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Learning and systems of innovation: Implications of growing cross-border interdependence

Abstract: Taking a multi-disciplinary approach, this paper highlights the importance of taking into account the role of non-domestic elements in an innovation system, which is traditionally studied by using the nation-state as the unit of analysis. Learning and knowledge accumulation is often assisted by inward and outward FDI, although this is sometimes overlooked in the study of innovation systems. Multi-level, multi-country interactions within a modern knowledge based economy means that firms are not always constrained by the limitations of their domestic resources. Nonetheless, there are factors that constrain and pre-determine the extent to which firms and locations can benefit from external knowledge sources, be they domestic or foreign.

The implications of growing cross-border interdependence for systems of innovation

It is largely uncontroversial that MNEs play a dominant role in the innovative activities of their home countries and control or own a large part of the world's stock of advanced technologies. These same MNEs undertake a growing share of their total production activities in host locations. Indeed the growing cross-border interdependence of economic units – be they firms or locations - is a hallmark of globalisation.

However, an important factor in understanding the dynamics of technology and globalisation is that these evolutionary processes do not occur in a vacuum. That is, firms do not make decisions about the kinds of products they will seek to develop, nor where they intend to develop and produce these goods and services, based simply on firm-specific issues and profit maximising motives and opportunities (see e.g., Hagedoorn and Narula 2001). First, firms exist as part of 'systems', much as individuals exist as part of society. They are embedded through historical, social and economic ties to other economic units, just as individuals are linked to a particular location through social, historical and cultural links to other individuals. Second, economic units of whatever size have finite resources. There are cognitive limits to what an economic unit can and cannot do, because it is constrained by its asset base or its potential to acquire these. Economic units are also constrained by the kinds of knowledge competences they can acquire and internalise by the extent of their technological capabilities. It takes years for firms to develop new competences, and decades to achieve a level of expertise that will provide them with a technological advantage to be a technological front-runner. The skills to acquire and successfully internalise require are non-trivial. In other words, *economic units are constrained in what they can learn by what they know.*

The problem of finite resources also applies to systems and countries. For instance, some of the characteristics of small economies are a function of size *per se*. The demand conditions restrain the sectors and kind of ownership advantages that firms of a particular nationality develop. Small market size constitutes a disadvantage in the development of process technology as the economies of scale are not present, but may provide a competitive advantage in product innovation (Walsh 1988). This applies to the kind of created asset location advantages small countries can provide[1] - they have fewer resources, and must either spread resources more thinly over the various disciplines, or it must select areas as priorities, and these often (but not always) are those in which they have a natural-asset advantage and lead to a specialisation of domestic firms in particular niche sectors (Soete 1987, Archibugi and Pianta 1992, Narula 1996). The industrial structure of small open economies tends to demonstrate a 'niche' character, with a high level of specialisation in few areas, where firms act as specialist suppliers, and thereby show a low level of product diversification. Bellak and Cantwell (1997) posit that these sectors will tend to be those in which they can achieve price-setter positions.

Understanding the systems view of technology accumulation, and the underlying dynamics of learning also helps us to understand the creation of competitive advantage on an industry or a national level. It also – if one takes a linear and developmental view of technological accumulation and innovation systems – helps us to understand how industrial development occurs. What I intend to illustrate by this line of thought is that systems always exist, but they do not always result in an efficient outcome in the sense that firms in that location are able to sustain a comparative advantage. Furthermore, systems may be 'incomplete' or 'unbalanced' because some aspects of the systems are inefficient, or simply non-existent. Nor, even where an efficient, complete and balanced system exists, does this imply that this happy state of affairs will continue *ad infinitum.*

The causes of inefficiency are many, and it is not my intention to go through all of these mechanisms here in any great detail. The main issue that I will raise here is the role of the MNE and its contribution to learning within innovation systems. Of the importance of cross-border flows of knowledge and capital there can be no doubt, and this is causally related to the spread of the MNE.

It is important to realise that few countries have truly ‘national’ systems. Of course, some innovation systems are more ‘national’ than others, and the term is indicative rather than definitive. For instance, smaller countries’ innovation systems may have a larger dependence on non-national actors. Others have argued that innovation systems need to be viewed from a industry-level (Nelson and Rosenberg 1993). It is certainly true that certain sectors (such as biotechnology) are less national and more global, while others are regional. However, by and large, most economic actors within an innovation system have a growing interdependence on economic actors outside their national boundaries.

Inter alia, this is as a result of the increasing internationalisation of production, through FDI and strategic alliances, as well as the growing need for complementary technological competences. However, despite the growth of international production and sales networks, empirical work on R&D internationalisation (e.g., Granstrand, et al 1992, Pearce and Singh 1992, Patel and Vega 1999, Kumar 2001) has demonstrated time and time again that – although decreasing- the bulk of innovatory activities of MNEs remain concentrated in their home location. Nonetheless, this varies considerably by country – over half the R&D expenditures of Dutch MNEs are undertaken outside the Netherlands (Hoesel and Narula 1999). Thus when one dissects the dynamics of industrial development one can only ignore the cross-border issues at one’s peril. The term ‘cross-border’ is used here in the broadest possible sense to signify *de facto* boundaries, rather than *de jure* ones.

This paper highlights two points. First, that few systems are purely based around national sources. The presence of inward FDI (*ceteris paribus*) provides domestic firms with linkages to economic actors outside their national boundaries. Domestic MNEs may seek to supplement their assets by engaging in outward FDI. The same is true through international collaborative activities by non-firm actors. Few systems are purely national, because knowledge flows occur through the collaboration between universities, government organisations and the like. Second, there are limits to learning through internationalisation. These are associated with finite constraints on resources that are available to economic units, as well as the presence of inertia within innovation systems.

Understanding the growing international dimension of learning

Some systems have a greater cross-border aspect than others. Much of the extant work on systems of innovation focuses on purely domestic or local sources, and excludes the international and cross border element. Indeed, a large component of research has focused on national systems (see e.g., Nelson (ed) 1993, Lundvall (ed) 1992). The work of Porter and associates based on Porter's (1990) diamond, can also be seen as studies on national systems, although the focus is much broader than systems of innovation. Rather, this body of work examines national systems of competitiveness, but the concept remains the same. Porter's original analysis as well as the strictly national model on which most national systems of innovation literature is based tends to examine competitive and technological advantage with little of no analysis of the MNE/FDI aspect, while Porter also largely ignores the dynamics of technological accumulation. Several variations of the Porter framework exist in the literature that seek to overcome the limitations of the porter model. Most notably, the work by Dunning (1992) sought to correct this oversight. Rugman and associates (see e.g., Rugman 1991, Rugman and Verbeke 1993, Rugman and D'Cruz 1993) and Barclay (2000) use a 'double diamond' approach which takes into account the cross-border aspect of national systems. There is also a large literature from the economic geography school examining systems of innovation from a regional (i.e., sub-national) level (e.g., Cooke 1998, Asheim and Isaksen, 1997, 2002 and also contributions to Braczyk, et al 1998). See also Howells (1999). Others have discussed regional systems from a multi-country perspective. This includes regions that span parts of several countries, and in other instances, systems of innovation that include components of several countries (see e.g., Bartholomew 1997, McKelvey 2000, SPRU 2001).

Learning processes are not just limited to intra-national interaction, but increasingly include international interaction. The pervasive role of MNEs in a globalising world, and their ability to utilise technological resources located elsewhere makes the use of a purely national systems of innovation approach rather limiting. Broadly speaking, individual national systems remain distinct: Technological specialisation patterns are distinct across countries, despite the economic and technological convergence associated with economic globalisation (Archibugi and Pianta 1992, Narula 1996). Studies have shown that these patterns of technological specialisation are fairly stable over long periods (see Cantwell 1989, Zander 1995) and change only very gradually, as do the technological profiles of firms (Fai and von Tunzelmann 2001, Fai 2002). The kinds of technologies across countries have shown to have converged because of, inter alia, increasing cross-border competition and the increasing interdependence of economic actors in different locations. Cantwell and Sanna-Randaccio (1990) have shown, for instance, that firms seek to emulate the technological advantages of leading competitors in the same industry, regardless of their national location.

The cross-fertilisation of technologies – whether through arms-length means, cooperative agreements or equity based affiliates - means that that few countries have truly 'national' systems. Of course, some innovation systems are more 'national' than others, and the term is indicative rather than definitive. Furthermore, firms need a broader portfolio of technological competences than they have in the past (Fai and Cantwell 1999). The exact causes of the growing role of the MNE and FDI are not germane to the present discussion. It suffices to say that it is so, and the degree to which this is, varies. In this section, I want to expand the discussion on the role of the MNE in national systems, introduced earlier

As discussed earlier, the sources of knowledge available in a typical ‘national’ system are a complex blend of domestic and foreign ones, as illustrated in a simplified (and stylised) framework depicted in Figure 1.

****FIGURE 1 ABOUT HERE***

In a purely domestic innovation system, the path of technological development is determined primarily by domestic elements. The technological development trajectory is driven largely by the changing demand of local customers. Likewise, domestic governmental organisations determine domestic industrial policy, which in turn determines domestic industrial structure. National non-firm sources of knowledge and national universities also determine the kinds of skills that engineers and scientists possess, and the kinds of technologies that these individuals have appropriate expertise in, the kinds of technologies in which basic and applied research is conducted in, and thereby the industrial specialisation and competitive advantages of the firm sector.

However few (if any) such purely national systems exist, and have not done so for the last two centuries. The wave of protectionism during the mid and late 19th century, and again in the inter-war years in the 20th century were largely attempts to create national champions, but even here, few countries developed purely in isolation. Almost every western nation undertook industrial espionage at some level, or by encouraging ‘immigration’ of skilled artisans (harris 1998). Emigration of skilled workers from Britain was illegal for most of the 18th century, while exports of British machinery was prohibited until 1843. (although not steam engines and some other machines). Sweden's metallurgical industries were transformed by Dutch immigrants such as Louis de Geer in the early 17th century (Zander and Zander 1996). De Geer is regarded by some academics as the founder of Swedish industry (Lindblad, in De Goey 1999). Further waves of (somewhat selective) immigration of entrepreneurs and artisans in the early 19th century led to the transfer of British manufacturing capabilities in mechanical engineering to several countries, including Sweden, Norway, US. The Dutch refused to recognise international patenting laws during the period 1869-1910, which allowed domestic firms to develop ownership advantages through pirated technologies. Likewise, British power looms and the technology behind high-speed spinning were highly sought after. These are numerous other cases of 'technology transfer' and of the development of domestic knowledge bases through arms-length 'loans' from foreign sources (see e.g., Bruland 1989, Bruland [ed] 1991). During the first half of the twentieth century borders became less porous and such technology transfer became less evident as most western economies focused on building up domestic capacity. This eventually extended to the developing world in the post second world war era, when almost every developing country attempted to nurture a domestic sector by excluding or limiting foreign involvement to arms-length transfers, with few exceptions such as Singapore and Taiwan. These achieved some limited success: Korean industrial development was achieved largely through excluding active participation of MNEs in its domestic milieu, as did China, Brazil and India.

Such largely domestic systems are artefacts of the past. Some countries have voluntarily accepted the limitations of an isolationist industrial development model based on import-substitution and an inward-looking orientation, others more reluctantly, as part of World Bank instituted structural adjustment programmes. Policies are oriented towards export-led growth and increased cross-border specialisation and competition, and most countries are now trying to promote economic growth through FDI and international trade – what has been referred to as the 'New Economic Model' (Reinhardt and Peres 2000). This wave of liberalisation is part of the new, received wisdom that is focused on tackling the deep-rooted causes that underlie market distortions.

Liberalisation is an important force in economic globalisation since it requires a multilateral view on hitherto-domestic issues and promotes interdependence of economies. It is implicit within this view that FDI and MNE activity can be undertaken with much greater ease than previously. This view is enforced because countries have explicitly sought to encourage MNE activity as a source of much-needed capital and technology. In addition to financial crises, the general warming of the attitudes towards FDI emanate from an accelerating pace of technical change and the emergence of integrated production networks of MNEs (Lall 2000).

In some countries, it is increasingly difficult to separate foreign knowledge sources from domestic ones. MNE subsidiaries are sometimes so well embedded that they are regarded as part of the domestic environment. This reflects not just the length of time that these subsidiaries have been present (e.g., ABB in Norway), or that the affiliate is jointly owned (E.g., Hindustan Lever in India) or has been acquired (e.g., Nycomed-Amersham, Unilever, Reed Elsevier), but also the nature of the industry, and the growing trend towards consolidation in sectors with low growth and opportunities of global rationalisation (e.g., metals, banking, automobiles). Nonetheless, the interaction between the domestic firm sector and foreign - owned firm sector varies considerably, either because the domestic sector is largely in different sectors, or because the two have evolved separately. Katrak (2002) shows that in the case of India, MNEs tend to benefit from knowledge spillovers from other MNEs, rather than to (or from) domestically owned firms. The MNE's degree of embeddedness can differ quite substantially, as explained by Sally (1996):

> "At one extreme, MNEs can be weakly embedded in national economies which are still strongly 'disintermediated', that is where MNE relations with

> external actors are brittle and frequently at arm's length. At the other extreme is strongly national embeddedness, in which MNEs are deeply interwoven in the institutional knitting of the economy in question, committed to organised long-term, usually historically defined, relations with a range of external actors" (p. 71).

Domestic firms, too, seek (and are sought as) partners in international R&D consortia because there is a convergence in technological trajectories across countries, as firms seek the best partners in a given industry regardless of their national origin (Narula and Hagedoorn 1999). Learning-by-alliances thus has a large international element, although there is significant variation by country. At 41.3% over the period 1980-1994, US firms are the least internationally involved, while the corresponding figure for Japan, Germany, France and the UK are 74.5%, 86.7%, 85.9% and 85.2% respectively. Hagedoorn (2002) points out that there is considerable variation by sector: the ratio of international to domestic partnerships over the period 1960-1998 are 0.9 for high tech sectors, 1.5 for medium tech sectors and 0.85 for low tech sectors. It is worth noting that R&D alliances are primarily learning devices. Santangelo (2000) has shown that firms with similar portfolios have a higher propensity to undertake strategic technology partnering, because it is easier to absorb each other's capabilities. This tendency extends to the non-firm sector. Universities and research institutes collaborate – both as organisations and as individual research groups – with other universities and research institutes in other countries, well illustrated by the multi-country task of the Human Genome Project.

Lastly, it is worth noting the role of outward FDI as a means for 'reverse technology transfer', whereby MNEs undertake R&D abroad with the explicit intention of seeking and acquiring technological assets from the host country. This concept is not new: but it has mainly been examined as means to improve the MNEs portfolio of knowledge and technological assets (i.e., intra-firm reverse technology transfer) (see e.g., Mansfield 1984, Cantwell 1995, Pearce and Singh 1992, Frost 1998, Håkanson and Nobel 2000, 2001, Castellani 2001, Lee 2001). However, reverse technology transfer may also have significant effects on the home country, when knowledge and resources are transferred back to the parent firms and spill over to the home economy through its linkages to domestic firms – i.e., inter-firm reverse technology transfer (see Pottelberghe and Lichtenberg 2001, Criscuolo and Narula 2001, 2002). MNEs of any given nationality with subsidiaries in several countries may have links with several different universities in several different countries, and may receive research subsidies from several national funding agencies. Such asset-seeking activity while not new, but has until quite recently been a much smaller phenomenon, restricted to the largest firms, or undertaken as a secondary objective alongside the primary objective of modifying and adapting existing products and techniques to host economy conditions (see e.g., Cantwell 1991, Dunning and Narula 1995, Kuemmerle 1996, Patel and Vega 1999, Pottelberghe and Lichtenberg 2001, Criscuolo, Narula and Verspagen 2001).

Reverse technology transfer implies that there is a process of 'feedback' from outward FDI whereby the subsidiary located abroad internalises concepts and technologies from the host country innovation system, and transfers these back to the MNEs operations in the home country (and over time this body of knowledge becomes available to the home country innovation system).

It is important to note that there is considerable variety in the kinds of activity that can be so defined. First, firms may seek to establish 'listening posts' which essentially monitor the activities of other firms and institutions in a particular environment. Such listening posts have a low R&D intensity, as their role is primarily that of technological reconnaissance, and not R&D per se. Such activities seek indirect spillovers, but do so deliberately and tend to be small in size. At the other extreme, firms may engage in R&D in a foreign location to avail themselves of complementary assets that are location specific (and include those that are firm-specific or institution-specific, which the laboratory in question seeks to use through collaboration). That is, such technological activities aim explicitly to internalise several aspects of the innovation system of the host location, by seeking direct spillovers, in addition to indirect spillovers. Such facilities may be small or large, depending largely on the resources and the objectives of the parent firm.

There is as yet no robust evidence that there are significant spillovers to the home country innovation system at large. The extent to which reverse technology transfer does in fact occur is intermediated by a number of factors, including the industry of affiliate, the size of the parent and its subsidiaries and most importantly the quality and nature of the innovation systems of the host and the home, the technological gap between the host and home, and the level of embeddedness of the parent and the foreign affiliate.

Limitations of cross-border learning

In a globalising world it seems clear that there are multiple and parallel opportunities for knowledge generation, learning and technological accumulation. Furthermore, learning can occur through a variety of organisational means (both intra-firm and inter-firm). However, it bears repeating that learning and technological accumulation is not costless or instantaneous. Developing and sustaining a technological or a competitive advantage is slow, reversible and highly uncertain.

Learning takes place at the firm level, but – as I have illustrated through this discussion of innovation systems – the success or failure of individual firms occurs in orchestration with an entire system of firm and non-firm actors. Thus, it is possible to speak of *national* technological or competitive advantages, which is not simply the sum of the innovators, but the synergistic effect of all these players within a given industry within boundaries of a *de facto* region or country.

Learning and the acquisition of knowledge themselves require skills and abilities that are non-obvious. Countries (I have used the term here as a synonym for innovation systems) in any given industry follow a trajectory of technological accumulation. Laggard 'economic units' (be they countries or firms) must possess (*inter alia*) the *social capability*[2] to catch up and converge with economic units at the frontier. Abramovitz (1995) distinguished between two classes of elements. One class includes the "basic social attitudes and political institutions", the other consists of elements that determine the ability of countries to efficiently absorb and internalise knowledge potentially available at the frontier, i.e., from the lead countries. This latter group has been dubbed as 'absorptive capacity'. Dahlman and Nelson (1995) define national absorptive capacity as "the ability to learn and implement the technologies and associated practices of already developed countries". To put it simplistically, if the institutions and organisations are absent or underdeveloped (i.e., a sub optimal innovation system) economic actors within the system will be unable to absorb and efficiently utilise knowledge that may potentially be made available to them. Absorptive capacity includes the ability to internalise knowledge created by others and modifying it to fit their own specific applications, processes and routines. It is worth noting that absorptive capacity is a subset of technological capability, which in addition to absorptive capability includes the ability to generate new technologies through *non-imitative* means. This does not imply that absorption is purely about imitation. Firms cannot absorb outside knowledge unless they invest in their own R&D, because it can be highly specific to the originating firm, since it has a partly tacit nature (Cantwell and Santangelo 1999). The extent to which a firm is able to exploit external sources of knowledge thus depends on its absorptive capacity which is assumed to be a function of its R&D efforts, and the degree to which outside knowledge corresponds to the firm's needs as well as the general complexity of the knowledge. An important component of absorptive capacity is the availability of appropriate supply of human capital, which in turn is not always specific to firms, but associated with the capabilities of the non-firm sector. Non-firms determine the knowledge infrastructure that supplements and supports firm-specific innovation. They account for a certain portion of the stock of knowledge at the national level which may be regarded as 'general knowledge' in the sense that it has characteristics of a public good, and potentially available to all firms that seek to internalise it for rent generation.

There thus exists a relationship between absorptive capacity and the stock of knowledge within any system. Furthermore, However, that a cumulative and interactive process between these two variables commences only if a "threshold" minimum knowledge base is initially present. Furthermore, as Criscuolo and Narula (2002) argue, the accumulation process proceeds at a slower pace as the country approaches the technological frontier.[3]

Thus, even where technological assets at the frontier are made available – either through licensing, or indirectly through spillovers from inward FDI – the domestic system may not be in a position to internalise these assets. Borzenstein *et al* (1998) and Xi (2000) have both shown that FDI has a positive impact on economic growth only in those developing countries that have attained a certain minimum level of absorptive capacity. Knowledge accumulation is much more rapid once the initial threshold level of absorptive capacity exists. Simply put, technology absorption is easier, once they have 'learned-to-learn' (Criscuolo and Narula 2002). However, at the frontier, technologies are pre-paradigmatic and unproven, and there may be several competing technologies, only a few of which will be adopted, and prove to be commercially viable (Narula 2001). The cost of imitation increases as the follower closes the gap with the leader and the number of technologies potentially available for imitation reduces. *This implies that there are diminishing returns on marginal increases in absorptive capacity at the upper extreme, at the frontier-sharing stage (i.e. for developed and industrialising countries).* Once a country is near the international best-practice a higher level of uncertainty is involved, and it is complicated to identify what is relevant, how to solve problems related to the exploitation of new technology: the task difficulty and the knowledge complexity rapidly increases. Besides, firms at the technological frontier are unwilling to sell state-of-the-art technologies to potential competitors, at least through arms-length transactions. Firms seeking access often resort to cooperative strategies such as joint ventures and R&D alliances, as markets for nascent and new technologies do not exist (Narula 1999).

Although the New Economic Model promoted by the Washington Consensus regards FDI as a primary – and explicit - means by which growth can be promoted, there are obvious limits to this strategy. The presence of MNEs and FDI is not a *sine qua non* for development (Narula and Dunning 2000). The experience of some of the Asian economies has fuelled this belief, and it is now promoted by the Washington Consensus as the cure for many ills. But underlying this view is the assumption that FDI is the same thing as technology imports, and that these technological imports will generate positive externalities and spillovers to domestic firms.

But it is by no means clear that this is the case, because there are 3 other conditions that need to be satisfied (Narula 2002):

1. The kinds of FDI being attracted should generate significant spillovers.
2. The domestic sector should have the capacity to absorb these spillovers. It is perhaps worth adding that some level of competence level *should exist* in the domestic sector.
3. The FDI that is being attracted should be either a substitute or complementary to domestic industry.

It is true that the determinants of economic development are similar to the determinants of FDI, but this does not mean that there is a simple cause and effect between them. Particular types of FDI tend to be attracted to countries with certain levels of economic development and appropriate economic structures (see Narula and Dunning 2000). But simply to ‘pump’ a country full of FDI will not lead to its catapulting to a higher stage of development. To assume FDI drives economic development is to assume that FDI is about capital, and that the lack of economic growth is about the lack of liquidity.

Indeed, the presence and condition of the domestic sector is crucial. If no domestic sector were to exist there can no opportunity to absorb spillovers from FDI: In a perfectly liberalised world, MNEs have no incentive to encourage the development of domestic firms to meet their needs because other MNEs would be able to do so, either through imports or FDI. In an extreme case, there may actually be no FDI inflow, because MNEs will prefer to locate production in a regionally optimal location, and simply import. Thus, FDI in a completely liberalised milieu does not necessarily lead to growth in the domestic sector. The benefits of FDI only occur when there is domestic investment, and where the domestic investment has the ability to internalise the externalities from FDI.

Nonetheless, such an idealised world does not exist, but the point that I want to illustrate is that FDI is not a guarantee of growth. FDI and economic development are highly correlated phenomena, both being strongly dependent on the specific resources, institutions, economic structure, political ideologies and social and cultural fabric of countries. The kind of FDI activity a country might attract (or wish to attract), too, at different stages of development, are different (Narula 1996). Indeed, these two issues are closely related. Globalisation has made the differences between groups of countries more rather than less noticeable, even though simultaneously they are becoming increasingly interdependent. Although every individual investment is a unique event, both the type of investment and the stage of economic development of the host country allow us to generalise that the situation currently faced by the least developed countries is fundamentally different from the catching-up and converging countries (Narula and Dunning 2000). Thus, in the scenario where the necessary absorptive capacity is not present, instead of learning from inward FDI, domestic investment may be ‘crowded out’ where the domestic innovation system is too weak to compete with the foreign sector (see e.g., Agosin and Mayer 2000). This is also the case for the formerly centrally planned economies of Central and Eastern Europe, although the ‘incomplete’ aspect of these economies is fundamentally different from that of (say) Africa. Although from a supply aspect of knowledge, these countries had considerable technological capabilities, the institutional setting within which knowledge and transactions could be organised efficiently was absent (Gomulka 1990). In other words the competence necessary to organise transactions efficiently, whether intra-firm or intra-market was unavailable.

There are also complications for firms in using reverse technology transfer. Such growing complex linkages, both of networks internal to the firm, and those between external networks and internal networks, require complex coordination if they are to provide optimal benefits. Such networks are not only difficult to manage, but also require considerable resources (both managerial and financial). It is no surprise, therefore, that external technology development is primarily the domain of larger firms with greater resources, and more experience in trans-national activity.

Conclusions

An innovation system is not a *systematically* organised group of economic actors, but the *systemic* inter-relationship between the various participants which defines the stock of knowledge. An innovation system is delineated by the concepts of ‘the institutional set up’ and “interactive learning”. The institutional set-up may be understood to constitute the framework conditions that characterise the contextual backdrop of the innovation system. In this perspective, the concept of interactive learning appears to work as a collective concept, describing the many knowledge creation processes that take place within and between the various constituents of the innovation system. The actual *content* of interactive learning seems largely determined *ad hoc* by the knowledge contributors to the different processes; the importance of which, at least in part, is generated by surrounding structural features. The concept of interactive learning works as a *collective* concept, describing the many knowledge creation processes that take place within and between the various constituents of the innovation system.

As various scholars have affirmed, economic growth is inextricably linked to technology accumulation, which in turn is a function of market conditions, demand conditions and supply conditions. It has been suggested that economic growth is a function of the rate of innovation and the national technological advantage, and that it is affected by the international trade and investment activities of firms. This also includes the shifting and transfer of resources and technology to and from other countries in the process of structural adjustment as a response to economic growth. Such international activity can act towards consolidating or weakening competitive advantage. Structural adjustment also refers to the acquisition and mastery of new technologies by the firms of a country and this occurs through technology transfer enabled through direct investment or arms-length technology sales.

I have also highlighted the importance of taking into account the role of non-domestic elements in an innovation system, which is traditionally studied by using the nation-state as the unit of analysis. Learning and knowledge accumulation is often assisted by inward and outward FDI, although this is sometimes overlooked in the study of innovation systems. In addition, foreign-located non-firms also contribute to the domestic innovation system, both directly by collaborating across borders, as well as indirectly by collaborating with MNE affiliates of both domestic MNEs located abroad, and foreign-owned MNEs located in the domestic sector. Learning-by-alliances and learning-by-interaction therefore are much more than just domestic, spatially limited phenomenon, and innovation systems are not limited by geographic distance (the complexities of learning-by-alliances is discussed in greater detail elsewhere). *Indeed, these multi-level, multi-country interactions within a modern knowledge based economy means that firms are not just constrained by the limitations of their domestic resources.*

Nonetheless, there are factors that constrain and pre-determine what firms can and cannot do. More importantly, they create inertia. Inertia is used here in the sense proposed by Isaac Newton. That is, an object in motion will remain in motion, and an object at rest will remain at rest, until and external force is applied. To paraphrase it for our purposes: *Economic units will prefer to maintain existing institutions with competitors, customers and external organisations, produce similar products and remain in similar locations, unless an external force is applied.* That is, they prefer to maintain their current state of equilibrium, if it does not threaten their survival. When an external force is applied – be it because of a new technology, change in the industrial or market structure, legal and governmental fiat - economic units will seek to modify their routines to accommodate this change to create a new 'equilibrium' preferably in close proximity to their existing routines. Firms loathe radical change. Radical change is costly and highly risky, and because routines and institutions develop slowly, *radical change that is undertaken rapidly is even more risky*. It is reputed that several years ago Lego (the Danish toy manufacturer) fired its US division manager for achieving revenue growth of 30% in one year, as opposed to a planned 10%, because the subsequent organisational costs of such rapid growth would be hard to handle.

However, every subsequent change becomes less costly, because the knowledge of developing new markets, technologies and institutions can be applied to future scenarios. That is, the economic unit has acquired the 'technologies of learning' – and these can be applied (ceteris paribus) to other situations. The experience of developing its first European affiliate by a US firm in (say) Germany makes it relatively easier to enter other similar markets such as Denmark and the Netherlands. This line of reasoning has been demonstrated time and time again for firms of all nationalities (see e.g., Johanson and Vahlne 1977, Hagedoorn and Narula 2001, Hogenbirk 2002).

To reiterate this more technically, within a innovation system framework, it is important to understand the forces that lead to a vicious or virtuous circle of competitiveness, or in other words, forces that lead to ‘positive’ or ‘negative’ inertia and lock-in. Interaction within an innovation system is a self-reinforcing mechanism which may or may not lead to <u>ex post</u> efficiency (see e.g. Cowan and Gunby 1996). Lock-in can also occur in a geographical location, particularly where a cluster of firms exist with a particular specialisation, the entire cluster can be ‘locked-in’ technologically to specific paradigms. That is, the self-reinforcing interaction between firms and infrastructure perpetuates the use of a specific technology or technologies, or production of specific products, and/or through specific processes. Increased specialisation often results in a systemic lock-in.

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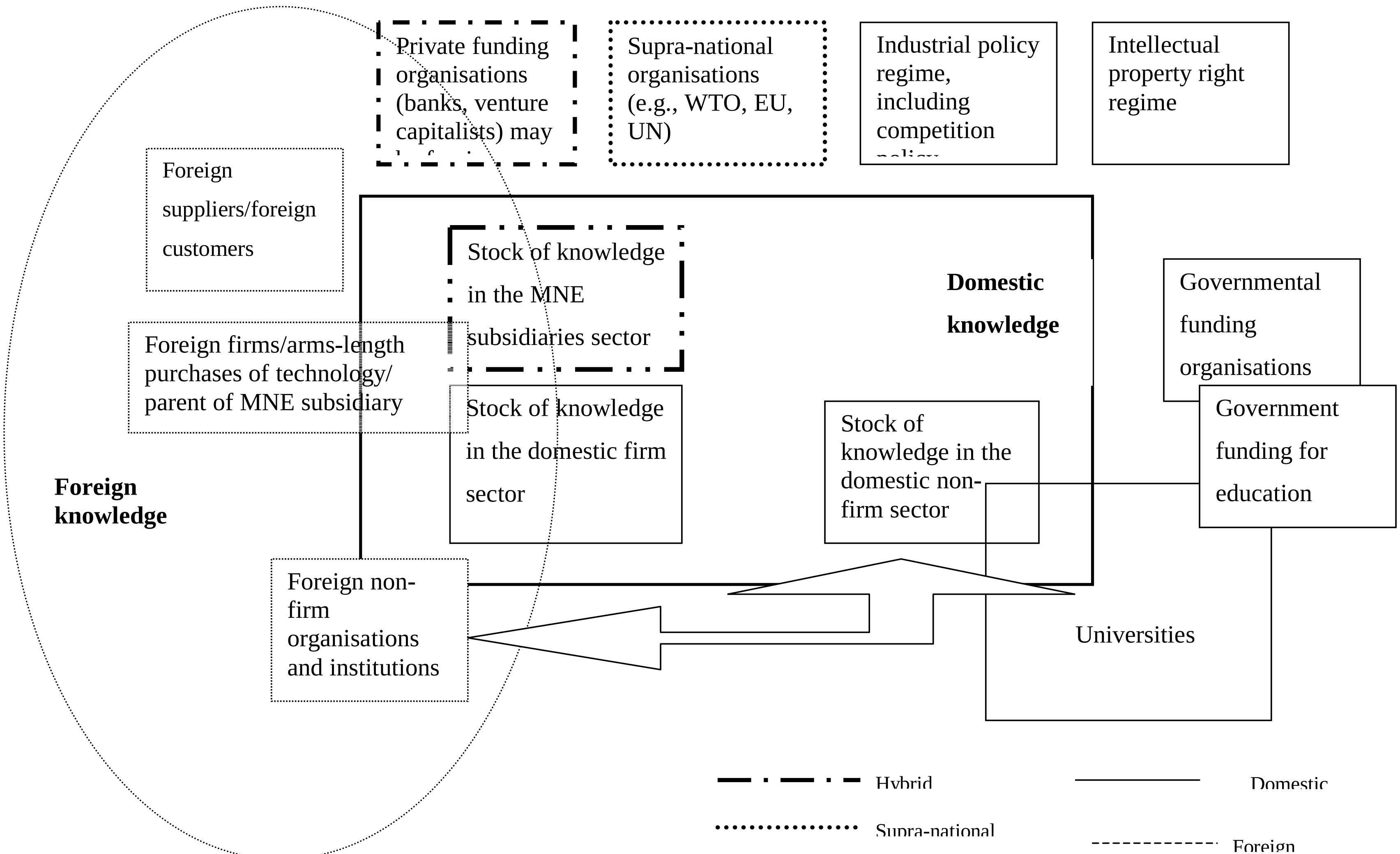

Figure 1 The inter-connectedness of domestic and foreign knowledge bases in an innovation system

ENDNOTES

[1] See Freeman and Lundvall (eds) (1988), van Hoesel and Narula (eds) (2000), Van den Bulcke and Verbeke (eds) (2001).

[2] The concept of social capability was first introduced by Ohkawa and Rosovsky (1973).

[3] The technological frontier is defined as the set of all production methods which at any given time are either the most economical or most productive in the world.