we now turn.

5. Are national systems of innovation still important?

Pavitt and Patel claim that, "far from being irrelevant, what happens in home countries is still very

[4] But it is still true that R&D and innovative activities are less internationalized than other activities of MNCs such as production and FDI (this was Pavitt and Patel's main point), and to the extent that R&D activities cross national borders they are still more international (involving more than one country's institutions) than global (involving most or all countries).

important in the creation of global technological advantage for firms. Thus, for policy analysis it becomes important to understand the nature of the country-specific factors that have an influence in creating national technological advantage, including the competitive climate, the financial system and education, training and basic research institutions" (Patel, 1997, p. 212).

On this point there is not much disagreement among authors. For example, Freeman (1995) argues that in spite of increasing internationalization of innovative activity, national and regional systems of innovation remain essential. Their importance derives from the networks of relationships, which are necessary for any firm to innovate. While external international connections are 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. In many ways, such institutions are what make each system unique. They represent a legacy of the past and change only very gradually, thereby creating strong path dependence. As Pavitt (1998) has argued, the national science base is socially constructed: it is influenced by the country's level of economic development and the composition of its economic and social activities. Nelson (1992), reflecting on a major comparative study of national innovation systems, notes that there are both similarities and differences among countries in institutional arrangements, that they are persistent over time, and that the distinctive national character of innovation systems is therefore likely to remain.

Many of the institutions relevant to innovation systems are national while others are important at the regional or even local level, and others yet are specific to particular sectors or technologies. Their influence may be positive or negative with respect to the evolution of an innovation system in a particular domain. The important point is that while institutions are important for the formation and functioning of particular innovation systems, they may also, by their very nature, impede internationalization of innovation systems.

For example, Foray (1995) analyzes the persistence of national specificities in the intellectual property rights systems. He shows that the path-dependent nature of any institutional arrangement is an obstacle to the international standardization of the national systems of intellectual property rights (p. 126):

"[T]he specificities of the innovation systems, to which each intellectual property rights regime is linked, are an obstacle to the standardization of these regimes. To achieve a single, global regime would thus require a reduction in the diversity of the innovation systems themselves. However, . . . this kind of diversity is a key feature of the process of scientific and technological change . . . [and] has been the central feature of western capitalism [which] has been . . . characterized by a truly extraordinary pattern of organizational diversity" (Foray, 1995, p. 128).

Other institutions exhibit similar features. Education (including higher education) is predominantly publicly funded in most countries. This gives the educational system in each country its distinctive features. This is likely to remain so. Even if high-level scientists and doctoral students work and study abroad, the international flows will not materially affect the large bulk of students at home. Also, most funding of basic research comes from public sources (some military) and tends to reinforce existing areas of strength in each country; international funding of transnational research projects is not likely to materially change the research profiles of nations. Other public infrastructure, financial institutions, fiscal, monetary and trade policies, laws and other institutions change only very gradually. For reasons such as these, Gregersen and Johnson (1997), for example, in discussing how the process of European integration affects national systems of innovation, argue that European integration will not do away with national systems of innovation in Europe and that only a very partial European system of innovation in a narrow sense of the term is likely to emerge.

6. Other barriers to internationalization

Besides institutions there are other impediments to internationalization of innovation systems. For example, R&D-intensive industries such as biotechnology, software and computers tend to be highly concentrated spatially. This is due in large measure to the nature of knowledge: often tacit and therefore difficult to transfer. Knowledge spillovers are mostly local, not national and certainly not international. Close geographic proximity and good connectivity among the entities are required for successful spillovers to take place; this

leads to the formation of clusters. Leading research universities tend to play an important role in such clusters. Foreign-owned multinational firms may locate activities in such environments in order to take advantage of spillover opportunities (through joint research ventures or hiring of competent personnel), thus overcoming the barriers imposed by the nature of knowledge. It is often easier to absorb new knowledge and appropriate the results within an organization than across organizational boundaries. Indeed, this is an important part of what internationalization of R&D is all about.

Industry clusters and regional innovation systems can thus be viewed as vehicles for internationalization of technology. The technology flows can obviously go both ways, i.e. both outbound and inbound. Mowery and Oxley (1997), for example, discuss the role of national systems of innovation in inward technology transfer during the post-war period. They reach three broad conclusions:

(i) The mix of channels through which an economy obtains technology from foreign sources appears to be less important than the overall effort to exploit foreign sources of technology.
(ii) The contribution of national innovation systems to the inward transfer of technology in the early stages of this process operates mainly through the creation of a skilled production and technical labor force.
(iii) The contribution of national innovation systems to inward technology transfer and competitiveness is critically affected by overall economic and trade policies, which are most successful when they enforce competitive pressure on domestic firms in a relatively stable macroeconomic environment (Mowery and Oxley, 1997, p. 162).

Mytelka (2000) also deals with the notion of national innovation systems as vehicles for integrating the role of transnational corporations and international rules and disciplines in learning and innovation in developing countries and transforming local clusters into innovation systems.

Some countries (especially Taiwan and South Korea) have built their development strategy on learning from the leaders in specific targeted areas. They have built their innovation systems to benefit from spillovers. For example, Chang (1999) studied how South Korea and Taiwan were able to catch up with the international leaders in semiconductors in the 1990s by systematically building their national innovation systems so as to take advantage of technology in the United States and Japan. Sung and Carlsson (2003) examined a similar strategy in building up computer numerical control technology capability in Korea. Both of these studies show how national policies (e.g. trade and industrial policies) and institutions (e.g. financial system and industrial research institutes) were built to support the activities of private firms.

Internationalization of innovation systems through strategies of tapping into innovation systems elsewhere as not confined to developing countries in a catching-up phase, however. For example, Carlsson (1995) shows that Sweden, arguably the world leader in the use of factory automation technology in the 1980s, relied on foreign suppliers and networking with foreign firms for three-quarters of the relevant technology. This is unlikely to be an isolated and rare case. The function of the relevant institutions at both the national and technology-specific levels is primarily to enhance the ability of entities within the system to learn from the leaders in the field regardless of location. One suspects that when innovation systems are studied at subnational levels, the knowledge and technology flows across geographic boundaries (including national borders) will be found to be substantial. But thus far there are not many studies of that sort. Studies of institutions that make up the innovation systems at the national level are unlikely to provide such evidence.

7. Reflections and conclusions

As shown in the preceding section, there is ample support for the claim by Pavitt that the innovative activities of firms are significantly influenced by their home country's national system of innovation. But there is also evidence that national innovation systems themselves are becoming internationalized, even if the institutions that support them remain country-specific.

Although there is a large literature on the internationalization of economic activity (including R&D) at the corporate level, there are relatively few studies of the degree of internationalization of innovation systems. The handful of studies that have addressed the issue empirically uniformly show increasing internationalization. To the extent that the far more numerous

studies of internationalization of corporate R&D discuss innovation systems at all, they point to the continued importance of national institutions to support innovative activity, even though that activity is becoming increasingly internationalized. Several studies have shown that there are barriers to internationalization inherent in innovative activity in the form of spatial boundedness of knowledge spillovers as well as certain features such as national specificities of intellectual property rights that make national innovation systems unique. Nevertheless, there are examples of strategies that have overcome such barriers, especially in Taiwan and Korea.

A few reflections on these findings seem warranted. One is that, in view of the fact that most studies of innovation systems focus on *national* innovation systems, it is not surprising that little direct evidence is found that innovation systems are becoming global. The main focus in this literature is on institutions at the national level. But national institutions may influence innovation systems at regional, sectoral or technological levels differently. However, at these lower levels there has been little work done with a view toward internationalization of *systems* (as distinct from corporate innovative activity). Also, not all institutions are national. For large firms, national institutions may be most important, while for small and new firms, subnational institutions may also be important.

Another reflection is that innovation systems may have become more 'leaky' over time. The role of tacit knowledge and the spatial limits on knowledge spillovers have caused firms to locate R&D facilities where new knowledge is being created. As their absorptive capacity increases and they learn to transfer knowledge within their organizations and in the networks and alliances in which they participate, these firms become vehicles for internationalization of innovation systems. It remains to be seen whether the organizational and institutional barriers to knowledge transfer will be reduced quickly enough for internationalization to continue or whether new barriers will arise similar to those that reduced international activities in the 1920s and 1930s.

Finally, it is worth noting that most studies of innovation systems deal mainly with generation and only to a limited extent with the diffusion of innovations, i.e. they look only at the supply side of innovation. In order to understand how successful innovation systems are in generating economic growth, one would have to include the demand side as well, including entrepreneurial activity and business formation.

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